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Convention on the Conservation of Migratory Species of Wild Animals

A GLOBAL ASSESSMENT OF DUGONG STATUS AND CONSERVATION NEEDS

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DUGONG MOU

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edited by
Helene Marsh, Phillipa Loates and Luisa Schramm

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Contact
For more information contact: CMS Office Abu Dhabi at CmsOffice.ae@cms.int.

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Dugong accompanied by juvenile golden trevally, *Gnathanodon speciosus*
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Cartography
Adella Edwards

Design and Layout
Catherine Kimeu-Onyango, UNON Publishing Services Section, Nairobi

Table of Contents

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This report was produced on the Bebegu Yumba campus of James Cook University in Townsville, Australia on the lands of the Wulgurukaba and Bindal peoples. We gratefully acknowledge First Nations Custodians of all lands which this report covers. We recognize the deep, lasting connections to Country, and pay respect to Elders past, present and emerging.

Contributors to the Report

The authors of the various chapters are pictured in no particular order in lines 1–8. Some of the experts who provided technical support are in line 9

Executive Summary

The Convention on the Conservation of Migratory Species of Wild Animals (CMS) contracted James Cook University to prepare a new edition of the 2002 publication: 'Dugong: status report and action plans for countries and territories'.

The new edition, which is titled 'A global assessment of dugong status and conservation needs', comprises eleven chapters, each written by the listed co-authors. The report has been edited by Helene Marsh, Philippa Loates and Luisa Schramm and reviewed by Abdelmenam Mohamed, Lauren Lopes, Yasmeen Tel Wala and Harris Wei-Khang. The report is arranged with an Executive Summary and 11 chapters as follows:

- This Executive Summary provides an overview of the project's Key Findings.
- Chapter 1: Global Context provides background material that is relevant to all the regional chapters.
- Chapters 2-10: provide information for each of the following regions: East Africa (Chapter 2), Red Sea (Chapter 3), Arabian/Persian Gulf (Chapter 4), South Asia (Chapter 5), Continental Southeast Asia (Chapter 6), Maritime Southeast Asia (Chapter 7), East Asia (Chapter 8), Pacific Islands (Chapter 9) and Australia (Chapter 10). Each of these regional chapters has been co-authored with several regional experts.
- Chapter 11 summarizes the Key Learnings from this report.

Chapter 1: Global Context

Evolutionary history

- The dugong, *Dugong dugon*, is a medium-sized marine mammal, one of four extant members of the mammalian order Sirenia (sea cows) and the only surviving member of the family Dugongidae.
- The lineage ultimately giving rise to the genus Dugong is thought to have originated in the Atlantic and moved from near modern-day Florida into the Pacific between 12 and 2.8 million years ago (mya), when the Central American Seaway closed.
- The modern species, *Dugong dugon*, might have originated as a result of a long-distance dispersal of an ancestor across the Pacific followed by range expansion from the Indo-Australian region across the Indo-West Pacific.

Geographic range

- The dugong's vast range spans coastal and island waters across approximately 135 degrees of longitude in the Indo-West Pacific and around 50 degrees of latitude; extending approximately 25 degrees both north and south of the equator.
- There are currently 48 countries and territories listed as Range States under the Convention on the Conservation of Migratory Species of Wild Animals (CMS) Memorandum[1] of Understanding on the Conservation and Management of Dugongs (*Dugong dugon*) and their Habitats throughout their Range (Dugong MOU) (https://www.cms.int/dugong/en/signatories-range-states).

Conservation status

- The International Union of the Conservation of Nature's (IUCN) Red List of Threatened Species lists the dugong as Vulnerable to Extinction at a global scale.
- IUCN has also listed the following 'subpopulations' at regional scales: Nansei, Japan (Critically Endangered); Eastern Africa coastal (Critically Endangered); New Caledonia (Endangered).
- The dugong is listed as migratory under Appendix II of the CMS Convention because: (1) individual animals must cross international boundaries on a regular basis at numerous locations throughout its range where Range States have contiguous coastal boundaries, and (2) it is listed as Vulnerable by IUCN.

1 The number of countries and territories listed as dugong Range States under the CMS depends on how France and its dependencies (Mayotte and New Caledonia) are counted.

Life history

- Dugongs are long-lived with a low reproductive rate, long generation time, and a high investment in each offspring.
- The age of sexual maturity is variable in both sexes but tends to be similar for males and females in the same population at the same time.
- Females bear their first calf when they are between six and 17 years old. The gestation period is long (around 12-14 months), with a usual litter size of one.
- The individual variation in dugong life history parameters seems to be linked to the status of their food supply, which in turn can be adversely affected by extreme weather events.
- Dugongs start eating seagrasses soon after birth and grow rapidly during the suckling period when they also receive milk from their mothers.
- A dugong population is unlikely to increase at more than 5% per year (mostly less), even under optimal conditions.

Genetics and population structure

- Dugongs exhibit considerable genetic diversity across their range and several major groupings can be recognized. This implies that regional populations exist that might need to be treated as distinct from one another in conservation planning.
- Dugongs in the Australian region, and especially in northern Australia, can probably be regarded as genetically healthy, with good levels of diversity at nuclear loci and in the mitochondrial genome. Such populations should be better able to respond to changing environmental pressures, including disease, than populations with lower genetic diversity.
- The very low mitochondrial diversity of dugong populations in the Western Indian Ocean, Palau and New Caledonia suggests relatively recent founding events. If low nuclear gene diversity is also typical of these populations, their long-term resilience might be reduced relative to Australian dugongs. This conclusion may also apply to some other populations for which genetic data are lacking.
- Within some regions, there is evidence of limited gene flow among populations. This limited gene flow occurs at a range of spatial scales, but few data are available for most parts of the dugong's range, restricting our ability to define the geographical extent of genetically connected populations. Without such information, it is difficult to use genetic data to inform the appropriate size of management units.
- Genetic data have strengths and limitations that need to be made explicit for correct interpretation and prior to using genetic information in conservation planning, which should be informed not only by genetics, but also by information that may not be associated with genetic structure, including: movements, vital rates, jurisdictional boundaries, and major threats.

Habitat, ecology and behaviour

- The habitat requirements of dugongs generally comprise shallow (less than or equal to 20 m deep), subtropical or tropical coastal waters supporting subtropical and tropical species of seagrass.
- Dugongs are seagrass community specialists. Seagrass is their main food. They feed on nine of the ten genera, and probably on most of the approximately 26 species of seagrass that occur within their range. Dugongs exploit a diet that includes macro-invertebrates and algae at times, as well as seagrasses.
- Dugongs are obligate bottom feeders with ventrally opening mouths. They utilize two different feeding modes: excavating and cropping. Only excavating dugongs leave obvious feeding scars in the sediment.
- Dugongs are limited to the sub-tropics and tropics, presumably because of their sensitivity to low water temperatures.
- Dugongs are usually sighted as solitary individuals or as cows with single calves.
- Dugongs spend a high proportion of their time feeding.
- Loose feeding aggregations of more than 50 and up to several hundred dugongs, including cows with attendant calves, can occur at predictable locations, including Moreton Bay and Shark Bay in Australia and the Gulf of Bahrain/Gulf of Sulwa in the Arabian/Persian Gulf. The determinants of these locations are not known. These aggregations do not occur at all locations that support large numbers of dugongs.
- Dugong vocalizations are social communication signals rather than navigational aids and are apparently particularly important between females and their nursing calves.

- Satellite tracking shows that some individual dugongs and cow-calf pairs can undertake directed movements of several hundred kilometres in a few days. There is no evidence of regular round-trip migrations of entire regional populations, although dugongs may make local adjustments in their space use to adapt to seasonal changes in their environments. No migratory corridors have been identified.
- Periodic seagrass loss driven by extreme weather events is likely to be the most important driver of large-scale movements in dugongs.
- Extra-limital reports of dugongs at locations such as the Cocos (Keeling) Islands and Fiji suggest that individual dugongs can move across deep ocean trenches.

Threatening processes

- Dugongs are vulnerable to anthropogenic influences due to their life history and their dependence on seagrasses in coastal habitats, which are often under pressure from human activities.
- The rate of dugong population change is most sensitive to changes in adult survivorship because of the lengthy period before first breeding, long gestation period and the usual litter size of one, as well as the long period of lactation.
- Given the extensive range of the dugong, individuals are exposed to a variety of threats, some of which are locally unique and some which span its entire range.
- Threats to dugong survivorship include: interactions with fisheries; traditional harvest, vessel strikes, stranding of orphaned calves, and predation.
- Threats to dugong fecundity include: habitat loss and degradation, climate change, acoustic pollution, dugong tourism, diseases, parasites, contaminants and plastics.

Methodologies

- Methodologies used to estimate and monitor dugong population size in ecologically useful time frames include: mark-recapture; abundance aerial surveys, distribution aerial surveys, vessel surveys, fisher surveys, citizen science, genetic techniques and land-based surveys.
- The most appropriate technique for a given location depends on its geography, spatial scale, the capacity of the survey team and the funding available. The results obtained using different techniques are generally not strictly comparable and most techniques are unsuitable for quantifying trends.
- Methodologies used to estimate the extent of seagrass meadows include: aerial photography, drop-down cameras, intertidal walking, scuba-diving and snorkelling, towed cameras, remote sensing and acoustic echo-sounding. The most appropriate technique for a given location depends on its geography, spatial scale, the capacity of the survey team and the funding available.
- Polygon (vector-based) maps have been used to estimate the area of seagrass habitat suitable for dugongs in each Range State in this report. Only seagrass areas that have been mapped with moderate to high confidence have been reported.

Blue Carbon

- Blue Carbon is the ecosystem service provided by the atmospheric carbon dioxide captured and stored in coastal vegetated ecosystems, including the dugong's seagrass habitats.
- The low-biomass seagrass meadows used by dugongs accumulate lower amounts of organic carbon than higher-biomass meadows. Nonetheless, the extent of the seagrass meadows in the dugong's range makes it relevant from a Blue Carbon perspective.
- Quantifying the Blue Carbon value of the dugong's seagrasses habitats and their potential to contribute to climate change mitigation at national or regional levels could provide further rationale for dugong habitat conservation.

Chapter 2: East Africa: Republic of Kenya (Kenya), Republic of Madagascar (Madagascar), France, Department of Mayotte (Mayotte), Republic of Mozambique (Mozambique), Republic of Mauritius (Mauritius), Republic of Seychelles (Seychelles), Federal Republic of Somalia (Somalia), Union of the Comoros (Comoros) and United Republic of Tanzania (Tanzania)

- Hunting and bycatch in fishing nets have caused very serious declines in the dugong populations in East Africa.
- Dugongs are probably extinct in the waters of both Mauritius and Rodrigues and apparently no longer occur in the Comoros outside Mohéli, and in the Seychelles outside Aldabra.
- The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species listed the coastal Eastern Africa subpopulation of dugongs as Critically Endangered in 2022.
- Dugongs in East Africa are likely to have limited resilience to extreme events as the genetic differences between individuals appear to be very low.
- The only location in East Africa where a globally significant number of dugongs is known to occur is the Bazaruto Seascape in Mozambique. This location has been recognized internationally as an Important Marine Mammal Area (IMMA) and a Key Biodiversity Area (KBA).
- Bazaruto dugongs and the threats to them are actively monitored by African Parks. There is significant community engagement in these activities.
- Scientifically designed local-scale surveys informed by local knowledge have the potential to provide important new information about dugongs in Zeyla Archipelago in Somaliland, Mohéli, Mayotte and Aldabra.
- In Madagascar, Nosy Berafia in Sahamalaze National Park, Nosy Hara Marine Park, Ampobofofo, Bay of Rigny Complex, and Ambodivahibe are important habitats for dugongs.
- The 'Northwest Madagascar and Northeast Mozambique Channel' IMMA, which spans the waters of Comoros, Mayotte and Northwest Madagascar, includes the dugong as one of 22 supporting species.
- Outside the Bazaruto Seascape, dugong numbers are apparently so low that management interventions focussed solely on dugongs are unlikely to attract much support. Interventions designed to protect all marine megafauna may be more successful and groups with an interest in the conservation of marine turtles and small cetaceans should be invited to incorporate dugong conservation in their management actions.
- The areas of seagrass habitat coverage in the region are likely to be underestimated. It will be important to undertake further mapping using modern techniques including unoccupied aerial vehicles (UAVs) or drones.
- An updated comprehensive 'Dugong Conservation Strategy in East Africa' would be a timely initiative, especially if a regional spatial risk assessment of the threats to dugongs in areas of local importance for the species were included.

Chapter 3: Red Sea: Arab Republic of Egypt, State of Eritrea, Kingdom of Saudi Arabia, Republic of Djibouti, Republic of Sudan and Republic of Yemen

- The dugong distribution in the Red Sea is fragmented, reflecting the availability of suitable seagrass habitat.
- The dugong population of the Red Sea was estimated to be up to 4,000 animals in the 1980s, an estimate extrapolated from an aerial survey of the number of dugongs in the Saudi Arabian waters of the Red Sea in 1987, plus interview surveys in Yemen in 1988.
- The current size of the dugong population of the Red Sea is unknown.
- Dugong research and conservation in Saudi Arabia and Egypt have increased in recent years. Nonetheless, there are few contemporary, quantitative data on both dugongs and their seagrass habitats for most countries bordering the Red Sea, especially the Range States along the western coast.
- Recent research assessing the status of dugongs in the region is largely conducted on a local-scale, including interviews with fishers, studies of feeding trails and photoidentification of individual dugongs. The results of recent aerial surveys along parts of the Saudi Arabian coast are unpublished at the time of writing.

- The following Important Marine Mammal Areas (IMMAs) of relevance to dugongs have been declared in the Red Sea: the 'Northern Red Sea Islands' and the 'Southern Egyptian Red Sea Bays, Offshore Reefs and Islands' in Egypt; and the 'Farasan Archipelago' in Saudi Arabia.
- In addition, there are Areas of Interest (AoIs) for potential designation as IMMAs for which the dugong is listed as a supporting species: (1) the 'Golfe de Tadjoura' and (2) 'Seven Brothers Islands and Godorya' in Djibouti; (3) 'Dhalak and Adjacent Southern Waters' in Eritrea; (4) 'Dungonab Bay–Mukawar Island', and (5) the 'Suakin Archipelago and Sudanese Southern Red Sea' in Sudan.
- It is likely that dugongs have declined in the Red Sea in recent decades due to human-caused mortalities resulting from past hunting pressure and current incidental bycatch and habitat loss.
- The Programme for the Environment of the Red Sea and Gulf of Aden (PERGSA) offers an established framework for regional cooperation on the marine environment and conservation in the Red Sea. A constructive way forward might be to invite PERSGA to coordinate a regional strategy for dugongs in the Red Sea.
- A key initiative could be a program of coordinated and replicable research on the distribution and abundance of dugongs and their seagrass habitats across the countries of the Red Sea. Such a program should use techniques that are appropriate to the capacity of each country and the known distribution of its dugongs but enable cross-country comparisons.
- Contemporary data on dugong abundance for the entire region could enable an International Union for Conservation of Nature (IUCN) Red List of Threatened Species subregional assessment of the status of the dugong in the Red Sea.

Chapter 4: Arabian/Persian Gulf (the Gulf): Islamic Republic of Iran (Iran), Kingdom of Bahrain (Bahrain), Kingdom of Saudi Arabia (Saudi Arabia), State of Qatar (Qatar) and United Arab Emirates (UAE)

- The core habitat for dugongs in the Gulf lies in the western and southern Gulf between about Ras Ghanadha, east of Abu Dhabi in the UAE, through Bahrain and Qatar to Ras Tanura on the Saudi Arabian central coast.
- Whether the coastal waters of Iran currently support a resident population of dugongs is uncertain and will only be determined by research explicitly designed to investigate this situation.
- The available evidence suggests that the Gulf supports a stable population of approximately 5,000 dugongs, around 3,000 of which are in the UAE. A coordinated series of surveys across the core habitat in the western and southern Gulf is required to confirm the status of the dugong in the Gulf, which may be eligible for a subregional Red List of Threatened Species assessment by the International Union for Conservation of Nature (IUCN).
- The largest dugong aggregations recorded globally occur in the Gulf of Bahrain/Gulf of Salwa region. These fluid groups account for approximately 60% of the dugongs found in Bahrain waters and an estimated 12% of all dugongs in the Gulf. The core occupancy area of these aggregations straddles the Bahrain– Qatar border, reflecting their transboundary nature.
- The global importance of the Gulf for dugongs has been recognized by the declaration of 'the Southern Gulf and Coastal Waters' and 'the Gulf of Salwa' as Important Marine Mammal Areas (IMMAs), both with the dugong as a qualifying species.
- Given the transboundary nature of the Gulf's dugong population, a regional network of Marine Protected Areas (MPAs) spanning all the dugong Range States to conserve the core dugong areas would be highly desirable and should encompass at a minimum: the Murawah MPA and the Al Yasat MPA in the UAE; the waters southwest of the main island down to the Hawar Islands and the two Fashts in Bahrain; the northwest coastal waters of Qatar; and the Gulfs of Bahrain and Salwa between the Kingdom of Saudia Arabia, Bahrain and Qatar.
- The Gulf is the world's hottest sea. The effects of climate change on dugongs and their habitats merit investigation in the context of the other threatening processes they are exposed to in the Gulf including fisheries interactions, coastal development and oil pollution, especially as dugong genetic diversity appears to be low in this region.
- The Regional Organization for the Protection of Marine Environment (ROPME) should be well placed to co-ordinate dugong research, monitoring and conservation management across the Gulf.

Chapter 5: South Asia: Republic of Bangladesh (Bangladesh), Republic of India (India) and Democratic Socialist Republic of Sri Lanka (Sri Lanka)

- Dugong distribution in the South Asian Region is apparently limited to: (1) the Gulf of Kutch in northwestern India; (2) Gulf of Mannar–Palk Bay region (between India and Sri Lanka); and (3) the Andaman and Nicobar Islands in Indian waters in the Bay of Bengal. Dugongs may also occur in some Sri Lankan coastal waters outside the Gulf of Mannar–Palk Bay region.
- No dugongs or seagrasses have been recorded in Pakistan. It is uncertain whether Bangladesh supports a resident dugong population. There is no evidence that dugongs ever occurred in the Laccadive (Lakshadweep) Islands (India) or in the Maldives.
- Research is required to determine if dugongs are resident: (1) along the Chittagong coast of Bangladesh and, (2) in Sri Lanka outside the northwestern region.
- The Gulf of Kutch supports an isolated, resident dugong population. The limited extent of the potential seagrass habitat means it is only able to support a relatively small dugong population, a situation which makes the prospects for their longtime survival there highly uncertain.
- The southern Gulf of Kutch has been identified as an Important Marine Mammal Area (IMMA) with the dugong listed as a qualifying species.
- The transboundary Tamil Nadu–Sri Lanka area, which includes the Gulf of Mannar–Palk Bay region, is the most important habitat for seagrasses and dugongs in South Asia. The 'Palk Bay and the Gulf of Mannar' region has been identified as an IMMA, with the dugong as the only qualifying species. The establishment of a dugong conservation reserve along part of the Tamil Nadu coast is a welcome first step towards dugong conservation in this region.
- Currently the Gulf of Mannar–Palk Bay region supports what appears to be a much lower number of dugongs than in the recent past. Procedures need to be developed to enhance the governance arrangements for this region including a focus on community participation in conservation and management. Targeted research is required to improve the management of dugong populations and their habitat (seagrass communities) in this region, with emphasis on reducing the impacts of fisheries, climate change and other threats on dugong populations and their habitats.
- Dugongs in the Gulf of Mannar–Palk Bay region may also face increased development pressures if India and Sri Lanka are connected by infrastructure across Palk Strait and/or if the petroleum and natural gas are exploited within the Gulf of Mannar Biosphere Reserve.
- The Andaman and Nicobar Islands support an isolated, resident dugong population. The limited extent of shallow coastal water around the Andaman and Nicobar Islands means that these archipelagos can support only a relatively small dugong population, a situation that makes their survival there very challenging for conservation managers.
- The 'Southern Andaman Islands' have been identified as an IMMA with dugongs as a qualifying species.
- Given the small sizes of dugong populations in both the Gulf of Kutch and the Andaman and Nicobar Islands, it may be effective and efficient to develop and implement conservation arrangements for marine megafauna, rather than dugongs *per se*.
- Dugongs in both the Gulf of Kutch and the Andaman and Nicobar Islands likely qualify for separate International Union for Conservation's (IUCN) Red List of Threatened Species 'subpopulation' assessments.
- Robust quantitative information on the size of the Gulf of Mannar–Palk Bay region dugong population would be essential for an IUCN Red List of Threatened Species 'subpopulation' assessment of the dugong population in this region.

Chapter 6: Continental Southeast Asia: Malaysia (Peninsular Malaysia only), Kingdom of Cambodia (Cambodia), Kingdom of Thailand (Thailand), Republic of the Union of Myanmar (Myanmar), Republic of Singapore (Singapore) and Socialist Republic of Viet Nam (Viet Nam)

- Dugongs face significant challenges in this region, primarily from incidental bycatch, habitat loss and degradation. The underlying causes of these threats vary across Range States, but their root causes include inadequate law enforcement, coastal development, and poverty.
- The status of dugongs in this region remains data deficient, despite the efforts by many researchers and NGOs.
- The following globally-important Important Marine Mammal Areas (IMMAs) with the dugong as a qualifying species have been recognized or are in the process of being evaluated: (1) Trang in Thailand (under evaluation); (2) the 'Mersing Archipelago' IMMA, off the eastern coast of Johor in Peninsular Malaysia; (3) the transboundary 'Kien Giang and Kep Archipelago' IMMA, which spans the Kep Province in Cambodia and the Kien Giang Province in Viet Nam; and (4) the 'Côn Đảo' IMMA in Viet Nam.
- The Andaman Sea coast of Thailand and the east coast of Johor in Peninsular Malaysia are the only locations with confirmed populations ranging from tens to hundreds of dugongs. Effective protection of these populations is particularly important.
- Throughout most of the region, dugongs persist in fragmented, relatively small populations in recognized areas of local importance. Thus, it may be more efficient and effective to consider dugong conservation in these locations in the context of the conservation of marine megafauna more generically than to develop specific dugong management plans.
- Increased attention to transboundary management and the conservation of seagrass meadows known to support dugongs would be highly desirable.
- The largest knowledge gaps are: (1) inadequate mapping of seagrass in most countries, particularly Myanmar; (2) lack of quantitative data about most of the dugong populations; (3) lack of understanding of the contemporary transboundary movements of dugongs; (4) the limited understanding of the genetic structure of dugong populations outside Thailand; (5) spatial understanding of the threats posed by fisheries; and (6) understanding the causes of the large-scale seagrass dieback along the Andaman coast of Thailand; (7) the human dimensions of dugong interactions with fisheries and coastal development.
- The dugong population in the Côn Đảo region of Viet Nam must be at high risk because of its isolation and may merit International Union for Conservation of Nature's (IUCN) Red List of Threatened Species evaluation as a 'subpopulation', depending on the availability of data.

Chapter 7: Maritime Southeast Asia: Brunei Darussalam (Brunei), Democratic Republic of Timor-Leste (Timor-Leste), Republic of Indonesia (Indonesia), Malaysia (East Malaysia only) and Republic of the Philippines (Philippines)

- The dugong populations in Maritime Southeast Asia are fragmented and data deficient because information is largely based on local sightings at a subset of possible habitats.
- Important Marine Mammal Areas (IMMAs) with the dugong as a qualifying species have been declared for the following sites in Indonesia: (1) 'Balikpapan, Adang and Apar Bays' in East Kalimantan; (2) 'Tolitoli' in Central Sulawesi; (3) 'Kaimana' in West Papua; and (4) the 'Eastern Lesser Sunda Islands and Timor Coastal Area'.
- The following areas are under evaluation by the Marine Mammal Protected Areas Taskforce (MMPATF) as IMMAs with the dugong as a qualifying species: (1) 'Brunei Bay' bordered by Brunei, the Malaysian state of Sarawak and the Malaysian Federal Territory of Labuan; and (2) 'Mayo and Pujada Bays' on the Pacific coast of Mindanao in the Philippines.
- It has been assumed that dugong populations are declining in the region because of unsustainable, historical hunting, incidental entanglement in gillnets, destructive fishing, boat collisions and seagrass habitat degradation but there are no quantitative trend data.
- It would be desirable to design and apply survey techniques suitable for both: (1) the spatial scale of the distribution of dugongs and their seagrass habitats, and (2) the local capacity in each Range State.

- The following sequence of surveys could provide important new information for management: (1) fisher surveys to identify dugong areas of local importance and threats to dugongs at the desired governance scale; (2) seasonal 'hotspot surveys' using small drones supplemented if possible by eDNA to provide baseline information on dugong distribution and abundance; (3) seagrass surveys using the Seagrass-Watch protocols being applied in the International Climate Initiative (IKI) Seagrass Ecosystem Service (SES) project; (4) focus groups with local experts to identify threats to dugongs and other megafauna and their habitats to inform: (a) a review of the adequacy of existing Marine Protected Areas (MPAs) to protect megafauna, including dugongs and their habitats; and (b) the design of new or modified MPAs to achieve effective conservation management of marine megafauna.
- Especially in Indonesia and the Philippines, there is a mismatch between the spatial scale of marine conservation, which is largely organized at a local level, and strategic planning for dugong conservation, which has been at a national level. Coordinated governance of marine conservation at a regional level could be advantageous.
- Given that most dugong populations are likely small, conservation planning and management may receive more community support if it were organized for marine megafauna rather than dugongs *per se*.
- At the key location of Brunei Bay on the island of Borneo, international coordination across the state government of Sarawak and the federal territory of Labuan in East Malaysia and the country of Brunei would be highly desirable.

Chapter 8: East Asia: 日本 (Japan) and People's Republic of China (China)

- Dugongs are in critically low numbers in the coastal waters of China (Viet Nam-China border to the northern border of the Fujian Province including offshore islands) and Japan (waters of the Nansei Islands).
- It is extremely unlikely that dugongs will recover in this region given the low likelihood of dugongs migrating into the area, successful captive breeding programmes, or translocating dugongs into the region from elsewhere.
- The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species formally classified the Nansei 'subpopulation' as Critically Endangered in 2019. An assessment for the Chinese 'subpopulation' would almost certainly reach the same conclusion.
- Given this situation, interventions designed to protect coastal marine megafauna more generically in China as part of its Ecological Conservation Redline strategy, may be more successful than dugong-specific interventions.
- Some segments of the Japanese public consider the remaining dugong population in Japanese waters to be very important, a situation that could be harnessed to address the threats to marine megafauna in the Nansei Islands region more generically.

Chapter 9: Pacific Islands: Independent State of Papua New Guinea (Papua New Guinea), New Caledonia (Semi-autonomous Territory of France, henceforth New Caledonia), Republic of Palau (Palau), Republic of Vanuatu (Vanuatu) and Solomon Islands (Solomon Islands)

- Dugongs persist in locations of local importance in all the Pacific Island Range States considered in this chapter.
- Information on dugong habitats, abundance and conservation status is limited outside New Caledonia, especially for Papua New Guinea (PNG) and the Solomon Islands. Lack of capacity and funding are the main drivers for this persistent gap in investment in research and monitoring. Designing and implementing survey techniques appropriate to Palau, PNG and Vanuatu to monitor the status of dugongs in each of these Range States should be a high priority.
- The Palau dugong population is not only the most isolated dugong population in the world but appears to have very low genetic diversity.
- The 'Southern Shelf Waters and Reef Edge of Palau' Important Marine Mammal Area (IMMA) was established in 2021 with the dugong as the sole qualifying species.
- The Palau 'subpopulation' may be eligible for the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species listing.
- The 'Main Solomon Islands' IMMA encompasses the coastal and offshore waters of the main group of Solomon Islands. The dugong is believed to be widely distributed within the IMMA and is one of the qualifying species.

- The status and size of the dugong population in Vanuatu is unknown. It is likely that the population is small, fragmented and widely distributed among the islands.
- IUCN listed the New Caledonia 'subpopulation' as Endangered in 2022. This 'subpopulation' appears to have very low genetic diversity.
- The dugong is explicitly cited as an attribute of the Outstanding Universal Value (OUV) in the Lagoons of New Caledonia World Heritage property.
- The 'New Caledonian Lagoons and Shelf Waters' IMMA was listed in 2021, with the dugong as a qualifying species.
- An important priority should be to build on the history of regional cooperation to develop a program of coordinated research on and monitoring of the distribution and abundance of dugongs and their seagrass habitats across the region, using techniques that are appropriate to the capacity of each Range State, but which would enable cross-country comparisons.
- Once this foundational work has been established, consideration should be given to understanding the connectivity between dugongs at locations within the region using modern genetics and tracking techniques, especially as genetic diversity appears to be very low for dugongs in both Palau and New Caledonia.

Chapter 10: Commonwealth of Australia (Australia): Queensland, Northern Territory, and Western Australia from Shark Bay north

- Australia is the most important location for dugongs and their seagrass habitats in the world. The vast areas of shallow continental shelf in northern Australia provide extensive areas of seagrass supporting habitat. The human population density of most of this region is very low.
- The total estimated dugong population is approximately 166,000 ± SE 21,500 animals. The total area of seagrass estimated with moderate to high certainty in the dugong's Australian range is approximately 57,500 km^2, including 24,076 km^2 in waters more than 15 m deep offshore from the urban coast of the Great Barrier Reef World Heritage Area (GBRWHA). This offshore area has not been surveyed for dugongs.
- The dugong is a Matter of National Environmental Significance (MNES) under national law and receives protection under the laws of all relevant jurisdictions in their Australian range.
- Ten Important Marine Mammal Areas (IMMAs) with dugongs as a qualifying species are recognized in Australian coastal waters: five in Queensland, one straddling Queensland and Northern Territory waters, and four in Western Australia. Dugongs in most of these IMMAs receive some statutory protection under marine park and/or fisheries legislation.
- The dugong population is explicitly recognized as an attribute of the Outstanding Universal Value (OUV) in both the Great Barrier Reef (GBR) and the Shark Bay World Heritage Areas.
- The results of the large-scale aerial surveys that have been conducted over dugong habitats in Australia since the 1980s suggest that dugong conservation status varies regionally within Australian coastal waters from increasing along the remote coast of the GBR World Heritage Area, stable along the Gulf of Carpentaria coast of the Northern Territory and Shark Bay World Heritage Area, declining along the urban coast of the GBRWHA, and uncertain in most other parts of their Australian range.
- Confidence in these assessments varies because of regional and temporal differences in survey recency, frequency, and methodological approach. Much of the dugong's range in Western Australia and the Northern Territory has been surveyed only once and key areas have not been surveyed for more than ten years including: Torres Strait, which supports the largest dugong population, the Gulf of Carpentaria coast of Queensland, and the Pilbara coast of Western Australia.
- With further information, the isolated and remote dugong 'subpopulation' of the Ashmore Reef-Sahul Bank region in Australian waters situated between the northwest coast of Western Australia and the island of Rote, Indonesia may be a candidate for an International Union for Conservation of Nature's (IUCN) sub-population listing.
- Dugong hunting by Traditional Owners (Aboriginal or Torres Strait Islander individuals or groups who have a traditional or historical connection, attachment, and/or relationship to an area of land or sea) is legal under Australian Law.
- The process of integrating seagrass data, aerial survey data and Traditional Ecological Knowledge (TEK) to identify the probability of dugong occurrence in Kimberley coastal waters should be explored with Traditional Owners for possible application in other areas.

- Extreme weather events (cyclones, floods, and marine heatwaves) have been the most significant threats to dugongs in their Australian range for at least the last 30 years. Loss of the seagrasses eaten by dugongs results in dugong life history changes including an increase in mortality, especially neonatal and early juvenile mortality, and a decrease in fecundity. In such circumstances, some dugongs undertake temporary emigration, presumably seeking locations where seagrass has not been lost.
- As a very highly developed country, Australia has the potential to conduct research and develop monitoring techniques that inform dugong conservation globally. A high proportion of modern dugong research has been conducted in Australia.
- The development of a national Wildlife Conservation Plan in conjunction with Traditional Owners could enable a more systematic and prioritized approach to research and monitoring than that observed to date. The Biologically Important Areas for dugongs being identified by the Australian Government could be a focus of this plan.

Chapter 11: Key learnings from this report

Need to revise global range information

- The International Union for Conservation of Nature (IUCN) Red List of Threatened Species lists the dugong as Vulnerable to Extinction at a global scale.
- The assessment includes a global range map, which this report indicates needs revision by the IUCN Sirenia Specialist Group.

Potential for additional 'subpopulation' listings

- The IUCN has listed the following dugong 'subpopulations' at a regional scale: Eastern Africa Coastal (Critically Endangered); Nansei, Japan (Critically Endangered); New Caledonia (Endangered).
- This report has identified a further 11 'subpopulations', including three transboundary 'subpopulations', as potentially appropriate for assessment for IUCN Red List of Threatened Species listing as Threatened.
- These assessments should be undertaken by the IUCN Sirenia Specialist Group.

Global prospects

- Dugong Range States are socioeconomically diverse and include some of the world's richest and most highly developed countries as well as some of the poorest and most war-torn.
- The dugong's prospects are uneven across its global range as confirmed by the evidence in Chapters 2-10 of this report and the current and prospective IUCN 'subpopulation' listings.
- Nonetheless, the conservation prospects for the dugong at a global scale should be better than for any other sirenian species because an extensive area of dugong habitat occurs in the waters of very highly developed countries with the capacity to implement effective conservation practices.
- The prospects for dugongs surviving in the coastal waters of Island Range States with low seagrass extent, relatively small areas of coastal waters shallower than 20 m and some level of isolation (e.g., separated from adjacent continental land masses or islands) are likely to be precarious.

Need for additional seagrass mapping

- The area of seagrass in sub-tropical and tropical Indo-Pacific waters shallower than 20 m deep can be used as a crude index of dugong carrying capacity.
- While not all shallow coastal waters are potential seagrass habitat, the area of seagrass known with moderate to high confidence as a proportion of the area of coastal waters less than 20 m deep shows the need to undertake additional seagrass mapping in all regions of the dugong's range, especially the Red Sea, the Asian regions and the Pacific Islands.
- The need to map dugong habitat is recommended for inclusion on the roadmap for the 2030 Seagrass Breakthrough, announced during the United Nations Framework Convention on Climate Change Conference of the Parties No. 28 in December 2023.

Desirability of prioritized revision of Dugong and Seagrass Toolkit

- The Dugong and Seagrass Research Toolkit contains many sections that need to be prioritized for updating.
- The section on estimating dugong abundance, which is of key relevance to evaluating dugong status and trends, is out-of-date.
- The Toolkit is silent on recent advances in methodology, such as in the use of unoccupied aerial vehicles (UAVs or drones) for population assessment and monitoring and condition assessment, eDNA, survey design and the analysis of trends.

Desirability of spatial risk assessment of threats at important locations

- The direct and indirect threats to dugongs are relatively consistent across their range, although their root causes differ with socioeconomic context.
- The relative importance of these threats varies at both regional and local scales.
- An important initiative would be to consider the relative risks, including the climate risks, to the globally and regionally important dugong habitats identified in this report.

Desirability of generic interventions to protect coastal megafauna

- Dugong density is now so low in many locations that there is little community awareness of dugongs or support for dugong-specific interventions.
- In Range States with low dugong density, generic interventions to protect coastal megafauna and their habitats could be a more efficient and effective approach to addressing threats that affect all megafauna, such as gillnetting. This approach also accords with some of the decisions of the Conference of the Parties to the Convention on Migratory Species of Wild Animals (CMS), which foreshadows a generic approach to develop methods to address threats that affect multiple CMS-listed species of marine megafauna.

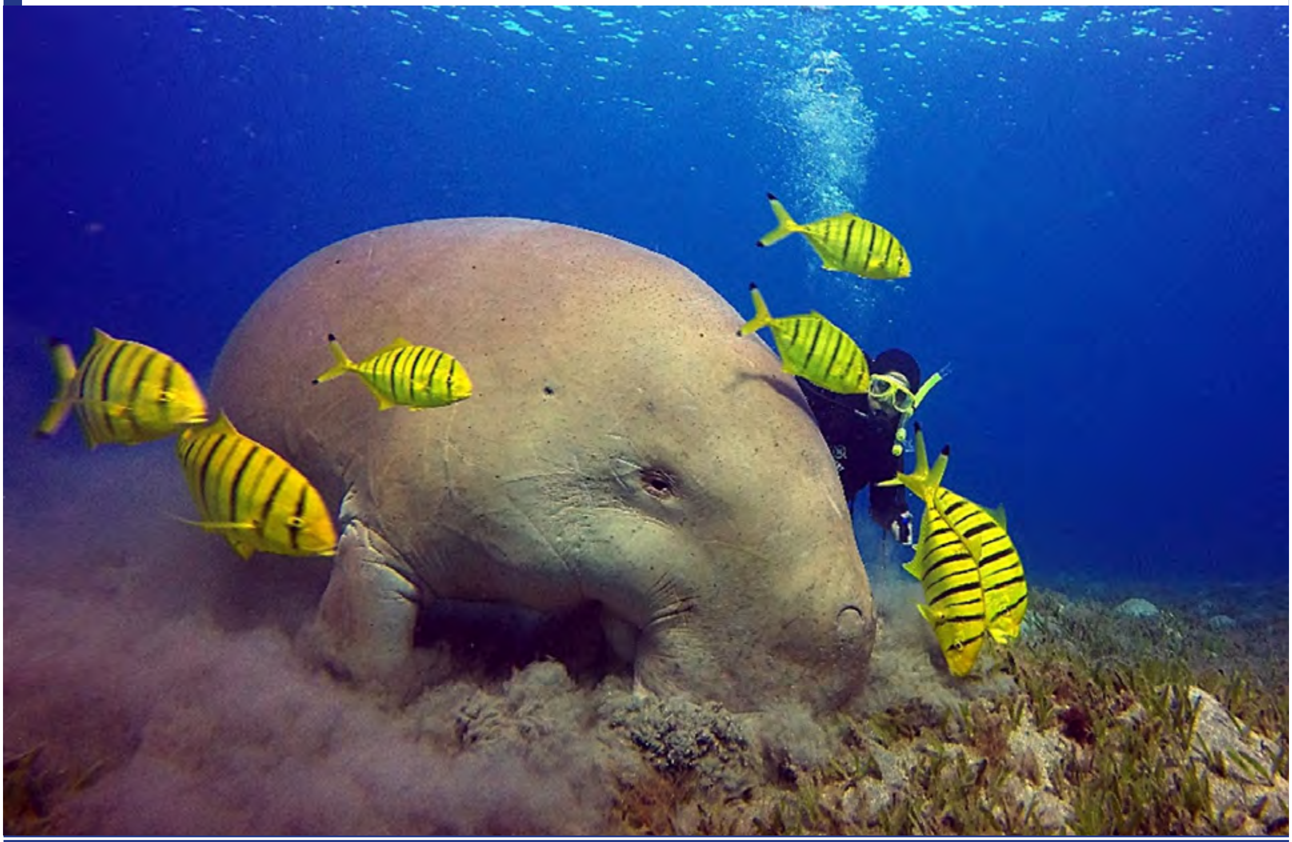
Desirability of increased regional cooperation

- Regional cooperation on dugong conservation management and research is at various stages of development across dugong Range States.
- It would be highly desirable for each of the regions in the dugong's global range to consider developing or updating a Regional Action Plan to guide the development and delivery of practical and resource-efficient conservation strategies for dugongs and their habitats (and if appropriate, associated marine megafauna).

Opportunity for keeping this report and the Dugong and Seagrass Research toolkit up to date

- The technology now exists to create and modify on-line content in an organized manner, while ensuring that the information remains of high quality. Such an approach could be used to keep this report and the Dugong and Seagrass Research Toolkit up to date with the assistance of the Dugong MOU Dugong Technical Advisory Group (DTAG).

Chapter 1



GLOBAL CONTEXT

Authored by: Helene Marsh, David Blair, Anna Lafratta, Janet Lanyon and Len McKenzie

Helene Marsh[1], David Blair[1], Anna Lafratta[2], Janet Lanyon[3], Len McKenzie[4]

[1]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[2]Centre for Marine Ecosystems Research, School of Science, Edith Cowan University, Joondalup, Western Australia, Australia.
[3]School of the Environment, The University of Queensland, Brisbane, Queensland, Australia.
[4]Centre for Tropical Water & Aquatic Ecosystem Research TropWATER, James Cook University, Cairns, Queensland, Australia.

Correspondence to Helene Marsh helene.marsh@jcu.edu.au.

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Cover image: Dugong feeding in a seagrass meadow accompanied by juvenile golden trevally (*Gnathanodon speciosus*) and a diver. Egypt, Red Sea. Ahmed Shawky photograph.

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Contents

Global Context
Evolutionary history
Geographic range
Conservation status
Life history
Genetics and population structure
Habitat, ecology and behaviour
Threats
Methodologies
Ecoystem Services: Blue Carbon

Summary

Evolutionary history

- The dugong, *Dugong dugon*, is a medium-sized marine mammal, one of four extant members of the mammalian order Sirenia (sea cows) and the only surviving member of the family Dugongidae.
- The lineage ultimately giving rise to the genus Dugong is thought to have originated in the Atlantic and moved from near modern-day Florida into the Pacific between 12 and 2.8 million years ago (mya), when the Central American Seaway closed.
- The modern species, *Dugong dugon*, might have originated as a result of a long-distance dispersal of an ancestor across the Pacific followed by range expansion from the Indo-Australian region across the Indo-West Pacific.

Geographic range

- The dugong's vast range spans coastal and island waters across approximately 135 degrees of longitude in the Indo-West Pacific and around 50 degrees of latitude; extending approximately 25 degrees both north and south of the equator.
- There are currently 48[1] countries and territories listed as Range States under the Convention on the Conservation of Migratory Species of Wild Animals (CMS) Memorandum of Understanding on the Conservation and Management of Dugongs (*Dugong dugon*) and their Habitats throughout their Range (Dugong MOU) (https://www.cms.int/dugong/en/signatories-range-states).

Conservation status

- The International Union of the Conservation of Nature's (IUCN) Red List of Threatened Species lists the dugong as Vulnerable to Extinction at a global scale.
- IUCN has also listed the following 'subpopulations'[2] at regional scales: Nansei, Japan (Critically Endangered); Eastern Africa coastal (Critically Endangered); New Caledonia (Endangered).
- The dugong is listed as migratory under Appendix II of the CMS Convention because: (1) individual animals must cross international boundaries on a regular basis at numerous locations throughout its range where Range States have contiguous coastal boundaries, and (2) it is listed as Vulnerable by IUCN.

Life history

- Dugongs are long-lived with a low reproductive rate, long generation time, and a high investment in each offspring.
- The age of sexual maturity is variable in both sexes but tends to be similar for males and females in the same population at the same time.
- Females bear their first calf when they are between six and 17 years old. The gestation period is long (around 12-14 months), with a usual litter size of one.
- The individual variation in dugong life history parameters seems to be linked to the status of their food supply, which in turn can be adversely affected by extreme weather events.
- Dugongs start eating seagrasses soon after birth and grow rapidly during the suckling period when they also receive milk from their mothers.
- A dugong population is unlikely to increase at more than 5% per year (mostly less), even under optimal conditions.

Genetics and population structure

- Dugongs exhibit considerable genetic diversity across their range and several major groupings can be recognized. This implies that regional populations exist that might need to be treated as distinct from one another in conservation planning.
- Dugongs in the Australian region, and especially in northern Australia, can probably be regarded as genetically healthy, with good levels of diversity at nuclear loci and in the mitochondrial genome. Such populations should be better able to respond to changing environmental pressures, including disease, than populations with lower genetic diversity.
- The very low mitochondrial diversity of dugong populations in the Western Indian Ocean, Palau and New Caledonia suggests relatively recent founding events. If low nuclear gene diversity is also typical of these populations, their long-

1 The number of dugong Range States listed under the CMS Dugong MOU depends on how the dependences of France are counted

2 'Subpopulation' is the technical term used by IUCN when making a regional assessment. 'Population' is the more accepted terminology and is used in this report, outside the context of an IUCN regional assessment.

term resilience might be reduced relative to Australian dugongs. This conclusion may also apply to some other populations for which genetic data are lacking.
- Within some regions, there is evidence of limited gene flow among populations. This limited gene flow occurs at a range of spatial scales, but few data are available for most parts of the dugong's range, restricting our ability to define the geographical extent of genetically connected populations. Without such information, it is difficult to use genetic data to inform the appropriate size of management units.
- Genetic data have strengths and limitations that need to be made explicit for correct interpretation and prior to using genetic information in conservation planning, which should be informed not only by genetics, but also information that may not be associated with genetic structure, including: movements, vital rates, jurisdictional boundaries, and major threats.

Habitat, ecology and behaviour

- The habitat requirements of dugongs generally comprise shallow (less than or equal to 20 m deep), subtropical or tropical coastal waters supporting subtropical and tropical species of seagrass.
- Dugongs are seagrass community specialists. Seagrass is their main food. They feed on nine of the ten genera, and probably on most of the approximately 26 species of seagrass that occur within their range. Dugongs exploit a diet that includes macro-invertebrates and algae at times, as well as seagrasses.
- Dugongs are obligate bottom feeders with ventrally opening mouths. They utilize two different feeding modes: excavating and cropping. Only excavating dugongs leave obvious feeding scars in the sediment.
- Dugongs are limited to the sub-tropics and tropics, presumably because of their sensitivity to low water temperatures.
- Dugongs are usually sighted as solitary individuals or as cows with single calves.
- Dugongs spend a high proportion of their time feeding.
- Loose feeding aggregations of more than 50 and up to several hundred dugongs, including cows with attendant calves, can occur at predictable locations, including Moreton Bay and Shark Bay in Australia and the Gulf of Bahrain/Gulf of Sulwa in the Gulf[3]. The determinants of these locations are not known. These aggregations do not occur at all locations that support large numbers of dugongs.
- Dugong vocalizations are social communication signals rather than navigational aids and are apparently particularly important between females and their nursing calves.
- Satellite tracking shows that some individual dugongs and cow-calf pairs can undertake directed movements of several hundred kilometres in a few days. There is no evidence of regular round-trip migrations of entire regional populations, although dugongs may make local adjustments in their space to adapt to seasonal changes in their environments. No migratory corridors have been identified.
- Periodic seagrass loss driven by extreme weather events is likely to be the most important driver of large-scale movements in dugongs.
- Extra limital reports of dugongs at locations such as the Cocos (Keeling) Islands and Fiji suggest that individual dugongs can move across deep ocean trenches.

Threatening processes

- Dugongs are vulnerable to anthropogenic influences due to their life history and their dependence on seagrasses in coastal habitats, which are often under pressure from human activities.
- The rate of dugong population change is most sensitive to changes in adult survivorship because of the lengthy period before first breeding, gestation period and the usual litter size of one, as well as the long period of lactation.
- Given the extensive range of the dugong, individuals are exposed to a variety of threats, some of which are locally unique and some which span its entire range.
- Threats to dugong survivorship include: interactions with fisheries; traditional harvest, vessel strikes, stranding of orphaned calves, and predation.
- Threats to dugong fecundity include: habitat loss and degradation, climate change, acoustic pollution, dugong tourism, diseases, parasites, contaminants and plastics.

3 In this chapter 'the Gulf' refers to the Arabian/Persian Gulf.

Methodologies

- Methodologies used to estimate and monitor dugong population size in ecologically useful time frames include: mark-recapture; abundance aerial surveys, distribution aerial surveys, vessel surveys, fisher surveys, citizen science, genetic techniques and land-based surveys.
- The most appropriate technique for a given location depends on its geography, spatial scale, the capacity of the survey team and the funding available. The results obtained using different techniques are generally not strictly comparable and most techniques are unsuitable for quantifying trends.
- Methodologies used to estimate the extent of seagrass meadows include: aerial photography, drop-down cameras, remote sensing, aerial surveys, intertidal walking, scuba-diving and snorkelling, towed cameras, and acoustic echo-sounding. The most appropriate technique for a given location depends on its geography, spatial scale, the capacity of the survey team and the funding available.
- Polygon (vector-based) maps have been used to estimate the area of seagrass habitat suitable for dugongs in each Range State in this report. Only seagrass areas that have been mapped with moderate to high confidence have been reported.

Blue Carbon

- Blue Carbon is the ecosystem service provided by the atmospheric carbon dioxide captured and stored in coastal vegetated ecosystems, including the dugong's seagrass habitats.
- The low-biomass seagrass meadows used by dugongs accumulate lower amounts of organic carbon than higher-biomass meadows. Nonetheless, the extent of the seagrass meadows in the dugong's range makes it relevant from a Blue Carbon perspective.
- Quantifying the Blue Carbon value of the dugong's seagrasses habitats and their potential to contribute to climate change mitigation at national or regional levels could provide further rationale for dugong habitat conservation.

1.1 Introduction

This chapter (Chapter 1: Global Context) provides background material that is relevant to all the regional chapters. It is not a comprehensive review of dugong biology. The treatment of each topic reflects the availability of synthesized material in published literature, rather than its importance to dugong conservation. For example, Genetics (Section 1.6) is relatively long, as it represents a new synthesis from which all the genetic information in the regional chapters is derived. In contrast, some of the other sections that are important to consider in a status and trends report, such as the sections on life history and movements, are shorter because the material has been synthesized in recent publications or is considered in detail in the regional chapters.

1.2 Evolutionary history

The dugong, *Dugong dugon*, is a medium-sized marine mammal, one of four extant members of the mammalian order Sirenia (sea cows; Marsh et al. 2011) and the only surviving member of the family Dugongidae. The other three extant species of sea cow are manatees, family Trichechidae, all of which occur in tropical and sub-tropical countries on both sides of the Atlantic Ocean. The African manatee, *Trichechus senegalensis*, occurs in 21 tropical countries in West Africa. The West Indian manatee, *Trichechus manatus*, has two sub-species: the Florida manatee, *Trichechus manatus latirostris*, which occurs in the southeastern United States and the Bahamas, and the Antillean manatee, *Trichechus manatus manatus*, which has a range across 19 countries from Mexico to Brazil. The Amazonian manatee, *Trichechus inunguis*, exists in four countries in the Amazon Basin.

The fifth recent sirenian was another dugongid, the giant Steller's sea cow, *Hydrodamalis gigas*, which was once distributed widely around the coastal waters of the North Pacific Ocean. It was rendered extinct in the 18th century, 27 years after its last remnant population was discovered by Europeans in the coastal waters of two islands near the Kamchatka Peninsula of Siberia (Marsh et al. 2011).

Heritage and Seiffert (2022) provide the most complete, recent review of the evolutionary history of the Sirenia. They used all publicly available genetic data as well as morphological and fossil data (including inferred ages of fossils) and geographical data in a 'total evidence' approach. Their analysis suggests that the lineage ultimately giving rise to the genus *Dugong* originated in the Atlantic and moved from near modern-day Florida into the Pacific between 12 and 2.8 mya, when the Central American Seaway closed. The modern species, *Dugong dugon*, might have originated as a result of long-distance dispersal of an ancestor across the Pacific, followed by range expansion from the Indo-Australian region across the Indo-West Pacific.

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1.3 Geographic range

The dugong's vast range spans coastal and island waters across approximately 135 degrees of longitude in the Indo-West Pacific and around 50 degrees of latitude; extending approximately 25 degrees both north and south of the equator (Marsh and Sobtzick 2019) (Figure 1.1).

The following countries and territories are listed as Range States under the Dugong MOU (UNEP/CMS Secretariat 2015): Australia, Bahrain, Bangladesh, Brunei Darussalam, Cambodia, China, Comoros, Djibouti, Egypt, Eritrea, France, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kenya, Kuwait, Madagascar, Malaysia, Maldives, Mauritius, Mayotte (France), Mozambique, Myanmar, New Caledonia (France), Oman, Pakistan, Palau, Papua New Guinea, Philippines, Qatar, Saudi Arabia, Seychelles, Singapore, Solomon Islands, Somalia, Sri Lanka, Sudan, Thailand, Timor-Leste, United Arab Emirates, United Republic of Tanzania, Vanuatu, Viet Nam, and Yemen.

Chapter 11 provides an updated list of Range States based on the information in Chapters 2-10 and an updated range map.

- The dugong's vast range spans coastal and island waters extending across approximately 135 degrees of longitude in the Indo-West Pacific and around 50 degrees of latitude; approximately 25 degrees both north and south of the equator.
- There are currently 48 countries and territories listed as Range States under the Dugong MOU[1].

1.4 Conservation status

The IUCN lists the dugong as Vulnerable to Extinction at a global scale (Marsh and Sobtzick 2019). IUCN has also listed the following 'subpopulations'[4] at a regional scale: Nansei, Japan (Critically Endangered; Brownell et al. 2019); Eastern Africa Coast (Critically Endangered; Trotzuk et al. 2022); New Caledonia (Endangered; Hamel et al. 2022). Chapter 11 lists other 'subpopulations' that are likely to be eligible for listing by IUCN.

The dugong is listed as migratory under Appendix II of the CMS because: (1) individual animals must cross international boundaries on a regular basis at numerous locations throughout its range where Range States have contiguous coastal boundaries, and (2) it is listed as Vulnerable by IUCN.

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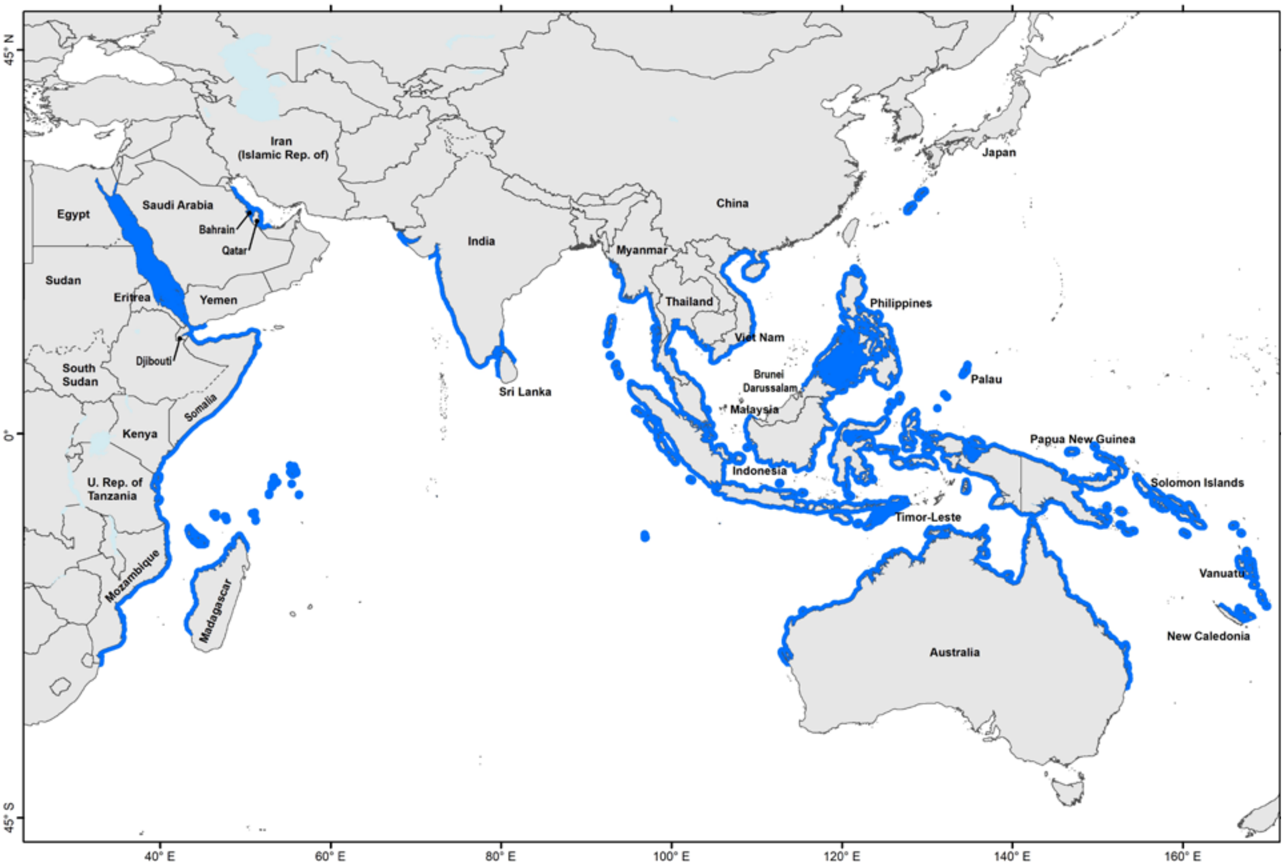
- The dugong is listed as migratory under Appendix II of the CMS because: (1) individual animals must cross international boundaries on a regular basis at numerous locations throughout its range where Range States have contiguous coastal boundaries, and (2) it is listed as Vulnerable by IUCN.

4 'Subpopulation' is the technical term used by IUCN when making a regional assessment. 'Population' is the more accepted terminology and is used in this report, outside the context of an IUCN regional assessment.

Figure 1.1. Map of the dugong's range based on Marsh and Sobtzick (2019). The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



1.5 Life history

The information on dugong life history and reproductive biology originally came from carcass analysis (Marsh 1980; Marsh et al. 1984 a,b,c) and has been subsequently enhanced by research on live dugongs obtained as part of the longitudinal study of dugongs in Moreton Bay, Queensland, Australia by Lanyon and her co-workers (see Lanyon et al. 2019 for a summary), and particularly the studies on dugong reproduction by Burgess et al. (2012 a, b, 2013); and Lanyon and Burgess (2014).

Marsh (1980) adapted the age-determination method developed for pinnipeds and toothed cetaceans to estimate the age of dugongs from the number of growth layer groups in their tusks and demonstrated that dugongs are long-lived with a low reproductive rate, long generation time, and a high investment in each offspring. The oldest dugong whose tusks have been examined for age determination was estimated to be 73 years old when she died (Marsh 1995).

The following information on dugong life history obtained from carcass analysis is based on Marsh et al.'s (2011) synthesis. The age of sexual maturity is variable in both sexes but tends to be similar for males and females in the same population at the same time. The youngest male with mature testes in the age-estimated sample was seven years old and the oldest male with immature or recrudescent (regenerating) testes was 19 years. Tusk eruption is a secondary sexual characteristic in males. The oldest male with unerupted tusks was aged 18.

Females do not bear their first calf until they are at least six and up to 17 years old (Marsh et al. 2011). The gestation period is long (12 – 14 months) and the usual litter size is one. There are occasional twins but no evidence of adoption (Marsh 2022). The calf suckles for an estimated 14 – 18 months or longer, and the period between successive births is spatially and temporally variable with mean estimates ranging from 2.5 to 6.8 years (Table 6.6 in Marsh et al. 2011).

The variation in dugong life history parameters seems to be linked to the status of their food supply, which in turn can be adversely affected by extreme weather events (Fuentes et al. 2016; Marsh et al. 2022), such as prolonged rain associated with the La Niña phenomenon, floods, cyclones, and marine heat waves. For example, after the 1992 loss of more than 1,000 km^2 of seagrass in Hervey Bay, Queensland, Australia, associated with two floods and a cyclone (Preen et al. 1995), the proportion of dugongs classified as calves fell from 22% in 1988 to 2.2% in 1993 (Preen and Marsh 1995). Sobtzick et al. (2012) did not see any calves during an aerial survey of the southern Great Barrier Reef (GBR) region in late 2011, after a series of extreme weather events in the previous summer, including major floods and three cyclones. The timing of this reduction in percentage of calves suggested a reduction in calf survivorship. After a marine heatwave in 2010 – 2011 killed more than 1,000 km^2 of temperate seagrass *Amphibolis antarctica* (Kendrick et al. 2019) in Shark Bay (Western Australia), Bayliss et al. (2018) recorded one calf only among the 356 dugongs sighted in high-abundance survey blocks.

Seagrass loss may not always be associated with extreme weather. An extensive seagrass dieback of unknown cause in Torres Strait (Australia) in the 1970s led to dugongs (Nietschman and Nietschman 1981) being unable to accumulate the fat stores required to become pregnant and/or sustain pregnancy (Marsh and Kwan 2008). Recruitment failure after seagrass loss may also lead to changes in fecundity lasting several years, a result that accords with Bayliss et al. (2018).

Dugongs start eating seagrasses soon after birth (Marsh et al. 1982; Thibault et al. 2024) and grow most rapidly during the suckling period when they also receive milk from their mothers. Population simulations indicate that even with the most optimistic combinations of life-history parameters (e.g., low natural mortality and no human-induced mortality), a dugong population is unlikely to increase by more than 5% y^{-1} (Marsh et al. 2004). Most rates of increase, if they occur will be much less than 5%.

- Dugongs are long-lived with a low reproductive rate, long generation time, and a high investment in each offspring.
- The age of sexual maturity is variable in both sexes but tends to be similar for males and females in the same population at the same time.
- Females bear their first calf between six and 17 years old. The gestation period is long (12-14 months). The usual litter size is one.
- The individual variation in dugong life history parameters seems to be linked to the status of their food supply, which in turn can be adversely affected by extreme weather events.
- Dugongs start eating seagrasses soon after birth and grow rapidly during the suckling period when they also receive milk from their mothers.
- A dugong population is unlikely to increase at more than 5% per year even under optimal conditions.

1.6 Genetics and population structure

1.6.1 Introduction

Studies of free-ranging animals using genetic techniques can provide information available in no other way on historical aspects of a species' evolution, population structure (i.e., whether local/regional populations exist and the extent of gene flow among them), past and present population size, breeding systems and the extent of inbreeding, gender-specific dispersal and more. For a general text on the topic, see Frankham et al. (2010).

Different types of genetic data exist and have their own associated strengths and weaknesses. Most of the relevant genetic studies on dugongs have used DNA sequence data from the mitochondrial genome and/or allele-based studies using frequencies of alleles in the nuclear genome (See Text Box 1.1). Data from mitochondrial genomes are primarily informative about female movements and evolutionary lineages, but other types of information can also be inferred from them (DeSalle et al. 2017). Nuclear genomes are biparentally inherited and can provide a more complete picture of population structure and status than mitochondrial data do. Comparisons of population differentiation using both mitochondrial data and nuclear genome/allele data can be informative about sex-biased gene flow.

Population genetics has traditionally used small, defined portions of the genomes (loci). With the improved technology now available, the field is maturing into 'population genomics' (e.g., Hohenlohe et al. 2021). A genomics approach samples far more of the genome to obtain stronger inferences of population processes (Hogg 2024). To date, this approach has been little used for dugongs but is the direction that future research needs to take (e.g., Baker et al. 2024; Tian et al. 2024; see also Sharko et al. 2021 for a study on Steller's Sea cow; Hoelzel et al. 2024, northern elephant seals; and Mather et al. 2020 for an overview).

Genetic studies on dugongs fall into several categories. Phylogenetic studies provide insights into the ways in which species have spread geographically and diverged through time. Population-genetic analyses give an indication of continuing movement and gene flow among populations. Gene flow is important for maintenance of genetic diversity in populations, especially as populations decrease in size.

Less directly related to dugong population genetics, genetic tools have been used to evaluate the fecal microbiota of dugongs, which may vary according to regional seagrass diversity and/or individual dietary choices (Mikkelsen et al. 2024). In a preliminary study, Baker (2012) indicated that fecal DNA might be useful for identifying species of seagrass consumed.

1.6.2 Physical sampling considerations

Dugong DNA has been successfully extracted from: (1) fresh or appropriately preserved tissue samples from dugongs (e.g., Blair et al. 2014), (2) bones and other material held in museums (e.g., Plön et al. 2019; McCarthy 2018), (3) bones from archaeological sites or refuse heaps (e.g. Haile 2008), (4) faeces collected in the ocean (Tikel et al. 1996; Baker, 2012; Tol et al. 2021; Ooi et al. 2023; Ozawa et al. 2024), and (5) seawater collected in the vicinity of dugongs (H. Heng and J. Lanyon unpublished data). Fresh tissue samples generally provide the highest quality material for genetic analysis, but recently developed techniques to recover and extract high quality DNA from fresh floating faeces (Ooi et al. 2023) and seawater hold promise for demonstrating the presence of dugongs in an area (for examples, see Hunter et al. 2018; Sigsgaard et al. 2020).

1.6.3 Range-wide phylogeography and population structure of the dugong

Mitochondrial sequence data were one focus of initial genetic studies on dugongs (theses by Tikel 1997; Palmer 2004; McDonald 2005; Baker 2012; Bushell 2013; McCarthy 2018; McGowan 2019 and see Blair et al. 2014; McGowan et al. 2023a). Partly for legacy reasons, therefore, virtually all subsequent studies have also generated mitochondrial data from the same, short part of the mitochondrial genome, thus building up a substantial database of sequences from regions across almost the entire geographical range of the dugong. The unrooted haplotype network in Figure 1.2 is derived from 914 such sequences of length (excluding alignment gaps) 410 base pairs (bp). Although this represents only a small portion of the mitochondrial genome, such data have provided useful insights.

The network in Figure 1.2 shows several major regional haplogroups. Two of these are found in Australian waters (the 'restricted' and 'widespread' haplogroups). The Western Indian Ocean (WIO) haplogroup is almost the only haplogroup found across the range of the dugong in East Africa, the Red Sea, Arabian Gulf and most of India. The Andaman Sea coast of Thailand has yielded samples with sequences assigned here to three haplogroups: the Andaman, East Indian Ocean and Northeastern haplogroups. The last of these is found across a large area from the Andaman coast of Thailand to Japan and Palau, and south to Indonesia. The amount of variation within each haplogroup varies considerably. Common statistics used to describe variation within a haplogroup are 'haplotype diversity' (h), 'nucleotide diversity' (π) and 'number of variable sites' (S). Values for these are shown for some haplogroups in Figure 1.2. Despite including the largest number of sequences, the Australian restricted haplogroup has relatively low values for haplotype and nucleotide diversity. Further interpretation of that result can be found in Chapter 10.

Haplogroups have likely diverged because of vicariance events, which have divided the dugong's range in the distant past. Within each haplogroup, additional variation has resulted from ongoing population-level factors. Interpretation and possible explanations are provided in relevant chapters. If Heritage and Sieffert (2022) are correct, then the dispersing ancestors of dugongs first encountered suitable habitat in the Australasian and/or Northwest Tropical Pacific regions. Certainly, the greatest mitochondrial diversity in dugong populations occurs in northern Australia, likely consistent with a long evolutionary history there.

Text Box 1.1 Brief definitions of some genetic concepts and terms relevant to this report

An **Allele** is a sequence variant at a specific location (locus) on a chromosome. The variant can involve a single nucleotide site (i.e., a single-nucleotide polymorphism) or a region of sequence.

Gene flow is the transfer of genetic material across generations and among individuals and/or populations. It occurs as a consequence of sexual reproduction and genetic recombination.

Genetic health, in the context of this report, is concerned with the level of genetic diversity within a population. High levels of diversity confer more resilience on a population, greater evolutionary adaptability and help mitigate the effects of inbreeding. If a population is greatly reduced or experiences a bottleneck, diversity is lost, inbreeding increases, heterozygosity is reduced and favourable alleles may be lost due to random chance. If this persists for too many generations, then genetic factors are among those that will hasten the species towards the 'extinction vortex' (Gilpin and Soulé 1986).

Genomics is a field of biology focused on studying all the DNA of an organism i.e., its genome. Such work includes identifying and characterizing all the genes and functional elements in an organism's genome as well as how they interact.

Mitochondria are organelles within the cytoplasm of cells. Their genomes are small, haploid, rapidly mutating and maternally inherited. All individuals inherit only their mother's mitochondrial genomes. Any unique mitochondrial sequence is referred to as a **haplotype**. Clusters of similar haplotypes are called a **haplogroup** or a **maternal lineage**.

The **nuclear genome** contains most of an individual's genetic material, housed on one set of chromosomes from each parent. Chromosomal recombination and sexual reproduction cause a random selection of each parent's genetic material to be passed on to the offspring.

Heterozygosity is the extent to which different alleles occur at loci across the genome within an individual and/or across a population. In the nuclear genome, containing two sets of chromosomes, any given locus is represented twice. If the DNA sequence differs between chromosomes at a locus, the individual is **heterozygous** at that locus. If the sequence does not differ, the individual is **homozygous** at that locus. High levels of heterozygosity tend to increase the evolutionary fitness of an individual and the resilience of a population. See 'genetic health' above.

Locus (pl. loci). This term simply refers to a specific place on a chromosome. See 'heterozygosity' above.

Microsatellites are a class of genetic marker based on regions of DNA with tandem, short repeat sequences. Such regions are very abundant in animal genomes and experience high mutation rates (usually in the form of loss or gain of repeats), rendering them highly variable and suitable for identification of individuals and population-genetic analyses.

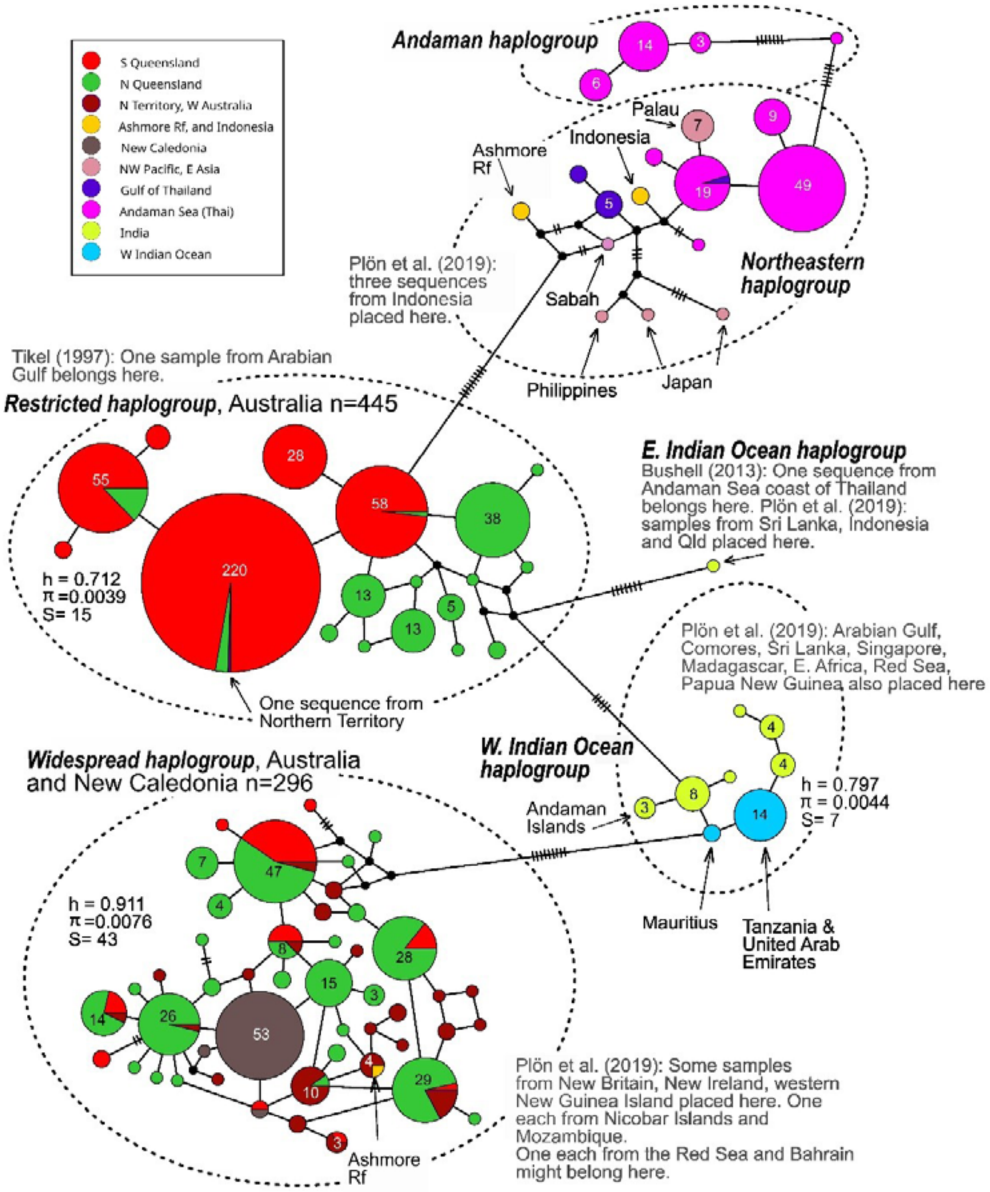
Phylogenetics is the study of evolutionary relationships of a group of organisms through time. Such studies can apply to individuals and populations of a single species (as here, for the dugong) or to taxa at higher levels (genera, families etc.). Phylogenetic analyses are typically presented as phylogenetic trees or as a network diagram (as here, in Figure 1.2).

Population-genetic studies reconstruct patterns of inheritance through generations and across populations. From this form of analysis various parameters can be estimated, primarily population structure and levels of gene flow, extent of inbreeding and genetic diversity.

Single-nucleotide polymorphism occurs when homologous individual nucleotides (i.e., at the same locus) differ between homologous chromosomes.

Sea-level changes through glacial cycles must have influenced present-day distribution and diversity of dugong haplogroups (Figure 1.3). The Arabian/Persian Gulf and much of the Red Sea were dry land or estuarine wetlands as recently as the last glacial maximum (around 20 thousand years ago [kya]; Ludt and Rocha 2014). Similarly, suitable habitat would have been non-existent or limited around New Caledonia at the eastern extremity of the dugong's current range and along the coast of East Africa in

Figure 1.2. Median-joining network based on an alignment of 914 mitochondrial partial control region sequences of dugongs from across the range of the species. The alignment without gaps is 410 bp. The sequences included are those listed in Garrigue et al. (2022; Table S2), plus several previously unpublished sequences from the United Arab Emirates (UAE, twelve identical sequences, GenBank accession number PP317829), Palau (six additional sequences identical to Genbank accession number EU835816), Tanzania (GenBank accession numbers PP317827 and PP317828). Note that many individuals often shared the same haplotype, represented in GenBank by a single accession number. For example, in the 'restricted' Australian haplogroup, the largest circle (GenBank EU835761) represents a haplotype found in 220 individual dugongs. Shorter sequences are also available but were not included in the construction of the network (e.g., Tikel 1997; Baker 2012; Plön et al. 2019), but their likely placements within the network are indicated using grey text. Some of the published sequences require confirmation. There are discrepancies between sequences, apparently from the same Thai dugongs, published by Bushell (2013) and by Poommouang et al. (2021).



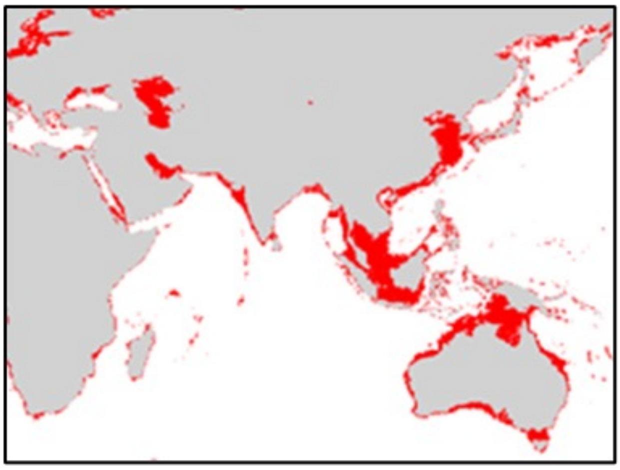
the far west (Ludt and Rocha 2014). There was no sea passage between northern Australia and the island of New Guinea from around 115 kya to around 7 kya (Blair et al. 2014). For much of that period, the continental shelf was exposed and there was very little suitable habitat for dugongs along the east coast of Queensland (McGowan et al. 2023a; see also Chapter 10). Glacial maxima also drained the Gulf of Thailand and exposed the Sunda and Sahul shelves (Voris 2000; Ludt and Rocha 2014), severely limiting tropical marine connectivity between the Indian and Pacific Oceans. The low mitochondrial diversity in the Western Indian Ocean and New Caledonia might reflect post-glacial recolonization of these areas by several dispersing individuals.

Note: The network in Figure 1.2 was drawn using PopArt (https://popart.otago.ac.nz) which required that ten sites were removed because of alignment gaps. Lines connecting haplotypes are approximately proportional to the number of mutation changes inferred as occurring along each. In the case of the "widespread" Australian haplogroup, the density of the network means that some lines cross others, and that some single-mutation connections are drawn disproportionally long. Numbers of mutations when more than 1 are indicated by hatch marks across the lines. The area of each circle is proportional to the number of individual dugongs it represents (shown in the circle if more than 2). Small black circles are median vectors. h = haplotype diversity, π = nucleotide diversity, S = number of segregating (variable) sites in the DNA sequence alignment being investigated.

1.6.4 Intra-regional population structure

Habitats suitable for dugongs tend to be discontinuous, with local populations within a region often separated by considerable distances (Section 1.7). The extent to which such local populations exchange genes via dispersing individuals is of great interest. This information indicates whether locally extirpated populations are likely to be re-established by immigrants from elsewhere. Conversely, if dispersal is sufficiently frequent, a localized 'sink' (e.g., due to excess anthropogenic mortality) could in theory deplete nearby 'source' populations as well.

Figure 1.3. Shorelines in the region that includes the contemporary range of the dugong at the last glacial maximum (25,00-15,000 BP). The Last Glacial Maximum land mass is shown in red. Modified from the global map in Ray and Adams (2001) ISSN 1363-5387. Reproduced under Creative Commons Attribution 3.0 Unported Licence.



To date, most intra-regional studies have focussed on Australia (e.g., McGowan et al. 2023), with some inferences also being made about dugong populations in Thailand (Chapter 6) and New Caledonia (Chapter 9). In the coastal waters of eastern Queensland (Australia), some restriction to gene flow has been inferred at various spatial scales (Chapter 10). In Thailand, there seems to be limited gene flow between the Andaman Sea and Gulf of Thailand populations on opposite sides of the Isthmus of Kra, the narrow neck of land connecting the Malay Peninsula to the Asian mainland.

1.6.5 Gender-specific dispersal?

In many mammal species, males tend to disperse more frequently than females (Dobson 1982). Evidence of this phenomenon in dugongs has been equivocal. McDonald (2005) found preliminary evidence of male-biased dispersal in Queensland waters (Chapter 10). Seddon et al. (2014) did not find any such evidence in the southern Queensland populations, whereas Cope et al. (2015) found some support for male dispersal in the same populations based on pedigree analysis. Bushell (2013) provided evidence for male-biased dispersal in Thailand (Chapter 6).

1.6.6 Historical and recent population changes and 'genetic health'

Virtually all field surveys indicate declines in dugong populations across their range, with the possible exceptions of the Gulf (Chapter 4) and some regions in northern Australia (Chapter 10). Population size (genetically effective population, Ne) and population fluctuations can be inferred from genetic data, subject to various assumptions (Wang et al. 2016). Blair et al. (2014) estimated changes in the Australian widespread and restricted haplogroups through time (Chapter 10). The same approaches have been used by others: Poommouang et al. (2021) inferred post-glacial population decline in the Thai Andaman coast population. Seddon et al. (2014) used microsatellite data to infer values of N_e in southern Queensland.

Tian et al. (2024) and Baker et al. (2024) used genomic approaches, which make it possible to use different and novel analytical techniques. Dramatic reductions have been inferred in numbers of dugongs at all sampled locations along the eastern Queensland coast (and Exmouth Bay in Western Australia) since about 100 kya (as retreating sea levels exposed the shallow continental-shelf habitats of seagrasses). The single genome from the Critically Endangered Nansei (Japanese) 'subpopulation' (Brownell et al. 2019) indicated continuous population decline for the last 400 kya (Tian et al. 2024).

Declining populations would be expected to be reflected in declining numbers of mitochondrial haplotypes through time. Reduced mitochondrial haplotype diversity was demonstrated by Plön et al. (2019) for Indian Ocean samples collected after 1950 (samples were from as early as 1827). A decline in diversity at nuclear loci through time was noted by Poommouang et al. (2021) using samples collected from Thai populations between 1990 and 2019.

Heterozygosity, calculated from nuclear genome data, is a common measure of genetic diversity (and hence of 'genetic health') within individuals and populations. There is no absolute value of heterozygosity that can be declared as 'healthy': that opinion must be based on comparisons with other appropriate populations or species. Tian et al. (2024) commented that levels of heterozygosity and low inbreeding in northern Australia were likely indicative of healthy populations. Seddon et al. (2014) inferred low levels of inbreeding in southern Queensland (Chapter 10). Poommouang et al. (2022) found some evidence of inbreeding in Thai waters, whereas Bushell (2013) did not (Chapter 6). Information on levels of inbreeding is lacking for most dugong populations.

1.6.7 Strengths and limitations of genetic data

Most dugong genetic data published to date consists of mitochondrial sequences. High mitochondrial haplotype diversity is likely correlated with high nuclear genome diversity and heterozygosity, and with low levels of inbreeding. But this correlation remains to be demonstrated empirically for dugongs and is not invariable among animal species (reviewed in Saitoh 2021). Saitoh (2021) also noted that species assigned higher-risk conservation status had significantly lower values of both mitochondrial and nuclear haplotype diversity but that the explanatory power of their conservation-status rank was low, especially for mitochondrial diversity. The very low mitochondrial diversity evident in New Caledonia (Chapter 9), Palau (Chapter 9) and in many parts of the WIO (Chapters 2-5) is of concern and might imply low nuclear heterozygosity and increased risk of inbreeding. In the case of New Caledonia, microsatellites demonstrated low nuclear diversity, but the situation for the WIO (and Palau) is unknown. A priority for future research should be investigation of nuclear heterozygosity and inbreeding in dugong populations, and especially in those with low mitochondrial diversity.

Parameters such as effective population size and population fluctuation through time can be inferred from mitochondrial sequence data. But these estimates are based on theories that make assumptions about demographic processes and are sensitive to sample size, sequence length and the value selected for mutation rate. Some of this is discussed in Blair et al. (2014). Inferences from nuclear data, and especially whole-genome data, are likely to be more robust.

The effects of sustained bottlenecks and reduction in genetic diversity due to population decline might not be apparent for decades in the case of long-lived species such as dugongs. If major reductions in populations have occurred within the lifetime of sampled individuals, those individuals will still collectively retain much of the pre-bottleneck level of diversity. This might explain the failure of McCarthy (2018) to find a marked reduction in genetic diversity in an Australian locality sampled before and after a major reduction in the local dugong population (Chapter 10). Genetic data might raise no cause for concern. However, with continued low population size, the stochastic effects of genetic drift and inbreeding will increase and accelerate loss of diversity (Bradke et al. 2021; see also Hoelzel et al. 2024 for the case of the northern elephant seal). In addition, the usual analytical methods for assessing the presence of population bottlenecks from genetic data might have low power, especially in long-lived species (Bradke et al. 2021) such as the dugong.

Dugongs exhibit considerable genetic diversity across their range, and several major mitochondrial haplogroups can be recognized. Genetic data can potentially provide information pertinent to deciding on the appropriate spatial scale for monitoring and managing of dugong populations. Nonetheless, as pointed out by Lowe and Allendorf (2010), genetic connectivity, which depends primarily on the absolute number of dispersers among populations is not the same as demographic connectivity, which depends on the relative contributions to population growth rates of dispersal compared with local recruitment and the survival and reproduction of residents. As explained in Section 1.7 the most important driver of larger-scale movements of an ecologically significant number of dugongs is likely to be periodic seagrass loss driven by extreme weather events. These animals are unlikely to be breeding (Section 1.5) and so may not affect the genetic structure of the population. Thus, factors additional to genetic connectivity need to be considered in deciding on the appropriate spatial scales for monitoring and managing dugongs, including movements, vital rates, jurisdictional boundaries, and major threats, which may not reflect genetic structure (see Cope et al. 2015).

- Dugongs in the Australian region, and especially in northern Australia, can probably be regarded as genetically healthy, with good levels of diversity at nuclear loci and in the mitochondrial genome. Such populations should be better able to respond to changing environmental pressures, including disease, than populations with lower genetic diversity.
- The very low mitochondrial diversity in the Western Indian Ocean, Palau and New Caledonia suggests relatively recent founding events. If low nuclear gene diversity is also typical of these populations, their long-term resilience might be reduced relative to Australian dugongs. This conclusion may also apply to other populations for which genetic data are lacking.
- Within some regions, there is evidence of limited gene flow among populations. Such limitations to gene flow occur at a range of spatial scales, but few data are available for most parts of the dugong's range, restricting our ability to define the geographical extent of genetically connected populations. Without such information, it is difficult to use genetic data to indicate the appropriate size of management units.
- Genetic data have strengths and limitations that need to be made explicit for correct interpretation, and prior to using genetics in conservation planning, which should be informed not only by genetics but also information that may not reflect genetic structure, including: movements, vital rates, jurisdictional boundaries, and major threats.

1.7 Habitat, ecology and behaviour

Dugongs mainly occur in shallow coastal waters supporting subtropical and tropical species of seagrass (Marsh and Sobtzick 2019). The largest seagrass meadows are located in areas with shallow (less than 100 m depth) enclosed seas (e.g., Arabian/Persian Gulf) or where the continental shelf supports large shallow gulfs (e.g., Gulf of Mannar–Palk Bay region, India and Sri Lanka; Shark Bay and Gulf of Carpentaria, Australia) and lagoons (e.g., Great Barrier Reef, Australia; McKenzie et al. 2020).

Dugong habitats tend to be fragmented and are often separated by extensive open coastal waters devoid of seagrasses e.g., Indian Ocean coast of Somalia north of Bajuni Archipelago (Chapter 2); most of the Indian Ocean coast of the Arabian Peninsula (Chapters 3 and 4), most of the Indian Peninsula outside of the Gulf of Kutch, Gulf of Mannar–Palk Bay, and the Andaman and Nicobar Islands (Chapter 5).

Seagrasses in coastal areas within the dugong's range may occur in waters deeper than those in which dugongs feed. For example, in the Great Barrier Reef World Heritage Area (GBRWHA), seagrass has been recorded to 76 m in clear water (Carter et al. 2021), whilst over 90% of dugong sightings on systematic large-scale aerial surveys have been in waters less than 20 m deep, with the majority in waters less than 10 m deep (Marsh and Cleguer unpublished data); only a few dugong feeding trails have been recorded in deeper water, to 33 m (Lee Long et al. 1996). In nearby Torres Strait, where a high proportion of dugongs have been sighted in the 5 – 20 m depth category during aerial surveys, few animals were sighted in waters deeper than 20 m (1% in 2006, 4% in 2011 and 3% in 2013; Hagihara et al. 2018). Nonetheless, dugongs can be sighted far from the coast where the continental shelf is wide and shallow. For example, a single dugong was photographed using a drone near Raine Island on the edge of the continental shelf around 130 km from the coast of Cape York in the northern Great Barrier Reef (A. Dunstan personal communication via email to Marsh 2022).

1.7.1 Feeding ecology

Even though dugongs exploit a relatively diverse diet, they are seagrass community specialists and their diet is comprised principally of seagrasses (Marsh et al. 2011, 2018). They feed on nine of the ten genera, and probably on most of the approximately 26 species of seagrass that occur within their range (Green and Short 2003), except the robust, highly fibrous, temperate seagrasses *Posidonia australis* and *Posidonia coriacea*. The relative importance of various seagrasses to the diet of the dugong differs among locations and may change within the same location during times of seagrass loss from plant dieback and extreme weather events (Marsh et al. 2011). When seagrass communities have been damaged by extreme weather events, dugongs apparently subsist largely on algae, if it is available, as evidenced by analysis of stomach contents (Spain and Heinsohn 1973; Marsh et al. 1982). Dugongs also occur on algal reefs in some locations. Whiting (2002) observed dugongs closely associated with algal-covered, rocky reefs in tropical Northern Territory, Australia over long periods, and feeding on macro algae (*Sargassum* spp., *Padina* spp., *Turbinaria* spp.).

Dugongs also deliberately eat infaunal invertebrates associated with seagrass communities, at least in the subtropics. These animals include thin-shelled burrowing mussels (*Botula vagina*) and possibly sea pens (*Virgularia*), ascidians (especially *Sycozoa pulchra*; Anderson 1989), unidentified chaetopterid worms (Preen 1995) and other metazoans including polychaetes (Thibault et al. 2024).

Dugongs have ventrally opening mouths (Marsh et al. 2011) and are obligate bottom feeders. Their mouthparts are better able to masticate soft and delicate seagrasses than fibrous seagrasses (Lanyon and Sanson 2006 a,b).

Dugongs use two different seagrass feeding modes: excavating (Figure 1.4) and cropping (*sensu* Wirsing et al. 2007a). They crop seagrass leaves when the seagrass roots and rhizomes are not accessible because of the size and structure of the plant, the hardness of the sediment or the rhizomes being too tough to consume e.g., the rhizomes of fibrous seagrasses, such as *Amphibolis antarctica, Enhalus acoroides, Thalassia hemprichi*i. Dugongs excavate whole plants with accessible roots and rhizomes, presumably because of the nutritional advantages in eating both the above- and below-ground components and/or the efficiency of harvesting both on a single foraging dive (see Marsh et al. 2011 for a comprehensive discussion).

Excavating dugongs leave distinct feeding scars in the sediment, termed feeding trails (Figure 1.5), which are often used as evidence of recent dugong feeding. However, the absence of feeding trails does not mean that dugongs are not using a seagrass meadow for feeding. Cropping scars are much more difficult to detect. Nonetheless, Nakanishi et al. (2008) reported that dugongs feeding on *E. acoroides* in Thailand cropped the seagrass at a constant above-ground height, leaving distinctive marks on the leaves.

As summarized in Marsh et al. (2011), some researchers who have analysed dugong digesta or studied dugong feeding behavior, have inferred that dugongs likely selectively target pioneer, low-biomass seagrass genera, especially *Halodule* and *Halophila*, in preference to more fibrous climax genera, such as *Zostera (Nanozostera)*[5] or *Thalassia*. Unfortunately, most of these claims about diet selectivity are not supported by confirmatory data on the biomass or nutrient concentrations of the available seagrasses, and no food choice experiments have been conducted on wild

Figure 1.4. Dugong feeding by excavating in a seagrass meadow accompanied by scavenging juvenile golden trevally (*Gnathanodon speciosus*) and a diver. Ahmed Shawky photograph; reproduced with permission.

Figure 1.5. Dugong feeding trails in a low-biomass, intertidal seagrass meadow at Yule Point, Queensland, Australia. The seagrass between the feeding trails enables vegetative recovery. Len McKenzie photograph; reproduced with permission.

5 Some species of *Zostera* have been reclassified in the genus *Nanozostera* by Sullivan and Short (2023).

dugongs. While there is some evidence to support these claims at certain locations (e.g., Moreton Bay, Queensland, Australia in summer; Preen 1992), there is counter evidence from other locations (Tol et al. 2016; Sheppard et al. 2010), indicating that it is inappropriate to generalize, especially as the determinants of dugong food quality are unknown (Aragones et al. 2006, 2012). For example, Tol et al. (2016) demonstrated that in the Cairns and Townsville regions of tropical Queensland, dugongs consumed seagrass species in proportion to their availability, with biomass being the primary determining factor; species composition and/or nitrogen content influenced consumption to a lesser degree. Budiarsa et al. (2021) documented inter-annual changes in feeding trails in seven intertidal mixed-species seagrass meadows in Balikpapan Bay, Indonesia. The interannual pattern was positively associated with seagrass biomass, the above-ground/below-ground biomass ratio, and wind speed (the bay provided some shelter from the wind). Rasheed et al. (2017) reported that the probability of the presence of dugong feeding trails in five meadows in the Gladstone region (in sub-tropical Queensland) was positively correlated with increased percentage cover and above-ground biomass of seagrass (which are highly correlated) of the seagrass community dominated by *Zostera (Nanozostera) muelleri*, although a large proportion of the spatial and temporal variation was unexplained. There were no strong seasonal patterns of meadow use. These three studies all assumed that excavating was the only feeding mode at the study sites, an untested assumption. In contrast, the leaves of *T. hemprichii*, a persistent species, on which dugongs feed by cropping, are an important food in Torres Strait (Johnstone and Hudson 1981; André et al. 2005), the area that supports the world's largest dugong population (Chapter 10).

Thus, the dugong's feeding preferences clearly vary with location, and likely by time of year within location. Seagrass biomass is also not a reliable indicator of habitat quality. For example, Bayliss et al. (2019) found that either the extent or percentage cover of sparse seagrass habitat was generally the most predictive of all the seagrass mapping variables for dugong distribution and abundance in Shark Bay.

D'Souza et al. (2013) reported that seagrass shoot densities of meadows used by dugongs in the Andaman and Nicobar Islands were more homogeneous than unoccupied meadows with similar species composition. These results suggest that dugongs find it energetically efficient to forage in areas with homogeneous seagrass cover.

Sheppard et al. (2010) conducted the most comprehensive study of factors influencing dugong diet selectivity in winter at a single site (24 km^2), an intensively used seagrass meadow in subtropical Hervey Bay, Queensland, Australia. They compared the dugongs' use of space (which they assumed was an index of their consumption of seagrass) with the species composition, biomass, and nutrient characteristics of the seagrass landscape, which they mapped in detail (Sheppard et al. 2007). Dugongs were associated with low biomass seagrasses *Halodule uninervis* and *Halophila spinulos*a only on daytime low tides, when their habitat choices were limited by tides and possibly vessel traffic, and with *Halophila ovalis* only at intermediate tides at night. The tracked animals tended to avoid areas supporting high densities of *H. spinulosa* and *Zostera (Nanozostera) muelleri*. These results are consistent with some of Preen's (1992) findings from Moreton Bay (Queensland, Australia) but demonstrate that the selection of seagrass by dugongs is probably influenced by many factors in addition to the prevalence of certain species, and that well designed studies in which all assumptions are explicit are required to determine which factors are influential at a particular site.

No sex or body-size differences in the diets of weaned dugongs have been detected from the analysis of mouth (Johnstone and Hudson 1981) or stomach contents (Marsh et al. 1982). Calves suckle from their mothers for 18 months or longer after birth (see Section 1.5), even though individual calves may start eating seagrass (including the rhizomes) within a few weeks of birth (Marsh et al. 1982). In Moreton Bay, calves are observed to remain with their mothers for years, sometimes until she has her next calf (J. Lanyon personal communication via email to Marsh 2024). How long calves suckle during such prolonged periods of care is not known. Thibault et al. (2024) used stable isotopes to investigate dugong feeding. They found that the diet of dugong calves overlapped with mature females more than mature males and that mature females used a more diverse range of food sources than mature males.

Dugongs live entirely in marine systems and apparently meet their water requirements from their food (Smoll et al. 2020).

1.7.2 Water temperature

All extant sirenians are limited to the sub-tropics and tropics, presumably as a result of their sensitivity to low water temperatures. The behavioural responses of the Florida manatee to water temperature have been extensively studied (for reviews see Marsh et al. 2011; Deutsch et al. 2022 a,b). Dugongs have higher metabolic rates than Florida manatees (Lanyon et al. 2006; 2024), presumably assisting them to tolerate water a few degrees colder than the Florida manatee's lower limit of about 20°C (Marsh et al. 2011; Horgan et al. 2014). Dugongs exhibit different summer and winter distributions in widespread higher-latitude habitats in western (Anderson 1982, 1986; Holley 2006; Holley et al. 2006) and eastern Australia (Allen et al. 2004). Some animals move to warmer oceanic waters at the high-latitude limits of their range in Moreton Bay in winter (Preen 1992; Zeh et al. 2018), Hervey Bay (Sheppard et al. 2006) and New Caledonia (Cleguer 2015; Cleguer et al. 2024). Most tracked dugongs spent relatively short periods (median duration 5.9 hr) in the oceanic waters outside Moreton Bay (Zeh et al. 2018).

1.7.3 Social and reproductive behaviours

O'Shea et al. (2022) reviewed the social and reproductive behaviours of dugongs. Dugongs are usually sighted as solitary individuals, or as cows with single calves. Aggregations of more than 50 and up to several hundred dugongs can occur at predictable locations, including Moreton Bay (e.g., Lanyon 2003; Hodgson 2004) and Shark Bay (e.g., Anderson 1982) in Australia, and the Gulf of Bahrain/Gulf of Sulwa in the Gulf (Marshall et al. 2018, Khamis et al. 2023). These large aggregations appear to be fluid feeding aggregations (Hodgson 2004; Khamis et al. 2023). The reason for these aggregations repeatably occurring at these locations is not known and they are not correlated with overall population size. For example, large dugong aggregations have not been sighted in aerial surveys of Torres Strait which supports the largest dugong population in the world (Hagihara et al. 2018; Chapter 10).

The mating systems of dugongs have been variously described as lekking (Anderson 1997) or scramble promiscuity (mating herds; Preen 1989). Lone mating pairs have been observed in areas of low dugong density (O'Shea et al. 2022). O'Shea et al. (2022) concluded that further research into the hypothesized leks is needed because scramble promiscuity has been observed in the same region as the behaviour that Anderson interpreted as lekking. There are no known specific locations for mating or birthing although there is anecdotal evidence of dugongs giving birth in shallow water (Marsh et al. 2011).

Dugong vocalizations are social communication signals rather than navigational aids and are likely to be particularly important between females and their nursing calves (see review in O'Shea et al. 2022). Janet Lanyon (personal communication via email to Marsh and Schramm 2024) found that that vocalization rates increase exponentially with increasing group size. Tanaka et al. (2017, 2023) documented 'vocal hotspots': areas of approximately 1 km^2 where dugongs showed elevated levels of vocal behaviour in the waters of Talibong Island, Thailand. The function of these hotspots is unknown; no cow-calf pairs have been observed there. Vocalization locations were relatively consistent in both the rainy and dry seasons (Tanaka et al. 2023).

1.7.4 Movements

Deutsch et al. (2022 a,b) provide comprehensive reviews of dugong movements at large and small spatial scales. These reviews are mostly based on tracking data from more than 200 dugongs. Satellite tracking shows that some individual animals undertake directed movements of several hundred kilometres over a few days. Nonetheless, there is no evidence of regular round-trip migrations of entire regional populations, although dugongs may make local adjustments in their space use to adapt to seasonal changes in their environments (Deutsch et al. 2022a).

Sheppard et al. (2006) analysed the individualistic patterns of movements of 70 tracked dugongs in Australia: 26 individuals were relatively sedentary (moving less than 15 km) during the tracking period, while 44 individuals including solitary individuals and cows with calves, made large-scale (more than 15 km) movements of up to 560 km from their capture sites. The mean time of the first large-scale movement post-capture for all animals was variable (mean = 33.4 ± 10.3 days; min = 0 days). Large-scale movements included macro-scale regional movements (more than 100 km) and meso-scale inter-patch local movements (15 to less than 100 km). Such movements were qualitatively different from the tidally driven micro-scale commuting movements between and within seagrass beds (less than 15 km). These data may be conservative about the frequency of large-scale movements. Most dugongs have been satellite tracked for a few months at best (Deutsch 2022 a).

Cope et al. (2015) used pedigree analysis to infer the movements of genetically tagged dugongs and concluded that the frequency of individual movements between Moreton Bay and Hervey Bay in southeast Queensland may be more frequent than indicated by satellite tracking.

Deutsch et al. (2022a) concluded that periodic seagrass loss driven by extreme weather events is likely to be the most important driver of larger-scale movements. After extreme weather resulted in the loss of approximately 1,000 km^2 of seagrass in Hervey Bay in early 1992, at least 15 dugong carcasses were recovered in New South Wales, including four south of Sydney, presumably because starving animals moved out of Hervey Bay and were caught in the south-flowing East Australian Current (Preen and Marsh 1995). Where individual dugongs travel when their food community is destroyed is unknown because it is not ethically acceptable to fit food-deprived animals with tracking devices. Gales et al. (2004) assumed that animals move to regions where coastal seagrass has not been lost, which is a problem when losses are widespread, such as the major flooding events in eastern Queensland in 2010–2011. In some areas, such as the GBRWHA where large meadows occur in deeper offshore waters (Carter et al. 2021), it is possible that dugongs move offshore, but that has not been established.

There is increasing evidence that sirenian calves learn the locations of key resources and the timing and direction of movements during their years of dependency (Section 1.5). Dugongs seem to 'hedge their bets' with only some animals undertaking temporary emigration following extensive seagrass loss (Preen and Marsh 1995; Sobtzick et al. 2012). Sheppard et al. (2006) and Deutsch et al. (2022a) suggested that the large-scale movements of individual dugongs may be a means of assessing the status of food sources at a scale larger than that required for their immediate needs.

Reports of dugongs at extra-limital locations such as the Cocos (Keeling) Islands (Hobbs et al. 2007) and Fiji suggest that individual dugongs can move across deep ocean trenches. For example, Hill-Lewenilovo et al. (2018) reported a stranding of a dead, subadult, female dugong in Fiji, more than 600 km from the nearest known dugong population and beyond the eastern edge of the species' range. These records have led to speculation about the role of ocean currents in dugong dispersal and range expansion over evolutionary time. The data are not available to estimate the likelihood of contemporary recolonization of isolated locations, but recolonization is presumably low given the depleted status of dugong populations throughout most of their range (Marsh and Sobztick 2019).

- The habitat requirements for dugongs generally comprise shallow (less than 20 m), subtropical or tropical coastal waters supporting subtropical and tropical species of seagrass.
- Dugongs are seagrass community specialists and feed on nine of the ten genera, and probably on most of the approximately 26 species of seagrass that occur within their range. Their diet that may also include macro-invertebrates and algae at times.
- Dugongs are obligate bottom feeders with ventrally opening mouths. They use two different seagrass feeding modes: excavating and cropping. Only excavating dugongs leave obvious feeding scars in the substratum.
- Dugongs are limited to the sub-tropics and tropics, presumably as a result of their sensitivity to low water temperatures.
- Dugongs are usually sighted as solitary individuals, or as females with single calves.
- Dugongs spend a high proportion of their time feeding.
- Loose feeding aggregations of more than 50 and up to several hundred dugongs, including females with attendant calves, occur at predictable locations, including Moreton Bay and Shark Bay in Australia, and the Gulf of Bahrain/Gulf of Sulwa in the Gulf. The determinants of these locations are not known. Aggregations do not occur at all locations that support large numbers of dugongs.
- Dugong vocalizations are social communication signals rather than navigational aids and are apparently particularly important between females and their nursing calves.
- Satellite tracking shows that some individual animals undertake directed movements of several hundred kilometres in a few days. There is no evidence of regular round-trip migrations of entire regional populations, although dugongs may make local adjustments in their space use to adapt in seasonal changes to their environments. No migratory corridors have been identified.
- Periodic seagrass loss driven by extreme weather events is likely to be the most important driver of large-scale movements in dugongs.

1.8 Threatening processes

Dugongs are vulnerable to anthropogenic influences due to their life history and their dependence on seagrasses in coastal and island habitats that are often under pressure from anthropogenic activities due to high human population density (see Chapters 2-10 for density values). Given the extensive range of the dugong (Section 1.3), there are a range of threats, some of which are spatially restricted and some which span its entire range. In many cases, anthropogenic and natural threats amplify each other. The text below deals first with threats to the survivorship of dugongs, followed by threats to their habitat. The threats are not necessarily listed in order of severity because that varies throughout their range. The effects of these threats are cumulative (Marsh et al. 2022).

1.8.1 Threats to dugong survivorship

Interactions with fisheries

Bycatch in fishing gear is considered the major contemporary cause of dugong mortality in most dugong Range States (Pilcher et al. 2017; Marsh and Sobztick 2019; Chapters 2-10). This pressure mostly comes from local artisanal fisheries throughout most of the dugong's range, but few quantitative data are available. Monofilament nylon gillnets were introduced in the 1960s, leading to a global expansion in the use of gillnets provided as aid to developing countries (Marsh et al. 2011). Muir and Kizka (2012) claim that some dugong declines in East Africa have coincided with the introduction of monofilament nylon nets.

The Dugong MOU Standardized Catch and Bycatch Questionnaire developed by Pilcher et al. (2017) provides a structured process for recording bycatch from fishers, which has been deployed in 18 countries across the Indo-Pacific region. Pilcher et al. (2017) reported that the questionnaire had resulted in information from 6,153 respondents (89% of which were fishers) in East Africa (Kenya, Madagascar, Mozambique and Tanzania), South Asia (Bangladesh, India and Sri Lanka), Southeast Asia (Cambodia, Malaysia, Myanmar, Philippines, Thailand and Viet Nam), and the Pacific Islands (New Caledonia, Palau, Papua New Guinea, Solomon Islands and Vanuatu). Pilcher et al. (2017) reported that gillnets and hook-and-line were the most common fishing gear, with the greatest proportion of the reported dugong bycatch catch in gillnets (27%), followed by hook and line (15%), beach seine (14%), purse seine (14%), longline (16%), bottom longline (12%) and trawl (1%). Respondents reported that 52% of accidentally bycaught dugongs were released alive; deceased dugongs were discarded (16%), eaten (16%), or sold or used as bait (11%). The fate of the other 5% was not recorded. The questionnaire continues to be used at many places in the dugong's range (Chapters 2-9).

Shark nets (large-mesh nets) set for public safety have been another source of dugong mortality. Between 1962 and 1995, shark nets set on 47 swimming beaches in Queensland, Australia from Cairns (16.9°S) south, netted 837 dugongs (Anon. 1992). The Catch Per Unit Effort (CPUE) in 1999 was only 3% of that in 1962 (Marsh et al. 2005), suggesting that the population had declined by over 90% in approximately 40 years, assuming that the dugongs had not learned to evade the nets. These nets have largely been removed and replaced by drumlines, which do not catch dugongs. Nonetheless shark nets remain in southeast Queensland where five dugongs (four of which drowned) were caught in the Queensland Shark Control Program in 2020 – 2023 (T. Shimada unpublished data 2024).

No data are available on the number of dugongs drowned in lost or discarded nets or Illegal, Unreported and Unregulated (IUU) fishing, although dugong mortality presumably occurs.

Hodgson et al. (2007) conducted experimental trials to test the behavioural response of dugongs to four and 10 kHZ acoustic alarms (pingers) in an array designed to simulate a net, with the aim of developing a method to reduce mortalities in gillnets in Australia. They concluded that these pingers were unlikely to alienate dugongs from critical habitats or reduce mortalities in fishing nets. Even if pingers had been an effective deterrent, they are unlikely to be a realistic solution in the less developed countries in the dugong's range because their cost would be prohibitive for most artisanal fishers.

As pointed out by Marsh and Sobtzick (2019) it is often very difficult to convince fishers or fisheries managers of the seriousness of the dugong bycatch problem. When dugong population sizes are low, their capture in fisheries is a rare event, which becomes rarer (and of decreasing concern to policy makers) as the dugong population declines (Pilcher et al. 2017).

Traditional harvest

The direct harvest of dugongs for their meat and body parts has a long history (see Marsh et al. 2011). Archaeological evidence confirms exploitation of dugongs from at least 6,000 years ago in the United Arab Emirates (Méry et al. 2009; Chapter 4) and 4,000 years ago in the Torres Strait region between Australia and Papua New Guinea (Crouch et al. 2007; McNiven 2013; Chapter 10). It is likely that traditional harvest has been widespread throughout the dugong's range for thousands of years.

Dugong hunting is now legally banned in most Range States (Marsh and Sobtzick 2019). There are important exceptions to this ban for the subsistence and ceremonial use by traditional peoples from the Andaman and Nicobar Islands (Chapter 5), Pacific Islands including New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu; (Chapter 9) and Australia (Chapter 10).

Pilcher et al. (2017) found that dugong hunting was still common in several countries and was reported by 7.8% of surveyed respondents, although not all respondents were asked about hunting as this was often considered a delicate subject. The greatest number of respondents reporting hunting of dugongs from a Range State where hunting is banned was from Tanzania (18% of all hunting reports).

Vessel Strikes

Vessel strikes are a potential source of mortality for dugongs, although there is little quantitative information. Nonetheless, mortality does not seem to be nearly as great as that for Florida manatees, presumably because dugongs are more likely to use open waters than Florida manatees (Ponnampalam et al. 2022). Despite the dugong population along the urbanized coast of Queensland being estimated at approximately 6,000 animals in 2016 (Sobtzick et al. 2017), the Queensland Stranding and Mortality Database (Meager 2016) recorded only four interactions between dugongs and watercraft between 2013 and 2015 inclusive; three dugongs had been killed. The corresponding figure for 2020–2023 was two dugong deaths (T. Shimada personal communication via email to Marsh 2024). Deaths of dugongs from collisions with watercraft have also been reported from the Arabian region (Shawky 2018; Gladstone 2000); Asia (Hines 2012; Ng et al. 2022 a,b), Africa (Marsh et al. 2002), and Thailand (Piyarat Khumraksa written communication to Marsh January 2025).

Vessel traffic in the dugong's range must increase the likelihood of anthropogenic mortality, especially as dugongs often occur in areas with high vessel traffic such as the Johore Strait that separates Malaysia from Singapore (Ng et al. 2022 a,b). Even small increases in mortality due to boat strikes are expected to have serious impacts on the small and fragmented populations of dugongs found in many parts of their range. As explained in Chapter 10, the risks to dugongs seem greatest in shallow water, especially large intertidal areas with high vessel traffic where: (1) dugongs are forced to spend more time close to the surface; (2) dugongs have little opportunity to escape to deeper water; and (3) vessels and dugongs can both be constrained to channels during low tide periods, increasing the probability of vessel interaction (Hodgson and Marsh 2007).

Stranding of orphaned, neonatal calves

At a population level, adult survivorship is more important than juvenile survivorship for long-lived, slow breeding animals such as dugongs (Marsh et al. 2011). Thus, the death of a neonatal dugong is unlikely to be a serious threat unless the source population is very small and/or the number of neonates lost is large. Nonetheless, appropriate responses to live stranded calves separated from their mothers can be particularly challenging for policy makers (Marsh 2022), because: (1) wild neonatal dugongs are typically dependent on their mothers for at least 18 months (Section 1.5); (2) holding dugongs in captivity, for rehabilitation or for public display purposes, presents considerable challenges for both the welfare of the dugong and for the holding facility; and (3) orphaned calves can generate considerable public concern. Marsh (2022) outlined options to help policy makers and managers identify the decision most appropriate to their circumstances.

Predation

As long-lived, slow breeding mammals, dugongs might be expected to undertake behaviours that maximise survival by actively reducing their risk from predation (Marsh et al. 2011). Tiger sharks (Heithaus 2001; Simpfendorfer et al. 2001; Marsh et al. 2011; Borsa et al. 2021), killer whales (Anderson and Prince 1985; H. Das personal communication via email to Marsh 2023), and saltwater crocodiles (Marsh et al. 2011) eat dugongs, but how much of this consumption results from active predation rather than scavenging is not known. It was not possible to tell whether the aerial photographs of a dugong in the mouth of a crocodile taken from a Coastwatch aircraft of Cape York, Australia on 16 April 1988 was alive or dead when approached by the crocodile (Coastwatch photographs supplied to Marsh in 1988). Marsh et al. (2011) includes an image of an adult dugong with healed scars from Cape York, Queensland indicating that it survived a large shark bite. Dugongs in Moreton Bay have also been observed displaying healed shark bite scars (J. Lanyon written personal communication to Marsh 2024). Anderson and Prince (1985) documented killer whales attacking a herd of dugongs in Shark Bay Western Australia, and H. Das (personal communication via email to Marsh 2023) shared video footage of killer whales in Abu Dhabi waters playing with a dugong cow and calf before killing and eating them. The very few anecdotal accounts of dugong calving suggests that it occurs in shallow water (Marsh et al. 2011), behaviour that has been interpreted as a strategy to reduce the risk of predation on neonates. Older animals use a range of behaviours to avoid sharks, especially maintaining their access to deeper water (Wirsing et al 2007 a,b,c; Garrigue et al. 2008; Wirsing and Heithaus 2012; Cleguer et al. 2020). The overall impact of predation on dugong populations is unknown.

1.8.2 Threats to fecundity

Habitat loss and degradation

Seagrass ecosystems are very sensitive to human influence and are being lost globally at rates that place them among the most threatened ecosystems on earth (Waycott et al. 2009). Waycott et al. (2009) undertook a comprehensive global assessment of seagrass loss and found that seagrasses have been disappearing at a rate of 110 km^2 $year^{-1}$ since 1980 and that 29% of the known areal extent has disappeared since seagrass areas were initially recorded in 1879. Rates of decline accelerated from a median of 0.9% $year^{-1}$ before 1940 to 7% $year^{-1}$ since 1990. Waycott et al. (2009) identified major causes of seagrass loss as: (a) direct impacts from coastal development and dredging activities, and (b) indirect impacts from declining water quality. Some fishing methods, such as trawling and trap netting also have direct adverse impacts on seagrass; land clearing and pollution contribute to indirect impacts (Hines 2012).

In addition, some episodic losses of hundreds of square kilometres of the dugong's seagrass habitats have been associated with extreme weather events such as some cyclones, coastal floods and marine heatwaves, especially in Australia (e.g., Preen et al. 1995; Poiner and Peterken 1996; Kendrick et al. 2019). Such events have caused extensive damage to seagrass communities through severe wave action, shifting sand, adverse changes in salinity and light reduction. These impacts are expected to be amplified by climate change (Marsh et al. 2022).

Dunic et al. (2020) reconstructed a bioregional time series of seagrass meadow areas. They estimated that in the Tropical Indo-Pacific bioregion, which includes virtually all the global range of the dugong, 16.25% of the total area of seagrass was lost between 1945 and 2018. The change was spatially variable: there was a net gain of 75 km^2 across some meadows and a net loss totalling 171 km^2 across others. These estimates were based on sampling a maximum total area of only 592 km^2, which is only 1.4% of the 41,000 km^2 of seagrass mapped with moderate to high confidence in waters less than 20m deep in this seagrass bioregion (Chapter 11). Given that 41,000 km^2 is an underestimate of the seagrass resources in the dugong's range, Dunic et al.'s estimates must be interpreted with caution. It is not known whether the loss of seagrass has limited the recovery of depleted dugong numbers in any Range State.

Climate change

The most important effects of climate change on dugongs are likely to result from changes to their seagrass habitats as detailed in Marsh et al. (2022). Climate change is expected to reduce both seagrass biomass and distribution at a global scale, even though seagrass habitats may expand with sea level rise in some locations where coastal armouring remains minimal. An overall loss of estuarine and coastal seagrass is expected to further reduce the global dugong carrying capacity.

Climate change is expected to alter the species composition of many seagrass meadows by favouring tropical species. The impact of marine heatwaves is likely to be greatest in meadows at the high-latitude limits to the dugong's range, which currently support both temperate and tropical species. A marine heatwave in Shark Bay, Australia in 2011 resulted in the loss of more than 1,000 km^2 of seagrass, following extensive defoliation and rhizome death of the temperate *Amphibolis antarctica*, the dominant seagrass. This loss enabled small, fast-growing tropical species eaten by dugongs, such as *Halodule uninervis*, to expand in the bay (Kendrick et al. 2019). The basis for the dugong's food choice is poorly understood, and determinants of food quality are unknown

(Aragones et al. 2006, 2012) as explained above. We do not know whether the dugong's preferred feeding locations reflect environmental parameters, food quality or quantity, socially transmitted knowledge of resources, or some combination of these factors, or how changes in food quality and/or biomass change will affect dugong time budgets, movements, mortality, or fecundity. Climate-induced extreme weather events and other causes of extensive seagrass loss have increased dugong mortality, reduced fecundity, and increased their movements (Sections 1.5 and 1.7). There is no published veterinary evidence of dugongs being affected by hyperthermia during marine heatwaves.

Acoustic Pollution

Despite consistent anecdotal reports of dugongs ceasing to use areas with high vessel traffic, there have been few formal attempts to study the effects of acoustic pollution from vessel traffic on the dugong. Hodgson and Marsh (2007) documented feeding being interrupted by the passage of motorized boats within 50–500 m of feeding dugongs in Moreton Bay, near the city of Brisbane, Queensland, Australia. They estimated that the dugong's feeding budget was reduced by a maximum of 0.8–6% as a result of these interruptions but concluded that the impact could be more substantial in areas with higher levels of vessel traffic.

Seismic surveys are a key component of offshore oil and gas exploration and are used to study rock strata below the seafloor. Marine seismic surveys use high-energy, low-frequency sound produced by arrays of airguns which are designed to project very strong sounds downward through the water. A considerable amount of sound propagates horizontally as well. Most seismic surveys are in deep water off the continental shelf and so are unlikely to affect dugongs, except where the continental shelf is narrow (R. McCauley personal communication via email to Marsh 2023).

Dugong tourism

Dugongs are generally much less attractive to tourists than many other marine mammals (Ponnampalam et al. 2022). They are less well-known, often occur in turbid waters with limited underwater visibility, do not exhibit spectacular surface behaviours, and can be wary and difficult to approach and may suddenly leave an area. Nonetheless, swim-with-dugong programs have developed in areas with clear water (Marsh et al. 2002), and some habituated dugongs have become local tourist attractions in Egypt (Chapter 3), Maritime Southeast Asia (Chapter 8), and Vanuatu (Chapter 9). Some of these ventures have centred around habituated animals, which have then disappeared after a few years. People have captured dugongs, tethered them in the shallows with ropes fastened to their tails, and attempted to feed them in order to domesticate them as tourist attractions for people to swim with (Ponnampalam et al. 2022). The effects of dugong tourism on dugong life history have not been quantified at individual or population levels.

Diseases and parasites

Diseases

Little is known about diseases in wild dugongs. Most of the information on dugong diseases comes from the necropsy of stranded animals, especially from the StrandNet program in Queensland, Australia, which produced annual reports from 1996 to 2015 (e.g., Haines and Limpus 2000; Greenland and Limpus 2007; Meager and Limpus 2012; Meager 2016). Many stranded dugongs are found in an advanced state of decomposition that makes it difficult to determine the cause of death, despite a well-developed necropsy protocol (Eros et al. 2007), especially if mortality is not caused by trauma, such as collisions with vessels, drowning in nets, stingray barbs or predation (Haines and Limpus 2000). Investigations are also hindered by limited information on dugong health and diseases, and paucity of knowledge of common or endemic pathological findings (Woolford et al. 2015). As a result, the cause(s) of death have not been determined in a large proportion of dugongs subject to veterinary examination.

Increases in dugong mortality have resulted from starvation associated with extensive seagrass loss, which is often but not always caused by cyclones and floods (Heinsohn and Spain 1974; Preen and Marsh 1995; Marsh et al. 2000; Greenland and Limpus 2007; Owen et al. 2013; Meager and Limpus 2014; Piyarat Khumraksa (written communication to Marsh January 2025)). Meager and Limpus (2012) recorded gross indicators of starvation including poor body condition, wasting and atrophy of blubber stores. Owen et al. (2013) also recorded epidermal hyperplasia, and secondary bacterial infection, serous atrophy of pericardial adipose tissue, and multisystem abscessation in dugongs from southeast Queensland, a high latitude limit of their range, especially during sustained periods when water temperature was more than 20°C. They interpreted these symptoms as evidence of cold-stress syndrome, a controversial diagnosis disputed by Horgan et al. (2014) and Lanyon et al. (2015) (but see Owen et al. 2015).

Carcass salvage is inherently biased because it identifies the incidence of mortality rather than health-related morbidity. Health assessments of wild dugongs in Moreton Bay, Queensland, Australia have been conducted annually since 2008 (Lanyon et al. 2010; Walsh et al. 2018) and have the potential to provide baseline data (e.g., Lanyon et al. 2023) to enable assessments of the temporal changes in the health of that population. These comprehensive health assessments involve the capture of wild animals and take advantage of the proximity of dugongs in Moreton Bay to the infrastructure and expertise available in a major city (Brisbane) and would be difficult to undertake in most locations in the dugong's range.

Records of dugong deaths from natural diseases are uncommon, and mostly involve single animals (Elliot et al. 1981; Greenland and Limpus 2007; Ladds 2009). Elliott et al. (1981) described a fatal case of salmonella in a captive, juvenile dugong in Cairns, North Queensland, Australia. Although the source of infection was not determined, the dugong had been offered a diet of seagrass from Cairns Harbour into which effluent from two sewage treatment plants and one abattoir was discharged.

Haines and Limpus (2000) reported that disease was involved in 30% of 80 dugongs for which the cause of death was recorded by the Queensland StrandNet program between 1996 and 2000. Marsh et al. (2000) summarized the reports of six dugong necropsies on animals in the Townsville region of north Queensland in 1999: one was diagnosed with a bacterial septicaemia, verminous bronchopneumonia, cachexia, and extensive skin and gastrointestinal tract abscessation; two others died from acute peritonitis secondary to rupture of a small intestinal abscess; and a neonate was believed to have starved, based on its extremely poor body condition. Ladds (2009) reported intestinal cryptosporidiosis in a terminally ill animal; however, it was not possible to comment on the clinical significance of this finding. Owen et al. (2012) examined 55 dugongs over a 14-year period (1997-2010). Several deaths were attributed to primary or secondary infections and idiopathic and degenerative diseases. A significant proportion of animals were found to have nonspecific signs of chronic debility, but the causes of disease and mortality in these cases were not identified. Woolford et al. (2015) examined six dugongs that were legally hunted in Torres Strait between northern Australia and Papua New Guinea (see Chapter 10). Recorded lesions not attributable to drowning were mild. Host reactions to the presence of trematode parasites in the intestinal tract predominated (see below and Appendix Table 1.1).

Epibionts

Barnacles are the most conspicuous inhabitants on dugong skin. Barnacles do not feed from the tissues of their hosts. However, they might cause irritation and skin damage, and can increase surface drag (Fertl and Newman, 2017). Thus, they are more accurately described as 'epibionts' which are, by definition, harmless to their hosts, rather than 'ectoparasites'.

The barnacle *Platylepas hexastylos* has been reported by Marlow (1962), Zann and Harker (1978) and Borsa et al. (2021). This species has been variously noted on the dorsal and ventral body surfaces of dugongs as well as the flippers. Dexler and Freund (1906) mentioned the barnacles Balanus sp. and *Chelonibia* sp. (mis-spelled as *Chelonobia*) on the dorsal surface. These barnacles also occur on other megafauna including manatees and a range of marine turtle species (Zardus 2021; Mignucci-Giannoni et al. 2022). It is not known if infestation with barnacles is associated with health of the host or environmental and other factors. Owen et al. (2012) mentioned that barnacles are common on dugongs in south-eastern Queensland, Australia, and Lanyon advises that barnacles are common only through the cooler months and are shed during spring and summer (J.Lanyon personal communication by email to Marsh 2024).

Woolford et al. (2015) reported that dugongs in the remote and warmer Torres Strait region, between northern Australia and Papua New Guinea, generally have clean skins and that barnacles are uncommon.

Campbell and Ladds (1981) mentioned 'intraepidermal cysts containing parasites superficially resembling copepods' in dugongs from northeastern Queensland. There is no further published information on these cysts.

Internal parasites

This account mainly refers to eukaryotic organisms other than fungi. Methods for detecting and collecting internal metazoan parasites of dugongs are in Blair (1981).

At least 16 trematode species and one nematode species are known to be internal parasites of dugongs (Appendix Table 1.1). (https://www.cms.int/dugong/en/publication/global-assessment-dugong-status-and-conservation-needs) It seems likely that many of these parasite species occur throughout the dugong's range. For example, at least two trematodes (*Solenorchis* species and *Rhabdiopoeus taylori*) and the nematode *Paradujardinia halicoris* are known from dugongs in Queensland, Australia and from the Red Sea.

Paradujardinia halicoris is the only nematode (roundworm) parasite known from dugongs. This ascaridoid nematode occurs, often in large numbers, in the cardiac gland of the dugong's stomach. As the most conspicuous of dugong parasites, it is the most frequently reported. The life cycle is unknown but may be direct (no intermediate host).

Infection with *Toxoplasma gondii* has been reported several times from dugongs. Owen et al. (2012) reported a fatal case of systemic toxoplasmosis in a dugong from southeast Queensland based on histology and immunohistochemistry. Wong et al. (2019) reported dugongs seropositive for *T. gondii* in southeast Queensland and noted that a single dugong in their sample of 114 animals was seropositive for another apicomplexan, *Neospora caninum*.

Satyaningtijas et al. (2020) examined blood smears of a dugong from Indonesia and identified a parasite in red blood cells that they suspected to belong to the genus *Babesia*. Species of *Babesia* are transmitted to several mammalian species around the world by (typically) ticks. This paper is a pointer to the lack of attention given to possible blood parasites in dugongs.

Do dugong parasites harm their hosts? The finding of parasites is often reported during post-mortem examinations (e.g., Campbell and Ladds 1981; Owen et al. 2013; Meager 2016), but the significance of these findings can be hard to gauge. Owen et al. (2012) explored the cause of death in 32 dugongs in Queensland but assigned parasitic disease as the clear cause in only one case (toxoplasmosis) and as a possible contributor in another. Most of the trematode species in dugongs probably cause little pathology. Even those that live in tissue sites do not seem to cause much local damage.

Despite the nematode, *P. halicoris*, occurring in large numbers, little or no pathology is usually reported (e.g., Marsh et al. 1977; Campbell and Ladds 1981; Adulyanukosol et al. 2004; Woolford et al. 2015). However, since these infestations are so conspicuous, it is tempting to assume that they must have a serious effect on the host. Thus, Norina et al. (2018) speculated that the more than 1,000 *P. halicoris* found in a dugong in Malaysia might have contributed to its death. Similarly, Owen et al. (2012) suspected a massive infestation (5,500 – 6,000 worms) of *P. halicoris* might be a partial explanation for the death of one Australian dugong but also commented that large numbers of these worms were common in apparently healthy animals. Relatively mild pathological changes in the stomach, such as congestion, haemorrhage and damage to the mucosa have been reported in animals infected with *P. halicoris* (e.g., Rajesh et al. 2023). However, severe pathology due to *P. halicoris* has also been reported. Gohar (1957) noted no effect of this parasite on seven infected dugongs in the Red Sea. However, in an eighth animal, the 540 *P. halicoris* present were associated with major damage involving the glandular and muscular layers of the stomach. Some worms had penetrated into the body cavity (Gohar 1957).

The apicomplexan (protist) parasites mentioned above and listed in Online Supplementary material as Appendix 1.1 (https://www.cms.int/dugong/en/publication/global-assessment-dugong-status-and-conservation-needs) presumably have terrestrial origins. The typical definitive hosts of *Toxoplasma gondii, Cryptosporidium hominis* and *Neospora caninum* are all terrestrial mammals (cats, humans and dogs, respectively). The presence of these organisms in dugongs is likely a consequence of contamination due to activities of humans and domestic animals (sewage and agricultural runoff from coastal developments). They are therefore probably "new" infective agents of dugongs. Some also occur in manatees (see Bando et al. 2014; Smith et al. 2016). The significance of these apicomplexans for dugong health is little understood. *Toxoplasma gondii* can certainly cause fatal disease in dugongs (Owen et al. 2012) and *Cryptosporidium hominis* might also cause disease. There is very real potential for the increasing human impacts on settled coastlines to increase the incidence of these diseases among dugongs. From the public-health perspective, Dubey et al. (2020) proposed that marine mammals can be sentinel species for contamination of waters with *T. gondii* oocysts. Similarly, McGowan et al. (2023) proposed that the dugong can act as a sentinel species for antimicrobial-resistant bacteria of public-health significance.

As the population of a host species, such as a dugong, declines, the parasite species present in the hosts might be expected to start disappearing because of the increased difficulty of successful transmission. Parasites produce enormous numbers of offspring to compensate for the low chance of any single individual encountering the next host. In addition, parasite species may self-regulate their development inside a host in a density-dependent manner. A possible example of this is the trematode, *Lankatrematoides gardneri*, that lives in the pancreatic ducts of dugongs: no matter how many worms are present in the pancreas, only a few are mature, the rest remaining as small immatures (Blair and Hudson 1992). Thus, there is a substantial buffering effect, that might allow continued parasite transmission even when the size of host populations have been greatly reduced. However, it is not known whether parasite species can persist in diminishing dugong populations.

Contaminants

As herbivores, dugongs have a low trophic position in food webs. Thus, their exposure to toxic substances is very different from that of most other medium-sized marine mammals, apart from manatees. As pointed out by O'Shea et al. (2018), many of the contaminants of concern for fish-eating marine mammals (such as organochlorine pesticides and metabolites, polychlorinated biphenyls [PCBs] and mercury) are found only in low concentrations in dugongs. Sirenians are hindgut digesters, with different nutritional metabolic capacities and digestive systems than other marine mammals, including long gut-retention times (146 – 166 hr for dugongs; Lanyon and Marsh 1995). Thus, challenges from toxic substances in their environments faced by dugongs are likely fundamentally different to most other marine mammals. These challenges are probably exacerbated because many dugong Range States are developing countries (Marsh et al. 2011) with limited pollution controls.

O'Shea et al. (2018) summarized the literature pertinent to the ecotoxicology of the dugong. Núñez-Nogueira et al. (2019) independently reviewed the concentrations of the heavy metals commonly considered as threats for marine mammals, including arsenic, chromium, mercury, lead and cadmium. Both O'Shea et al. (2018) and Núñez-Nogueira et al. (2019) concluded that dietary intake was the most likely exposure pathway for many toxic substances. Unlike piscivorous marine mammals that are exposed to biomagnified lipophilic substances in their prey, concentrations of organochlorine pesticides and metabolites, PCBs, and methyl mercury in dugong tissues are low, presumably because they feed largely on marine plants. Toxic substances that can accumulate in sediments and tissues of seagrasses are thus of greatest concern, particularly in nearshore habitats close to human urban, industrial, or agricultural sources. These substances include toxic elements such as copper, cadmium, aluminium, and lead, as well as dioxans and furans (PCDD/Fs) and potentially biotoxins. In contrast to Florida manatees, O'Shea et al. (2018) found no evidence of dugong mortality from biotoxins. Núñez-Nogueira et al. (2019) considered the risks to people from traditional and illegal human consumption of dugong tissues and concluded that levels of arsenic and cadmium in dugong muscle had the potential to exceed the recommended daily allowance.

O'Shea et al. (2018) concluded that sampling of dugongs for toxic substances was rudimentary and incomplete. They considered that long-term monitoring of persistent contaminants in accessible populations has the potential to offer important insights in the face of ongoing habitat degradation and climate change.

Plastics

Pollution involving macro, micro and nano plastics is a marine environmental issue of global concern (Stubbins et al. 2021). The impact of plastic on dugongs was highlighted by 'Mariam', an orphaned dugong calf found by local villagers in the Andaman Sea and relocated to a sheltered area around Koh Libong in Trang Province in Thailand in 2019 (Chapter 6). 'Mariam' died from infections resulting from plastic ingestion (Ponnampalam et al. 2022). Dugongs are likely to be exposed to microplastics on seagrass leaves. Li et al. (2023) conducted a systemic review of the incidence of microplastics in seagrass ecosystems and found evidence of fibrous and fragmented plastics on seagrass leaves within the range of the dugong, including on the leaves of species eaten by dugongs: *Cymodocea serrulata, Enhalus acoroides* and *Thalassia hemprichii.* Li et al. (2023) concluded that the impacts of microplastics on the seagrass ecosystem is inconclusive and under-studied. Apart from 'Mariam', we know of no other evidence of the direct impacts of plastic pollution on dugongs.

- Dugongs are vulnerable to anthropogenic influences due to their life history and their dependence on seagrasses that occur in habitats under pressure from human activities.
- The rate of population change is most sensitive to changes in adult survivorship because of the lengthy periods before first breeding in females, long gestation periods and usual litter size of one, as well as a long period of lactation.
- Given the extensive range of the dugong, there are a range of threats, some of which are locally unique and some which span its entire range.
- Threats to dugong survivorship include interactions with fisheries, traditional harvest, vessel strikes, stranding of orphaned and neonatal calves, and predation.
- Threats to dugong fecundity include habitat loss and degradation, climate change, acoustic pollution, dugong tourism, diseases, parasites, contaminants and plastics.

1.9 Methodologies relevant to this report

This section provides an overview of the methodologies used to estimate the size and extent of dugong populations and seagrass habitats in Chapters 2–10. References to the specific methods used are provided in each relevant regional chapter.

1.9.1 Estimating dugong population sizes

Methods to estimate dugong population size relevant to monitoring dugong status and trends in conservation relevant time frames are described in the Dugong and Seagrass Research Toolkit (Dugong and Seagrass Hub n.d.) under the heading 'Estimating abundance'. The Toolkit outlines the techniques and tools most suitable to the required spatial scale, and the users' capacity, budget, and timeline as summarized in Table 1.1. The Toolkit provides key references for each technique. It is important to understand that estimates obtained by different techniques are not comparable and most are unsuitable for quantifying trends. The Toolkit's treatment of drone surveys and use of cameras in conventional aircraft are out of date (Table 1.1). More up-to-date references are provided in the relevant regional chapters as well as Chapter 11.

1.9.2 Estimating the extent of seagrass in dugong Range States

Seagrass mapping

Methods used to map seagrasses in the dugong's range are also described in detail in the Dugong and Seagrass Research Toolkit (Dugong and Seagrass Hub n.d.). The Toolkit outlines the techniques and tools most suitable to the spatial scale required, and the users' capacity, budget and timeline as summarized in Table 1.2. The Toolkit provides key references for each technique.

Current initiatives to improve seagrass extent maps in dugong Range States such as Indonesia (Chapter 6) are commendable. Nonetheless, accurately mapping seagrass extent poses challenges, especially in tropical regions, where seagrass ecosystems are diverse and dynamic, with considerable spatial and temporal variations in distribution and abundance. Tropical seagrasses often have low above-ground cover, grow in a variety of complex substrates, and can exist in optically complex waters (McKenzie et al. 2020).

New technologies and improved mapping approaches are showing some promise to address the challenges. Earth-observing platforms like satellites and unoccupied aerial vehicles (UAVs or drones) are increasingly used, and when coupled with effective field validation, can produce seagrass maps of high confidence at scale (McKenzie et al. 2022). The use of remote air-borne or satellite sensors enables large areas of shallow water seagrass to be rapidly mapped, although use of such technology can become problematic in complex multi-habitat seascapes, or optically complex waters. In deeper waters, autonomous underwater vehicles (AUVs or robots), remotely operated underwater vehicles (ROVs) and drop-cameras present new opportunities for collecting visual data over large spatial areas. Improved field validation methods and standardized tools enhance map confidence, and provide opportunities for data capture by the broader community (McKenzie et al. 2023). Emerging technologies such as machine- and deep-learning are also rapidly evolving, leading to more accurate and efficient seagrass maps of higher confidence, and facilitating future upscaling of seagrass mapping (McKenzie et al. 2022).

Table 1.1. Summary of techniques to estimate the population size (abundance) of dugongs.

Technique	Cost	Spatial scale	Expertise required				Relevant chapters
			Logistics	Study design	Data collection	Data analysis	
Mark-recapture study	High	Small	High	High	High	High	10
https://toolkit.dugongseagrass.org/media/toolkit-guidelines/mark-recapture-study.pdf							
Abundance aerial survey	High	Large	High	High	High	High	2, 3, 4, 6, 10
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/abundance-aerial-survey.pdf							
Distribution aerial survey	High	Variable	High	Medium	Medium	Medium	2, 3, 4, 5, 6, 7, 8, 9, 10
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/distribution-aerial-survey.pdf							
Vessel survey	Medium	Small and medium	Medium	High	Medium	High	2, 3, 5, 6, 7, 8, 9
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/boat-based-survey.pdf							
Fisher survey	Low	Variable	Low	Medium	Medium	Medium	2, 3, 4, 5, 6, 7, 9
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/cms-dugong-mou-questionnaire.pdf							
Citizen science	Medium	Variable	Medium	Medium	Medium	Medium	2, 4, 5, 6, 7
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/citizen-science-programs-guidelines.pdf							
Land-based survey	Low	Small	Low	Medium	Medium	Medium	7
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/land-survey.pdf							
Scales:							
Cost: Low (less than USD 1,000); Medium (USD 1,000 to 50,000); High (more than USD 50,000).							
Spatial scale: Small (less than 10 km^2); Medium (10 to 100 km^2); Large (more than 100 km^2).							
Expertise: Training in relevant technique; Low (degree not required); Medium (undergraduate degree); High (postgraduate research degree).							

Table 1.2. Summary of techniques to measure the extent of seagrass in water depths less than 20 m in the dugong's range.

Technique	Cost	Spatial scale	Expertise required			
			Logistics	Study design	Data collection	Data analysis
Aerial photos (aircraft or drone)	Medium	Small	High	High	High	High
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/aerial-photography-(aircraft-drone).pdf.						
Drop down camera	Medium	Variable	Low	High	Low	High
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/drop-down-camera.pdf						
In situ intertidal (walking)	Low	Small	Low	High	Medium	High
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/in-situ-observation-walking-at-low-tide.pdf						
In situ subtidal (scuba & snorkelling)	Medium	Small	Medium	High	Medium	High
https://toolkit.dugongseagrass.org/media/toolkit-guidelines/in-situ-observation-scuba-snorkelling.pdf						
Towed camera	Medium	Variable	Low	High	Low	High
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/towed-video-camera.pdf						
Acoustic/echo-sounding	High	Medium	High	High	High	High
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/acoustic-echo-sounding.pdf						
Satellite	Medium	Medium / Large	High	High	High	High
http://toolkit.dugongseagrass.org/media/toolkit-guidelines/satelite-imagery.pdf						
Scales:						
Cost: Low (less than USD 1,000); Medium (USD 1,000 to 50,000); High (more than USD 50,000).						
Spatial scale: Small (less than 10 km^2); Medium (10 to 100 km^2); Large (more than 100 km^2).						
Expertise: Training in relevant technique; Low (degree not required); Medium (undergraduate degree); High (postgraduate research degree).						

Methods used in this report to estimate the area of seagrass in dugong habitat in each Range State

As explained in Section 1.7, dugongs are predominantly found in shallow coastal waters. In mapping the extent of seagrass habitat potentially used by dugongs in each Range State, we assumed that dugong habitat was restricted to waters shallower than 20 m deep. Data were assembled from published and available sources, using exclusively polygon (vector-based) maps for measures of spatial extent (*sensu* McKenzie et al. 2020). Where a time series of spatial data was available for a Range State, a temporal composite was used, representing the full spatial extent of all datasets collected. Prior to individual country area calculations, available polygon data were overlaid with Exclusive Economic Zones (EEZ) to 200 nm (Flanders Marine Institute 2018). The area of coastal waters shallower than 20 m depth was estimated for each dugong Range State using the General Bathymetric Chart of the Oceans (GEBCO) bathymetry grid model for ocean, with a spatial resolution of 15 arc seconds (GEBCO Compilation Group 2023). For the Australian coastal waters shallower than 20 m depth, a composite dataset was prepared using five datasets, including: AusBathyTopo 250 m (Beaman 2023a); Great Barrier Reef 30 m (Beaman 2017); AusBathyTopo (Torres Strait) 30 m (Beaman 2023b); Northern Australia 30 m (Beaman 2018); and Northwest Shelf 30m (Lebrec 2021).

The area of seagrass was calculated using a GIS with ArcMap® software (version 10.8.1) in square kilometres in the Mollweide equal area cylindrical WGS-84 projection (except for Australia, where Australian Albers was used). Only seagrass areas of moderate to high confidence have been reported (*sensu* McKenzie et al. 2020; McKenzie et al. 2022). No confidence intervals are available. The estimates provided in Chapters 2–11 are almost certainly underestimates.

- Methodologies used to estimate dugong population size include: mark-recapture, abundance aerial surveys, distribution aerial surveys, vessel surveys, fisher surveys, citizen science, and land-based surveys.
- The most appropriate technique for a given location depends on its geography, spatial scale, the capacity of the survey team and the funding available. The results obtained using different techniques are generally not comparable and most are not suitable for quantifying trends.
- Methodologies used to estimate the extent of seagrass meadows include aerial photography, drop-down cameras, intertidal walking, scuba-diving and snorkelling, towed cameras, and acoustic echo-sounding.
- The most appropriate technique for a given location depends on its geography, spatial scale, the capacity of the survey team and the funding available.
- Polygon (vector-based) maps have been used to estimate the area of seagrass habitat suitable for dugongs in each Range State in this report. Only seagrass areas that had been mapped with moderate to high confidence have been reported.

1.10 Ecosystem Services: Blue Carbon

Costanza et al. (1997) defined ecosystem services as the benefits provided to humans through the transformations of resources (or environmental assets, including land, water, vegetation and atmosphere) into a flow of essential goods and services e.g., clean air, water, and food. The Millennium Ecosystem Assessment (2005) identified four categories of ecosystem services:

1. Provisioning services, such as food and water.
2. Regulating services, such as flood and disease control.
3. Supporting services, such as nutrient cycling, that maintain the conditions for life on Earth.
4. Cultural services, such as spiritual, recreational, and cultural benefits.

The provisioning and cultural services provided by dugongs are discussed in Chapters 2–10 in the sections on cultural values. The supporting services provided by the Blue Carbon sequestered dugong habitats are outlined below because of the burgeoning interest in Blue Carbon as an additional rationale for conserving seagrass communities and their associated sediments.

1.10.1 Blue Carbon

Blue Carbon refers to the atmospheric carbon dioxide (CO_2) captured and stored in coastal vegetated ecosystems (i.e., seagrasses, mangroves and tidal marshes), as plant biomass or sedimentary organic carbon (C_{org}) in the soils (sediments) (Nellemann et al. 2009). These vegetated coastal ecosystems are recognized as making a significant contribution to the global carbon cycle due to their capacity to efficiently store C_{org} in their soils for millennia and at rates that can be orders of magnitude higher than in most terrestrial ecosystems (McLeod et al. 2011; Duarte et al. 2013) salt-marshes, macroalgae and mangroves. In fact, despite occupying only about 0.2% of the ocean surface (Duarte and Cebrián 1996; Duarte et al. 2005), vegetated coastal ecosystems represent approximately 50% of total C_{org} sequestration in marine sediments (Duarte et al. 2013). Seagrasses are among the most threatened ecosystems on Earth due to human activities and climate change (Waycott et al. 2009) and are being lost at an alarming rates in some locations. The extraordinary C_{org} sequestration capacity of vegetated coastal ecosystems and their high rates of loss globally make them of particular interest as nature-based solutions for climate change mitigation and adaptation strategies (Cohen-Shacham et al. 2016; Bindoff et al. 2019)

The majority of the C_{org} stocks in Blue Carbon habitats are found in the soil (Duarte et al. 2013). In particular, seagrass ecosystems hold more than 90% of total C_{org} stock in their soils (Serrano et al. 2019). The capacity of different seagrass ecosystems to accumulate C_{org} can vary substantially. Differences in C_{org} soil stocks have been reported to be up to 45-fold among seagrass habitats, while their annual carbon accumulation rates can vary by up to 70-fold (Lavery et al. 2013; Serrano et al. 2019; Mazarrasa et al. 2021). This variation depends on several factors (e.g., species composition, soil characteristics, geomorphological settings, biological features), which interact to control the C_{org} capture and storage in seagrass ecosystems (Serrano et al. 2016; Mazarrasa et al. 2018). The interaction between seagrasses and other organisms such as dugongs, is an important factor that can influence the capacity of seagrass to accumulate $C_{org.}$ Herbivores can stimulate the growth and health of seagrass meadows by stimulating productivity (e.g., Nichols 2004; Kuiper-Linley et al. 2007) and reducing the accumulation of excess detritus and enhancing oxygenation, consequently supporting the ecosystem services seagrasses provide, including C_{org} sequestration (Mazarrasa et al. 2018; Scott et al. 2018). On the other hand, overgrazing can cause the opposite effect and dramatically decrease the health of a seagrass meadows, leading to significant removal of C_{org} (Atwood et al. 2015). Indeed, excessive removal of leaves may decrease the capacity of seagrass to enhance particles trapping and accumulation, and sediment exposure to currents and waves can facilitate sediment erosion with associated loss of C_{org} (Dahl et al. 2016). As explained in Section 1.7, seagrasses, especially low-biomass tropical species (i.e., *Halodule* spp., *Halophila* spp.) found in waters shallower than 20 m deep, are the primary food of dugongs. Compared to high-biomass persistent seagrasses (e.g., *Posidonia* or *Enhalus*) (Lavery et al. 2013; Kennedy et al. 2022), these low-biomass seagrasses accumulate lower amounts of C_{org}. Nonetheless, the extent of the seagrass meadows in the dugong's range (Chapters 2-11) makes it relevant from a Blue Carbon perspective. However, as the effect of dugongs on C_{org} sequestration by seagrasses has not yet been fully explored (Wirsing et al. 2022), the Blue Carbon potential linked to the presence of dugongs cannot yet be quantified. Nonetheless, quantifying the Blue Carbon value of the dugong's seagrasses habitats and their potential to contribute to climate change mitigation at national or regional levels could provide additional rationale for conservation of dugong habitat.

- Blue Carbon is the ecosystem service provided by the atmospheric carbon dioxide captured and stored in coastal vegetated ecosystems, including the dugong's seagrass habitats.
- The low-biomass seagrass meadows used by dugongs tend to accumulate lower amounts of organic carbon than higher-biomass meadows. Nonetheless, the extent of the seagrass meadows in the dugong's range makes it relevant from a Blue Carbon perspective.
- Quantifying the Blue Carbon value of the dugong's seagrass habitats and their potential to contribute to climate change mitigation at national or regional levels could provide further rationale for dugong habitat conservation.

1.11 Concluding remarks

This chapter sets the scene for the remainder of this report. The dugong is a long-lived, slow breeding species, largely dependent on subtropical and tropical seagrass habitats in water less than 20m deep. These habitats are being lost at an alarming rate in some parts of the dugong's range, a situation that is likely to be exacerbated by climate change. Nonetheless, major gaps remain in the biological knowledge required for effective dugong conservation. These include the factors that determine food quality, how to estimate the carrying capacities of various dugong habitats, how dugongs navigate over large distances, and their capacity to recolonize restored seagrass habitats.

In addition, estimating dugong population sizes and trends is extremely difficult in many Range States. The human dimensions of dugong conservation are also complex, especially given the huge range of socioeconomic conditions in the Dugong Range States as explained in the regional chapters that comprise most of the remainder of this report.

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Chapter 2

EAST AFRICA

Authored by: Helene Marsh, Asma Hadi Awadh, Lea Bernagou, David Blair, Vic Cockcroft, Damboia Cossa, Almeida Guissamulo, Anna Koester, Len McKenzie, Mohamed Omar Mohamed, Ben Anthoy Moussa and Evan Trotzuk

Helene Marsh[1], Asma Hadi Awadh[2], Lea Bernagou[3], David Blair[1], Vic Cockcroft[4], Damboia Cossa[5], Almeida Guissamulo[6], Anna Koester[7], Len McKenzie[8], Mohamed Omar Mohamed[9], Ben Anthoy Moussa[10], Evan Trotzuk[11]

[1]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[2]School of Environmental and Earth Sciences, Pwani University, Kilifi, Kenya.
[3]Plan National d'Actions en Faveur du Dugong à Mayotte, Association des Naturalistes de Mayotte, Mamoudzou, Mayotte.
[4]Institute for Coastal and Marine Research, Nelson Mandela University, Gqeberha, South Africa.
[5]Department of Biological Sciences, Eduardo Mondlane University, Maputo, Mozambique.
[6]Museu de História Natural, Universidade Eduardo Mondlane, Maputo, Mozambique.
[7]Seychelles Islands Foundation, Victoria, Mahé, Seychelles.
[8]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Cairns, Queensland, Australia.
[9]Marine and Coastal Research Centre, Kenya Wildlife Service, Mombasa, Kenya.
[10]Mohéli National Park, Mohéli, Union of Comoros.
[11]Bazaruto Archipelago National Park, African Parks, Vilankulo, Mozambique.

Correspondence to: Helene Marsh helene.marsh@jcu.edu.au.

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Cover image: Part of a group of dugongs in the northern Bazaruto Seascape, Mozambique. Evan Trotzuk photograph.

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Contents

Range/Signatory States

Range States	Signatory States
Somalia?	Yes
Kenya	Yes
Tanzania	Yes
Mozambique	Yes
Madagascar	Yes
Comoros	Yes
Mayotte (France)	Yes
Seychelles	Yes
Mauritius	No

The East African region comprises nine coastal countries, all of which except Mauritius, where dugongs are extinct, are signatories to the CMS Dugong MOU. These countries encompass key habitats along the Western Indian Ocean, forming the western boundary of the dugong's distribution within the Indian Ocean.

Regional findings

East African counties considered: Republic of Kenya (Kenya), Republic of Madagascar (Madagascar), France, Department of Mayotte (Mayotte), Republic of Mozambique (Mozambique), Republic of Mauritius (Mauritius), Republic of Seychelles (Seychelles), Federal Republic of Somalia (Somalia), Union of the Comoros (Comoros), United Republic of Tanzania (Tanzania).

- Hunting and bycatch in fishing nets have caused very serious declines in the dugong populations in East Africa.
- Dugongs are probably extinct in the waters of both Mauritius and Rodrigues[1] and apparently no longer occur in the Comoros outside Mohéli, and in the Seychelles outside Aldabra.
- The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species listed the coastal Eastern Africa subpopulation[2] of dugongs as Critically Endangered in 2022.
- Dugongs in East Africa are likely to have limited resilience to extreme events as the genetic differences between individuals appear to be very low.
- The only location in East Africa where a globally significant number of dugongs is known to occur is the Bazaruto Seascape in Mozambique. This location has been recognized internationally as an Important Marine Mammal Area (IMMA) and a Key Biodiversity Area (KBA).
- Bazaruto dugongs and the threats to them are actively monitored by African Parks. There is significant community engagement in these activities.
- Scientifically designed local-scale surveys informed by local knowledge have the potential to provide important new information about dugongs in Zeyla Archipelago in Somaliland, Mohéli, Mayotte and Aldabra.
- In Madagascar, Nosy Berafia in Sahamalaze National Park, Nosy Hara Marine Park, Ampobofofo, Bay of Rigny Complex, and Ambodivahibe are important habitats for dugongs.
- The 'Northwest Madagascar and Northeast Mozambique Channel' IMMA, which spans the waters of Comoros, Mayotte and Northwest Madagascar, includes the dugong as one of 22 supporting species.
- Outside the Bazaruto Seascape, dugong numbers are apparently so low that management interventions focussed solely on dugongs are unlikely to attract much support. Interventions designed to protect all marine megafauna may be more successful and groups with an interest in the conservation of marine turtles and small cetaceans should be invited to incorporate dugong conservation in their management actions.
- The areas of seagrass habitat in the region are likely to be underestimated. It will be important to undertake further mapping using modern techniques including unoccupied aerial vehicles (UAVs) or drones.
- An updated comprehensive 'Dugong Conservation Strategy in East Africa' would be a timely initiative, especially if a regional spatial risk assessment of the threats to dugongs in areas of local importance for the species were included.

1 Rodrigues is an autonomous outer island of the Republic of Mauritius
2 IUCN uses the term 'subpopulation' in the assessment of a regional population. The term 'subpopulation' is used here with reference to IUCN documentation only.

2.1 Regional setting

2.1.1 Geographic overview

This chapter considers the status of the dugong along the approximately 13,476 km coast of East Africa from the Djibouti-Somalian border in the Gulf of Aden (11.46° N, 43.26° E) to the Mozambique-South African Border (26.86° S, 32.89° E) and the offshore islands along the East African coast. The region comprises the coastal waters of the following countries, which are ordered here from north to south: Federal Republic of Somalia (henceforth Somalia), Republic of Kenya (henceforth Kenya), the United Republic of Tanzania (henceforth Tanzania), Republic of Mozambique (henceforth Mozambique), and the offshore islands of the Republic of Madagascar (henceforth Madagascar), the Union of the Comoros (henceforth Comoros), Department of Mayotte (henceforth Mayotte, which is an overseas department and region of France), the Republic of Seychelles (henceforth Seychelles), the Republic of Mauritius (henceforth Mauritius and/or Rodrigues) and Réunion (overseas department and region of France) (Figures 2.1–2.4). Réunion is not considered further in this chapter and is hereafter referred to as a former Range State as it is believed the dugong never occurred there due to the lack of suitable habitat (Kiszka et al. 2004).

Figure 2.1. Geographic context of East Africa showing placenames mentioned in the text. Dugong Range States and former Range States (*) are (ordered counterclockwise around the region starting with Somalia): Somalia, Kenya, Tanzania, Mozambique, Madagascar, Comoros, Mayotte, Seychelles, Mauritius and Réunion*. IMMAs with the dugong as a qualifying species are shown in blue. The KBA is shaded in blue lines. Inset left: Bazaruto Archipelago. Inset right: Nosy Hara Marine Park. Note: Dugongs are unlikely to occur on the open, high-energy coast of Somalia between the Gulf of Aden and the Bajuni Islands. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

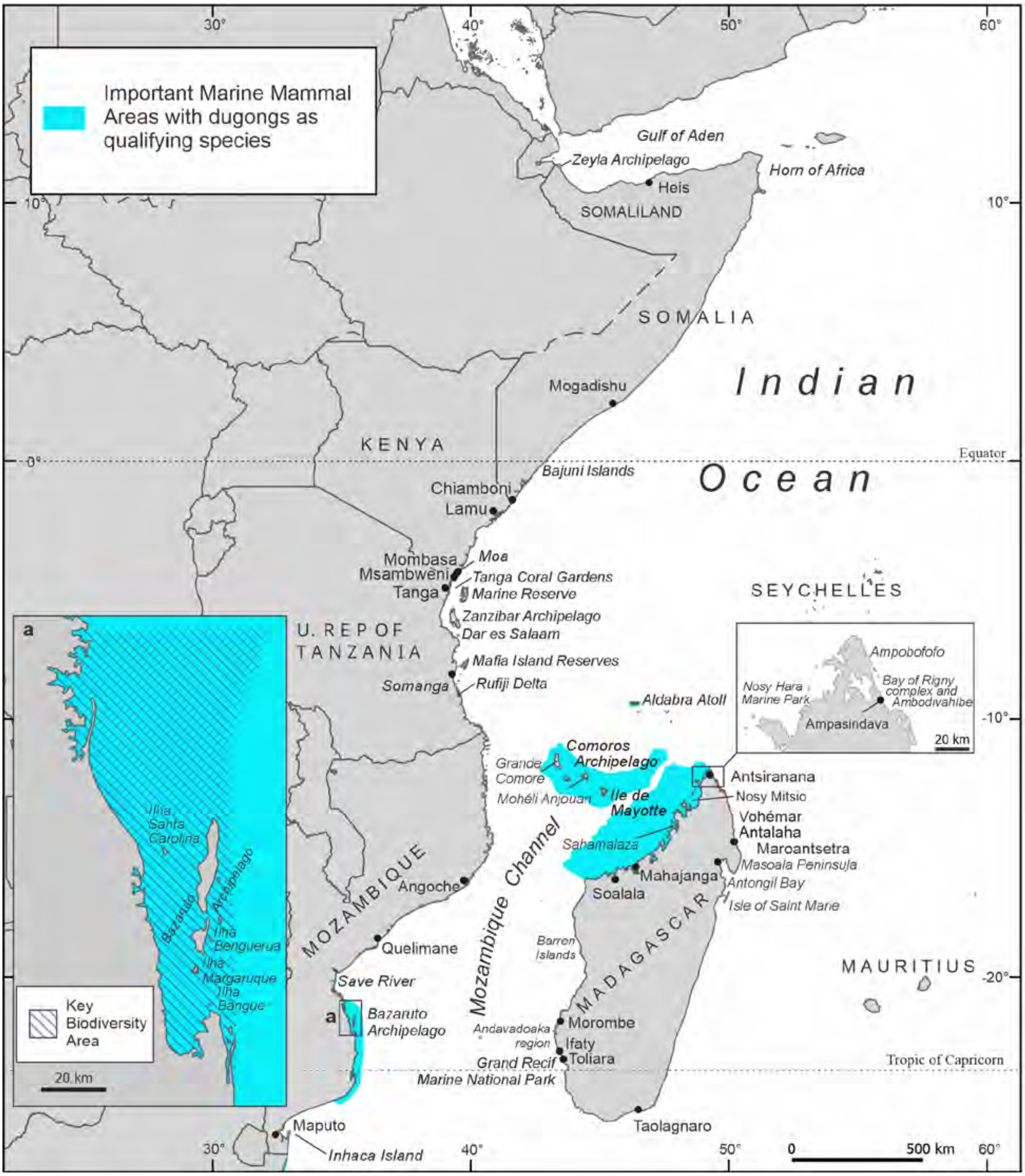
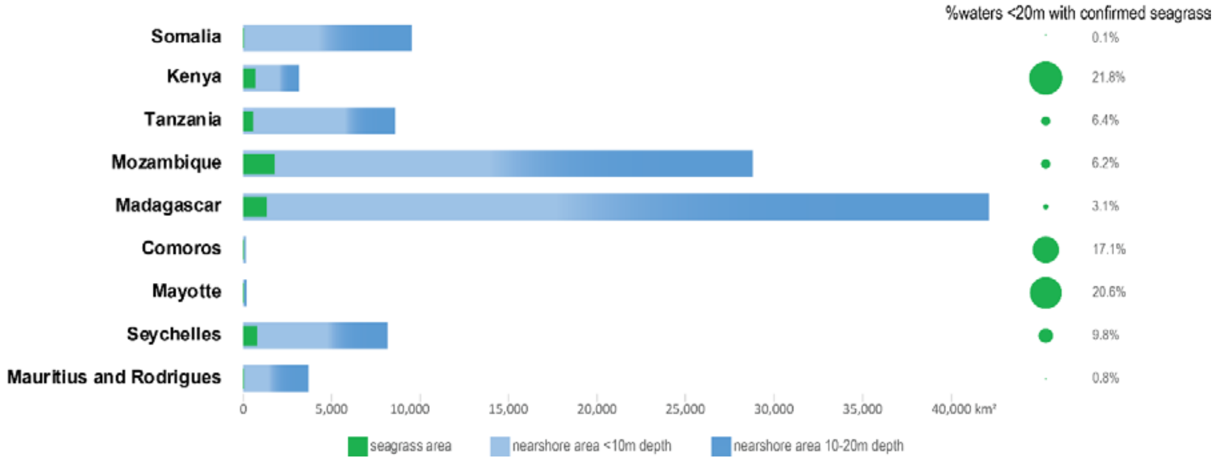
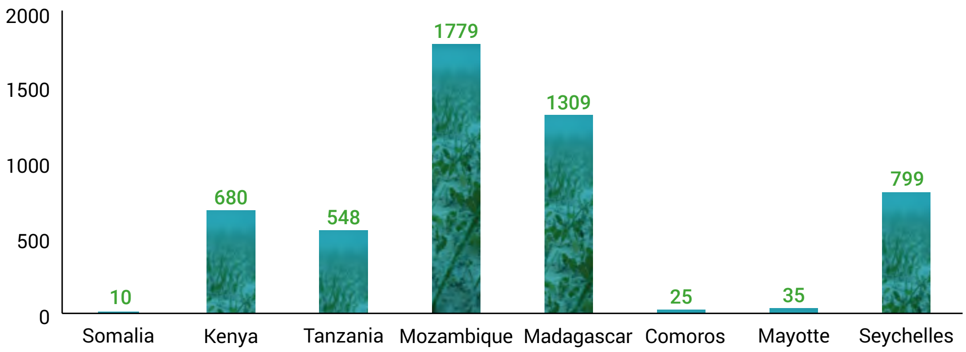


Figure 2.2. Histogram showing the known areas of seagrass and coastal waters less than 10m and less than 20 m deep for each dugong Range State in the East African region. The areas of seagrass are almost certainly underestimates and do not include reef associated seagrasses. The value for Somalia includes Somaliland; the value for Mauritius includes Rodrigues. The very small areas of water shallower than 20 m deep indicate that Comoros and Mayotte could never support a large dugong population. The dugong is likely extinct in Mauritius and Rodrigues Len McKenzie figure; reproduced with permission.



Seagrass Mapped Area (km²)

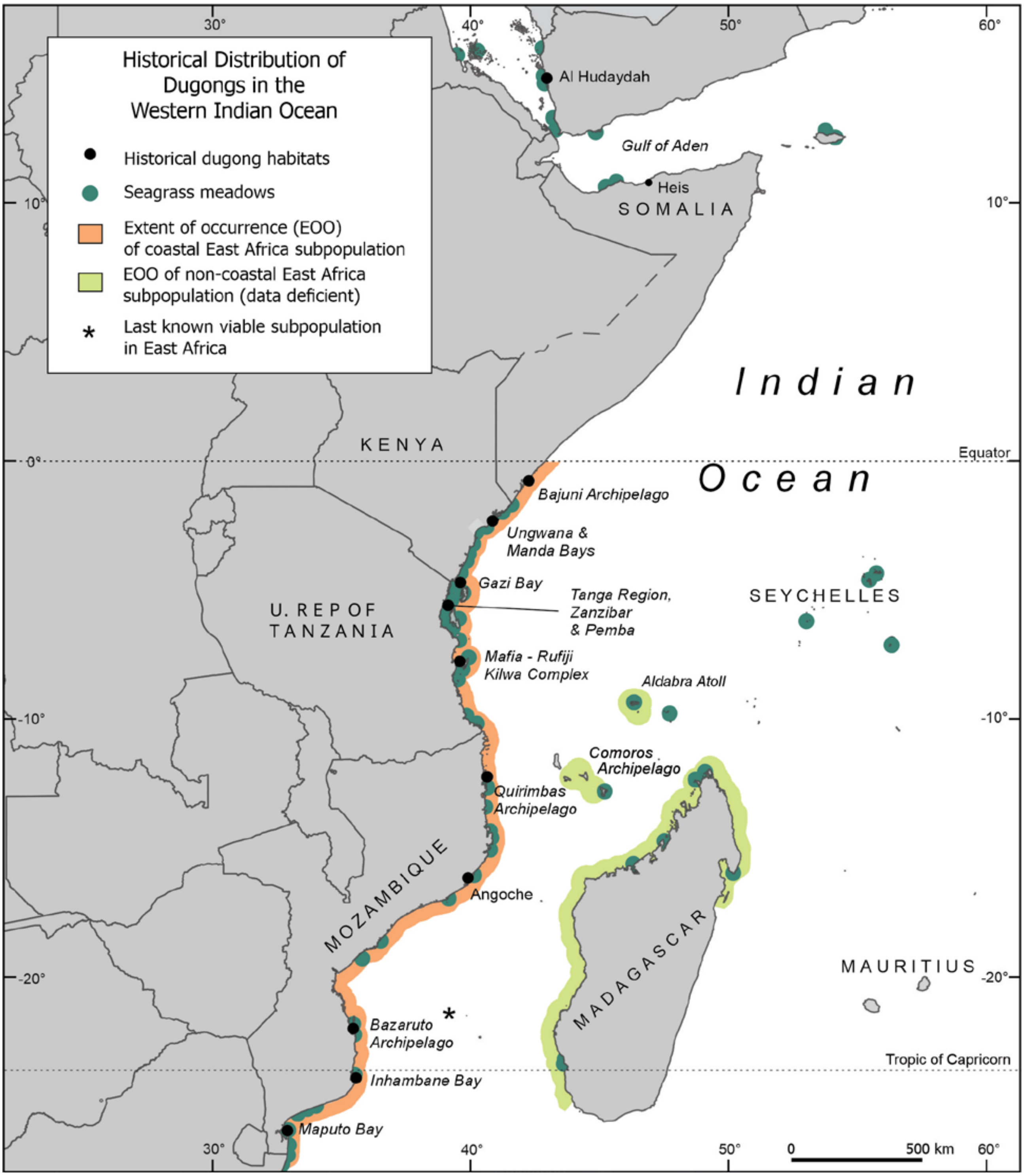


Seagrass habitats in East Africa are under-mapped, with current estimates likely representing underestimation of the actual areas Mozambique has the largest mapped seagrass area (~1,779 km²), offering significant potential for supporting dugong populations.

This region is the western boundary of the dugong's range in the Indian Ocean and is part of the Tropical Indo-Pacific seagrass bioregion (Short et al. 2007). Estimates of the total areas of seagrass within the region (Figure 2.2), which are likely to be underestimates, are as follows: Somalia (including Somaliland) 10 km² (Allen Coral Atlas 2020); Kenya 680 km² (Traganos et al. 2022); Tanzania 548 km² (Traganos et al. 2022); Mozambique 1,779 km² (Bandeira et al. 2014; Traganos et al. 2022); Madagascar 1,309 km² (Traganos et al. 2022); Comoros 25 km², including Mohéli 4 km² (Poonian et al. 2016; Allen Coral Atlas 2020); Mayotte 35 km² (Allen Coral Atlas 2020); Seychelles 799 km² (Lee et al. 2023); and Mauritius 25 km² excluding Rodrigues (Turner et al. 2000; Turner and Klaus 2005); Rodrigues 5 km² (Chapman and Turner 2004; Allen Coral Atlas 2020) (all areas rounded to nearest km², confidence intervals are not available, all estimates with moderate to high confidence).

Given that the dugong is a seagrass community specialist that eats most available seagrass species (Chapter 1), seagrass areas (Figure 2.2) are crude indices of dugong carrying capacity. Thus, these seagrass area estimates suggest that: (1) Mozambique has the potential to support a sizable dugong population (which it does, with an estimate in the Bazaruto Archipelago of 406 ± SD 146 animals; Trotzuk et al. 2022a); and (2) the dugong population(s) around Comoros, Madagascar and Mayotte merit further investigation. Dugongs have not been observed in the central or northern regions of the Seychelles in modern times (Eastern Africa Marine Ecoregion [EAME] 2004). These northern island groups are separated from the southern region, where Aldabra Atoll in situated, by deep oceanic waters and approximately 1,000 km.

Figure 2.3. Distribution of the dugongs and seagrass in the Western Indian Ocean see Trotzuk et al. 2022a for details of historic ranges. Modified by Adella Edwards from Figure 1 in Supplementary Information in Trotzuk et al. 2022a and BANP 2022; reproduced with permission. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations.



The dugong population in East Africa is fragmented. In Somalia alone, the distance along the coast from the Bajuni Islands (the northern-most record of dugongs along the east coast of Africa), further north, around the horn of Africa to the Zeyla Archipelago near the border with Djibouti is almost 3,000 km (Figure 2.1), much further than documented large-scale movements of dugongs of up to 625 km (Deutsch et al. 2022), apart from occasional vagrant animals (Hobbs et al. 2007; Hill-Lewenilovo et al. 2018). While it may be possible for dugongs to move along this coast between Somalia and the Gulf of Aden, dugong abundance appears to be very low in southern Somalia, and it is likely that such movements, if they occur, are rare (Deutsch et al. 2022). Similarly, although it is theoretically possible for dugongs to move between the coastal populations of dugongs in Mozambique and the offshore islands of Aldabra (Seychelles; approximately 740 km from Pemba to Aldabra), Comoros and Madagascar (approximately 640 km from the east coast of Comoros to the northern tip of Madagascar), the genetic evidence, albeit limited and excluding Aldabra, suggests that this may be a rare event (see Section 2.2.6).

2.1.2 Geopolitical and socioeconomic context

This information is provided as an indication of the challenge for each of the various dugong Range States in the region to consider the conservation of dugongs and their habitats in the context of their socioeconomic development needs. The East African region has a population of some 200 million people, increasing at an average of 2.2% p.a. (United Nations Department of Economic and Social Affairs [UNDESA] 2022). Approximately 35% of the population (70 million) live within 50 km of the coastline; 23% (46 million) within 10 km (Schiavina et al. 2023; Chapter 11, Figure 11.2). These peoples are amongst the world's poorest (World Population Review 2024). Comoros, Madagascar, Mozambique, Somalia and Tanzania are all classified as Least Developed Countries (Table 2.1; United Nations Development Programme [UNDP] 2022). They are low-income countries that face significant challenges in developing a sustainable and self-supporting economy. As of March 2024, such challenges were particularly acute because of the food crises in Somalia and Kenya caused by drought in the Horn of Africa (Somali Peninsula) (Bedasa and Bedemo 2023). The livelihoods of coastal inhabitants of the region are largely dependent on coastal and marine resources, such as artisanal fisheries and mangroves (EAME 2004).

2.1.3 Genetics of dugong populations

For an overview of techniques, definitions, relevant genetic studies and general findings on dugong population genetics, refer to Chapter 1, particularly Figure 1.2.

There are limited genetic data for dugongs in East Africa. No data are available from nuclear genetic markers[3]. The available mitochondrial control-region sequence data indicate very little diversity along the coast of the region. Two previously unpublished sequences (410 bp) from Tanzania (now GenBank PP317827-PP317828) are identical and consistent with all the shorter sequences (n=17) from the coast of East Africa reported in Plön et al. (2019) and with most of those from the Red Sea in the same paper. The same haplotype also occurs in the Arabian Gulf (Chapter 4). This haplotype, and the related ones reported in Plön et al. (2019) belong to the Western Indian Ocean (WIO) haplogroup. Only one short sequence from Plön et al. (2019) (MH704426; 156 bp), labelled as from Mozambique, is anomalous; it matches several haplotypes in the Australasian widespread lineage (Chapters 9 and 10). It is unclear

Table 2.1. Human Development Index (HDI) status and rank and Gross Domestic Product (GDP) per capita rank of the dugong Range States in East Africa. The countries in this table are ordered north to south, left to right around the region starting with Somalia. Countries with the highest HDI or GDP have the lowest ranks. 189 countries were ranked for both indices. N.A. = not available.

Range State	HDI status	HDI rank 2023[i]	GDP per capita rank[ii]
Somalia	N.A.	N.A.	N.A.
Kenya	Medium	152	134
Tanzania	Low	160	154
Mozambique	Low	185	173
Madagascar	Low	173	168
Union of the Comoros	Medium	156	149
Seychelles	High	72	53
Mayotte[iii]	Very High	23	N.A. (France: 25)

i 2023 HDI data from https://hdr.undp.org/data-center/country-insights#/ranks (downloaded January 2024).
ii 2023 per capita GDP from https://www.worldometers.info/gdp/gdp-per-capita/ (downloaded June 2024).
iii France's 2023 HDI data is used as Mayotte is a Non-Self-Governing Territory of France. A separate HDI for Mayotte could not be found.

3 All genetic terms are defined in Chapter 1.

whether this result should be taken at face value. Although deposited in GenBank, this sequence was not included in the analyses reported in Plön et al. (2019).

Five sequences from Madagascar and the Comoros, reported by Plön et al. (2019) form a distinct subclade within the WIO haplogroup. This indicates a separate evolutionary history for these populations, which, Plön et al. (2019) considers should be considered for special conservation status.

A further two sequences from a refuse dump (17th–18th Century) in Mauritius (EU826002-03) are identical and differ from the common East African haplotype at only a single site (Haile 2008). The sequences were derived from adjacent rib bones that may have belonged to the same individual.

The low variation in mitochondrial sequences across East Africa, the Red Sea (Chapter 3) and the Arabian Gulf (Chapter 4), suggest relatively recent colonisation of the region from further east or recovery and expansion from a genetic bottleneck (and see Furness et al. 2024). Only additional data from across the region, including from nuclear genomes will help to clarify this.

- The only genetic data available for dugongs from East Africa are from the mitochondrial control region.
- These DNA sequences are all very similar and belong to the WIO haplogroup.
- A subclade within the WIO haplogroup occurs in Madagascar and the Comoros.
- The limited mitochondrial diversity implies relatively recent colonisation of the region from further east or recovery and expansion from a genetic bottleneck.
- Preliminary genetic information suggests that dugongs from Madagascar and the Comoros form a distinct group indicating a separate evolutionary history for these populations.

2.2 Distribution, abundance and trends in Range States

2.2.1 Somalia

William Travis journeyed to Somalia in the early 1920s to establish a turtle cannery. In his book 'Voice of the turtle', written in 1924 and published 43 years later, Travis (1967) convincingly describes herds of dugongs:

'off the open coast, with the nearest swamp 300 miles to the south, I found huge herds, sometimes as many as 500 strong, swimming freely within and without the reef'

This account is presumably from the waters of the Bajuni Islands about 120 km north of the Kenyan border. Cockcroft and Young (1998) reported anecdotal accounts of large groups of dugongs moving between Lamu in northern Kenya and southern Somalia (Figure 2.1). No contemporary accounts of such behaviour have been found, although it is plausible, because fringing reefs and barrier islands provide sheltered waters along this coast (Carbonne and Accordi 2000). Outside the Gulf of Aden (Figure 2.1), the exposed, high-energy coastline of central and northern Somalia is unlikely to be suitable dugong habitat due to lack of seagrass (United Nations Environment Programme World Conservation Monitoring Centre [UNEP-WCMC] and Short 2021).

Somalia is one of the least developed countries of the world (UNDESA 2021). The country has been wracked by armed conflicts (linked to piracy, militant groups and war) and political instability for decades and the southern coast has largely been inaccessible to scientists for security reasons for many years. The situation is more stable in Somaliland, an autonomous region in northern Somalia on the southern coast of the Gulf of Aden (Filho and Oliveira da Motta 2021) (Figure 2.1). Braulik et al. (2022) undertook a scoping trip to Somaliland in January 2022 to evaluate the potential for collaborative marine science and conservation work. Fishers reported that dugongs were seen near Hiis (or Heis) in the past and there were contemporary sightings in the Zeyla archipelago near the border with Djibouti (Figure 2.1). These reports included recent sightings plus very regular sightings over a long period suggesting a resident population of dugongs (Braulik et al. 2022).

The IUCN Marine Mammal Protected Area Task Force (MMPATF) is in the process of identifying IMMAs in many parts of the world including East Africa. IMMAs are discrete portions of habitat, which are important to marine mammal species and have the potential to be delineated and managed for conservation. The MMPATF has identified the Gulf of Aden and Socotra Archipelago as an Area of Interest (AoI) for potential designation as an IMMA (IUCN-MMPATF).

In February 2024, Somalia submitted its first candidate properties to the United Nations Educational Scientific and Cultural Organisation (UNESCO) World Heritage Tentative List. Somalia proposed two natural sites, one of which is 'Bushbushle National Park', with an area of over 3,300 km^2 (UNESCO 2024). Bushbushle National Park is located south of the Bajuni Archipelago where dugongs were known to occur as explained above (see also Figure 2.3).

- Although the fringing reefs and barrier islands between the border of Kenya and the Bajuni Islands are believed to have supported significant numbers of dugongs in the past, there is no contemporary information regarding dugongs in this region.
- North of the Bajuni Islands, the open coastline is unlikely to provide habitat for dugongs.
- There is anecdotal evidence that dugongs occur in the Zeyla archipelago near the border with Djibouti.

2.2.2 Kenya

Herds of dugongs were reported in the Gazi-Funzi area in the 1950s (Pertet and Thorsell 1980; Figure 2.4). However, the literature suggests that dugongs have been declining along much of the Kenyan coast since at least the middle of the 20th century (Jarman 1966), despite undated anecdotal sightings of large herds at Mombasa and Malindi (Jarman 1966; Figure 2.4). Low numbers of dugongs were sighted during aerial surveys along the Kenyan coast conducted in 1993 through 1998 (Cockcroft et al. 1994; Cockcroft 1995; Wamukoya et al. 1997; Cockcroft and Young 1998). In 2016 and 2017, transect aerial surveys were performed at historical areas of local importance (Kiunga to Kipini and Gazi to Vanga; Wamukoya et al. 1996) plus shoreline surveys along the remaining Kenyan coast (Cockcroft et al. 2018). Only two 'possible dugongs' were sighted, one in the south (Gazi to Vanga) and one in the north (Kiunga to Kipini).

Awadh et al. (2021) used a literature review and semi-structured questionnaires, guided interviews, and focus group discussions with a total of 378

Figure 2.4. Geographic context of Kenya showing placenames mentioned in the text. Inset: Manda Bay. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

fishers in six fishing villages (Vanga, Shimoni, Msambweni, Matondoni, Kizingitini and Kiunga; Figure 2.4), to obtain information on the status and distribution of dugongs in Kenya. Their results suggested that the Kenyan dugong population is currently very small and scattered. Fishers in the northern areas, especially within Kiunga Marine National Reserve, consistently reported higher numbers than in the southern region. Anecdotal information suggests a small population exists from just south of Msambweni to Funzi creeks and north from the Siyu channel through Kiwayuu to Kiunga (Figure 2.4). Awadh et al. (2021) estimated that there are about 20 dugongs in Kenyan waters with at least 10 in Kiunga, making Kiunga the most significant dugong conservation site with the rest scattered in the other locations (Shimoni, Msambweni, Matondoni and Kizingitini). This conclusion is consistent with Jarman (1966), who considered the Lamu region to be the major stronghold of the dugong on the Kenyan coast.

The IUCN MMPATF identified the Lamu to Kiunga Archipelago as an AoI for potential designation as an IMMA (IUCN-MMPATF). The dugong was the only supporting species listed as of March 2024.

- The Kenyan dugong population is currently very small and scattered.
- Anecdotal information suggests that a small population exists just south from Msambweni to Funzi creeks and north from the Siyu channel through Kiwayuu to Kiunga.

2.2.3 Tanzania

Information on dugong distribution and abundance in Tanzania is mostly derived from anecdotal reports and incidental sightings. Kingdon (1971) reported two main areas for dugongs in Tanzanian waters: the coastal waters of the Pemba-Zanzibar Channel and the Rufiji-Mafia area (Figure 2.1). Interviews with fishers between 2000 and 2003 yielded 38 reports of sightings (31 incidental captures; seven live; EAME 2004). The general level of awareness of dugongs amongst interviewees was high with nearly 70% recognising the dugong on an identification card. Seventy-nine percent of respondents reported a dramatic decline in dugong numbers since the mid to late 1970s.

The most likely place for any remaining dugongs in Tanzania is off the Rufiji Delta (EAME 2004), where two animals were caught in gillnets in January and March 2004, providing the first concrete evidence of the existence of dugongs in this area for 74 years. Infrequent sightings have also been reported from Moa in the north; these dugongs may be connected with those in southern Kenya (Figure 2.1). No dugongs were sighted during: (1) two transect aerial surveys of the Rufiji Delta-Mafia area between 2006 and 2008 (Muir 2006; Mbugani 2008), or (2) transect aerial surveys in the region between Somanga (Kilwa district) and the northern Rufiji Delta and across the Mafia Channel to western Mafia Island, or (3) inside the 30 m isobath in 2016 and 2017 (Cockcroft et al. 2018). Braulik et al. (2017) sighted two dugongs north of Mafia Island in 2014. There was a dead dugong photographed in Pemba Island in 2023 reported to the Tanzania Whale Network, another in May 2017 as well as a live sighting in 2018 (G. Braulik personal communication via email to Marsh and Schramm July 2023). Cockcroft et al. (2018) also found feeding trails around Pemba Island providing further evidence of their presence in this area.

The ecology of the Rufiji Delta–Mafia area depends on its seasonal nature and is influenced by the wet season inflow of water and sediment from the Rufiji River, which is being altered by the large Julius Nyerere Hydropower Project and its associated dam (IUCN 2019). The dam has a storage capacity of 34 billion cubic meters. How this dam will affect the seagrass habitat in the Delta or the livelihoods of the people living there is not yet known (IUCN 2019).

The IUCN MMPATF identified the Rufiji to Mafia-Kilwa coast as an AoI for potential designation as an IMMA (IUCN MMPATF). The dugong was the only qualifying or supporting species listed as of March 2024.

- The dugong population in the waters of Tanzania is currently very small and scattered. The most likely place for any remaining dugongs is the coastal waters off the Rufiji Delta.

2.2.4 Mozambique

Dugongs have been reported from: Maputo, Inhambane, and Bazaruto Bays, as well as the Primeiras and Segundas (Angoche) and Quirimbas Archipelagos (Hughes and Oxley-Oxland, 1971; Cockcroft et al. 1994; Cockcroft and Young 1998; Findlay et al. 2011). Cockcroft et al. (1994, 2018) concluded that observations and strandings of dugongs were very rare outside the Bazaruto Seascape (approximately 21° S to 22° S; Figures 2.1, 2.3). Dugongs have usually been sighted in shallow, near-shore waters or sheltered areas such as within

Bazaruto Bay or in mangrove-fringed estuaries along the mainland coast (Trotzuk et al. 2022b). Most individuals have been observed in shallow waters (less than 20 m deep), within approximately 10 km of the coast; individuals (including calves) have been occasionally detected over 20 km offshore or in water deeper than 30 m (Bazaruto Archipelago National Park [BANP] 2022). Groups as large as 70 individuals have been observed as recently as 2021, and large groups of 10 – 20 individuals are regularly encountered during aerial surveys and by boats (BANP 2022).

Robust estimates of dugong abundance in the Bazaruto Seascape have been obtained using aerial transect surveys and distance sampling since 2006-2007 (Findlay et al. 2011; Cockcroft et al. 2018; Trotzuk et al. 2022b; BANP 2022). The most recent visibility- bias-corrected estimate from strip transect aerial surveys in 2022 was 406 ± SD 146 individuals. Dugongs were seen throughout the entire survey area but were clustered into two areas of importance: (1) the north of Bazaruto Bay (Figure 2.5) and (2) the mangrove-fringed estuaries near the Save River. The percentage of calves was 14%, suggesting a successful breeding population. The relatively large confidence intervals around all the survey estimates make it very difficult to detect significant trends in the population. Thus, it cannot be confirmed whether the size of the Bazaruto population has increased, decreased or remained stable since the population was surveyed by Findlay et al. (2011) in 2006-2007 (Trotzuk et al. 2022b).

Trotzuk et al. (2022b) conducted Population Viability Analyses using a range of parameters. The most liberal analyses estimated that the population could endure the removal of up to six adult dugongs per year before a decline would begin, while the most conservative estimates were that the removal of more than one adult was unsustainable.

Figure 2.5. Part of a large, scattered group of dugongs in the northern Bazaruto Seascape in December 2021. Evan Trotzuk photograph; reproduced with permission.

The 'Bazaruto Archipelago and Inhambane Bay' region (Figure 2.1) was declared an IMMA in 2020 (IUCN-MMPATF 2020) and Great Bazaruto has been established as a KBA due, in part, to the presence of dugongs (KBA Partnership 2024).

- The Bazaruto Seascape is the only location in East Africa where a globally important dugong population is known to occur.
- This location has been recognized internationally as an IMMA and a KBA.
- Bazaruto dugongs and the threats to them are actively monitored by African Parks.

2.2.5 Madagascar

Petit (1927), cited by Davis et al. (2022), reported that dugongs were common and present in herds and large groups around Madagascar's vast coastline. However, over the past half century they are believed to have suffered a precipitous decline, with sightings now very rare. Cockcroft (1993) reports anecdotal data suggesting that dugongs may have occurred on the south-west coast of the island at that time; six dugongs were allegedly caught at Morombe in 1992. Socioecological interview surveys from 2008-2013 at 15 locations along the west coast from Nosy Mitsio to Ifaty (Figure 2.1), and on the north-east coast at Masoala Peninsula (Cerchio et al. 2012 in Davis et al. 2022) suggest a severe decline in dugong populations in recent decades, especially during and after the 1980s and 1990s.

Fisher interviews and anecdotal communications including photographed kills provide recent information on dugongs in the coastal waters of Madagascar (Davis et al. 2022). Dugongs have been infrequently observed in the extreme northern region between the Sahamalaza Peninsula in the west and Vohémar in the east (Figure 2.1) as recently as 2010.

Intensive interview surveys have been conducted with fishers since 2009 across northern Madagascar by various researchers. Davis et al. (2022) concluded that methodological differences preclude meaningful comparisons. Community Centred Conservation's (C3) studies between 2009 and 2017, across the regions of Nosy Hara Marine Park, Ampobofofo, Bay of Rigny complex and Ambodivahibe, confirm that these areas are still important habitats for dugongs, with cow-calf pairs consistently sighted in the bays and around the islets of Nosy Hara Marine Park (C3 2010a).

A fisher opportunistically encountered and killed a dugong at Andovokonko near the village of Ivovona in the Ambodivahibe region in 2018 (Davis et al. 2022). Anecdotal evidence indicates that dugongs were encountered and targeted by fishers in the southwest region around Andavadoaka as recently as 2010 (Davis et al. 2022). Another dead dugong was reported in 2020 in Baie de Baly National Park (feedback from managers and fishermen to L. Benagou personal communication 2024).

An initial survey of Sahamalaze fishers as part of a regional cooperation project underway between Naturalistes and Madagascar National Parks identified a location near Berafia, where a group of six dugongs was observed in 2018. In addition, a group of 10 dugongs was spotted at Analalave in 2020 (L. Benagou personal communication via email to Marsh and Schramm 2024).

Aerial surveys also suggest that dugongs may occur over a wide area in Madagascar at very low densities. Dugongs were sighted on seven occasions during an aerial survey of northern and western Madagascar for cetaceans in 2009 (Laran et al. 2012). The transect design was not a fine-scale assessment of coastal or shallow-water dugong habitat and there were no corrections for detection bias. Thus, the 2009 survey will likely have underestimated dugong numbers. One dugong was seen in the Ampasindava region of the northwest within Nosy Hara Marine Park, supporting anecdotal evidence of an extant population in this region (Cooke et al. 2003; C3 2010a). Six sightings occurred on an approximately 150 km stretch of coast in the northwest between Mahajanga and Sahamalaza. Dugongs were not sighted in other survey areas including the central west coast and the Barren Islands; the southwest coast, including the Andavadoake region; and the northeast coast, including Antongil Bay and the Masoala Peninsula.

The waters of the Mozambique Channel off the northwest coast of Madagascar support numerous marine mammal species including dugongs and have been declared the 'Northwest Madagascar and Northeast Mozambique Channel' IMMA with dugongs as one of 22 supporting species (IUCN-MMPATF 2021, Figure 2.1).

- Dugongs are believed to have suffered a precipitous decline in the waters of Madagascar over the last 50 years. Aerial surveys and fisher interviews suggest that they still occur over a wide area at very low densities.
- Nosy Hara Marine Park, Ampobofofo, Bay of Rigny complex, and Ambodivahibe are still important habitats for dugongs.
- The 'Northwest Madagascar and Northeast Mozambique Channel' IMMA, which spans the waters of Comoros, Mayotte and Northwest Madagascar, includes the dugong as one of its 22 supporting species.

2.2.6 Union of the Comoros, Mayotte, Seychelles, Mauritius and Rodrigues

2.2.6.1 Union of the Comoros

The Union of the Comoros comprises three volcanic islands (Grande Comore [with capital Moroni], Anjouan, and Mohéli), located north of the Mozambique Channel (Figure 2.1). Prior to 1970, dugongs were recorded around all three islands; Muir and Kiszka (2012) concluded they were limited to the waters of Mohéli. In 2022, 182 people were interviewed in 17 Mohéli villages by Mohéli National Park and the Naturalistes de Mayotte association (Bernagou et al. 2023). Approximately 45% of respondents were aged between 36-55 years. Sixty-one percent of respondents were familiar with the dugong and could recognize one from a photograph. Most believed that numbers had declined during their lifetime. People familiar with the dugong were asked to estimate the size of the population around the island. About half considered that the population would be less than 10 individuals; approximately 30% thought that it would be greater than 21 individuals.

- In the Comoros, dugongs seem to occur only in the waters of Mohéli, where villagers are familiar with dugongs and most believe the population is declining.

2.2.6.2 Mayotte

Mayotte forms part of the Comoros Archipelago but is approximately 100 km from the nearest Comorian Island and is administered by France (Figure 2.1). Kiszka et al. (2007) collated opportunistic sightings from 1999 to 2005 (n=53), surveyed 35 local fishers from six villages, and undertook aerial surveys between July and November 2005. They sighted five dugongs including one cow-calf pair in the lagoon of Mayotte, despite sub-optimal aerial survey conditions in some parts. They concluded that dugongs were common in the lagoon before the 1980s, and then declined significantly due to hunting pressure and bycatch in fishing nets. Nonetheless, recreational dive operators and microlight aircraft pilots still report opportunistic sightings in many places in the lagoon. For example, 360 opportunistic sightings of dugongs were reported between 2006 and 2023, and a cow-calf pair was observed in July 2023 (L. Bernagou personal communication via email to Marsh and Schramm 2023).

Bernagou and Beudard (2022) used the same questionnaire to survey 557 people (426 fishers) from 55 villages around the coast of Mayotte. Around 46% of respondents were over 56 years of age, 38% were aged 36-55, 13% were 18-35 and 3% were younger than 18. Respondents reported 'recent' sightings including cow-calf pairs. A very high percentage of respondents (approximately 91%) knew the dugong and could recognize one from a photograph. Most perceived that dugong numbers had declined during their lifetime. People familiar with the dugong were asked to estimate their numbers in the Mayotte lagoon. More than 70% considered that the population would be of less than 10 individuals, approximately 10% between 10 and 21 individuals; only seven respondents thought there would be more than 21 dugongs in the region.

- Dugongs including cow-calf pairs are regularly sighted in Mayotte lagoon, where recreational dive operators and microlight aircraft pilots report opportunistic sightings of them.

2.2.6.3 Seychelles

The Republic of Seychelles comprises 115 islands off the coast of East Africa. Although historically dugongs are thought to have occurred around the granitic islands of Seychelles (McAteer 2002; EAME 2004), sightings over the past 50 years are restricted to the Aldabra Group of islands (Aldabra, Assomption, Cosmoeldo, Astove; EAME 2004). This remote island group is located more than 1,000 km from Seychelles' populated main islands, around 780 km off the Rufiji delta in Tanzania and 300–400 km from the Comoros, Mayotte and Madagascar, suggesting that the Seychelles dugong population is isolated. Aldabra Atoll, a UNESCO World Heritage site, is the only location where dugong sightings have been recorded since the 1970s (Hermans and Pistorius 2008; Hamylton et al. 2012; Appoo et al. 2019). Mapping over the last decade recorded 75.4 km^2 of seagrass habitat within Aldabra's lagoon (including 4.3 km^2 dominated by seagrass and the remainder sparsely mixed with macroalgae; Hamylton et al. 2018) and 15.5 km^2 of seagrass habitat at Aldabra's outer reefs (including 14 km^2 dominated by seagrass and the remainder dominated by macroalgae with interspersed seagrass; Haupt et al. 2015). It is uncertain what proportion of these habitats are used by dugongs.

Records of dugong sightings are available from Aldabra Atoll since 1970. Muir et al. (2004), Hermans and Pistorius (2008), Hamylton et al. (2012) and Appoo et al. (2019) reported 31 and 42 opportunistic shore and vessel sightings during 1970-2009 and 2010-2018, respectively, by researchers and staff of the Aldabra research station. Small groups of dugongs including cow-calf pairs have been seen at irregular intervals inside Aldabra Atoll's shallow 200 km^2 lagoon and on the seaward reefs (A. Koester personal communication via email to Marsh and Schramm 2024). The largest group of dugongs seen at Aldabra comprised at least 10 individuals in 2021 (A. Koester personal observation 2021).

Dugongs have been recorded in all months suggesting a resident population (Appoo et al. 2019). A partial aerial survey of the Aldabra Atoll lagoon conducted in February 2013 using a gyrocopter and helicopter recorded 14 dugongs including two calves (Seychelles Island Foundation [SIF], unpublished data in Appoo et al. 2019). In 2022, SIF launched the first systematic aerial surveys using UAVs with the aim of obtaining a population estimate of dugongs at Aldabra. Preliminary analysis of survey images collected in 2023 indicates records of 19 individual dugongs, including calves (SIF, unpublished data).

- A resident population of dugongs occurs in the Aldabra Atoll lagoon, a UNESCO World Heritage site.
- The lagoon contains approximately 75 km^2 of seagrass habitat.
- Dugongs no longer occur in the granitic islands of Seychelles.

2.2.6.4 Mauritius and Rodrigues

The C3 Madagascar and Indian Ocean Islands Programme (C3 2010b) undertook a comprehensive, systematic study to determine whether the dugong still existed in Mauritius and Rodrigues (Figure 2.1). Their literature review found convincing accounts of dugongs from the 1600s until the end of the 18th century, written by Dutch captains, colonial governors and early French explorers and naturalists. Seventeenth century Portuguese sailors allegedly referred to Mauritius as the 'Island of the

Siren' or *Ilha do Cirne* (from Sirene) on account of the abundance of dugongs in its coastal waters (Valledor de Lozoya 2004).

From 1638 to 1710, Dutch colonists at Fort Frederik in the southeast of Mauritius relied on dugong meat as a major component of their diet, as evidenced by large quantities of dugong remains found in archaeological excavations of the site (Cheke and Hume 2008; Gill 2009; Peters et al. 2009). Nonetheless, C3 (2010b) found no accounts of dugongs around Mauritius after 1800, although they were still described from Rodrigues in the mid-1800s (Pridham 1849).

Herds of 300-400 dugongs were reported from Rodrigues in the early 1700s (Leguat 1708). These animals provided large quantities of salted meat to Mauritius (d'Heguerty in de Lozoya 2004). Although Abbey de Pingré (1766, in Dupon 1969) noted that dugongs had become rare, small numbers were still observed at the end of the 18th century (Marragon 1795 in Dupon 1969). Stoddart (1972) claimed that sightings of single animals or small groups were reported from all around Mauritius in the 17th and 18th centuries, although it is possible that some of these sightings were of seals.

C3 (2010b) interviewed 105 fishers at six landing sites in Mauritius in 2008, and 97 fishers at five landing sites in Rodrigues in 2009. Three Mauritian fishers recognized the dugong from a photo and stated that they had seen the animal between the years of 1935 and 2008. Rodrigues' fishers recognized a photo of the dugong. Some were familiar with the French name for dugong (Lamentin); however, it became apparent upon further questioning that they were referring to seals.

- Dugongs are probably extinct in the waters of both Mauritius and Rodrigues.

2.3 Cultural values

Dugongs occupy an important cultural role in East Africa. In Tanzania, Comoros and northern Mozambique, they are called *nguva* (mermaid) or sometimes even *binamana* (human) (Muir and Kiszka 2012), suggesting an intimate likeness between humans and dugongs. In Shimaore (a regional language of Mayotte), elders call dugongs *doutzi*, though the most common name is now *lambohara*, as in Madagascar (L. Bernagou personal communication via email to Marsh and Schramm 2024). Kingdon (1971) claimed: '*to this day fishermen in Zanzibar who have caught a female dugong have to swear they have not interfered with it*' (p. 398). It is a similar story in Mayotte and the Union of the Comoros where fishers had to swear on the Koran not to have interfered with captured female dugongs (L. Bernagou personal communication via email to Marsh and Schramm 2024). In Kenya, dugongs are known as *nguva* but are differentiated from mermaids/mermen, which are known as *kitunusi*. Muir and Kiszka (2012) report that consuming dugong meat is commonly believed to improve longevity, and some East African fishers believe that dugong bones ward off evil spirits. Rich folklore, beliefs, and taboos defined Malagasy peoples' traditional interactions. Davis et al. (2022) report that members or descendants of the Anjoaty tribe in north Madagascar (known as mystics), were the only people, apart from the chief fisherman of the village, with the right to preside over ceremonial slaughter. Iyengar (2018) conducted a cultural study in the southwestern, northeastern, and northwestern regions of Madagascar and concluded that dugong hunting was neither frequent nor indiscriminate in the past. In Kenya, dugongs were hunted for their meat and oil, used as food and medicine (Awadh 2021; Awadh et al. 2021). In Mayotte and Comoros dugong bones were crushed and mixed with water to form a paste and believed to have aphrodisiac and medicinal properties (L. Bernagou personal communication via email to Marsh and Schramm 2024).

The dugong is now used as a symbol for the Bazaruto Seascape, featuring on the logo of the Bazaruto Archipelago National Park, the names of local lodges, and as the mascot for various regional events and initiatives (BANP 2022).

2.4 Threatening processes

The root causes of the threats to dugongs in East Africa are the limited capacity for effective law enforcement in most dugong Range States, lack of political will, corruption, human migration to coastal areas, armed conflict and high human population growth rates. These circumstances put severe pressure on marine ecosystems to support food provisioning. Climate change is likely to exacerbate the situation as it is a threat multiplier (Marsh et al. 2022).

Threatening Processes

Bycatch and illegal hunting: are the principal causes of population decline.

Habitat loss and degradation: Driven by coastal development and pollution.

Apparently low genetic diversity: a significant challenge to population resilience and recovery.

The cumulative impacts of these threats necessitate targeted conservation interventions across the region, emphasizing habitat protection and the mitigation of human-induced threats.

The list of threats to dugongs and their habitats below is modified from Trotzuk et al. (2022a), who considered the risks to the dugongs in the coastal waters of East Africa from southern Somalia south. Davis et al. (2022) list similar threats to dugongs in Madagascar.

2.4.1 Threats to dugong survivorship

- Incidental capture in fishing gear (e.g., gillnets and seine nets); illegal, unreported, and unregulated (IUU) fishing, particularly if incidental captures are 'targeted' for later consumption; entanglement in marine debris including discarded fishing gear, ghost gear and plastic litter (see Burt et al. 2020; Vogt-Vincent et al. 2023).
- Hunting and targeted fishing: historically legal, currently illegal.
- Vessel strikes.
- Extreme natural events (e.g., storm surges and tsunamis).

2.4.2 Threats to dugong fecundity due to habitat loss, fragmentation, and modification

- Habitat damage caused by human settlements and infrastructure development on coasts and associated riverine systems; oil and gas exploration and production; shipping; destructive fishing (netting and trawling).
- Degradation of seagrass habitat, including from untreated sewage disposal, coastal dredging and reclamation, sand mining for heavy metals; inshore commercial trawling, declining water quality due to land clearing and resultant erosion.
- Extreme weather and climate change impacts on seagrass communities (e.g., extreme tropical storms, marine heatwaves).
- Chemical pollution (e.g., oil spills and heavy metal loads).

Another possible threat of unknown impact is the seismic testing proposed seaward of Bazaruto Bay. Dugongs mostly occur in shallow water, where the propagation of sound is limited (R. McCauley personal communication via email to Marsh 2023). The proposed seismic survey is off the continental shelf edge in waters over 200 m deep. Thus, it is unlikely that the animals to the west of the Bazaruto Archipelago would be impacted by the seismic survey. However, problems may arise for dugongs on the eastern (towards Mozambique Channel) side of the Bazaruto Archipelago, or dugongs making deep water crossings (R. McCauley personal communication via email to Marsh 2023).

The only confirmed dugong population known to be in the hundreds of animals in East Africa is in the Bazaruto Seascape (Section 2.2.4), a situation which exacerbates these risks to the regional population. The seagrasses that support the Bazaruto population could be severely damaged by disease, an extreme weather event or a series of extreme events. Unlike the situation in eastern Australia (Preen and Marsh 1995; Marsh et al. 2022; Cleguer et al. 2023), Bazaruto dugongs have limited opportunities to move to well-protected, alternative seagrass communities, while seagrass recovers. There is no evidence that the historical dugong strongholds in East Africa have been recolonised (see Sections 2.2.1. Somalia, 2.2.2. Kenya and 2.2.5. Madagascar above), suggesting limited capacity for range extension in the region in human timeframes.

With the exception of Aldabra Atoll, a UNESCO World Heritage site, tensions between biodiversity conservation and the imperative for resource extraction, infrastructure and other forms of development are acute throughout East Africa, especially in areas where dugongs are already rare and unlikely to be a conservation priority. For example, large-scale infrastructure development such as the proposed port expansions for Lamu and Maputo (Figure 2.1), the construction of the East Africa Crude Oil Pipeline in northern Tanzania, offshore gas extraction in Mozambique's Rovuma Basin and mining for sand, oil, and gas around the Bazaruto Archipelago could all lead to dugong mortality and habitat loss as explained by Trotzuk et al. (2022a).

Climate change, which is predicted to increase the intensity (but not the frequency) of tropical storms is likely to adversely affect the demography of the East Africa dugong population in the future (see Marsh et al. 2022). A series of floods and storms caused the loss of roughly 1,000 km² of seagrass in Hervey Bay, Queensland, and the mortality of at least 99 dugongs in 1992 (Preen and Marsh 1995). A similar series of events in the Bazaruto Seascape must be a significant extinction risk to dugongs in East Africa, especially given the low genetic diversity of dugongs in this region (Section 2.1.3).

2.5 Conservation initiatives

2.5.1 International conventions

All East African dugong Range States are Parties to the Convention on Biological Diversity[4] (CBD) and the Convention on the Conservation of Migratory Species of Wild Animals (CMS). They are also Signatory States to the CMS Memorandum of Understanding on the Conservation and Management of Dugongs (*Dugong dugon*) and their Habitats throughout their Range (Dugong MOU) and Parties to the United Nations Framework Convention on Climate Change (UNFCCC). All but Somalia are Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

2.5.2 National laws

Muir and Kiszka (2012) claimed that dugongs were protected under fisheries and/or wildlife laws throughout East Africa but noted with concern that these laws are rarely adequately enforced. The current situation may be even less satisfactory than they thought. Davis et al. (2022) noted that although dugong hunting was banned in Madagascar in the 1920s, dugongs (and other marine mammals) have technically fallen out of national legal protection as Decree 2006-400 (which does not list the dugong) has replaced pre-existing Decree 61-096 (which listed dugongs). This was confirmed by a 2018 government report (France, Ministry of Environment, Ecology and Forests 2018).

In France, a ministerial decree prohibits the targeted hunting of all marine mammals including the dugong (Decree of 1 July 2011, amended in 2020). Thus dugong hunting is illegal in Mayotte, which is a Department of France. There are no specific legal texts on the protection of dugongs in the Union of the Comoros. Nonetheless, the species appears on the list of taxa protected by a decree (Order No. 01/031/MPE/CAB) on the protection of species of wild fauna and flora of the Comoros. The decree prohibits the capture, detention and killing of all fully protected species which includes the dugong. Exportation of live or dead specimens, and any disruptions during periods of reproduction are also prohibited actions. In addition, the Mohéli National Park has identified the dugong as a conservation priority. In the Seychelles, dugongs are protected under the Fisheries Act which prohibits targeted hunting but are not specifically listed under the *Wild Animals and Birds Protection Act* (A. Koester personal communication via email to Marsh and Schramm 2024).

As explained in Section 2.2, dugongs are also protected in several parks and reserves including: Kiunga Marine National Reserve (Kenya), Bazaruto Archipelago National Park (Mozambique), Nosy Hara Marine Protected Area (Madagascar) and Parc Naturel Marin de Mayotte (Mayotte's entire EEZ). Aldabra Atoll has been managed by SIF since 1979 and was designated a Special Reserve in 1981 under the National Parks and Nature Conservancy Act. In 1982, Aldabra Atoll was inscribed as a UNESCO World Heritage Site. In most locations in East Africa, there is a severe lack of funding to adequately enforce the conservation of dugongs, even when they are legally protected.

2.5.3 Conservation status

Although its assessments of conservation status are usually conducted at a global scale, the IUCN allows assessments of isolated regional population (which IUCN refers to as 'subpopulations') for species with heterogeneous regional status such as the dugong. The IUCN declared the East African coastal 'subpopulation' from southern Somalia through Mozambique to be Critically Endangered in 2022 (Trotzuk et al. 2022a). Even though the designation of Critically Endangered is based on Criterion C, the

4 The Republic of Mauritius is not considered here as the dugong is believed to be extinct in its waters

full range of IUCN Red List categories, under which this 'subpopulation' qualifies for listing, has been included below as evidence of the rationale for the IUCN assessment:

- Criterion B: Vulnerable (VU B2ab(v))
- Criterion C: Critically Endangered (CR C2a(ii))
- Criterion D: Endangered (EN D)

The justification for this assessment was:

- the number of mature individuals in the geographically isolated Eastern Africa subpopulation was estimated to be fewer than 250 in 2022;
- more than 90% of all mature individuals occur at only one location – the Bazaruto Seascape;
- pressures, including habitat loss and unsustainable fishing techniques, continue to threaten the entire subpopulation; and
- participatory appraisals in coastal communities throughout the region over the past 30 years indicate continuing decline.

The status of the dugong in: (1) the coastal the waters of the Gulf of Aden, and (2) around the offshore islands of East Africa have not been formally assessed by IUCN.

2.5.4 Other conservation initiatives

- Non-Government Organisations (NGOs) have developed education and awareness programs in several important dugong locations in the region. C3 Madagascar has focused intense efforts on outreach to remote communities of Nosy Hara Marine Park, which includes incidental monitoring by members of the marine park committees, school awareness campaigns, theatre and events organized by the Junior Ecoguards Youth Network (Davis et al. 2022). In Sahamalaza National Park, Madagascar, ranger capacity building and monitoring were initiated in 2016 under the Global Environment Facility (GEF) Dugong and Seagrass Conservation Project. Outreach campaigns include the production of communication materials on dugongs (signboards, posters, brochures, children's storybooks, and touring theatre), training in seagrass and dugong ecology, conservation, and monitoring (Rakotoarimino and Davis 2017).
- In a project funded by the Dugong MOU, the NGO Sea Sense implemented the '*Thamani wa Nguva*' project in the Kibiti and Kilwa districts of Tanzania. The project raised public awareness of the dugong as a flagship species through hosting events to celebrate 'World Seagrass Day' in March 2023; engaging with national and local decision-makers, implementing a school education program, and building capacity of community fisheries managers to appreciate the importance of protecting dugongs and conserving seagrass meadows.
- In Mayotte, a second National Action Plan for the Dugong (2021-2025; Anon 2024) has been adopted by the French government. The main objectives of this plan are to reduce dugong mortality by addressing direct threats and improving knowledge about the species and its habitats to enable effective management. Planned activities include: (1) consultation and awareness-raising activities for fishers; (2) subtidal seagrass studies; (3) drone flights for photo-identification of dugongs; (4) collection of environmental DNA (eDNA) in collaboration with Bazuruto Archipelago National Park in Mozambique; (5) community awareness raising; and (6) regional cooperation including training of Mohéli National Park staff in drone protocols and seagrass monitoring with plans to train Madagascar National Parks staff in the same protocols in 2025. A collaborative platform to centralize data and create a regional dugong photo-identification catalogue is currently under development. There are also plans to develop monitoring methods using underwater cameras and acoustic techniques.
- In Mohéli, Comoros, the Mohéli National Park team has conducted an environmental education program for conservation target species including the dugong over the past 23 years across 20 villages (M. Ben Anthoy personal communication via email to Marsh and Schramm 2024). This program aims to support local communities as well as encourage political and judicial authorities to join the Mohéli National Park team in conservation and protection efforts for its target species (M. Ben Anthoy personal communication via email to Marsh and Schramm 2024).
- Numerous Mozambique government and NGO initiatives aimed at conserving dugongs have been developed in the Bazaruto Seascape (see Box 2.1).

Text Box 2.1 Factors influencing the prospects of effective dugong conservation in the Bazaruto Seascape (E. Trotzuk, African Parks, in writing to Helene Marsh October 2024)

History and geography

- In contrast to situation along the Swahili Coast (coastal southern Somalia, Kenya, Tanzania, and northern Mozambique), the Matswa communities on the mainland of the Bazaruto Seascape were principally agrarian rather than seagoing. The Vahoca of the Bazaruto Archipleago migrated to the islands in the 19th century. Thus, the dugong has historically been of limited cultural importance in this region.

Current situation

- The Bazaruto Seascape is defined by the 5,236 km^2 Greater Bazaruto Key Biodiversity Area (KBA), which includes the 1,430 km^2 Bazaruto Archipelago National Park (BANP), first established in 1971, and the adjacent 439 km^2 Vilankulo Coastal Wildlife Sanctuary (the Sanctuary). There is also a broader Important Marine Mammal Area (IMMA) that includes the Bazaruto Seascape along the broader Inhambane Coastline.
- The average monthly salary in Mozambique is around USD 29, and most people are highly dependent on natural resources for their livelihoods. Along the coastline, artisanal fisheries are a major source of food security and income.
  - In the Bazaruto Seascape, seine netting is the most profitable and widespread type of fishing because upwellings in nearby coastal waters support large schools of small coastal pelagics.
  - Approximately 400 individual fishing boats operate in the Greater Bazaruto KBA.
  - Gill netting is prohibited in and around BANP and the Sanctuary (BANP 2022). It is illegal to leave any type of gear (gill nets included) unattended anywhere in Mozambique. The Mozambique government has approved a regulation for maritime fishing in 2020 to ban the use of beach seines nets to enable the recovery of seagrass.
- In 2017, the Mozambique government entered into a 25-year co-management agreement with African Parks to provide:
  - Community Development
    - > Engagement
    - > Economic and development programs
    - > Education
  - Biodiversity Conservation
    - > Restoration of critical ecosystems
    - > Conservation law enforcement
    - > Research and monitoring
  - Park Revenue Generation
    - > Tourism
    - > Sustainable valorization and use of natural resources
  - Management and Infrastructure
    - > Planning
    - > Infrastructure
    - > Sound governance and compliance
  - In Mozambique, African Parks currently employs around 250 staff, of which 99% are nationals, and has an annual operating budget of around USD 3 million.
- The Bazaruto Seascape is an established international tourism destination. Revenue is generated by entry and activity fees, as well as concession fees for lodges inside BANP.
  - The Mozambique Government mandates that 16% of BANP's income from tourism goes to local communities. This totalled around USD 80,000 in 2023 and is projected to grow to over USD 200,000 in 2025. This money is managed directly by the community for development projects that bring widespread benefits (improved education, healthcare, etc). Improved tourism revenue linked to effective conservation programs correlates directly to increased benefits for islanders.
- There is strong government buy-in to these arrangements. National, provincial, and district governments are supportive of conservation initiatives.

2.6 Research and monitoring initiatives

2.6.1 Techniques used to date

2.6.1.1 Distribution and abundance of dugongs and their habitats

As outlined in Section 2.2 above, extensive shoreline and transect aerial surveys have been carried out for dugongs in many parts of their East African range. Outside of the Bazaruto Seascape, most of these surveys have been exploratory snapshots that have detected too few dugongs to make population estimates, even in areas of historically-higher dugong density.

The Bazaruto Seascape is the only place where a time series of population estimates has been attempted, largely on an opportunity basis between 2006–2016. Since entering into a co-management agreement with the Mozambican government in 2017, African Parks has started flying surveys on an annual basis (BANP 2022). However, the relatively large confidence intervals around the survey estimates mean that the power of the time series to detect significant trends in the population is weak using frequentist statistics but may be improved using Bayesian methodologies (Marsh et al. 2020 Appendices 8-11; Cleguer et al. 2023). These surveys are critical and should continue with high priority. The optimum survey interval should be informed by a power analysis.

Questionnaire surveys of fishers have provided valuable anecdotal information on dugong distribution, relative abundance and trends throughout much of the region outside Somalia, as discussed in Section 2.2 (see C3 2010a; Awadh et al. 2021; Cerchio et al. 2012 in Davis et al. 2022; Bernagou and Beudard 2022; Bernagou et al. 2023). This approach should be extended to the Zeyla Archipelago (Somaliland) and Bajuni Islands (Somalia).

Information on the distribution, extent of and trends in seagrasses in the region is very limited, as explained in Section 2.2.1. High resolution (25 cm) satellite images were used to search for seagrasses in Mozambique and to map seagrass meadows in the Bazaruto Archipelago (Cockcroft et al. 2018). This approach is likely to be of limited value in seagrass meadows with low above ground biomass often favoured by dugongs, especially subtidal meadows in turbid water, and it may be fruitful to consider using the range of large-scale, seagrass mapping approaches and techniques outlined in the Dugong and Seagrass Research Toolkit (Dugong and Seagrass Hub n.d.). At Aldabra Atoll, remote sensing and ground-truthing studies were conducted to map the Aldabra Atoll lagoon (Hamylton et al. 2018) and seaward reefs (Haupt et al. 2015).

2.6.1.2 Dugong biology

Little is known as to how the biology of East African dugongs differs from that of better studied populations elsewhere and outlined in Chapter 1. It is unlikely that their life history, ethology and behavioural ecology are sufficiently different to preclude meaningful inferences from populations outside the regions.

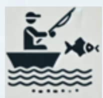
Other Priorities for Action

In addition to acting to resolve the matters listed above, the following priorities were identified for East Africa:

Developing cases for dugongs at the following locations to be listed as subpopulations by IUCN: (1) Aldabra Atoll (Seychelles); (2) Mohéli (Comoros) as well as:

Updating the comprehensive **'Dugong Conservation Strategy in East Africa'.**

Using small drones to conduct local scale surveys at key locations including: including **Aldabra Atoll (Seychelles)** and **Maputo Bay (Mozambique)**, **Mayotte** and **Mohéli.**



Conducting fisher surveys in the **Zeyla Archipelago (Somaliland)** and **Bajuni Islands (Somalia).**

Analysing the available samples **(mostly bone, teeth, and skin)** from East Africa to better understand the genetics of East African dugongs.

2.6.1.3 Dugong genetics

As outlined in Section 2.1.3, dugong genetics work to date has been hampered by small sample sizes. Cockcroft et al. (2018) identified 54 samples (mostly bone, teeth, and skin) from East Africa to better understand the genetic discreetness and structure of East African populations. This work is ongoing. Any connectivity between areas of local importance (Table 2.2) will be difficult to determine without very comprehensive genetic research unless accompanied by satellite tracking. In 2024, Trotzuk commenced a program of satellite tracking dugongs in the Bazaruto seascape in collaboration with Australian experts (C. Cleguer verbal communication with Marsh August 2024).

Genetic threats may arise when effective population sizes have declined, and/or when historically connected populations become isolated. These threats may reduce population viability due to loss of genetic diversity or inbreeding depression. There is a need for genetic analysis of additional samples from East Africa. Whole-genome data, even from one or a few individuals, would greatly help clarify population and demographic histories in the region. Such research has the potential to provide insights into the susceptibility of the East Africa population of dugongs to threats such as climate change and disease, especially if there is further evidence that genetic diversity is low.

2.6.2 Additional research techniques that may be applicable

2.6.2.1 Distribution and abundance of dugongs and their habitats

UAVs or drones, some of which are relatively inexpensive and easy to use, are increasingly used to conduct local scale seagrass and dugong surveys in various parts of the dugong's range including Aldabra Atoll (Section 2.2.6 Seychelles) and Maputo Bay, Mozambique (Cossa et al. 2023), Mayotte and Mohéli. This approach has potential to provide information on dugong distribution and abundance at the areas of local importance listed in Table 2.2 and inform understanding of the relationship between the dugong's fine-scale habitat use and their biophysical environment in the Bazaruto Seascape.

2.6.2.2 Spatial risk assessment of threats

A regional spatial risk assessment of the threats, including climate vulnerability of dugong areas of local importance, could form a framework for prioritizing management interventions for localities outside the Bazuruto Seascape.

Table 2.2. Summary of confirmed and possible (*) dugong areas of local importance in the East African region from north to south (Figures 2.1, 2.3, 2.4).

Country	Region
Somalia	Zeyla archipelago, Somaliland*
	Bajuni Islands*
Kenya	Kiunga to Kipini
	Gazi to Vanga
Tanzania	Kilulu south through Tanga to Pangani
	Coastal waters of Unguja and Pemba Island
	Somanga northwards to the northern Rufiji Delta and across Mafia Channel to western Mafia Island
Mozambique	Ruvuma Bay south through the Quirimbas Archipelago to Ponta do Diabo*
	Save River Mouth south through Bazaruto Archipelago to Cabo São Sebastião
	Morrumbene south through Inhambane Bay to Cabo da Barra
	Ponta da Macaneta south through Maputo Bay and Inhaca island to Cabo de Santa Maria*
Madagascar	Extreme northern region between the Sahamalaza Peninsula and Vohémar, including *Nosy Berafia in Sahamalaza National Park,* Nosy Hara Marine Park, Ampobofofo, Bay of Rigny complex and Ambodivahibe
	Mahajanga coast*
Comoros	Coastal waters of Mohéli
Mayotte	Coastal waters of Mayotte
Seychelles	Aldabra Atoll

2.7 Regional co-operation

Regional cooperation is well-developed in East Africa, outside Somalia. The EAME team produced a comprehensive 'Dugong Conservation Strategy in East Africa' in 2004 (EAME 2004). A joint project was conducted to collate information on the identity, distribution, status, threats, and management of the dugong in the Western Indian Ocean (WIO) region involving scientists from Kenya, Mozambique, South Africa, and Tanzania under the aegis of the Association for the Conservation and Protection of Dugongs and Marine Mammal Species (Cockcroft et al. 2018). A special session on dugongs was held at the Western Indian Ocean 12th Scientific Symposium in 2022 (WIOMSA 2022).

A regional cooperation project led by Naturalistes de Mayotte primarily involving Mayotte and Mohéli, was conducted with the aim of identifying target sites for dugong conservation, transferring expertise, and standardizing monitoring methods for seagrass beds and dugongs between the two islands (Mission Report 2023 unpublished). A similar project is planned by Naturalistes de Mayotte between Mayotte and Madagascar (L. Bernagou personal communication via email to Marsh and Schramm 2024).

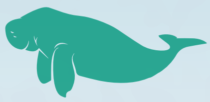
Outside the Bazaruto Seascape, dugong numbers are apparently so low that management interventions focussed solely on dugongs are unlikely to attract much support. Interventions designed to protect marine megafauna more generically are likely to be more successful and regional co-operation could be extended to groups with an interest in the conservation of marine turtles and small cetaceans.

2.8 Regional summary

In the East African region, dugongs persist in small populations in areas of local importance listed in Table 2.2 below. The only place with a confirmed population of hundreds of dugongs is the Bazaruto Seascape, although other areas may also support larger populations than currently confirmed (e.g., Zeyla Archipelago, Comoros Archipelago [Mohéli and Mayotte] and Aldabra Atoll). The ongoing persistence of the dugong in the region will depend on the successful conservation management of the species in as many of these areas as possible, particularly the Bazaruto Seascape.

It would be timely if the current regional co-operation (Section 2.7) led to an updated comprehensive 'Dugong Conservation Strategy in East Africa'.

Confirmed Significant Locations



Bazaruto Seascape (Mozambique)

~400

(2022 estimates).

Madagascar

Scattered populations, no population estimates.

Mohéli (Comoros)

Important habitat, no population estimates.

Aldabra Atoll (Seychelles)

Important habitat, no population estimates.

The **Bazaruto Seascape in Mozambique** represents the only location in East Africa where a globally significant dugong population persists, with ~400 individuals as of 2022.

This area is a Key Biodiversity Area and an Important Marine Mammal Area. The waters of the Mozambique Channel off the northwest coast of Madagascar support numerous marine mammal species including dugongs and have been declared the 'Northwest Madagascar and Northeast Mozambique Channel' IMMA with dugongs as one of 22 supporting species.

The Gulf of Aden and Socotra Archipelago and the Rufiji to Mafia- Kilwa coast have been designated as Areas of Interest (AoI) for potential designation as an IMMA

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Chapter 3

RED SEA

Authored by: Luisa Schramm, David Blair, Amgad El Shaffai, Abdulqader Khamis, Len McKenzie, Tekle Mengstu, Nicolas Pilcher, Ahmed Shawky and Helene Marsh

Luisa Schramm[1], David Blair[2], Amgad El Shaffai[3], Abdulqader Khamis[4], Len McKenzie[5], Teklexd Mengstu[6], Nicolas Pilcher[7,8], Ahmed Shawky[9], Helene Marsh[2]

[1]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Townsville, Queensland, Australia.
[2]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[3]Egyptian Environmental Affairs Agency, Ministry of Environment, Cairo, Egypt.
[4]Faculty of Biology, University of Barcelona, Barcelona, Spain.
[5]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Cairns, Queensland, Australia.
[6]Ministry of Marine Resources, Massawa, Eritrea.
[7]National Centre for Wildlife, Riyadh, Saudi Arabia.
[8]Marine Research Foundation, Kota Kinabalu, Sabah, Malaysia.
[9]EcoPro Training Center, Ismailia, Egypt.

Correspondence to: Helene Marsh helene.marsh@jcu.edu.au.

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Cover image: A dugong surrounded by snorkelers at Marsa Mobarak, Egypt. Ahmed Shawky photograph.

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Contents

Range/Signatory States

Range States	Signatory States
Djibouti	No
Eritrea	Yes
Sudan	Yes
Egypt	Yes
Israel?	No
Saudi Arabia	Yes
Yemen	Yes

We know of no recent evidence of dugongs occurring the Red Sea waters of Israel or Jordan. They may still occur in Israeli waters. Whether this is a resident population is unknown.

Regional findings

Countries considered in the chapter include: Red Sea: Arab Republic of Egypt, Eritrea, Kingdom of Saudi Arabia, Republic of Djibouti, Republic of Sudan and Republic of Yemen

- The dugong distribution in the Red Sea is fragmented, reflecting the availability of suitable seagrass habitat.
- The dugong population of the Red Sea was estimated to be up to 4,000 animals in the 1980s, an estimate extrapolated from an aerial survey of the number of dugongs in the Saudi Arabian waters of the Red Sea in 1987, plus interview surveys in Yemen in 1988.
- The current size of the dugong population of the Red Sea is unknown.
- Dugong research and conservation in Saudi Arabia and Egypt have increased in recent years. Nonetheless, there are few contemporary, quantitative data on both dugongs and their seagrass habitats for most countries bordering the Red Sea, especially the Range States along the western coast.
- Recent research assessing the status of dugongs in the region is largely conducted on a local-scale, including interviews with fishers, studies of feeding trails and photo-identification of individual dugongs. The results of recent aerial surveys along parts of the Saudi Arabian coast are unpublished at the time of writing.
- The following Important Marine Mammal Areas (IMMAs) of relevance to dugongs have been declared in the Red Sea: the 'Northern Red Sea Islands' and the 'Southern Egyptian Red Sea Bays, Offshore Reefs and Islands' in Egypt; and the 'Farasan Archipelago' in Saudi Arabia.
- In addition, there are Areas of Interest (AoIs) for potential designation as IMMAs for which the dugong is listed as a supporting species: (1) the 'Golfe de Tadjoura' and (2) 'Seven Brothers Islands and Godorya' in Djibouti; (3) 'Dhalak and Adjacent Southern Waters' in Eritrea; (4) 'Dungonab Bay–Mukawar Island', and (5) the 'Suakin Archipelago and Sudanese Southern Red Sea' in Sudan.
- It is likely that dugongs have declined in the Red Sea in recent decades due to human-caused mortalities resulting from past hunting pressure and current incidental bycatch and habitat loss.
- The Programme for the Environment of the Red Sea and Gulf of Aden (PERGSA) offers an established framework for regional co-operation on the marine environment and conservation in the Red Sea. A constructive way forward might be to invite PERSGA to co-ordinate a regional strategy for dugongs in the Red Sea.
- A key initiative could be a program of coordinated and replicable research on the distribution and abundance of dugongs and their seagrass habitats across the countries of the Red Sea. Such a program should use techniques that are appropriate to the capacity of each country and the known distribution of its dugongs but enable cross-country comparisons.
- Contemporary data on dugong abundance for the entire region could enable an International Union for Conservation of Nature (IUCN) Red List of Threatened Species subregional assessment of the status of the dugong in the Red Sea.

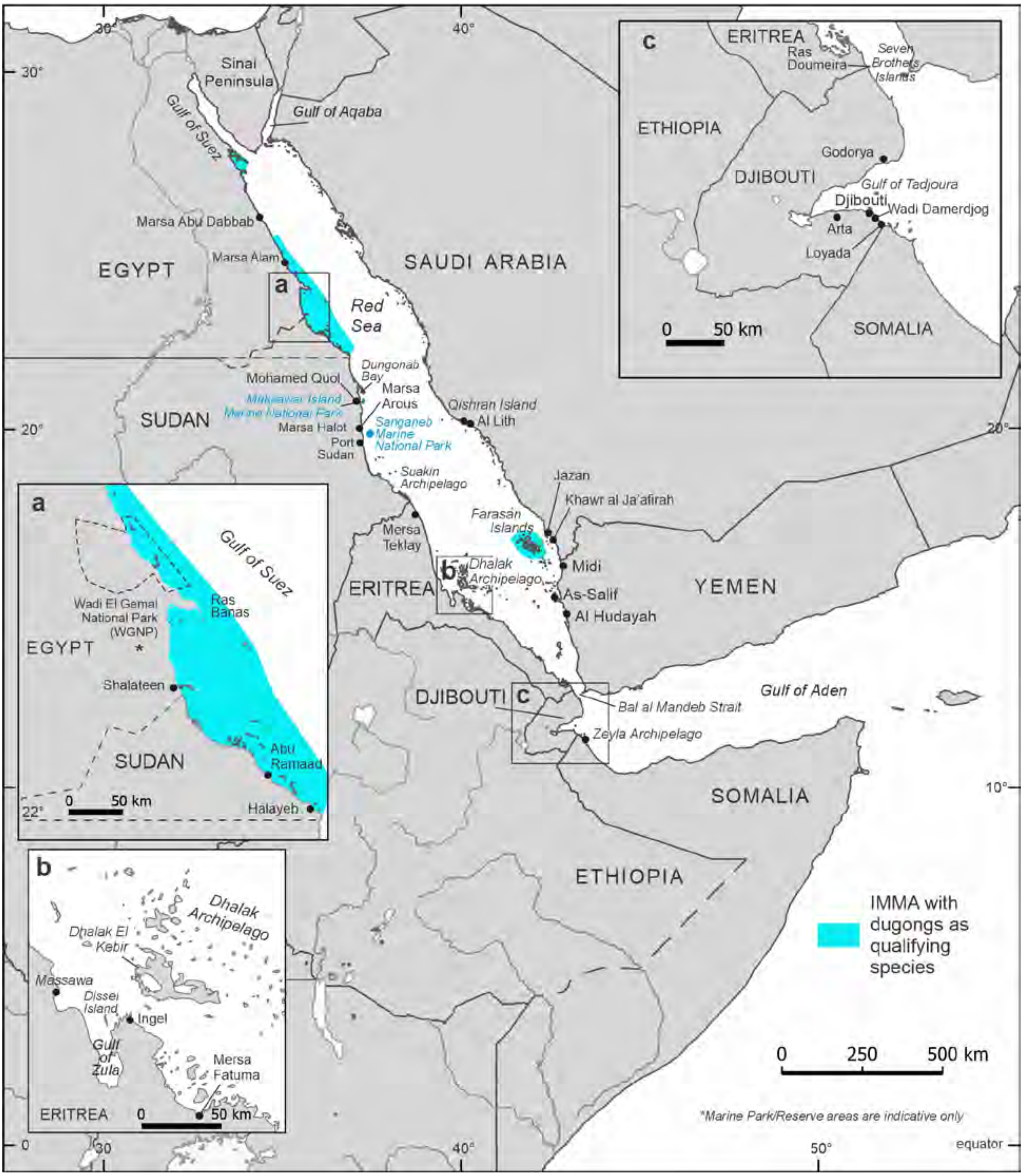
3.1 Regional setting

3.1.1 Geographic overview

This chapter considers the status of the dugong along the approximately 12,860 km coastline of the Red Sea, from the Somalia-Djibouti border in the southwest, north through the Red Sea to the Gulfs of Suez and Aqaba, and south back to Aden, Yemen in the southeast. The region is divided into three sections: (1) the tip of the Sinai Peninsula south to the Bab el-Mandeb Strait, (2) the Gulf of Aqaba, and (3) the Gulf of Suez (and Suez Canal) (Figures 3.1, 3.2). The Red Sea is connected to the Gulf of Aden via the narrow (26 km wide) and relatively shallow (186 m deep) Bab-el-Mandeb Strait, between Djibouti and Eritrea on the coast of the Horn of Africa to Yemen on the Arabian Peninsula.

Section 1 is bordered by coastlines of the following dugong Range States (counterclockwise from the border with Somalia): Republic of Djibouti (henceforth Djibouti), State of Eritrea, Republic of the Sudan (henceforth Sudan), Arab Republic of Egypt (henceforth Egypt), Kingdom of Saudi Arabia (henceforth Saudi Arabia), and Republic of Yemen (henceforth Yemen). The Gulf of Suez and the Suez Canal are entirely within Egyptian waters, and the Gulf of Aqaba is bordered by Egypt, Israel, Jordan and Saudi Arabia. Dugongs in Jordan and Israel are not considered further here as there is no recent

Figure 3.1. Geographic context of the Red Sea showing placenames mentioned in the text. Dugong Range States are ordered clockwise around the region starting with Djibouti: Djibouti, Eritrea, Sudan, Egypt, Saudi Arabia and Yemen. IMMAs with the dugong as a qualifying species are shown in blue. Insets: (a) Egypt-Sudan border with Wadi El Gemal National Park (WGNP); (b) Dhalak Archipelago in Eritrea; (c) Djibouti. In accordance with UNEP policy, the dotted black lines in inset (a) indicate an area of contested jurisdiction. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



evidence of resident dugongs in either country. Nonetheless, Lipkin (1975) studied the stomach contents of three dugongs from the Gulf of Aqaba (Eilat) suggesting that dugongs may have occurred in the Gulf waters of Israel at some time.

The Red Sea is a 2,000 km long, deep, narrow, semi-enclosed sea spanning 16° of latitude. Its maximum width is 306 km, greatest depth 3 km, and its area around 450,000 km^2 (Augustin et al. 2014; Rasul et al. 2015). It is likely that the shallow Bab-el-Mandeb Strait causes the Red Sea to act as a standalone body of water, possibly as a barrier to species distributions. Coastal regions have low rainfall and scant vegetation, and until recently, human populations along the coast have generally been sparse and centred on a few cities and towns (Carvalho et al. 2019).

The dugong distribution in the Red Sea is fragmented, reflecting the availability of suitable seagrass habitat (Preen 1989; Al-Mansi 2016). In the northern Red Sea, substrates suitable for seagrasses are restricted by the extensive fringing reefs that drop off steeply into deep water (Preen 1989). In other regions of the Red Sea, seagrass beds are largely restricted to the shallow, soft bottom areas of sharms and marsas (inlets and bays) or intertidal and submarine wadi (dry riverbed) outwash plains, and some shallow areas in the lee of offshore islands (Khamis et al. 2022). There are extensive shallows in the Al Wajh Bank (Figure 3.2) and further north in the extreme northeast of the Red Sea, in the vicinity of NEOM (a futuristic, urban area currently under construction by Saudi Arabia, see Section 3.4.4). The continental shelf is wider and shallower in the southern Red Sea, and the sedimentary substrates suitable for extensive seagrass communities are more abundant (Preen 1989; El Shaffai 2011, 2016).

The Red Sea is part of the Tropical Indo-Pacific seagrass bioregion (Short et al. 2007). Twelve seagrass species have been recorded (El Shaffai 2016), most of which usually grow in the shallow subtidal regions (up to 10 m deep) (Lipkin et al. 2003), with some species found as deep as 70 m (El Shaffai 2016). The central Red Sea has the highest diversity of seagrass with all 12 species (El Shaffai 2016), and the northern Red Sea has recorded up to eight species (Jones et al. 1987). The distribution of seagrass meadows progressively increases in extent towards the south, due in part to a shallower, wider shelf; a higher proportion of unconsolidated sediments; and less extreme temperatures and salinities (Bruckner et al. 2012). Estimates of the total area of seagrass (Figure 3.3) within the region are as follows (countries ordered counterclockwise, starting with Djibouti): Djibouti 4 km^2 (Allen Coral Atlas 2020); Eritrea 278 km^2 (Allen Coral Atlas 2020); Sudan 48 km^2 (Allen Coral Atlas 2020); Egypt 129 km^2 (El-Regal et al. 2012; Allen Coral Atlas 2020); Saudi Arabia 117 km^2 (Bruckner et al. 2012; Chalastani et al. 2020); and Yemen 89 km^2 including the Gulf of Aden (Allen Coral Atlas 2020). All areas are rounded to the nearest km^2, confidence intervals are not available, all estimates were made with moderate to high confidence and are minimum estimates.

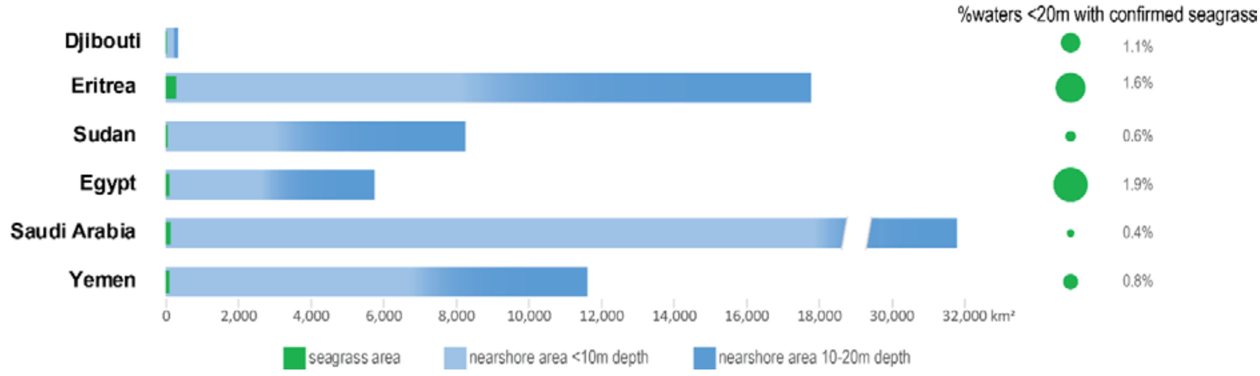
Aerial surveys of the Saudi Arabian coastline conducted in 1987 by Preen remain the only published large-scale, systematic study of dugongs for the Red Sea region, but are now unlikely to provide an accurate estimate of the dugong population. Preen (1989) used a strip transect technique based on Marsh and Sinclair (1989) and corrected for detection biases. He estimated the total dugong population of the entire Red Sea to be up to 4,000 individuals (Preen et al. 2012), an estimate extrapolated from the survey estimate of 1,820 ± SE 380 in Saudi Arabian waters plus some interview surveys in Yemen in 1988 (Preen 1989). Preen assumed that dugong density on the western coast of the Red Sea would be comparable with that on the eastern coast, given the similarity in geomorphology. Dugong density within his survey area was similar to those of the Gulf[1] and eastern Australia (0.22–0.047 individuals km^{-2}). Preen's (1989) estimate was much higher than previous estimates of dugong populations in the Red Sea (Ormond 1978; Frazier et al. 1987), which were based on incidental sightings from boats. The relevance of Preen's estimate to the contemporary situation is unknown.

There is a lack of contemporary, quantitative data on both dugongs and their seagrass habitats for most countries bordering the Red Sea, especially the Range States along the western coast. Recent research assessing the status of dugongs in the region has largely been at the local-scale, including interviews with fishers (Hanafy et al. 2006; El Shaffai 2015; Shawky et al. 2024; Al-Qahtani unpublished data), studies of feeding trails (e.g., Shawky 2018, 2019b, 2024; Khamis et al. 2022; Nasif 2022), photo-ID of individual dugongs (Shawky et al. 2019) and underwater laser photogrammetry (Shawky 2019b).

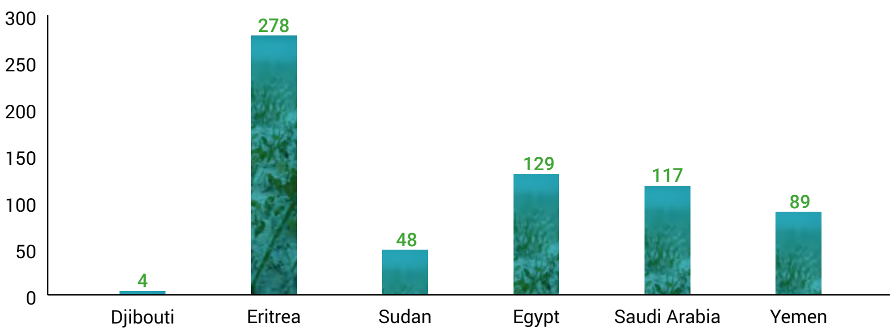
1 In the present report 'the Gulf' refers to the Arabian/Persian Gulf.

Figure 3.2. Geographic context of the Gulfs of Suez and Aqaba within the Red Sea with place names mentioned in the text. In accordance with UNEP policy, the dotted black lines indicate areas of contested jurisdiction. The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Adella Edwards figure; reproduced with permission.

Figure 3.3. Histogram showing the known areas of seagrass and coastal waters shallower than 20 m deep for each dugong Range State in the Red Sea region. The areas of seagrass are almost certainly underestimates and do not include reef associated seagrasses. Len McKenzie figure; reproduced with permission.



Seagrass Mapped Area (km²)



Seagrass communities are under-mapped with current estimates likely underestimates.

There are unpublished reports of recent aerial surveys along parts of the Saudi Arabian coast (see Section 3.2.5 below).

The geography of the region suggests that it is extremely unlikely that the Red Sea dugong population is currently linked to the Arabian/ Persian Gulf population, which is approximately 3,400 km (12.68° N, 43.46° E to 26.38° N, 56.48° E) to the northeast and separated from the Gulf of Aden by the open Indian Ocean coast of the Arabian Peninsula. The Djibouti population is likely connected to the population in Somaliland (Chapter 2).

3.1.2 Geopolitical and socioeconomic overview

This information is provided as an indication of the challenge for each of the Range States in the region to consider the conservation of dugongs and their habitats in the context of their socioeconomic development needs. The Red Sea region is home to around 226 million people, increasing at approximately 1.77% p.a. (United Nations Development Programme [UNDP] 2022). The human population growth rate around the Red Sea is expected to double in the next 20–30 years (Fine et al. 2019). The Human Development Index (HDI) status and Gross Domestic Product (GDP) of the dugong Range States bordering the Red Sea is very diverse (Table 3.1). Saudi Arabia has a Very High HDI, while its neighbour Yemen had the seventh lowest HDI of any country in 2023. Egypt has a High HDI, Djibouti, Sudan and Eritrea, Low HDIs (UNDP 2022). The per capita GDP data follow a similar pattern (Table 3.1).

There is ongoing geopolitical instability in the Red Sea region (Dunne 2021). As nations across the Horn of Africa push to settle inter- and intra-state disputes, global powers are investing in the region. Even though the region continues to undergo extensive development, the opening of a northern sea route across the top of Russia as the climate changes could slow the region's growth (Blunden 2012), a situation that may be hastened by the instability in the Middle East Region.

More than 10% of global trade passes through the Red Sea each year (Dunne 2021). The threat of oil pollution is serious as the region remains a vital route for the global oil trade, connecting oil rich

Table 3.1. Human Development Index (HDI) status and Gross Domestic Product (GDP) per capita rank of the dugong Range States in the Red Sea. Consistent with the remainder of this chapter, the countries in this table are ordered counter-clockwise around the Red Sea starting with Djibouti. Countries with the highest HDI or GDP have the lowest ranks. 189 countries were ranked for both indices. N.A. = not available.

Range State	HDI	HDI Rank 2023[i]	GDP per capita rank[ii]
Djibouti	Low	171	N.A.
Eritrea	Low	176	N.A.
Sudan	Low	172	144
Egypt	High	97	94
Saudi Arabia	Very High	35	20
Yemen	Low	183	179

i 2023 HDI data from https://hdr.undp.org/data-center/country-insights#/ranks (downloaded from the internet January 2024);
ii 2023 per capita GDP from https://www.worldometers.info/gdp/gdp-per-capita/ (downloaded from the internet June 2024).

Arabia to Europe. The Suez Canal has undergone recent expansions to combat blockages such as the 2021 'Ever Given' blockage, to increase capacity and minimise waiting time for transiting ships (Suez Canal Authority 2019).

Many of the coastal communities along the largely undeveloped western coast of the Red Sea rely heavily on marine resources, especially fisheries (e.g., Djibouti and Sudan; Gladstone et al. 2003). Along the Saudi Arabian Red Sea, the major cities are industry and shipping hubs, with tourism and fisheries of less financial value. Smaller towns and villages still rely on fisheries as key income sources. Much of the Red Sea consists of clear, oligotrophic environments and is considered a key location for diving and snorkelling tourism (Carvalho et al. 2019; Chalastani et al. 2020). Dugongs are a significant tourist attraction in some coastal areas in Egypt (Ayad 2021).

3.1.3 Genetics of dugong populations

For an overview of genetics-relevant techniques, definitions, studies and general findings, refer to Chapter 1, particularly Figure 1.2.

The Red Sea has very high levels of species endemism (DiBattista et al. 2016), implying a long evolutionary history. At the last glacial maximum, the Red Sea was almost isolated from the greater Indian Ocean and its waters were hypersaline (DiBattista et al. 2016). It seems unlikely that a dugong population could have persisted there during glacial maxima, especially as waters less than 60 m in depth were rare (Ludt and Rocha 2015), and seagrasses likely absent. DiBattista et al. (2016) suggested that the Gulf of Aden might have served as a glacial refugium for many Red Sea endemics. However, this region also had little or no shallow water at glacial maxima (Ludt and Rocha 2015). It therefore seems likely that dugongs dispersed into the Red Sea only after post-glacial sea-level rise.

Plön et al. (2019) have reported the only genetic data for dugongs in the Red Sea. Using material from historical museum collections, they generated between 122 and 309 basepairs of sequence from the mitochondrial control region for 26 individuals. Most were compatible with the common Western Indian Ocean haplotype (that from Tanzania and UAE in Chapter 1, Figure 1.2) or differed at only 1-3 sites from this haplotype. Two sequences are exceptions to this: (1) MH704339 (from an undated, unregistered specimen in the Natural History Museum, London) seems most like sequences of the restricted haplogroup from Australia (Chapter 10); and (2) MH704345; also from the London collection, dated 1946 and from Jordanian waters at Aqaba, is a unique haplotype (placed in the widespread Australasian haplogroup, Figure S4 in Plön et al. 2019). Both sequences include some ambiguities, suggesting technical difficulties in sequencing. The Jordanian sequence might represent an endemic Red Sea/Gulf of Aqaba population, but this is only speculation.

- The genetic data for dugongs from the Red Sea is limited to partial mitochondrial control region sequences.
- The mitochondrial haplotypes are almost identical to the common haplotype from East Africa and the Arabian Gulf (Western Indian Ocean haplogroup).
- Genetic diversity seems to be limited in the Red Sea, as in the Western Indian Ocean more broadly.

3.2 Distribution, abundance and trends in Range States

The accounts in this Section have been arranged counterclockwise around the Red Sea starting with Djibouti.

3.2.1 Djibouti

There appears to be no contemporary information on dugongs in Djibouti waters. Robineau and Rose (1982) reported 23 observations (mainly dead net captures) between 1966–1980 in the coastal waters of the Gulf of Tadjoura, between the border with Somaliland and Obock (Figure 3.1). In December 1980, they undertook a helicopter flight to explore the coastal waters from Ras Doumeira (12.70° N, 43.13° E) in the Bab-el-Mandeb Strait, down to Loyada (11.45° N, 43.25° E), close to the border with Somaliland. They saw 32 dugongs including calves between Wadi Damerdjog and Wadi Arta, west of Loyada.

Djibouti has two AoIs for potential designation as IMMAs for which the dugong is listed as a supporting species: (1) the Golfe de Tadjoura and (2) Seven Brothers Islands and Godorya (IUCN-MMPATF IMMA searchable database). These AoIs need to be further evaluated before they can be formally recognized.

- Information on dugongs in Djibouti is extremely dated and limited to a helicopter flight in 1980, which recorded 32 dugongs.

3.2.2 Eritrea

More research is required to determine the distribution and abundance of dugongs in Eritrea, especially given the significant area of known seagrass (278 km²). Teclemariam et al. (2007) reported the results of survey trips and interviews with fishers and coastal locals between 2004 and 2007. They found dugong remains (bones, jaws, skin, skulls) in fishing camps and villages in almost all the areas surveyed, and reported 34 sites (coastal villages, coastal areas, or islands) where dugongs occurred based on fishers' reports. Dugongs were also sighted during boat surveys (Y. Teclemariam personal communication via email to Marsh and Schramm 2024). Most of these sites are near-shore, shallow embayment areas supporting seagrass. They concluded that '*it is clear that Eritrea has a significant dugong population*', which they estimated to be 300 to 400 individuals based on the apparent stability of catches and effort and an assumed natural rate of increase of 5% per annum. Teclemariam et al. (2007) reported that dugongs were scattered all along the coastal waters, especially in the central part of the Eritrean Sea, north of Massawa to Mersa Teklay, south of Massawa to Mersa Fatuma including the Dahlak Archipelago, Assab Bay and surrounding areas (Figure 3.1).

Although there were no historical records to establish trends, Teclemariam et al. (2007) inferred that dugong numbers were likely to be stable because fishers considered that there was no evidence of decline. They estimated that fishers caught around 20 individuals per year incidentally in gillnets. The sustainability of this take is uncertain. Live animals were released and drowned individuals consumed locally. Some villages (Dissei, Dhalak El Kebir and Ingel; Figure 3.1) reported consuming three to five individuals each year (Teclemariam et al. 2007). Fishers reported that sightings of dugongs were rare. Nonetheless, all fishing villagers interviewed, reported dugongs being slaughtered. The only exception was for villages preferentially practicing agriculture such as villages in the North of Massawa and in the Gulf of Zula.

Although Lipkin (1987) and Lipkin et al. (2003) reported that seagrass communities were sparse and uncommon in Dhalak Archipelago, Dhalak and Adjacent Southern Waters have been listed as an AoI for potential designation as an IMMA pending more information, with the dugong as a supporting species (IUCN-MMPATF). Dhalak Archipelago, Hawakil Bay and Offshore Islands have been confirmed as a Key Biodiversity Area (KBA) (KBA Partnership 2024a). Dhalak Archipelago is also a foraging ground for green turtles (Al-Mansi et al. 2021).

- Dugong abundance in Eritrea was estimated at 300–400 individuals based on interviews and boat surveys between 2004–2007.

3.2.3 Sudan

Information on the distribution and abundance of the dugong in Sudan is sparse. Ormond (1978) estimated the Sudanese dugong population to be 20–40 animals. Nocturnal vocalizations were heard in Dungonab Bay and Marsa Halot in 1973 by staff of the Fisheries Research Section (Nasr et al. 2019). Nasr et al. (2019) reported that dugongs were found throughout Sudanese waters, from Suakin harbour and archipelago (south of Port Sudan) and in the various wadis to the north of Port Sudan such as Marsa Arous and Marsa Halot, and off Mohammed

Quol, which lies south of the wide entrance to Dungonab Bay (Figure 3.1).

Dungonab Bay – Mukkawar Island Marine National Park was inscribed on the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage List in 2016 as part of a serial nomination. The Statement of Outstanding Universal Value (OUV) states that Dungonab Bay supports 'a globally significant dugong population, given that the Red Sea and the Persian Gulf [sic] host the last remaining healthy populations of this species in the Indian Ocean' (UNESCO 2016; Claudino-Sales 2019; but see Chapter 2). Dungonab Bay – Mukawar Island and Suakin Archipelago have been confirmed as KBAs (KBA Partnership 2024b). Dungonab Bay–Mukawar Island, and the Suakin Archipelago and Sudanese Southern Red Sea, have also been declared IMMA AoIs that require further evaluation (IUCN-MMPATF).

- Information on the distribution and abundance of dugongs in Sudan is limited and dated.
- The Dugonab Bay - Mukkawar Island Marine National Park was listed as a World Heritage site in 2016 with the dugong listed in the statement of OUV.

3.2.4 Egypt

Anecdotal information on dugong distribution in Egypt has been obtained using a variety of techniques over many years. Gohar (1957) recorded 16 individuals within the 70 km between Hurghada immediately south of the Gulf of Suez and Ras Gemsha, near Safaga (Figure 3.2). These animals were caught for research over 14 years using fishing nets. Hanafy et al. (2006) reported a low-density population throughout the area with 12 to 17 individuals in the period 2001–2003 based on interview surveys from Hurghada to Shalateen about 200 km north of the border with Sudan (Figures 3.1, 3.2). These respondents reported eight adults and three juveniles around Marsa Alam and six adults and one juvenile in Wadi El Gemal (Figure 3.1). They also reported five dugong carcasses on the Egyptian Red Sea coast between 1999 and 2004 with injuries consistent with netting entrapment (Hanafy et al 2006). Shawky et al. (2024) estimated the dugong population size in the Egyptian Red Sea as 73-97 animals based on interview questionnaire surveys and photo identification.

Shawky et al. (2024) administered 207 Dugong MOU Standardized Catch and Bycatch Questionnaires developed by the Convention on Migratory Species of Wild Animals (CMS) Dugong Memorandum of Understanding (Dugong MOU) (Pilcher et al. 2017) between August 2015 and May 2016. Fishers and some other stakeholders at 20 sites in seven regions were interviewed; Elba Protected Area (EPA, one site), Marsa Alam (five sites), Northern Islands Protected Area near Hurghada (NIPA; one site), Qosseir (two sites), Ras Banas (three sites), Southern Sinai (one site) and Wadi El Gemal National Park (WGNP; seven sites). More than 97% of the respondents were 15–75 years old, and the largest age group was 26–50 years (77%) with a mean age of 35 ± 6 years. Ninety-eight percent of respondents were aware of dugongs and encountered them during fishing (27%) or in transit to fishing areas (more than 39%). They reported 1,322 dugong sightings 1980–2016; many of these are almost certainly repeat sightings. A total of 24 strandings (five live and 19 dead) were recorded between 1986 and 2023. Of those, 15 cases occurred during the last decade (i.e., since 2013; (12 dead and three live). Over the last three decades, two large dugongs were stranded in gillnets in the village of Abou Ghoson when local fishers left their nets unattended near the shore. Those dugongs were consumed, and the skin used as armour.

Based on these fisher interviews, Shawky et al. (2024) reported dugongs from 95 sites along the western coast of the Egyptian Red Sea, including nine in Hurghada, 31 in Marsa Alam, 11 in Qosseir, five in Ras Banaas, three in Safaga, two in south Sinai, 17 in WGNP, and 17 in Abou Ramaad, Halayeb and Shalateen regions (Figures 3.1, 3.2). Sixty-one percent of respondents estimated the dugong population to be about two to ten individuals in key areas. Approximately 89% of the fishers claimed that the trend in the net capture of dugongs was decreasing. This result should be interpreted with caution, as the decrease could reflect a decrease in captures as a consequence of an overall decrease in population size as pointed out by Plicher et al. (2017). Ninety-six percent of respondents had encountered a dugong at least once in the previous year; more than 72% of dugongs were released alive; 13% were reported as eaten. Although 66% of fishers stated that dugongs were not hunted in their village, more than 25% claimed that they were captured in other villages. Four percent of the respondents claimed that dugong numbers were declining and over 79% believed that dugongs could be extinct in the future.

A lone male dugong calf was found stranded in WGNP in 2015 and released on the same day (Shawky et al. 2016). After 12 days the calf was found dead on a reef close to the original stranding site.

Shawky (2018) and Shawky et al. (2019) used photographic identification of permanent notches and scars to estimate dugong numbers at 30 inshore dive sites between December 2015 and October 2017. Thirty individuals including four calves were recognized across 22 sites over 180 km: 14 sites in Marsa Alam, and eight in WGNP (Figure 3.1). Identified males outnumbered females 7:1 at both sites. Although eight individuals were recorded undertaking long- and short-distance movements within the study sites, no identified individual was recorded moving between Marsa Alam and WGNP. (Figure 3.1).

Two IMMAs have been declared in the coastal waters of the Egyptian Red Sea: The 'Northern Red Sea Islands' (declared in 2020 with the dugong as a supporting species; IUCN-MMPATF 2020), and the 'Southern Egyptian Red Sea Bays, Offshore Reefs and Islands' (declared in 2021 with the dugong as a qualifying species; IUCN-MMPATF 2021b).

- Small groups of dugongs have been reported from 95 sites along the western coast of the Egyptian Red Sea.
- The size of the dugong population in the Egyptian Red Sea has been estimated as 73-97 animals based on interview questionnaire surveys and photo identification.
- Two IMMAs of relevance to dugongs have been declared in the coastal waters of the Egyptian Red Sea: The 'Northern Red Sea Islands' (in 2020) and the 'Southern Egyptian Red Sea Bays, Offshore Reefs and Islands' (in 2021).

3.2.5 Saudi Arabia

The dugong population along the Red Sea coast of Saudi Arabia was considered to be of global significance on the basis of comprehensive large-scale aerial surveys conducted in 1987 (Preen et al. 2012). Preen (1989) conducted strip-transect quantitative aerial surveys over around 22,370 km^2 of dugong habitat in seven zones along about 70% of the Saudi Arabian Red Sea coastline (excluding the Gulf of Aqaba) in the summer of 1987. He concluded that the bathymetry of the remaining coast suggested unsuitable dugong habitat. After correcting for detection biases using the *Marsh and Sinclair Method* (Marsh and Sinclair 1989), Preen (1989) estimated that there were 1,818 ± SE 382 dugongs in Saudi Arabian waters, concentrated in three areas: the Al Lith area, Al Wajh Bank and Jizan (Jazan, Gizan).

Although there is no published repeat of Preen's baseline study, there is unpublished information of relevance. Pilcher (2022) led an aerial survey from the Farasan Islands to the Gulf of Aqaba (Figure 3.1) in 2022 and recorded around 40 dugong sightings (including five cow-calf pairs), half the total number of sightings recorded by Preen in 1987 for the same region. Although the results of the 2022 survey are yet to be analysed; the comparison of the number of sightings with Preen's (1989) results over a vast spatial scale suggests a population decline.

There have also been some local-scale surveys. Gladstone sighted 27 dugongs on an aerial survey in the Jizan area in in 1993 (W. Gladstone personal communication in Nasr et al. 2019). A survey in 2009 using underwater SCUBA equipment as well as incidental sightings from vessels recorded two dugongs in shallow onshore waters in the Farasan Islands (Al-Mansi 2016). Baldwin (2018) estimated a population of approximately 98 dugongs (95% CI 54-141) in the NEOM area in the north-eastern Red Sea. This estimate was corrected for availability bias based on Preen (1989) but was not corrected for perception bias. There was a further survey of this region in 2023 using an Unoccupied Aerial Vehicle (UAV); the results were not available at the time of writing (May 2024). No dugongs were sighted in UAV surveys in Al-Wajh Lagoon in Saudi Arabia by Nasif (2022) although feeding trails were observed. There were seven off-effort sightings of dugongs within the study area (Nasif 2022). Preen (1989) saw too few dugongs in this region to estimate the population size.

Khamis et al. (2022) conducted large-scale, in-water surveys of dugong feeding trails across 27 seagrass meadows. They covered around 4,061 km^2 of nearshore and offshore waters in the NEOM area (Figure 3.2) and recorded 13 dugong feeding sites based on the presence of feeding trails. Many of the feeding trails were clustered around five main sites: Al-Muwaylih, Sanafir Island, Sindalah Island, Tiran Island and Ras Al-Shaykh Humayd (Figure 3.2).

The 'Farasan Archipelago', which includes the dugong as a qualifying species, was declared an IMMA in 2021 (IUCN-MMPATF 2021a). The associated Marine Protected Area (MPA) has also been nominated by Saudi Arabia as a tentative World Heritage Site with the dugong as a 'key taxon' (UNESCO 2019). The Farasan Archipelago was identified as a 'Man and Biosphere Reserve' in 2021.

- The dugong population along the Red Sea coast of Saudi Arabia was considered to be of global significance on the basis of an aerial survey conducted in the summer of 1987, which resulted in a population estimate of approximately 1,800 animals.
- An aerial survey from the Farasan Islands to the Gulf of Aqaba in 2022 recorded only half the total number of sightings recorded in 1987 for the same region. Although the results of the 2022 survey are yet to be analysed; the comparison of sighting numbers is of concern and suggests a population decline.
- The 'Farasan Archipelago', which includes the dugong as a qualifying species, was declared an IMMA and a Man and Biosphere Reserve in 2021.

3.2.6 Yemen

Research concerning dugong status in Yemen is limited to interviews with fishers by Preen (1989). The lack of aerial surveys can be attributed to the historical and current conflicts faced by the country. At the time of writing, Yemen is experiencing a major humanitarian crisis, exacerbated by civil war and famine. Currently, 80% of the population needs humanitarian aid and protection, and 58% of the population lives in extreme poverty. (United Nations Office for the Coordination of Humanitarian Affairs 2021).

Dugongs occur as far south as Al Hudaydah on the eastern coast of the Red Sea (Preen 1989; Nasr et al. 2019; Figure 3.1). Two fishers interviewed by Preen (1989) claimed that the main area for dugongs is between Midi and As-Salif (Figure 3.1), a stretch of narrow coast that was known as *taweelah al bahr*. Preen et al. (2012) estimated that the waters of Yemen supported up to 200 dugongs, based on interviews with fishers in and the extent of shallow water habitat suitable for seagrasses.

- Information on the dugong population of Yemen has not been updated since 1987.
- Population size was estimated to be around 200 animals in 1987 based on interviews with fishers and the extent of shallow water habitat suitable for seagrasses.
- Dugongs occurred as far south as Al Hudaydah on the eastern coast of the Red Sea.
- Fishermen claimed that the main area for dugongs is between Midi and As-Salif, a stretch of coast that was known as *taweelah al bahr*.

3.3 Cultural values

In historic times, dugong skin was an important product in the Red Sea region. It is believed that the coverings of the biblical Tabernacle housing the Ark of the Covenant were made from dugong skin (Cansdale 1970). In Eritrea, dugong skin was used for covering of the holy book Birana and to protect nets stored on the beach from the sun (Teclemariam et al. 2007). Sandals made from dugong skin are mentioned in the Bible (e.g., The Holy Bible: Exodus 25: 1-9, Numbers 4: 4–6). Egyptians used dugong hide for shoemaking, often purchasing the hides from Al-Wajh, Saudi Arabia (Gohar 1957) (Figure 3.2). Fishers in Yemen sold dugong skins in Aden and Djibouti for use as shields and helmets (Preen 1989). The skin was dried and used by Beja tribesman for shields (Nasr et al. 2019).

Other historical uses of dugongs in the Jizan area were like those East African Range States (Chapter 2): oil was used as a treatment for kidney failure and indigestion; bones were used as a treatment for rheumatism (Preen 1989). Dugong meat was also an important source of nutrition (Nasr et al. 2019).

Gohar (1957) claimed that the origin of the mermaid legend may lie in the resemblance of the dugong to human females and speculated that dugongs may have been used as surrogate females by sailors on long voyagers. He did not provide evidence for such claims.

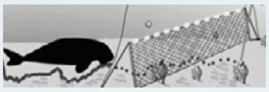
3.4 Threatening processes

3.4.1 Interactions with fisheries

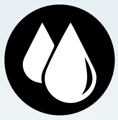
The major current drivers for dugong consumption are poverty and declining fish stocks (Nasr et al. 2019). In the past, dugongs were actively hunted on both sides of the Red Sea. Sudanese fishers speared dugongs and then hammered wooden plugs into their nostrils to drown them (Nasr et al. 2019). Interviews conducted by Preen (1989) confirmed that dugongs were historically hunted in the Al Wajh Bank, up to *'one or two generations'* prior to his study. Preen (1989) noted a decreased demand for dugong meat and attributed the decline to the economic development of the region.

In Eritrea, incidental captures of dugongs in gillnets designed for sharks and large pelagic fish is the main threat (Teclemariam et al. 2007). Artisanal fishers and navy personnel living along the coast used to hunt dugongs. An extensive awareness

Threatening Processes



The principal causes of dugong population decline



The Red Sea is a major transport route for European imports and oil

Ports are being established for economic and military reason in several African Red Sea states

The exceptional clarity of the waters of the Red Sea makes it an important site for dugong snorkel tourism, especially in Egypt

Apparently low genetic diversity: a significant challenge to population resilience and recovery

The cumulative impacts of these threats make targeted conservation interventions across the region very important, especially habitat protection and the mitigation of human-induced threats.

campaign was implemented from 2004–2007 aimed at educating locals to avoid the hunting of dugongs and marine turtles. Since, there has been a decrease in deliberate dugong hunting (Y. Teclemariam personal communication via email to Marsh and Schramm 2024). In addition, the Ministry of Marine Resources introduced two enforcements: (1) no person may fish any marine mammal or other protected species in Eritrean waters; (2) any marine mammal or other protected species caught accidentally must be released immediately and returned with the least injury to the waters from which it was caught. Failure to release any bycaught protected species is punishable with a fine of ERN 50,000 (USD 3,333). In the case of a subsequent conviction, the fine doubles to ERN 100,000 (USD 6,667) (Eritrean Fisheries proclamation No. 176/2014).

Many coastal residents in Sudan rely on marine resources for their livelihoods. Hand-lining is the most common fishing method (Vine 1986), though large nets used to catch sharks sometimes catch dugongs (Ormond 1976; Gladstone 2000; PERSGA 2001). Dugong bycatch has been reported in gillnets in Sudan. Recent reports are few.

In Egypt, more than 50% of the fishers surveyed by Shawky (2018) said that there is no enforcement and penalties are not imposed. Nine percent of the fishers working in the Elba Marine Park in Egypt interviewed by Rouphael et al. (2013) in 2006 reported catching dugongs in their nets; this percentage had increased to 20% nearly a decade on (Rouphael et al. 2015). Thirty-five percent of Shawky's (2018) interviewees in Egypt believed that fishing nets are the main reason for the dugong's decline; 11% reported that the accidental capture of dugongs in fishing nets had increased; 72% claimed they released them back to the sea.

Information about the impact of fishing on dugongs in the Red Sea is variable. Nasr et al. (2019) claim that dugongs are no longer actively hunted by fishers in Saudi Arabia. If a dugong is encountered, the relevant authorities are informed. Enforcement of reporting is extremely strong (N. Pilcher personal communication via email to Marsh and Schramm 2024). Khamis et al. (2022) reported boats fishing with gillnets around the offshore islands off the Saudi coast in the north-eastern Red Sea. Nasr et al. (2019) consider that it is likely that dugongs accidentally drown in gillnets throughout most of their range in the Red Sea. Fishers in Tuwal (north of Jeddah in Saudi Arabia) do not eat dugong meat and either release dugongs back to the sea or donate the carcass to universities for study (Nasr et al. 2019).

3.4.2 Oil pollution

Red Sea dugongs face serious threats from oil pollution because the region is an important oil transport route (Preen et al 2012). For example, coastal communities in war-torn Yemen were at serious risk of losing their livelihoods for eight years while a rusting oil supertanker remaining moored in their waters presented a very significant risk of a major oil spill for from 2015 (Huynh et al. 2021). A United Nations-led operation transferred the oil to another vessel in 2023 avoiding what the UN Secretary-General described 'a potential monumental environmental and humanitarian catastrophe' (United Nations News 2023). Nonetheless, oil pollution remains an ongoing threat. In 2023, a tanker sank in international waters of the Red Sea; in 2021, another sank in Yemen (The Maritime Executive 2021).

3.4.3 Port development

There is the potential for port development on the African coast of the Red Sea to damage seagrass communities, due to the region's geostrategic location at the intersection of shipping lanes of global importance (Styan 2020). The Red Sea is a corridor for Europe's imports and oil and links the Horn of Africa to world markets. At the time of writing, Djibouti was expanding its ports with international assistance (Styan 2020). There are geopolitical as well as economic reasons for port development with major powers establishing military bases that require port access and deploying economic assistance and trade deals to achieve influence in the Red Sea African states (Dunne 2021). There is no debate on the environmental impacts of these developments (Styan 2020), which could lead to dugong mortality from vessel strikes and cause seagrass loss.

3.4.4 Tourism

Ecotourism has resulted in the establishment of snorkelling tourism, because of the exceptionally clear water in the Red Sea. At Marsa Alam in Egypt, large groups of divers may observe habituated dugongs for lengthy periods (Shawky 2018; see Figure 3.4). In Saudi Arabia, NEOM (Figure 3.2) is being constructed as a futuristic mega-city along the north-eastern coast of the Red Sea covering 26,500 km^2, an area only slightly smaller than Belgium (Aly 2019). Khamis et al. (2022) surveyed the coastal waters of NEOM and identified dugong feeding sites close to proposed hotels and fishing harbours subject to high boat traffic fishing and coastal development. Further south the Amaala, Red Sea and Tuwal developments (Red Sea Global) further threaten important dugong feeding and development habitats.

3.4.5 Climate change and severe weather

As in other regions (Marsh et al. 2022), climate change and severe weather have the potential to impact the seagrass habitats of dugongs. Extensive flash flooding has been reported in Marsa Alam,

Figure 3.4. A dugong surrounded by snorkelers at Marsa Mobarak, 55 km north of Marsa Alam and close to Port Ghalib on the Red Sea coast of Egypt from where vessels arrive daily bringing tourists. Ahmed Shawky photograph; reproduced with permission.

Egypt as recently as November 2023, increasing sediment loads to adjacent waters. These floods have obvious implications for seagrass habitats.

3.5 Conservation initiatives

3.5.1 International conventions

All dugong Range States bordering the Red Sea are parties to the Convention on Biological Diversity. All except Djibouti are signatories to the CMS Dugong MOU. All are signatories to the United Nations Framework Convention on Climate Change (UNFCC), although Yemen had not ratified this agreement as of November 2023.

Many threats to the marine environment of the Red Sea such as pollution and resource depletion (including overfishing), are trans-boundary harms requiring regional cooperation. In recognition of this reality, PERSGA was initiated in 1974 in collaboration with the Arab League Educational, Cultural and Scientific Organization (ALECSO) with the support of United Nations Environment Programme (UNEP). In 1982, the program was strengthened by Somalia, Sudan, Djibouti, Egypt, Jordan, Saudi Arabia, and Yemen signing the 'Regional Convention for the Conservation of the Red Sea and Gulf of Aden Environment' (Jeddah Convention), the 'Protocol Concerning Regional Cooperation in Combating Pollution by Oil and Other Harmful Substances in Cases of Emergency' and the 'Action Plan for the Conservation of the Marine Environment and Coastal Areas in the Red Sea and Gulf of Aden'. These three instruments entered into force in August 1985. The Jeddah Convention was further consolidated by the signing and ratifying of two additional regional protocols in 2005: the 'Protocol Concerning the Conservation of Biological Diversity and the Establishment of Network of Protected Areas in the Red Sea and Gulf of Aden' (PERGSA) and the 'Protocol Concerning the Protection of the Marine Environment from Land-Based Activities in the Red Sea and Gulf of Aden'. In addition, a 'Protocol Concerning Cooperation in Management of Fisheries and Mariculture in the Red Sea and Gulf of Aden' was finalised in 2017. That protocol provides the legal basis for collaborative and coordinated mechanisms among PERSGA states to regulate fisheries, combat illegal, unreported and unregulated (IUU) fishing, adopt regional biosecurity and bio-safety systems in aquaculture, and implement ecosystem approach to fishery management and aquaculture development, a very important addendum to the 1982 Jeddah Convention.

The signing of the 'Protocol Concerning the Conservation of Biological Diversity and the Establishment of Protected Areas' by PERSGA member states has enabled a regionally coordinated approach to establishment of a MPA Network. Gladstone et al. (2003) recorded 75 proclaimed and recommended MPAs in the Red Sea. Although theoretically this initiative should bode well for biodiversity conservation in the Red Sea, the level of protection afforded to dugongs is unknown outside Egypt (Rouphael et al. 2015) because it has not been measured. Rouphael et al. (2015) assessed the capacity of two Egyptian MPAs to protect megafauna including the dugong. They concluded that the Elba and Wadi El Gamal National Parks (WGNP) were not providing comprehensive protection for dugongs; similar proportions of fishers used nets irrespective of whether they lived inside or outside the MPAs. Although a greater proportion of fishers living outside the MPAs had caught dugongs in nets, the proportions of fishers living inside the MPAs who had caught dugongs (20%) in nets was higher than some ten years earlier (Rouphael et al. 2013), and a greater proportion of fishers were using nets in 2013 than before. Rouphael et al. (2013) concluded that it was unlikely that the MPAs outside Egypt are improving protection for dugongs, illustrating the challenge of enforcing dugong conservation across the Red Sea.

Due to the lack of enforcement and establishment of most MPAs (PERSGA 1998; Gladstone 2000), the number of MPAs in the Red Sea was reduced to 12 (see Figure 1 in Gajdzik et al. 2021). PERSGA and other national initiatives that followed (mainly in Egypt and Saudi Arabia) resulted in a substantial increase in MPA coverage from around 2 km^2 prior to 1983 to more than 16,600 km^2 in 2014 (One Shared Ocean 2015). Nonetheless, most MPAs in the Red Sea remain 'paper parks' with no implementation, management, or legal enforcement (UNEP-WCMC and IUCN 2020).

More recent 'in-house' protection efforts for dugongs at NEOM (Figure 3.2) and Amaala and Red Sea developments along the Saudi coast bode well for protecting dugong habitat, although concern remains that activities within these developments (e.g., boating) will adversely impact dugongs. Similarly, the development of a Management Plan for the Farasan Islands also presents opportunities for protection of dugongs and their habitat in this fragile ecosystem in the southern Saudi Arabian Red Sea.

3.5.2 Other conservation initiatives

The Red Sea and Gulf of Aden Strategic Ecosystem Management GEF Project (2012-2018) had a final project development objective: 'To improve management of selected MPAs by local communities and strengthen information sharing between PERSGA member countries' (World Bank 2019). The project was developed in recognition of the need for the littoral countries of the Red Sea to have the capacity to coordinate and work together to monitor, manage, and protect the region's fragile environmental resources, despite their very different stages of development. The project improved the protection of over 200,000 hectares of marine waters in the pilot sites of Dungonab Bay–Mukkawar Island Marine National Park in Sudan and WGNP in Eygpt, which are known dugong areas, with updated zoning plans and assigned user rights informed by consultations with community members, and the completion of ten community-based alternative livelihood sub-projects to reduce pressure on marine resources.

Gajdzik et al. (2021) concluded that Red Sea biodiversity is only nominally protected by the non-cohesive network of small MPAs, most of which are 'barely implemented'. They argued that a large-scale connectivity-informed MPA approach would be an avenue to unite the Red Sea's coastal nations toward acting for the common good of conservation and reverse the global decline in marine biodiversity. They did not suggest the dugong as a flagship species for this approach, but it could be an appropriate candidate.

3.6 Research and monitoring initiatives

3.6.1 Techniques used to date

Aerial surveys conducted for dugongs along the Saudi Arabian coast by Preen (1989) remain the benchmark for systematic survey for megafauna in the region. Pilcher (2022) repeated the survey however, no population estimates have been calculated from these data.

Along the coast of the Red Sea there have also been local and regional scale survey efforts for dugongs and their seagrass habitats using a range of techniques as summarized in Table 3.2. However, apart from the work of Preen (1989), these approaches have rarely been coordinated. In addition, there are assumptions inherent in each approach. These assumptions have rarely been made explicit.

Table 3.2. Summary of research to date on dugongs and their seagrass habitats in the Red Sea ordered by date within survey type.

Technique	Country	Extent	Date of surveys	Reference
Aerial survey qualitative	Djibouti	Ras Dumeira to Loyada	December 1980	Robineau and Rose (1982)
	Saudi Arabia	Al Wajh to Yemen border	June-August 1987	Preen 1989
	Saudi Arabia	Jizan	1993	Gladstone personal communication in Nasr et al. 2019)
Aerial survey systematic with detection bias correction	Saudi Arabia	22,371 km^2 across approximately 70% of Saudia Arabian coastline	1987	Preen (1989)
Aerial survey systematic without detection bias correction	Eritrea, Sudan, Saudi Arabia	Farasan Islands to Gulf of Aqaba (4,250 km^2)	2022	Pilcher (2022)
UAV survey	Saudi Arabia	Al-Wajh Lagoon (4,000 km^2)	July – December 2021	Nasif (2022)
Feeding trail surveys	Egypt	Qosseir, Marsa Alam, WGNP	2018 – 2019 (Autumn 2018 – Summer 2019)	Shawky (2019b) Shawky et al. (2024)
	Saudi Arabia	NEOM – mouth of Gulf of Aqaba to south of Duba Port (4,061km^2)	October – November 2020	Khamis et al. (2022)
	Saudi Arabia	Al-Wajh Lagoon	July – December 2021	Nasif (2022)
Interview surveys	Saudi Arabia	Al Wajh, Jizan	July-August 1987	Preen (1989)
	Yemen	Durhalmi, Al Hudaydah, Urj, Khobha, Luhalyah, Midi, Sanaa	January 1988	Preen (1989)
	Egypt	Hurghada to Shalateen	2001 – 2003	Hanafy et al. (2006)
	Eritrea	34 sites from Mersa Ibrahim Village to Gahro Village	2004 – 2007	Teclemariam et al. (2007)
	Egypt	Suez to Shalateen (735 km^2 area but dugongs only sighted in 1.9 km^2)	2011	El Shaffai (2016)
Fisher surveys using Pilcher et al. (2017) technique	Egypt	Hurghada, Safaga, Qosseir, Marsa Alam, WGNP, Ras Banaas, Shalateen, Abu Ramaad, Halayeb	August 2015 – May 2016 (Reports ranging from 1980-2016)	Shawky in Nasr et al. (2019) Shawky et al. (2024)

Table 3.2 *(continued)*

Technique	Country	Extent	Date of surveys	Reference
Fisher surveys using Pilcher et al. (2017) technique	Saudi Arabia	Entire Red Sea coast	94 questionnaires collected 2018	T. Qahtani personal communication via email to Marsh and Schramm 2024
Photo-identification	Egypt	180 km shoreline of Marsa Alam & WGNP	December 2015 – October 2017	Shawky (2018) Shawky et al. (2019)
Vocalizations	Sudan	Dungonab Bay, Marsa Halot	1973	Nasr et al. (2019)
	Saudi Arabia	Al-Wajh and Tuwal		Nasr et al. (2019)
	Yemen	Al Hudaydah		Nasr et al. (2019)
Net captures	Egypt	Hurghada to Ras Gamish	1942 - 1955	Gohar (1957)
	Djibouti	Gulf of Tadjoura	1966 – 1980	Robineau and Rose (1982)
	Egypt	Red Sea coast	1999 – 2004	Hanafy et al. (2006)
Dugong remains	Eritrea	34 sites from Mersa Ibrahim Village to Gahro Village	2004 – 2007	Teclemariam et al. (2007)
Strandings	Egypt	Wadi El Gemal National Park	22 September – 4 October 2015	Shawky et al. (2016)
Vessel & SCUBA	Saudi Arabia	Farasan Bank	5 – 28 April 2009	Al-Mansi (2016)
	Saudi Arabia	Al-Wajh Lagoon	July – December 2021	Nasif (2022)
	Egypt	Marsa Alam, WGNP	2017, 2019	Shawky et al. (2017, 2019)
Underwater Laser Photogrammetry	Egypt	Qosseir, Marsa Alam	2019	Shawky (2019a) Shawky (2019b)

3.6.2 Future research

An important initiative would be to develop a program of coordinated and replicable research on the distribution and abundance of dugongs and their seagrass habitats across the countries of the Red Sea. Such a program would need to use techniques that are appropriate to the capacity of each country, but which would enable cross-country comparisons. Once this foundational research has been completed, consideration should be given to understanding the connectivity between dugongs at locations within the region using modern genetics and tracking techniques.

Other Priorities for Action

Developing coordinated and replicable research on the distribution and abundance of dugongs and their seagrass habitats across the countries of the **Red Sea** using techniques that are appropriate to the capacity of each country, but which would enable cross-country comparisons.

Developing a framework for regional co-operation on the marine environment and conservation of the various dugong Range States bordering the **Red Sea** as a component of a regional strategy for megafauna

Understanding the connectivity between dugong populations within the **Red Sea** using modern genetics and tracking techniques.

Obtaining robust estimate for dugong abundance in the entire Red Sea as a basis for an IUCN subpopulation evaluation for the region .

3.7 Regional summary

It is likely that dugongs have declined in the Red Sea in recent decades due to human-caused mortalities relating to past hunting pressure and current incidental bycatch and habitat loss. Dugong distribution throughout the region is patchy, reflecting the availability of suitable habitat, a serious cause for concern when considering the potential for population recovery. Given that the Red Sea dugong population is likely isolated, it should be possible to undertake an IUCN Red List of Threatened Species subregional assessment of its status, when contemporary data on abundance for the entire region become available.

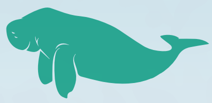
It is impossible to provide a comprehensive list of contemporary areas of local importance within the Red Sea as seagrasses are sparsely distributed, presenting challenges for surveying these areas. Large areas of the Red Sea are remote, and scientists face many logistical challenges working in the region (Preen et al 2012). Table 3.3. provides a summary of confirmed and possible areas of local importance in the Red Sea region.

Table 3.3. Summary of dugong areas of local importance in the Red Sea region by country counter-clockwise from the border between Somalia and Djibouti.

Country	Region
Djibouti	Gulf of Tadjoura, Seven Brothers Islands and Godorya
Eritrea	North of Massawa to Marsa Teklay, south of Massawa to Mersa Fatuma, Dahlak Archipelago, Assab Bay and surrounding areas
Sudan	Dungonab Bay Mukkawar Island Marine National Park
Egypt	Western coast of the Egyptian Red Sea, including Hurghada, Safaga, Qosseir Marsa Alam, Wadi El Gemal National Park (WGNP), Northern Red Sea Islands, Southern Egyptian Red Sea Bays, Offshore Reefs and Islands, Nabq Protected Area and southern Gulf of Suez at Ras Raya (south of El Tor)
Saudi Arabia	Al-Muwaylih, Sindalah, Sanafir Island, Tiran Island and Ras Al-Shaykh Humayd, Wajh Bank, Al Lith area, Jizan, Farasan Archipelago
Yemen	Between Midi and As-Salif

There has not been regional cooperation on dugong specific conservation in the Red Sea to date. PERGSA offers an established framework for regional co-operation on the marine environment and conservation, despite the challenges created by differences in the socio-economic status of the various dugong Range States bordering the Red Sea. A constructive way forward might be to invite PERSGA to coordinate a regional strategy for dugongs in the Red Sea as a component of a regional strategy for megafauna, or for one country to take the lead in promoting dugong conservation and research and bringing together key specialists in the region to initiate such efforts. An essential

Confirmed Significant Locations



Eritrea

Dugong abundance in Eritrea was estimated at

300–400

individuals based on interviews and boat surveys between 2004–2007.

Egypt

Small groups of dugongs have been reported from

95 sites

on the western coast of the Egyptian Red Sea. The 'Northern Red Sea Islands' and the 'Southern Egyptian Red Sea Bays, Offshore Reefs and Islands' have been declared Important Marine Mammal Areas with the dugong as a qualifying species.

Saudi Arabia

The Red Sea coast of Saudi Arabia supported an estimated dugong population of

~1800

individuals in 1987.
The 'Farasan Archipelago', which includes the dugong as a qualifying species, has been declared an Important Marine Mammal Area. The associated Marine Protected Area has also been nominated as a tentative World Heritage Site with the dugong as a 'key taxon'.

foundational element in such a strategy would be the coordinated regional survey efforts using techniques appropriate to the capacity of the various countries as suggested in Section 3.6.2.

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Chapter 4

ARABIAN/PERSIAN GULF (THE GULF)

Authored by: Helene Marsh, Tareq Alqahtani, Silvia Arosa, Mark Beech, David Blair, John A. Burt, Himansu Das, Abdulqader Khamis, Philippa Loates, Christopher Marshall, Len McKenzie, Nicolas Pilcher, Lotfi Rabaoui and John Wong

Helene Marsh[1], Tareq Alqahtani[2], Silvia Arossa[2], Mark Beech[3], David Blair[1], John A. Burt[4], Himansu Das[5], Abdulqader Khamis[6], Philippa Loates[7], Christopher Marshall[8], Len McKenzie[9], Nicolas Pilcher[2,10], Lotfi Rabaoui[2], John Wong[11]

[1]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[2]National Centre for Wildlife, Riyadh, Saudi Arabia.
[3]Natural History Museum Abu Dhabi Department of Culture and Tourism, Al Saadiyat Island, Abu Dhabi, United Arab Emirates.
[4]Mubadala Arabian Center for Climate Change and Environmental Sciences (Mubadala ACCESS), New York University, Abu Dhabi, United Arab Emirates.
[5]Environment Agency Abu Dhabi, Al Nahyan, Abu Dhabi, United Arab Emirates.
[6]Arab Regional Centre for World Heritage, Manama, Kingdom of Bahrain.
[7]Freelance Consultant, UAE.
[8]Department of Marine Biology and Department of Ecology and Conservation Biology, Texas A&M University, Galveston, Texas, United States of America.
[9]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Cairns, Queensland, Australia.
[10]Marine Research Foundation, Kota Kinabalu, Sabah, Malaysia.
[11]Ministry of Environment and Climate Change, Doha, Qatar.

Correspondence to: Helene Marsh helene.marsh@jcu.edu.au.

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Cover image: Dugong sculpture in Doha City, Qatar. Nicolas Pilcher photograph.

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Contents

Range/Signatory States

Range States	Signatory States
Oman?	No
United Arab Emirates	Yes
Qatar	No
Bahrain	Yes
Saudi Arabia	Yes
Kuwait?	No
Iran?	No

We know of no recent evidence of dugongs occurring in the waters of Iraq, Kuwait or Oman. There is some recent evidence of dugongs in Irani waters, and it is possible that they occur in Kuwait and Oman. Whether there are a resident populations is unknown.

Regional findings

This chapter considers the countries of the Arabian/ Persian, Gulf (the Gulf): Islamic Republic of Iran (Iran), Kingdom of Bahrain (Bahrain), Kingdom of Saudi Arabia (Saudi Arabia), State of Qatar (Qatar) and United Arab Emirates (UAE)

- The core habitat for dugongs in the Gulf lies in the western and southern Gulf between about Ras Ghanadha, east of Abu Dhabi in the UAE through Bahrain and Qatar to Ras Tanura on the Saudi Arabian central coast.
- Whether the coastal waters of Iran currently support a resident population of dugongs is uncertain and will only be determined by research explicitly designed to investigate this situation.
- The available evidence suggests that the Gulf supports a stable population of approximately 5,000 dugongs, around 3,000 of which are in the UAE. A coordinated series of surveys across the core habitat in the western or southern Gulf is required to confirm the status of the dugong in the Gulf, which may be eligible for a subregional Red List of Threatened Species assessment by the International Union for Conservation of Nature (IUCN).
- The largest dugong aggregations recorded globally occur in the Gulf of Bahrain/Gulf of Salwa region. These fluid groups account for approximately 60% of the dugongs found in Bahrain waters and an estimated 12% of all dugongs in the Gulf. The core occupancy area of these aggregations straddles the Bahrain–Qatar border, reflecting their transboundary nature.
- The global importance of the Gulf for dugongs has been recognized by the declaration of 'the Southern Gulf and Coastal Waters' and 'the Gulf of Salwa' as Important Marine Mammal Areas (IMMAs), both with the dugong as a qualifying species.
- Given the transboundary nature of the Gulf's dugong population, a regional network of Marine Protected Areas (MPAs) spanning all the dugong Range States in the Gulf to conserve the core dugong areas would be highly desirable and should encompass at a minimum: the Murawah MPA and the Al Yasat MPA in the UAE; the waters southwest of the main island down to the Hawar Islands and the two Fashts in Bahrain; the northwest coastal waters of Qatar; and the Gulfs of Bahrain and Salwa between the Kingdom of Saudia Arabia, Bahrain and Qatar.
- The Gulf is the world's hottest sea. The effects of climate change on dugongs and their habitats merit investigation in the context of the other threatening processes they are exposed including fisheries interactions, coastal development and oil pollution, especially as dugong genetic diversity appears to be low in this region.
- The Regional Organization for the Protection of Marine Environment (ROPME) should be well placed to co-ordinate dugong research, monitoring and conservation management across the Gulf.

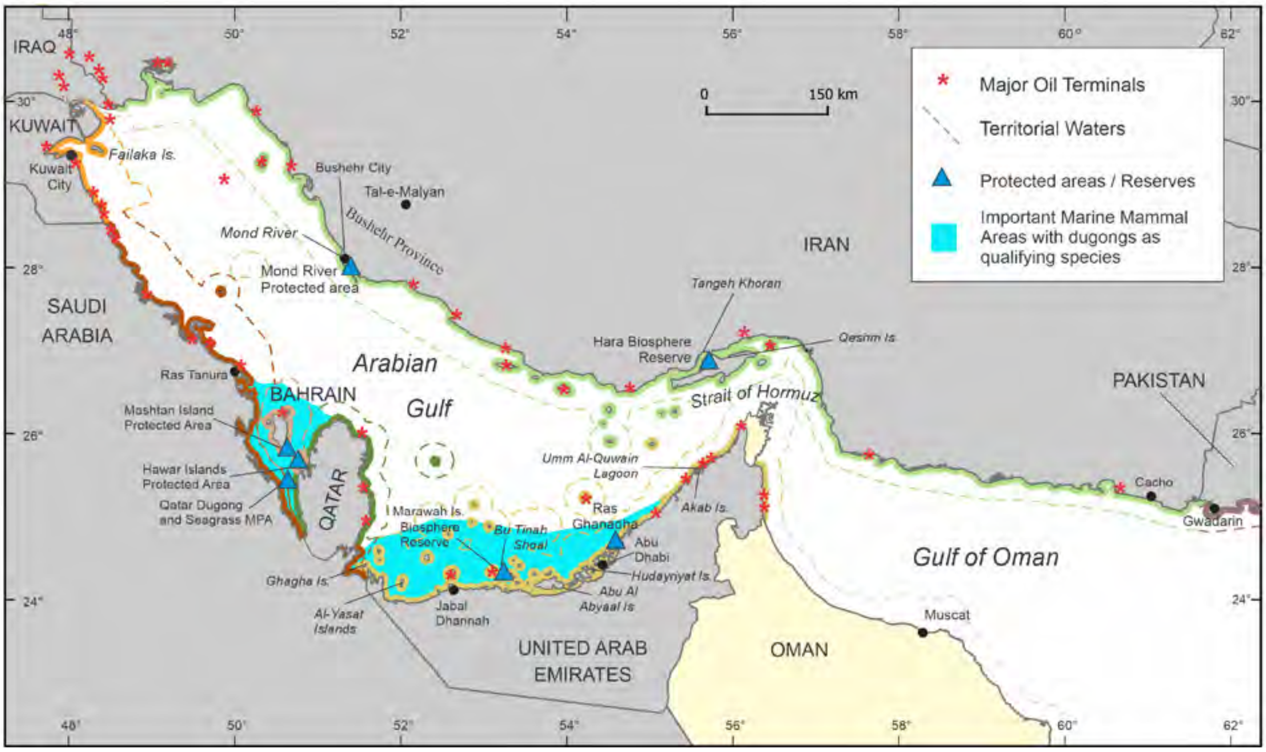
4.1 Regional setting

4.1.1 Geographic overview

This chapter considers the status of the dugong along the approximately 7,656 km coastline (including major offshore islands) of the Arabian/ Persian Gulf (henceforth the 'Gulf'). The United Nations refers to the region as the 'Persian' Gulf; most dugong Range States in the region prefer the 'Arabian' Gulf. The Gulf is a largely enclosed sea beginning at the Strait of Hormuz and extending along the coasts of the following countries (clockwise from the south-east): Oman, United Arab Emirates (henceforth UAE), State of Qatar (henceforth Qatar), Kingdom of Bahrain (henceforth Bahrain), Kingdom of Saudi Arabia (henceforth Saudi Arabia), State of Kuwait (henceforth Kuwait), Republic of Iraq (henceforth Iraq) and the Islamic Republic of Iran (henceforth Iran). East of the Strait of Hormuz, the Gulf connects with the Gulf of Oman, which is bordered by Oman in the south and Iran in the north (Figure 4.1). Oman, Kuwait and Iraq are not considered further in this chapter as no dugongs have been confirmed in the waters of either country in modern times. In Chapter 11, Oman and Kuwait are classified as Range States that possibly support resident populations of dugongs, but further investigation is required to confirm the situation.

The Gulf, which spans six degrees of latitude (24°–30° N), is a shallow sea with an average depth of around 30 m and a maximum depth of approximately 100 m in the 'shallow subterranean valley' parallel to the Iranian coast (Burt and Paparella 2023). The Gulf has an area of around 241,000 km^2, a length of approximately 990 km, and a width that varies from a maximum of around 340 km to a minimum of 55 km in the Strait of Hormuz (Evans 2024; Figure 4.1.). The Strait of Hormuz acts as an 'environmentally isolating bottle neck' at the entrance to the Gulf (Burt and Paparella 2023).

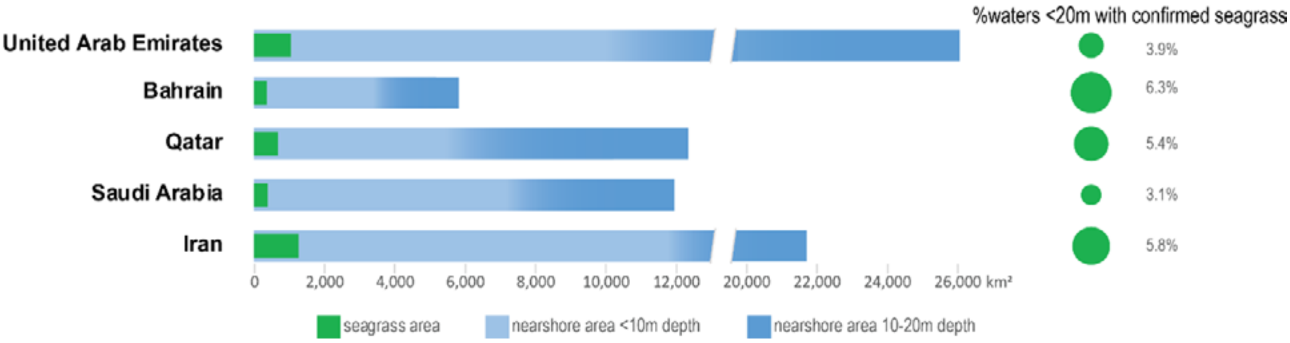
Figure 4.1. Upper figure: Geographic context of the Gulf showing placenames mentioned in the text. Confirmed and possible dugong Range States are ordered clockwise around the region starting with the United Arab Emirates (UAE), with coloured coastlines as follows: UAE (yellow), Qatar (dark green), Saudi Arabia (brown), Bahrain (tan) and Iran (light green). Kuwait (orange) and Iraq (grey) are not confirmed dugong Range States but are included due to their archaeological importance. Left figure: The Gulfs of Bahrain and Salwa showing placenames mentioned in the text; territorial waters are shown in coloured dashed lines. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

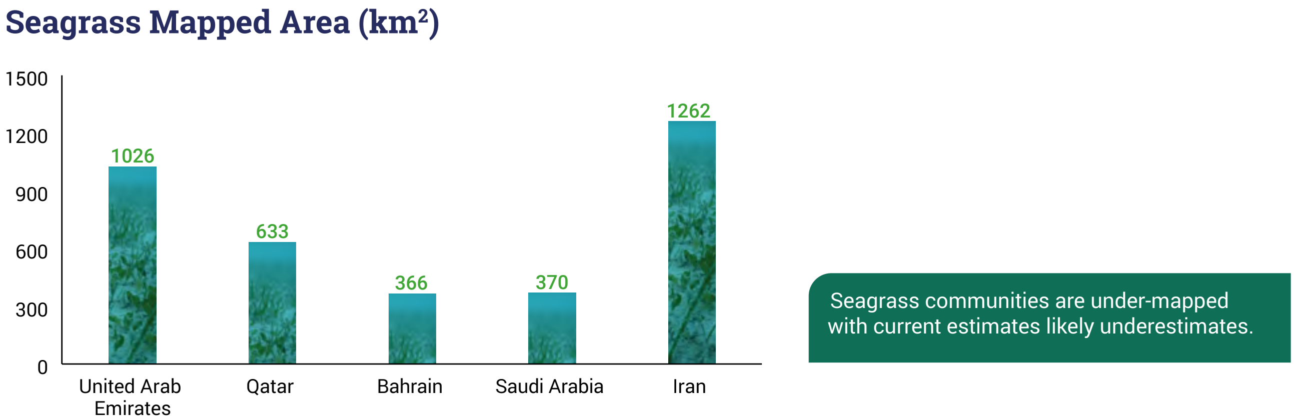


The modern Gulf is one of the world's youngest seas and the contemporary coastline was established only 3,000–6,000 years ago (Riegl and Purkis 2012; Smith et al. 2022). The Gulf climate is transitional between tropical and subtropical and occurs at the subtropical high-pressure zone that results in low cloud cover, limited precipitation, high solar insolation and high evaporation rates – a climatic setting that creates unusually extreme marine environmental conditions (Paparella and Burt 2023). While geographically situated in the subtropics, the surrounding arid environment results in the summer climate being tropical (Vaughan et al. 2019).

The Gulf is a biogeographic sub province of the northwestern Indian Ocean province (Spalding et al. 2007). Its shallow waters support extensive seagrass meadows, which form part of the Tropical Indo-Pacific seagrass bioregion (McKenzie et al. 2020). The following seagrass areas have been recorded in the Gulf with moderate to high confidence (Figure 4.2): UAE 1,026 km^2 (Erftemeijer and Shuail 2012); Qatar 633 km^2 (Jones 1985; Abdelbary and Al Ashwal 2021); Bahrain 366 km^2 (Jones 1985; UNEP-WCMC and Short 2021); Saudi Arabia 370 km^2 (Jones 1985; UNEP-WCMC and Short 2021) and Iran 1,262 km^2 (Al-Shuail 2007; Erftemeijer and Shuail 2012).

Figure 4.2. Histogram showing the known areas of seagrass and coastal waters shallower than 20 m deep for each dugong Range State in the Gulf region. The areas of seagrass are almost certainly underestimates and do not include reef associated seagrasses. Although not all coastal waters shallower than 20 m will be suitable dugong habitat, the figure highlights the need for further seagrass mapping in the region. Len McKenzie figure; reproduced with permission.





The Gulf is a stressful environment for seagrasses (Erftemeijer and Shuail 2012). Natural salinities in the coastal waters where seagrasses occur range from 38–70 PSU (Practical Salinity Units) and water temperatures from 10° to 39° C (Price et al. 1993). Vaughan et al. (2019), (see also Fawzi et al. 2022; Fiesler et al. 2023) considered the Gulf to be the hottest sea on the planet during summer, particularly in the shallow southern basin where sea surface temperatures regularly exceed 35°C in August, and occasionally exceed 37° C (Burt et al. 2019). High temperatures and related biological oxygen demand can also result in recurrent periods of hypoxia and occasional anoxic events during summer in shallow regions of the southern Gulf (de Verneil et al. 2021). There is a large and growing oxygen minimum zone in the central Gulf that represents a looming threat to coastal ecosystems and fauna (Lachkar et al. 2022).

Only three species of seagrass occur in the Gulf: *Halodule uninervis, Halophila stipulacea* and *Halophila ovalis*. Species of *Halodule* and *Halophila* are eaten by dugongs at many locations in their global range (Marsh et al. 2011) and there are aerial observations of dugongs feeding in *Halodule uninervis* and *Halophila ovalis* communities in the Gulf (Marshall et al. 2018). Dugongs have also been observed foraging on mixed *Halodule* and *Halophila* seagrass meadows (Marshall et al. 2018; A. Khamis personal communication via email to Marsh and Schramm 2024). Nonetheless, not all areas of seagrass in the Gulf are potentially suitable habitat for a resident dugong population, because in some inshore areas of the northern Gulf (i.e., northern Saudi Arabia and Kuwait), the water is likely to be too cold for them over winter (Preen 2004; Preen et al. 2012), with sea surface temperatures reaching minima of 13–15° C (Burt and Paparella 2023). In addition, the confirmed area of seagrass in Kuwait is only 7.6 km^2, which is unlikely to be sufficient to support a resident dugong population (Al-Shuail 2007; Erftemeijer and Shuail 2012).

Preen (1989, 2004) and Preen et al. (2012) considered that the core habitat for dugongs lies in the western and southern Gulf between about Ras Ghanadha, east of Abu Dhabi in the UAE through Bahrain and Qatar to Ras Tanura on the Saudi central coast (Figure 4.1).

The information regarding dugongs outside this core area follows:

- Preen (1989, 2004) and Preen et al. (2012) report small numbers of dugongs in the limited seagrass habitat coast between the Oman border and Ras Ghanadha in the UAE. Beech (2010) report four archaeological sites containing dugong remains in the region; Al-Abdulrazzak and Pauly (2017) report two post 1950 records (Figures 4.1, 4.5).
- Neither Beech (2010) or Al-Abdulrazzak and Pauly (2017) provided any evidence of dugongs occurring in the coastal waters of Saudi Arabia north of Ras Tanura. Interview surveys with fishers along the Saudi Arabian Gulf coast in 2018 did not report sightings of dugongs north of the Abu Ali peninsula 27.3° N (T. Alqahtani personal communication via email to Pilcher 2024), with all 33 reports of dugongs occurring below this latitude.
- Beech (2010) (see also Al-Abdulrazzak and Pauly 2017) reported two archaeological sites with dugong remains in Kuwait dating from 50 BC–700 AD and 300 BC–100 AD, including 'moderate' quantities of dugong bones from the excavation on Failaka Island including a rib with butchery chop marks.
- There are no known records of dugongs from Iraq, which has a very short (around 60 km) coastline and highly turbid waters unsuitable for seagrass growth as a result of the discharge of the Tigris and Euphrates rivers.

The geography of the region indicates that it is extremely unlikely that the Gulf dugong population is currently ecologically connected to the Red Sea dugong population (Chapter 3), which is approximately 3,500 km (12.68° N, 43.46° E to 26.38° N, 56.48° E) away, separated by the open Indian Ocean coast of the Arabian Peninsula. This conclusion is strengthened by the lack of suitable habitats to act as steppingstones for genetic transfer between the two regions, as no seagrasses are known to occur on the Arabian Sea coast of Oman and Yemen, and only a few isolated areas in northern Oman (Green and Short 2003).

If dugongs are resident in Iran, they may be connected to the animals in the southern and western Gulf, a distance which is within the range of recorded large-scale movements in Australia (Deutsch et al. 2022). The nearest known dugong population to the east is the small, isolated population in the Gulf of Kutch in India (Chapter 5), approximately 1,900 km from the easternmost (unsubstantiated) record in Iran (Figures 4.1, 4.5).

4.1.2 Geopolitical and socioeconomic overview

This information is provided as an indication of the challenge for each of the various dugong Range States in the region to consider the conservation of dugongs and their habitats in the context of their socioeconomic development needs. The nations bordering the western and southern Gulf have experienced unprecedented population growth in the past 50 years due to the regional oil boom of the 1970s (Burt 2014). Such rapid growth has resulted in large-scale urban development, primarily in coastal areas, where population centres have 'evolved from small fishing and trading villages into globally interconnected megacities' (Burt and Bartholomew 2019).

The Human Development Index (HDI) status and Gross Domestic Product (GDP) of the dugong Range States bordering the Gulf (Table 4.1) indicate that all have a Very High or High HDI and per capita GDP ranking.

The geopolitical situation between the countries bordering the Gulf is complex, delicate and variable. While there have been some successes in cross-border collaboration in environmental research

Table 4.1. Human Development Index (HDI) status and rank and Gross Domestic Product (GDP) per capita rank of the dugong Range States in the Gulf. Consistent with the remainder of this chapter, the countries in this table are ordered clockwise around the Gulf starting with the UAE. Countries with the highest HDI or GDP have the lowest ranks. 189 countries were ranked for both indices.

Range State	HDI	HDI Rank 2023[i]	GDP per capita rank 2023[ii]
UAE	Very High	26	6
Qatar	Very High	42	5
Bahrain	Very High	35	19
Saudi Arabia	Very High	35	20
Iran	High	78	81

i 2023 HDI data from https://hdr.undp.org/data-center/country-insights#/ranks (downloaded from the internet January 2024);
ii 2023 per capita GDP from https://www.worldometers.info/gdp/gdp-per-capita/ (downloaded from the internet June 2024).

and monitoring (e.g., Burt et al. 2021), for the most part the geopolitical situation complicates collaboration between regional nations with regards to research, conservation, and management (Fawzi et al. 2022; Fieseler et al. 2023). There can also be complications within countries. In the UAE, each of the seven emirates has its own environmental regulatory authority. In addition, fiscal structures within government agencies often preclude covering costs outside direct agency expenses.

This situation has presented challenges for collaboration between and within Range States with regards to infrastructure and research, monitoring and conservation of dugongs and their seagrass habitats in the past, but this appears to be improving in recent years. For example, work has resumed on new causeway between Bahrain and Qatar. At a recent regional meeting in Abu Dhabi (May 2023), there was a commitment and a call by dugong specialists from these countries to increase collaboration on research and conservation efforts (UNEP/CMS 2023).

4.1.3 Genetics of dugong populations in the Gulf

For an overview of genetics-relevant techniques, definitions, studies and general findings, refer to Chapter 1, particularly Figure 1.2.

The Gulf was a freshwater wetland around 20,000 years ago at the Last Glacial Maximum (LGM) (Friis et al. 2024). As with the Red Sea (Chapter 3), dugongs can only have dispersed into the Gulf during post-glacial sea-level rise. During the LGM, the Gulf of Oman likely had little shallow water suitable for seagrass growth (Ludt and Rocha 2015), so was likely not a suitable glacial refuge for dugongs.

Pyenson et al. (2022) reported the finding of a sirenian rib, suspected as being from a dugong, in a Pleistocene deposit in Qatar. This was dated to about 125,000 years ago. This finding hints at the presence of dugongs in the Gulf during the interglacial period before the present one, at a time when sea levels would be similar to those of today. Extraction of DNA from this or other ancient samples from this region has not been attempted.

There have been no studies on dugongs from the Gulf using nuclear genetic markers[1]. Twelve previously unpublished mitochondrial control region sequences (410 bp) from the UAE (now in GenBank with accession number PP317829) are all identical. Plön et al. (2019) published 18 sequences derived from historical museum material from the Gulf. The museum collections came from the UAE and Bahrain. All but one of these sequences were also identical with the most common West Indian Ocean haplotype (Chapter 1, Figure 1.2). The exception (MH704326) had affinities with the Australasian haplogroup (Chapters 9 and 10) but had several ambiguities at diagnostic sites, suggesting technical difficulties in determining the sequence. Tikel (1997) reported a short (194 bp) mitochondrial sequence from a dugong from the Gulf as being identical with the commonest haplotype of the Australian restricted haplogroup (Chapter 10).

- As for the Red Sea (Chapter 3) and the Western Indian Ocean more generally (Chapters 2 and 5), the available mitochondrial sequences from dugongs from the Gulf indicate limited genetic diversity.

4.2 Distribution, abundance and trends in confirmed dugong Range States

The Gulf is believed to host the largest population of dugongs in the world after Australia. Based on comprehensive strip-transect aerial surveys and using the *Marsh and Sinclair Method* (1989) methodology to correct for detection bias, Preen (1989) estimated that the Gulf's dugong population was approximately 7,300 ± SE 1,300 dugongs in the summer of 1986. Preen (2004) reanalysed his data and revised this estimate to approximately 5,400 ± SE 930.

Preen et al. (2012) concluded that the most important dugong areas (Figure 4.1) were:

1. The Marawah Island area, between Abu al Abyad Island, Jabal Dhannah, and Bu Tinah shoal in the UAE;
2. Between UAE and Qatar in the southern Gulf;
3. Between Bahrain and Qatar; and
4. Between Bahrain, and Saudi Arabia, south of the King Fahad Causeway and north of Al Uquair, Khawr Duwayhin.

4.2.1 UAE

Preen's 1986 surveys provided a robust baseline for further work on the dugong population in the Gulf. Preen replicated the UAE component of his

1 All genetic terms are defined in Chapter 1.

1986 surveys in 1999 (Preen 2004). Since then, monitoring in Abu Dhabi waters has been conducted by the Environment Agency Abu Dhabi (EAD) (e.g., Das et al. 2021). Preen et al. (2012) pointed out that the results of these surveys are not strictly comparable with the results of the surveys he led in 1986 and 1999 because of the differences in areal and transect coverage and analysis including corrections for detection bias. Nonetheless, Preen et al. (2012) concluded that the important finding was that dugong numbers in the UAE remain relatively constant. Based on the long-term monitoring conducted in the UAE, Das et al. (2021) concluded that that the population of almost 3,000 dugongs in the UAE was relatively stable. Differences were observed between surveys in the distributions of individuals and large groups.

The 'Southern Gulf and Coastal Waters' IMMA extends through the coastal waters of UAE from Qatar to the northern border of the Dubai Emirate (IUCN-MMPATF 2021b).

- Long-term monitoring suggests that UAE waters support a relatively stable population of almost 3,000 dugongs.
- Dugong distribution within the coastal waters of UAE, including the distribution of large groups, can differ between surveys.
- The 'Southern Gulf and Coastal Waters' IMMA extends through the coastal waters of UAE from Qatar to the northern border of the Dubai Emirate.

4.2.2 Bahrain, Qatar and Saudi Arabia

These Range States are considered together because all three border the Gulf of Bahrain/Gulf of Salwa region (Figure 4.1), a key habitat for dugongs in the Gulf. During his comprehensive survey of the waters of the southern Gulf, Preen (1989) detected two neighbouring, very large, aggregations of dugongs close to the Qatar-Bahrain border in the winter of 1986: one containing an estimated 577 animals; the other 97. He did not see such aggregations during his summer 1986 survey and concluded that the grouping behaviour was a winter phenomenon.

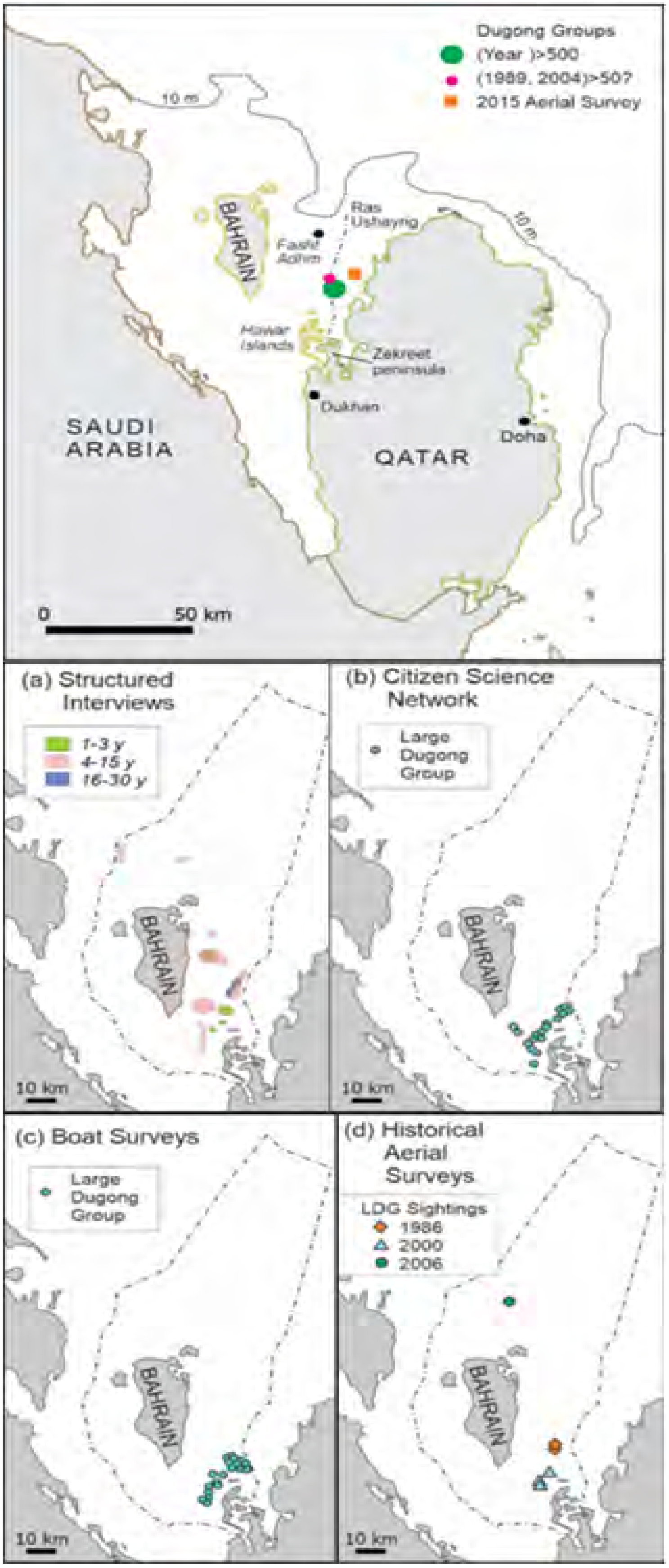
Hodgson (2009) conducted a large-scale survey in the waters of Bahrain to the 10 m isobath in October 2006 (autumn). Sightings included a large aggregation of more than 50 dugongs in the north of the survey region. Preen et al. (2012) noted that the results of Hodgson's survey were not strictly comparable with the results of the surveys Preen led in 1986 due to differences in areal and transect coverage and analysis.

The occurrence of large aggregations of dugongs in this region in the winter has been reinforced by recent studies of large dugong groups (aggregations of over 500 animals; Marshall et al. 2018; Khamis et al. 2023). Aggregations of up to 700 animals were sighted on several occasions along the northwest Qatar-Bahrain border, the Hawar Islands and Bahraini coastal waters (Figures 4.3, 4.4). Recent, but unpublished, data using unoccupied aerial vehicles (UAVS, or drones) indicated aggregations of more than 1,500 individuals in this region (C. Marshall personal communication via email to Marsh 2024).

Khamis et al. (2023) provided convincing evidence that that large fluid aggregations of dugongs occur almost year-round in this region on the basis of historical records, structured interview surveys, citizen science network reports, and boat, helicopter and UAV surveys covering nearly all Bahrain waters up to the 10 m isobath (Figures 4.3, 4.4). These aggregations, which are the largest dugong groupings recorded globally, account for an estimated 60% of the dugongs found in Bahrain and 12% of all dugongs in the Gulf (Khamis et al. 2023). Their core occupancy area (145 km^2) straddles the Bahrain–Qatar border, reflecting their transboundary nature (Khamis et al. 2023; Figures 4.3, 4.4). The region has abundant seagrass, less extreme

Figure 4.3. An aerial photograph of a large dugong aggregation (more than 50 dugongs) encountered in summer (October 4, 2021) to the north of Hawar Island, Bahrain. Janez Lotric photograph, Diplomatic Protocol Communications. Reproduced from Khamis et al. (2023) (RightsLink Licence number 5722730990410).

Figure 4.4. Geographic context of the Gulfs of Bahrain and Salwa showing the locations and approximate timings of the large dugong aggregations (LDG) reported by Preen (1986); Bell (2001), Hodgson (2009), Marshall et al. (2018) and Khamis (2023) (LDG) redrawn from Marshall et al. (2018) (RightsLink licence number 5722730522049) and Khamis et al. (2023) (RightsLink Licence number 5722730990410). The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



summer and winter temperatures than some other parts of the Gulf, and is sheltered from turbulent waters caused by shamal winds during the winter months (Burt and Paparella 2023; Alagha et al. 2025) a situation which may influence the quality of the area as an aggregation site. Khamis et al. (2025) used binomial modeling to investigate the variables associated with the summer and winter locations of the large aggregations around Hawar Island. The modeling indicated that the presence of seagrass meadows was the primary factor associated with the distributional patterns.

The 'Gulf of Salwa' IMMA (IUCN-MMPATF 2021a; Figure 4.1) spans the Gulfs of Bahrain and Salwa.

A project funded jointly by the Convention for Migratory Species (CMS Secretariat) and the Arab Regional Centre for World Heritage (ARC-WH) used the Dugong MOU Standardized Catch and Bycatch Questionnaire to obtain information from fishers from Bahrain to better understand the factors driving the behaviour of the large dugong aggregations around the Hawar Islands by establishing a citizen science observer network. A key finding from interviews with 44 fishers was that large herds of dugongs were seen between Bahrain Island and Fasht Jarim in the north, as well as between Bahrain Island and Hawar Islands to the southwest (Anon. 2023).

Rabaoui et al. (2021) used fisher questionnaires, opportunistic sighting records, and boat-based transect surveys between February 2016 and 2020 to: (1) determine the distribution and density of different species of marine mammals present in Saudi Arabian Gulf waters, and (2) characterize the ecological traits of these animals, paying special attention to the effect of environmental factors on their distribution in this area. Cetaceans were their primary focus and apart from the fisher surveys; the methods they used were unsuitable for dugongs. They concluded that there were few dugongs in Saudi waters, that sightings were more frequent during the cool season (November–February) in the Gulf of Salwa and Ras Abu Gamis (at the Saudi border with Qatar and United Arab Emirates) and that cross-jurisdictional conservation strategy was required to protect dugongs. Alqahtani (T. Alqahtani unpublished data 2024) also used the Dugong MOU Standardized Catch and Bycatch Questionnaire to determine dugong presence along the Saudi coast of the Gulf in 2018 and documented 33 sighting records, of which only one was of a stranded dugong, the balance being live sightings.

- Large fluid aggregations of dugongs occur during most of the year in the Gulf of Bahrain/ Gulf of Salwa region.
- These aggregations, which are the largest dugong groupings ever recorded globally, account for an estimated 60% of the dugongs found in Bahrain and 12% of all dugongs in the Gulf.
- A core occupancy area of these aggregations straddles the Bahrain–Qatar border, reflecting their transboundary nature.
- The global importance of this region has been recognized by its designation as the 'Gulf of Salwa' IMMA with the dugong as a qualifying species.

4.2.3 Iran

Dugong remains have been recorded in southern Iran since archaeological times but whether the coastal waters currently support a resident population is uncertain. The following information suggests that a small resident (Chapter 11) population may currently exist there:

- Based on bathymetry and latitude, Preen et al. (2012) predicted that dugongs could potentially occur around Qeshm Island (26° N) in the Strait of Hormuz (Figure 4.1). Qeshm Island (120 km long and up to 30 km wide) is separated from the Iranian coast by the narrow Tangeh Khoran (Khoran Strait) and is the site of the Hara Biosphere Reserve (2,062 km^2). Braulik et al. (2010) noted: (1) two sightings of dugongs in the mangroves of the Hara Protected Area, including a single dugong (Keijl and van der Have 2002) in January 2000; and (2) a record of three separate individuals in November 2000 (Green 2000).
- In 2012, a report was made to the Plan for the Land Society that a deceased female dugong was found stranded along the coast near Cacho village, eastern Chabahar, Sistan and Baluchistan Province (N. Mohsenian personal communication via email to Marsh 2024).
- There are several reports of dugongs in Bushehr Province of Iran (Figures 4.1, 4.5) including:
    - archaeological records from Siraf (27.67° N, 52.34° E) dating from 400 AD 1600 AD (Beech 2010),
    - an unconfirmed, sighting of two individuals in the Mond River estuary (around 100 km south of Bushehr City) (Firouz 2005), and
    - recent confirmed records of two adult dugongs in the Mond Protected Area; (29.92° N, 51.15° E) in 2021 and 2022 (Tollab et al. 2023): (1) a moderately decomposed,

probable female, found floating in offshore waters of the Motaf fishing ground on 30 April 2021 (spring), and (2) another adult female entangled in a set gillnet in inshore waters of the same area on 29 December 2022 (winter). The second animal was released alive.

- There have also been anecdotal reports of dugong sightings in Gwadarin, in the Gulf of Oman near the Iran-Pakistan border (Braulik et al. 2010).
- The area of seagrass that can be confirmed with high confidence is large (1,262 km^2; Section 4.1.1).

Four hundred interview surveys were conducted in 2022 to obtain information regarding sea turtle and shark and ray bycatch and their overlaps with fisheries, along the entire coast of Iran. No dugong sightings were reported (N. Pilcher personal communication via email to Marsh and Schramm 2024). If a resident dugong population occurs in Iran, the numbers are likely to be small.

- More research is required to confirm whether Iran supports a resident dugong population.

4.3 Cultural values

In the Gulf, dugongs are variously known as: *bugarah al bahr* (cow of the sea) or *alatoom* (Bahrain, Qatar, and UAE) or, *arus al bahr* (bride of the sea: Saudi Arabia, and Bahrain) (Preen et al. 2012).

People have exploited Gulf dugongs since before the modern coastline was established around 7,000 or more years ago (Burt and Paparella 2023). Dugongs were exploited by both pre-historical and historic coastal peoples. The oldest site at the island of Marawah in Abu Dhabi Emirate dates to more than 7,500 years ago (Beech 2010). The waters around the island of Marawah are: (1) very important contemporary dugong habitat (Figure 4.1 and Section 4.2), where large dugong aggregations are sighted (Das et al. 2021), and (2) the site of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Marawah Marine Biosphere Reserve.

Dugongs were a source of economically valuable products such as meat, oil, fat and hide (Beech 2010). Dugong meat and bone marrow were eaten, hides were used to make sandals, and handles for Sheikh's swords were fashioned using tusks. Artefacts were also manufactured from dugong bones and tusks at several prehistoric sites (Beech 2010). Dugong remains have been found at Tal-e-Malyan, a second millennium BC highland urban site in Iran (Beech 2010; Figure 4.5), suggesting that they were traded.

Dugongs were also used for ritual purposes. Based on the initial excavations, Prieur and Guerin (1991) and Jousse et al. (2002) interpreted the site they studied on Akab Island in Umm al-Quwain lagoon in north-eastern UAE (Figure 4.6), which dates from approximately 5,500 years ago, as a small butchery camp, which specialized in dugong fishing. After further excavations, Charpentier and Méry (2008) and Méry et al. (2009) reinterpreted the 'dugong mound' as a ritual site featuring a structured platform of dugong bones, containing skulls laid parallel and ribs in sets, together with artefacts of the Neolithic period. They considered that the site was the oldest known ritual site in Arabia and the world's oldest known ritual site associated with the dugong. Its excavation has provided new data on the relations between humans and their environment in Neolithic Arabia, in particular, on the symbolic use of animals, which lies at the core of the system of cultural and social representations. In another example of ritual use of dugong remains, Beech (2010) discovered their use in association with an Islamic burial practice during the recent historical period on Marawah Island in Abu Dhabi Emirate.

Ancient dugong bone mounds are found on many of the islands in Abu Dhabi Emirate. Most have not been studied (H. Das personal communication to Lousia Ponnampalam 2021 in Ponnampalam et al. 2022). All this archaeological evidence demonstrates the apparent longevity of the importance of dugongs to the peoples of the Gulf region.

Beech (2010) detailed the extensive archaeological evidence of the use of dugongs at 15 sites around the Gulf (Figure 4.5) as follows: UAE (nine sites), Bahrain (three sites), Kuwait (two sites) and Iran (one site). These locations include six sites in the present core area in the southwestern Gulf and eight locations where suitable habitat is now rare.

Since Beech (2010), an additional six archaeological sites from the UAE have been identified. These include one Neolithic site from Jebel Fayah, Sharjah Emirate, UAE, and three Neolithic coastal sites in Umm Al Qaiwain in the UAE. A pendant made from raw dugong ivory was located from Jebel Fayah (Figure 11 in Uerpmann et al. 2012); there was a raw piece of dugong tusk at the same site which is dated between 4,900 and 4,200 BC. This may be

Figure 4.5. Records of dugongs at archaeological sites in the Gulf redrawn from Beech (2010) and showing contemporary placenames mentioned in the text with advice from Mark Beech. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

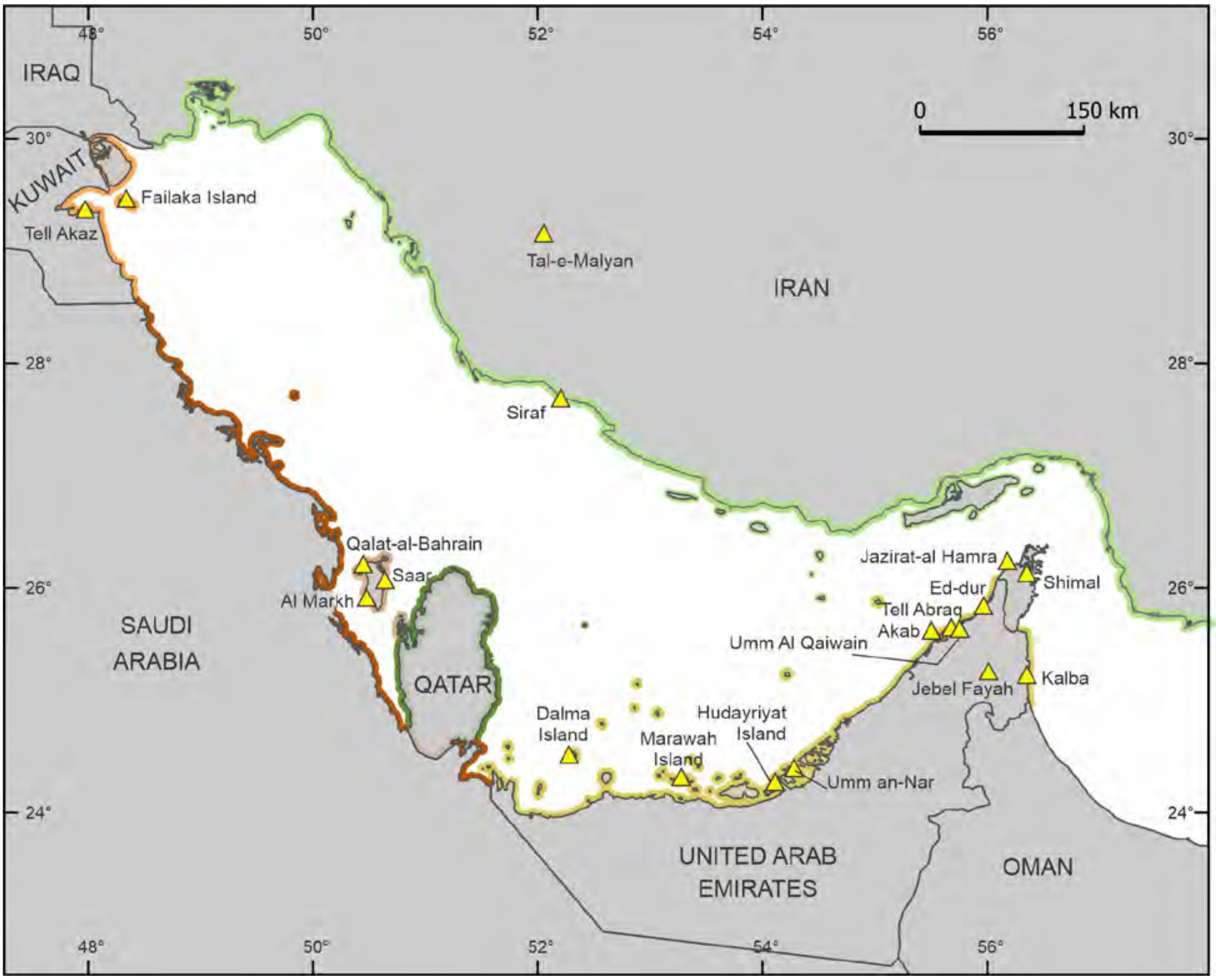
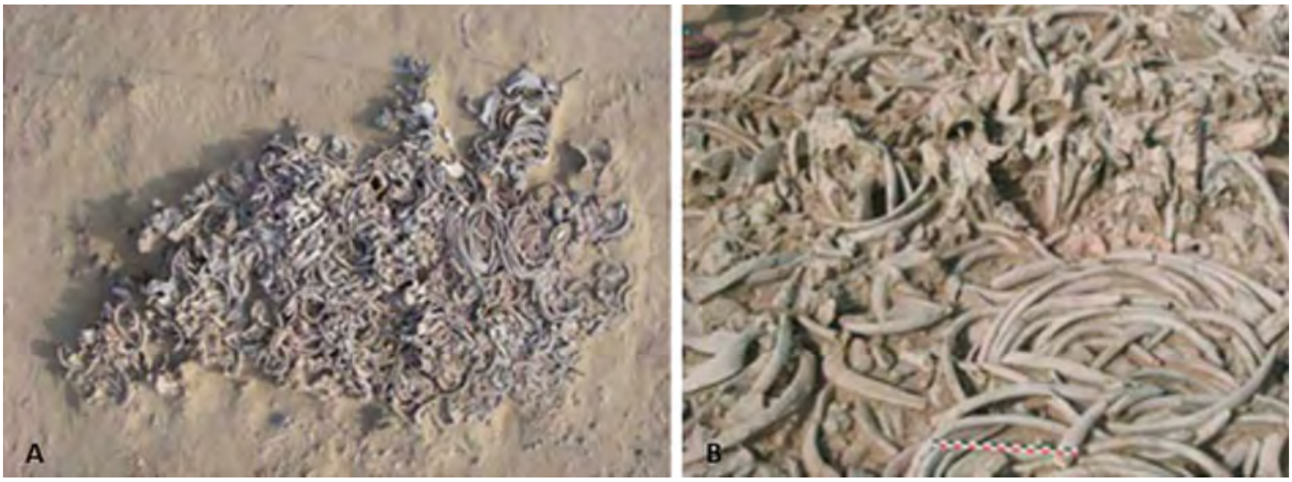


Figure 4.6. **(A)** Dugong bone mound and **(B)** the rostra and skulls of dugongs placed in anatomical positions and aligned ribs in Akab Island, Umm Al Quwain lagoon. Reproduced from Méry et al. (2009) (RightsLink licence number 5722760958242).



amongst the earliest evidence for the use of dugong ivory, pre-dating a statuette from Mesopotamia (now south-central Iraq) dated between 2,250 and 2,120 BC (Caubet and Poplain 2003). The discovery of further dugong bones at Neolithic sites located near the Umm Al Qaiwain lagoon further confirms the importance of dugongs in the local area.

Dugong remains have also been reported from the recent archaeological excavations at the Bronze-Iron Age settlement site at Kalba, located on the east coast of the UAE (K. Lidour personal communication via email to Marsh 2024). This result is interesting since there are no shallow waters with seagrass in this area and the waters become deep close to the shore. A late Islamic period midden of butchered dugong, turtle, shark and fish bones has been discovered in the southern shoreline of Hudayriyat Island, just adjacent to the capital – Abu Dhabi Island. This midden included a large number of marine shells, mainly *Pinctada radiata* pearl oyster shells, and results from the traditional communities, which were primarily involved in fishing and pearling. This site is now fenced off and protected by the Department of Culture and Tourism (DCT Abu Dhabi), Modon and the Department of Municipalities and Transport, along with a cluster of other shell middens as part of the Hudayriyat Heritage Trail. Heritage information signs are provided that inform visitors about the traditional use of these marine resources.

The fact that the Gulf currently supports the second largest dugong population globally is an ongoing source of pride in the UAE. In 2009 CMS and EAD signed a partnership agreement establishing a CMS Office in Abu Dhabi, which hosts the CMS Dugong MOU Secretariat. In Qatar, a sculpture of a giant iridescent dugong by world famous artist Jeff Koon graced the Corniche in the heart of Doha for the FIFA World Cup in 2022 (Figure 4.7).

4.4 Threatening processes

The main threats that affect dugongs in the Gulf are common throughout its global range: incidental and deliberate capture in fishing gear, mortality from vessel-strike, pollution, habitat loss, and climate change. Each of these threats is discussed below. However, as pointed out by Natoli and Al-Hameli (2023): (1) there have been no systematic threat assessments to inform management interventions; and (2) there is no cross-jurisdictional stranding network to enable standardized data to be shared across jurisdictions. This situation prevents the cross-border collaborations that are desirable for management of species than can undertake large-scale movements such as the dugong. The situation is further complicated by the complex geopolitical situation.

Figure 4.7. Jeff Koon's dugong sculpture in Doha City, Qatar, where it was exhibited during the FIFA World Cup in 2022. Nicolas Pilcher photograph; reproduced with permission.

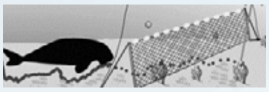
4.4.1 Deliberate and incidental capture

The archaeological evidence (Section 4.3) indicates that dugongs were harvested in the Gulf for thousands of years. Dugongs were located, or chased, into shallow water where they were surrounded by many people and clubbed to death (Preen 1989). According to fishers in Abu Dhabi interviewed by Preen (1989) in 1986, active dugong hunting in UAE ceased in the 1960s after Sheik Zayed, ruler of the UAE, decreed that fishers must not actively hunt dugongs and that only animals caught in nets could be sold. Netting gradually replaced hunting as the main cause of mortality for dugongs in the Gulf.

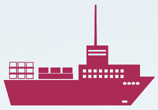
Based on interviews with the manager and two fishers in the Abu Dhabi fish souk (market) in 1986, Preen (1989) estimated that between 70 and 100 dugongs were sold in the market annually and concluded that this did not represent the total number being caught at that time.

Pilcher et al. (2017), Marshall et al. (2018) and Marsh and Sobtzick (2019) concluded that incidental capture in mesh nets was a major threat to dugongs in most parts of their range and is likely to be the most significant chronic threat in the Gulf (Preen et al. 2012). In the UAE, Preen (1989, 2004) estimated that net mortality was unsustainable in the 1980s on the

Threatening Processes



Interactions with small-scale fisheries, especially gillnet fisheries are the principal causes of dugong mortality and population decline.



Industrialization and urban development is increasing the risk of vessel strike.

Cumulative impacts from coastal development, overfishing, industrial expansion and other population-driven stressors', have made the Gulf amongst the World's most degraded marine eco-regions.

The Gulf has 68% of the world's oil reserves and more than 40% of gas resources; around 60% of global oil transport occurs in the region.Major oil spills have already occurred.

The Gulf is the world's hottest sea and already a harsh environment for seagrasses. Other changes with advise impacts on dugongs and their seagrass habitats seem inevitable.

Apparently low genetic diversity: a significant challenge to population resilience and recovery.

The cumulative impacts of these threats necessitate targeted conservation interventions across the region, emphasizing habitat protection and the mitigation of human-induced threats.

basis of his 1986 survey results and the mortality estimates he inferred from interview surveys. In 1998, 12 dugong carcasses were found tied under mangroves on Marawah Island, near an area where large-meshed gillnets were set (Preen 2004, Preen et al. 2012). This is the same area where the remains of 28 dugongs were reported by Baldwin and Cockcroft (1995). Baldwin et al. (1999) reported the remains of an additional 55 dugongs, over 90% of which had died within the previous two years. Most were found near the fishing village of Liffah on Marawah [Merewah] Island. Many appeared to be victims of deliberate harvest. The sale of dugong meat in the UAE was banned in 1999 (Preen et al. 2012; Section 4.5).

Hodgson (2009) and Preen et al. (2012) reported that most gillnet fishers were using a drift technique in Bahrain. This technique was prohibited, but operations were conducted at night and no records were kept that allowed the level of bycatch to be estimated (Preen et al. 2012). A Ministerial decree banning the deliberate killing or sale of dugongs was issued in Bahrain in 2003 (Preen et al. 2012, Section 4.5).

One of the dugongs reported from Iran in 2020 by Tollab et al. (2023) had been caught in a gillnet set by recreational fishers who disentangled the dugong by cutting the net. The animal was released alive into the sea at high tide, two hours later.

4.4.2 Vessel strike

Industrialization and urbanization of coastal areas often increases marine traffic, escalating the risk of vessel strikes which can cause dugong mortality, although the threat is less problematic for dugongs than for Florida manatees (Ponnampalam et al. 2022). Quantitative data are not available but given the large amount of commercial vessel traffic engaged in the oil and gas and port industries in the Gulf, vessel strikes may be a significant source of mortality (Natoli and Hameli 2023; Mateos-Molina et al. 2023). Wong and Patel (2023) reported one adult and four neonatal dugong carcasses from the Khor Al Udaid, southeastern shore of Qatar with wounds attributed to the propellers of jet skis or speed boats.

4.4.3 Habitat loss and degradation

Burt (2014) concluded that 'as a result of cumulative impacts from coastal development, overfishing, industrial expansion and other population-driven stressors', the Gulf is 'now considered among the most degraded marine eco-regions in the world'. The coastal marine environment of the southwestern Gulf has experienced extremely rapid urbanization and industrialization since the 1970s, leading to declines in marine ecosystems and their associated fauna (Burt 2014; Burt et al. 2023 for the UAE; Burt et al. 2017 for Qatar; and Burt et al. 2013 for Bahrain – three key dugong areas). Al-Mansoori and Das (2024) concluded that seagrass beds have been under acute pressure from coastal development, island creation, dredging and sedimentation in some of the most heavily modified areas in the UAE (e.g., lagoons and in shallow environments around oil concessions). Unfortunately, seagrass surveys only began in the late 1990s in the UAE, and it is unknown to what extent seagrass beds were impacted by earlier developments there or in the other countries in the core dugong habits in the southern and western Gulf (Zainal et al. 2012).

The ongoing occurrence of dugongs in the waters around the main island of Singapore (Chapter 6) demonstrates that dugongs can continue to exist on hyper-urbanized coastlines (Ng et al. 2022 a,b). There is increasing evidence from Florida manatees that: (1) sirenians have a highly developed spatial memory; (2) information is transmitted from mother to calf during the long period of calf dependency; and (3) females return to their place of birth to give birth (natal philopatry) (Deutsch et al. 2022; O'Shea et al. 2022). It is plausible that the extensive changes to the coastline in the core area of dugong habitat in the southern and western Gulf are contributing to the number of live stranded neonatal calves reported by (Wong (2022), however, this hypothesis has not been tested.

4.4.4 Pollution

The Gulf has 68% of the world's oil reserves and more than 40% of gas resources; around 60% of global oil transportation takes place through the region (Hassanshahian et al. 2020). Much of the core dugong habitat in the southern and western Gulf is close to offshore oilfields making oil exploration, extraction, treatment, and transfer potential threats (Preen et al. 2012; Figure 4.1). Oil contamination is a chronic ongoing threat to dugongs and seagrass communities. Even though Gulf dugongs have demonstrated resilience to low-level oil pollution (Preen et al. 2012), the levels of petrogenically-sourced Polycyclic Aromatic Hydrocarbons (PAHs) in their tissues have rarely been measured, despite Yaghmour et al.'s (2020) finding that 71% of the 22 stranded green sea turtles they examined from the Gulf of Oman coast of the UAE between 2016-2018 contained harmful levels of these compounds in their tissues. Rabaoui and Arossa (2024 unpublished, see Appendix 4.1 in Online Supplementary Material) (https://www.cms.int/dugong/en/publication/global-assessment-dugong-status-and-conservation-needs) examined pollutants in skin, muscle, and bone samples of dugongs from the Arabian Gulf, using samples collected from stranded individuals along the Saudi coast (17 PAHs, 22 total petroleum hydrocarbons [TPHs], and 21 trace elements). Pollutant analysis indicated generally low contamination levels, with most of the trace elements, including cadmium and mercury, consistently below or close to detection limits. PAHs and TPHs were found to average 149.48 μg/kg and 15.12 mg/kg dry weight, respectively; most of the values fell within safe limits for marine mammals. This result is consistent with the situation in many other areas (O'Shea et al. 2018; Núñez-Nogueira 2019) and not unexpected considering the dugong's low tropic position and how fast PAHs are usually metabolized by the mammalian cytochrome P450 enzymatic system (Kannan and Perrotta 2008).

Nonetheless, the risk of a catastrophic oil spill is an ongoing concern. The Gulf has experienced major oil spills including the Noruz oil spill in 1983 and the Gulf War spill of 1991 (Preen 2004; Preen et al. 2012). At least 37 dugongs washed up on the shores of Saudi Arabia and Bahrain after the Noruz oil spill (Preen 1989). Their causes of death were not confirmed as no necropsies were conducted. Nonetheless, Preen et al. (2012) estimated that 150 dugongs were killed by this event after adjusting for areas not searched, the distribution of dugongs and the dispersal patterns of the oil. No dugongs were encountered after the 1991 oil spill despite extensive daily searches for strandings along the Saudi Arabian coastline (N. Pilcher personal communication via email to Marsh and Schramm 2024).

Twenty-five of the green turtles examined by Yaghmour et al. (2020) also contained harmful levels of organochlorine pesticides including DDT in their tissues. Plastic contamination in dugongs or seagrasses has not been studied in the Gulf despite it being of increasing concern elsewhere including in 14 stranded green turtles on the Gulf of Oman coast of the UAE (Yaghmour et al. 2018).

4.4.5 Climate change

As for other regions in the dugong's range (Marsh et al. 2022), the impacts of climate change on dugongs and their seagrass habitats are difficult to predict, especially as the upper limit of the thermal tolerance of dugongs is unknown. There are no known confirmed diagnoses of hyperthermia in necropsied dugongs from the Gulf (D. Denk, veterinary pathologist, personal communication via email to Marsh 2024). Marsh et al. (2022) concluded that most of the adverse changes relevant to dugongs would be to their demography (delayed breeding and increased mortality) and movements and to the distribution and community composition of their seagrass diet. Marsh et al. (2022) also pointed out that climate change would be a threat multiplier exacerbating other anthropogenic stressors such as those listed above. The Gulf is already a harsh environment for seagrasses, supporting only three species that tolerate a wide range of temperatures and salinities (Section 4.1). However, other adverse changes to dugongs and their seagrass habitats seem inevitable (Marsh et al. 2022). Increases in the frequency and severity of marine heat waves in the region are well documented (Burt et al. 2019). Gulf temperatures have increased by 0.6° C per decade, a rate that is double the global average (Lachkar et al. 2022), suggesting that thermal pressure is increasing.

4.5 Conservation initiatives

4.5.1 International conventions

Excepting Saudi Arabia, all confirmed dugong Range States in the Gulf are parties to the Convention on Biological Diversity. All except Qatar are signatories to the Convention on Migratory Species of Wild Animals and its associated Dugong Memorandum of Understanding (CMS Dugong MOU). Bahrain signatories to the United Nations Framework Convention on Climate Change; UAE, Qatar and Saudi Arabia have ratified that convention. All are signatories to the Convention on International Trade in Endangered Species (CITES).

4.5.2 National laws

4.5.2.1 UAE

After completing a regional red-list assessment, dugongs were listed as a threatened species in the Abu Dhabi Emirate (Javed et al. 2020).

In the UAE, marine mammals are protected under *Federal Law No. 23, Chapter 4, article 28 of the year 1999 concerning Exploitation, Protection and Development of the Living Aquatic Resources in the State of The United Arab Emirates* which states:

"…It is also impermissible to catch whales, sea cows (Alatwam) and other sea mammals of all species and sizes… except for scientific research purposes and after obtaining a written permission from the Competent Authority."

Dugongs in UAE waters are protected by *Federal Law No. 23 (1999) for Protection of the Marine Environment, Article 28/2000 of the Amiri Decree, which prohibits the exploitation of dugongs in the UAE, and by Federal Law No. (24) of 1999 for the Protection and Development of the Environment.*

4.5.2.2 Bahrain

Dugong and seagrass meadows are protected by: (1) the *Environment Law,* which aims to combat against all forms of pollution through activities and practices related to environmental protection; and (2) the *Wildlife Law,* which focuses on preserving species and rehabilitating suitable habitats for wildlife. *Article 1 of Ministerial Order No. 4 1986* explicitly prohibits the fishing of dugongs throughout the Kingdom of Bahrain, where the dugong is listed in the national Red List as vulnerable to extinction.

4.5.2.3 Saudi Arabia

Dugongs are protected by the Environment Law issued by the *Royal Decree No. (m/165),* dated 19/11/1441 Hijri, with the responsibility for implementing the law in relation to dugongs and seagrasses undertaken by the National Center for Wildlife. The law has provisions for enforcement and issuance of fines not exceeding SAR 20 million (5.3 million USD).

4.5.2.4 Qatar

The legal framework and guidelines for protection of Qatar marine resource including dugongs are as follows:

- *Decree 55 of 1978* provides guidelines for the protection of marine environment from pollution.
- *Law 4/2002* regulates hunting of animals, birds, and reptiles and legally bans hunting in protected areas.
- *Law 7/2006* declares Qatar NW Al Reem as a UNESCO Man and the Biosphere reserve, protecting terrestrial animals and plants as well as marine animals including dugongs, sea turtles, sea birds and seagrass habitat.

In 2008, the Qatar government declared the Qatar National Vision 2030 and announced the Protection Area Action Plan 2008-2013. This empowered the Ministry of Environment Wildlife Department to prohibit and control activities in natural habitats that cause damage to protect endangered species.

The Qatar National Development Strategy 2011-2016 provided guidelines for Biodiversity Protection. In 2021, Qatar National Marine Resource Conservation and Management Action Plan was adopted, and MPAs were identified to cover 30% of the Exclusive Economic Area including the NW Qatar water for the protection of dugongs and seagrass.

The Ministry of Environment and Climate Change has recently appointed a team of in-house marine scientists to study dugongs in Qatar and to provide advice for the conservation of dugongs in the country.

4.5.2.5 Iran

Iran is not yet confirmed as a dugong Range State Dugongs are not formally protected in Iran though there are laws protecting the nation's wider wildlife. Iran's Constitution includes a statement regarding the protection of the environment and the prevention of pollution and degradation. The *Law on Hunting and Fishing 1967* requires those wishing to hunt or fish to first obtain a licence, issued by the Fishing and Hunting Organisation, later replaced by the Department of Environment in 1971.

The *Environmental Protection Law 1975* states that the Department of Environment and the High Council for Environmental Protection are responsible for establishing a system of supervision and monitoring for wildlife and marine resources, as well as establishing limitations for hunting and shooting in some protected areas.

4.5.3 Protected areas of relevance

The protected areas in the various Range States of relevance to dugongs are listed below. Van Lavieren and Klaus (2013) question their effectiveness. Naser (2016) sought the views of conservation practitioners, academics, and other relevant bodies on the management of Bahrain's MPAs. He concluded that although MPAs are contributing to the protection of critical coastal and marine habitats and their associated flora and fauna, their effectiveness could be enhanced by developing management plans, implementing regulatory measures, and investing in long-term monitoring and research.

Given the transboundary nature of the Gulf's dugong population, it will be important to work towards a regional network of protected areas as suggested by Khamis et al. (2023) and in Section 4.7 below.

4.5.3.1 UAE

- **UNESCO designated Marawah Biosphere Reserve (MMBR)** in 2007. This reserve was declared a protected area through the *Emirate Decree No. 18 of 2001*. The total area of the Reserve is 4,255 km^2 and it has a core area of 606 km^2 which includes marine and terrestrial habitats comprising numerous islands and a coastline stretching over 120 km. Seagrass communities (three species of seagrass), coral reefs, macroalgae outcrops and mangrove vegetation are included. There are also buffer and transition zones. UNESCO rates Marawah Biosphere reserve to be of 'global importance' as a shelter and feeding ground for dugongs. Fishing is allowed only in designated areas and is limited to traditional fishing methods that include fixed net (*Hadhra*), shore net (*Al Sakkar*), and seine nets (*Daffara*). The reserve is managed by the Environment Agency Abu Dhabi (EAD).
- **Al Yasat MPA in the western coastal waters of Abu-Dhabi Emirate** is a 2256 km^2 MPA (IUCN category IV) which was established in 2005 and is managed by EAD.

4.5.3.2 Qatar

In 2017, a Plan for the Conservation and Management of Dugongs within the State of Qatar, including a plan for establishing a dugong stranding program was submitted to the Ministry of the Environment by Marshall and ExxonMobil Research Qatar. Most (approximately 1650 km^2) of Qatar's western territorial waters to its borders with Bahrain and Saudi Arabia were designated a Dugong and Seagrass MPA in 2022 by the Ministry of Environment and Climate Change (Wong and Patel 2023).

4.5.3.3 Bahrain

Most of the information in this section has been sourced from Naser (2016).

- **Hawar Islands Protected Area.** Nationally, the Hawar Islands were declared as a wildlife sanctuary by the Prime Minister *Order No. 16 of 1996* in accordance with the Legislative Decree No. 2 of 1995 with respect to the Protection of Wildlife. Several subsequent regulations were issued to support the protection of the Islands and their territorial waters, including the *Ministerial Order No. 6 of 1996* with respect to the relevant recommendations of the National Commission for Wildlife Protection. This order prevents all fishing around Hawar Islands and their territorial waters and only allows the use of traditional fishing gear such as *hadrah* (an intertidal fixed stake trap), cages, and trolls. Fishing around Hawar Islands is regulated by the *Order of the Public Commission for the Protection of Marine Resources, Environment and Wildlife No. 13 of 2005,* prohibiting fishing in commercial quantities and overfishing around the Hawar Islands and their territorial waters. It also prevents the use of any tools, machines, or materials that can pose a threat to the marine resources in the region. An amendment of this order based on *Order No. 4 of 2010* has now restricted the use of *hadrah* to a license from the General Directorate for the Protection of Marine Resources. The Hawar Islands were designated as a Ramsar (Convention on Wetlands of International Importance) site in 1997 due to the abundance of globally significant, rare, and endangered bird species. The islands are on the tentative list of natural World Heritage sites and are being assessed by local authorities as a potential Man and Biosphere Reserve (A. Khamis personal communication via email to Marsh and Schramm 2024).

- **Mashtan Island Protected Area.** Mashtan is a small offshore sandy island (0.2 km^2) located between Bahrain and the Hawar Islands (Figure 4.1). The waters surrounding Mashtan Island are characterized by widespread growth of seagrass beds that provide feeding grounds for many species, including dugongs. Mashtan Island is nationally protected based on relevant provisions of the Order of the National Commission of Wildlife Protection No.1 of 2002.

4.5.3.4 Iran

- Iran is home to an UNESCO Biosphere Reserve: the **Hara Biosphere Reserve.** The reserve is located in the Mehran River delta in the south of Iran, near the Straits of Khuran between Qeshm Island and the mainland. The site is a Key Biodiversity Area due to its *Avicennia* mangrove ecosystem and, while dugongs are not listed in the ecological characteristics, the site may offer some protected habitat.
- **The Mond MPA** is located southwest of Bushehr Province in the Bord Khun District. The Protected Area was established in 1976 and may offer some protected habitat for dugongs.
- Iran has three Ramsar sites along the Gulf coast, ordered west to east: **Sheedvar Island,** located in Hormozgan Province, the Khuran Straits, located in the lower Mehran River delta and, **the Deltas of Rud-e-Shirin and Rud-e-Minab.** These protected wetlands could offer some protection to the marine environment adjacent to them.

4.5.4 Other conservation initiatives of potential relevance to dugongs

- Surface net-fishing was banned in the waters of Abu Dhabi Emirate in UAE in 2018, following *Resolution No. 542* issued by the Ministry of Climate Change and Environment on the amendment of the provisions of *Ministerial Resolution No. 598 of 2017*. The ban was made to help the recovery of fish stocks; this change should also reduce dugong morality (H. Das personal communication via email to Marsh and Schramm 2024).
- In Saudi waters, oil and gas installations are surrounded by an exclusion radius of 500 m, which fishermen and other unauthorized vessels are prohibited from entering (Rabaoui et al. 2021).
- Orphaned neonatal calves are rescued in UAE and Qatar (Wong 2022; Wong and Patel 2023). As in the rest of the world (Marsh 2022), none of these animals has been confirmed as surviving after release. One dugong, named 'Malqout' is being successfully reared in captivity in the UAE.
- Exxon Mobil Research Qatar (EMRQ) has established a stranding network and has been involved in the rescue and rehabilitation of dugong calves since 2015 (C. Marshall personal communication via email to Marsh 2024). EMRQ has been working in collaboration with Qatar University (QU) and Texas A&M University in the United States after signing a tri-party agreement with support from the Private Engineering Office (PEO) and the Ministry of Environment in 2014.

4.6 Research and monitoring initiatives

4.6.1 Techniques used to date

Preen's (1986) quantitative aerial surveys remain the benchmark for systematic surveys for dugongs in the region and have informed the monitoring conducted by the UAE for more than 20 years (e.g., Das et al. 2021). Marshall et al. (2018) and Khamis et al. (2023) have used a range of techniques to study the large dugong groups in the Gulf of Bahrain, including historical records, structured interview surveys, citizen science network reports together with boat, helicopter, and UAV surveys at several spatial scales. Additionally, ExonMobil Research Qatar (ERMRQ) have been actively promoting to the Ministry of the Environment and Climate Change, dugong recovery plans, fishermen interviews, and standardized stranding efforts in Qatar, as well as rehabilitation efforts of stranded calves. Stranding efforts include the collections of tusks and body size for age determination, as well as documenting bycatch incidents. In Bahrain, extensive seagrass and dugong herbivory in-water surveys were conducted to explore seagrass-dugong interactions under the harsh environmental settings of the Gulf (A. Khamis personal communication via email to Marsh and Schramm 2024).

4.6.2 Future research and monitoring

The most urgent priority, which is under active development in 2024 (Section 4.7.1), is the development and implementation of a coordinated cross-jurisdictional survey and monitoring strategy for the dugong in the Gulf. It is likely that no single survey technique will be appropriate for every Range State. The challenges are to maximise the likelihood that the data from each jurisdiction will be high quality and comparable, and that the data collection technique will minimise the likelihood of major cross-jurisdictional movement within the period of the survey, a situation that will be particularly challenging in the Gulf of Bahrain/Gulf of Salwa region.

Other research and monitoring initiatives that could be considered in cross-jurisdictional workshop(s) include:

1. **Satellite tracking of dugongs** to evaluate their movement patterns and delineate their migration corridors. Experience in other parts of the dugong's range (Deutsch et al. 2022) indicates that movements of individual animals are variable, and it will be necessary to track a substantial number of animals (suggest more than 20) to obtain a clear understanding of movement patterns. These studies should be conducted only by experienced experts in dugong tracking and under strict protocols, paying due consideration to all relevant animal welfare ethics.
2. **Establishing a coordinated Gulf marine wildlife carcass salvage program,** which enables standardized data collection protocols and data sharing, including:
   a. determining the cause of death using established veterinary standards as is done in Abu Dhabi;
   b. measuring the levels of heavy metals, organic contaminants and plastics in tissues using standardized techniques;
   c. stable isotope analyses to obtain additional information on dugong diet (Thibault et al. 2024); and
   d. determining the (nuclear) genetic diversity of dugongs of the Gulf, along with information on their demographic history and levels of inbreeding.
3. **Explicitly investigating whether dugongs are resident in Iran** using a range of techniques including fisher interviews, citizen science, eDNA (environmental DNA), and UAV surveys of locations where dugongs have been seen this century such as the Hara Protected Area north of Qeshm Island, and the coastal waters of Bushehr Province.

4.7 Regional co-operation

The Cooperation Council for the Arab States of the Gulf (مجلس التعاون لدول الخليج العربية), also known as the Gulf Cooperation Council (GCC, مجلس التعاون الخليجي), is a regional intergovernmental, political, and economic union comprising Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE. Following the CMS Dugong MOU Regional Meeting on Science and Management for Dugongs in the Gulf in 2023, the UAE, Qatar, Bahrain and Saudi Arabia have been discussing how to implement coordinated dugong aerial surveys. The GCC has endorsed a regional convention calling for the conservation of threatened species, including dugongs (A. Khamis personal communication via email to Marsh and Schramm 2024). Recent efforts by the Smithsonian Institution and colleagues, both in and out of the region, have been promoting science diplomacy in the Qatar region and the need for international data sharing and scientific cooperation (Fieseler et al. 2023).

Other Priorities for Action

Developing and implementing a coordinated cross-jurisdictional survey and monitoring strategy for the dugong in the **Gulf** especially the waters of **UAE, Qatar, Bahrain** and **Saudi Arabia to enable** an IUCN evaluation of the Gulf as a dugong subpopulation.
Satellite tracking of dugongs to evaluate their movement patterns and delineate their migration corridors.
Establishing a coordinated Gulf marine wildlife carcass salvage program.
Explicitly investigating whether dugongs are resident in **Iran** using a range of techniques.
Conducting further genetic analysis to provide information on genetic diversify, demographic history and inbreeding.

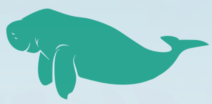
Khamis et al. (2023) proposed establishing a regional network of MPAs spanning all the dugong Range States in the Gulf to conserve dugong core areas and any migration corridors. The proposed network would encompass, at minimum: (i) UAE: Murawah Island and Al Yasat Island, (ii) Bahrain: Hawar Island, Fasht Buthur, and Fasht Jarim, (iii) Qatar the north-western waters of Qatar, and (vi) the shallow waters between Saudi Arabia, Qatar, and United Arab Emirates.

The Regional Organization for the Protection of Marine Environment (ROPME), which is a non-administered UNEP Regional Seas Program should be well placed to co-ordinate dugong research, monitoring and conservation management across the Gulf. ROPME provides a comprehensive framework for addressing the critical coastal and marine environmental challenges facing the Gulf and other divisions of the ROPME Sea Area (RSA). This framework aligns with global, regional, and national priorities, including the United Nations Sustainable Development Goals and the UNEP Regional Seas Strategic Directions. Furthermore, ROPME launched new strategic directions for 2026-2030 supported by targeted programs and initiatives to ensure the long-term sustainability of the marine and coastal environments in the RSA, including: (1) securing diverse, healthy and resilient ecosystems; (2) an integrated marine database for sharing knowledge (SMEK); (3) increased engagement public awareness and partnerships to strengthen national, regional, and international collaboration for conservation of marine biodiversity, restoring critical habitats, combating pollution, and addressing the impacts of climate change. Implementation of these initiatives should have a positive impact on conservation of dugongs in the RSA and development of their habitats (ROPME 2020).

4.8 Regional summary

The status of the dugong in the Gulf is uncertain and should be clarified by an IUCN Red List of Threatened Species 'subpopulation'[2] assessment when the required data are available. Al-Abdulrazzak and Pauly (2017) examined historical changes in dugong distribution and estimated that the dugong range in the Gulf may have contracted by 25% since 1959. The authors attribute the decrease to a number of threats including coastal development and dredging, trawling and land reclamation, as well as incidental bycatch and oil spills. This conclusion must be regarded as tentative given the large number of unstated assumptions in their analysis. In contrast, recent studies suggest that the Gulf dugong population may be stable. These studies include: (1) the surveys conducted by Abu Dhabi Emirate (i.e., Das et al. 2021); and (2) the research by Khamis et al. (2023) in the Gulf of Bahrain. The 2021 winter survey of UAE conducted by Das et al. (2021) recorded 16.7% calves suggesting a reproductively healthy population. In comparison, the percentage of calves reported between Qatar and Bahrain was 5.4–9.9% and 6–6.4% Marshall et al. (2018) and Khamis et al. (2023), respectively.

Confirmed Significant Locations



United Arab Emirates

Coastal waters from Ras Ghanadha to border with **Qatar**, around **Marawah Island.**

Qatar

Gulfs of **Salwa** and **Bahrain, Khor Al Udaid**

Bahrain

Gulf of **Bahrain**, especially around **Hawar Islands** and **Fasht Jarrim**.

Saudi Araba

Coastal waters from **southern Gulf of Salwa** to **Ras Tanura**.

Both the '**Southern Gulf** and **Coastal Waters**' and '**the Gulf of Salwa**' have been declared to be Important Marine Mammal Areas (IMMAs), with the dugong as a qualifying species.

2 IUCN uses the term 'subpopulation' in the assessment of a regional population. The term 'subpopulation' is used here with reference to IUCN documentation only.

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Chapter 5

SOUTH ASIA

Authored by: Luisa Schramm, Yashpal Anand, David Blair, Jeyaraj Antony Johnson, Len McKenzie, J.K. Patterson Edward, K. Sivakumar, Dipani Sutaria, Balaji Vedharajan and Helene Marsh

Luisa Schramm[1], Yashpal Anand[2], David Blair[3], Jeyaraj Antony Johnson[4], Len McKenzie[5], J.K. Patterson Edward[6], K. Sivakumar[7], Dipani Sutaria[3], Balaji Vedharajan[8], Helene Marsh[3]

[1]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Townville, Queensland, Australia.
[2]Gujarat University, Ahmedabad, Gujarat, India.
[3]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[4]Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand, India.
[5]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Cairns, Queensland, Australia.
[6]Suganthi Devadason Marine Research Institute, Tuticorin, Tamil Nadu, India.
[7]Pondicherry University, Chinna Kalapet, Kalapet, Puducherry, India.
[8]OMCAR Foundation, Velivayal, Rajamadam, Tamil Nadu, India.

Correspondence to: Helene Marsh helene.marsh@jcu.edu.au.

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Cover image: Dugong feeding trails at Chepri Reef in the Gulf of Kutch Marine National Park. Sameeha Pathan photograph.

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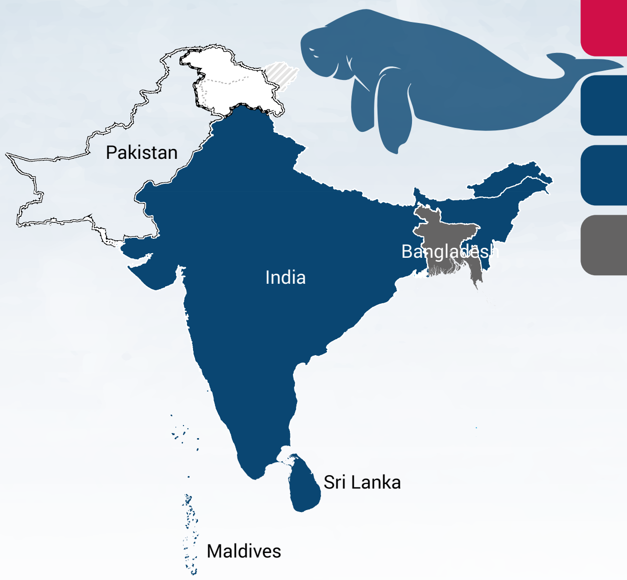
Contents

Range/Signatory States



Range States	Signatory States
India	Yes
Sri Lanka	Yes
Bangladesh?	Yes

We know of no recent evidence of dugongs occurring the waters of Bangladesh, although they may be present. Whether there is a resident population is unknown. There is no evidence of dugongs ever occurring in Pakistan or the Maldives.

Regional findings

Countries considered in South Asia: 'People's Republic of Bangladesh (Bangladesh), Republic of India (India) and countries considered in South Asia: Democratic Socialist Republic of Sri Lanka (Sri Lanka)

- Dugong distribution in the South Asian Region is apparently limited to: (1) the Gulf of Kutch in northwestern India; (2) Gulf of Mannar–Palk Bay region (between India and Sri Lanka); and (3) the Andaman and Nicobar Islands in Indian waters in the Bay of Bengal. Dugongs may also occur in some Sri Lankan coastal waters outside the Gulf of Mannar–Palk Bay region.
- No dugongs or seagrasses have been recorded in Pakistan. It is uncertain whether Bangladesh supports a resident dugong population. There is no evidence that dugongs ever occurred in the Laccadive (Lakshadweep) Islands (India) or in the Maldives.
- Research is required to determine if dugongs are resident: (1) along the Chittagong coast of Bangladesh and, (2) in Sri Lanka outside the northwestern region.
- The Gulf of Kutch supports an isolated, resident dugong population. The limited extent of the potential seagrass habitat means it is only able to support a relatively small dugong population, a situation which makes the prospects for their longtime survival there highly uncertain.
- The southern Gulf of Kutch has been identified as an Important Marine Mammal Area (IMMA) with the dugong listed as a qualifying species.
- The transboundary Tamil Nadu–Sri Lanka area, which includes the Gulf of Mannar–Palk Bay region, is the most important habitat for seagrasses and dugongs in South Asia. The 'Palk Bay and the Gulf of Mannar' region has been identified as an IMMA, with the dugong as the only qualifying species.
- Currently the Gulf of Mannar–Palk Bay region supports what appears to be a much lower number of dugongs than in the recent past. Procedures need to be developed to enhance the governance arrangements for this region including a focus on community participation in conservation and management. Targeted research is required to improve the management of dugong populations and their habitat (seagrass communities) in this region, with emphasis on reducing the impacts of fisheries, climate change and other threats on dugong populations and their habitats.
- Dugongs in the Gulf of Mannar–Palk Bay region may also face increased development pressures if India and Sri Lanka are connected by infrastructure across Palk Strait and/or if the petroleum and natural gas are exploited within the Gulf of Mannar Biosphere Reserve.
- The Andaman and Nicobar Islands support an isolated, resident dugong population. The limited extent of shallow coastal water around the Andaman and Nicobar Islands means that these archipelagos can support only a relatively small dugong population, a situation that makes their survival there very challenging for conservation managers.
- The 'Southern Andaman Islands' have been identified as an IMMA with dugongs as a qualifying species.
- Given the small sizes of dugong populations in both the Gulf of Kutch and the Andaman and Nicobar Islands, it may be effective and efficient to develop and implement conservation arrangements for marine megafauna, rather than dugongs *per se*.
- Dugongs in both the Gulf of Kutch and the Andaman and Nicobar Islands likely qualify for separate International Union for Conservation's (IUCN) Red List of Threatened Species 'subpopulation'[1] assessments.
- Robust quantitative information on the size of the Gulf of Mannar–Palk Bay region dugong population would be essential for an IUCN Red List of Threatened Species 'subpopulation' assessment of the dugong population in this region.

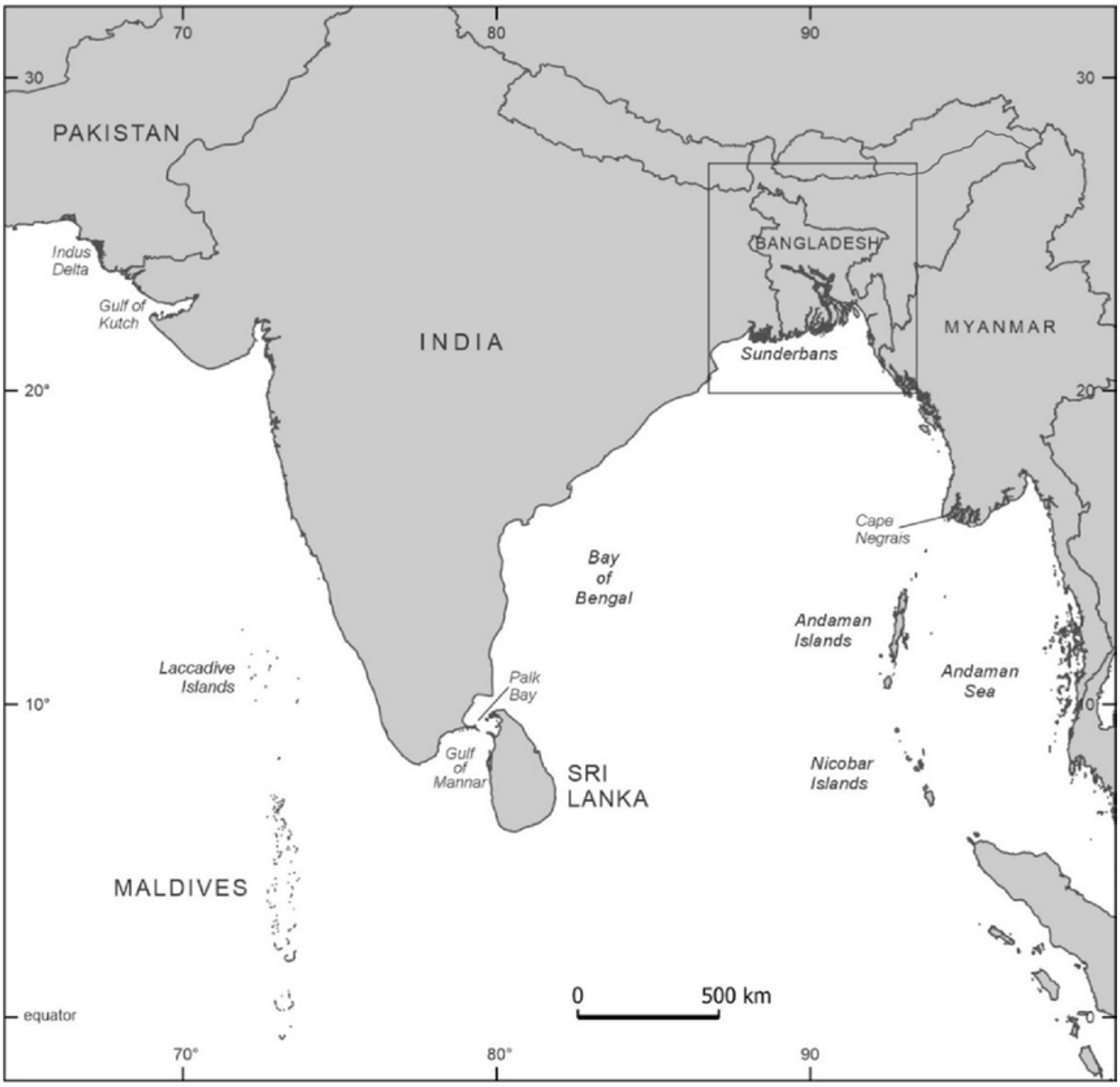
5.1 Regional setting

5.1.1 Geographic overview

This chapter considers the status of the dugong along the approximately 12,581 km coast of South Asia from the Pakistan-Iran border in the west (25.17° N, 61.62° E) to the Bangladesh-Myanmar border in the east (20.73° N, 92.37° E), including Sri Lanka. The region includes the following areas that support confirmed dugong populations: the Gulf of Kutch (Kachchh, Cutch, Kachh, GoK) on the northwest coast of India, the Gulf of Mannar–Palk Bay region between the southeast of India and the northwest of Sri Lanka, the remaining coast of Sri Lanka, and the Indian offshore island groups of the Andaman and Nicobar Islands in the Andaman Sea (Figure 5.1).

1 IUCN uses the term 'subpopulation' in the assessment of a regional population. The term 'subpopulation' is used here with reference to IUCN documentation only.

Figure 5.1. Geographic context of South Asia showing placenames mentioned in the text. Countries (ordered west to east) are Pakistan, India, Sri Lanka, and Bangladesh. Confirmed dugong Range States are India and Sri Lanka. Inset: Bangladesh showing placenames mentioned in the text. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



There has been no study of the dugong in Bangladesh despite its proximity to the Rakhine coast of Myanmar where dugongs are known to occur (Chapter 6). Shah-e-Alam (2011) notes that there are several reports of dugongs in Bangladesh from the nineteenth and twentieth centuries including Maheshkhali Island, the mouth of the Matamuhuri River, and in 1976, the Maheshkhali Channel near Cox's Bazar just north of the Myanmar border (Figure 5.1). It is not known whether these animals were vagrants or part of a resident population. Kanal and Short (2009) reported five species of seagrass (published records of three) in Bangladesh including at Cox's Bazar, but there are no records of their extent.

Contemporary evidence indicates that dugongs do not occur in Pakistan. Len McKenzie (personal communication via email to Marsh 2024) advises that there are no records of seagrass meadows or dugongs, even though the border between Pakistan and India is only 210 km from the mouth of the Gulf of Kutch. In the 1970s, researchers from the University of Karachi visited almost all major settlements around the Pakistan-Indian border. Pakistani fishers, who had operated in the Gulf of Kutch in the early 1940s and were aware of dugongs occurring there, claimed that dugongs did not occur in the Indus Delta. Fishers in Gwater Bay (between Pakistan and Iran) in the 1980s made the same claim (M. Khan personal communication via email to Marsh and Schramm 2024).

Husar (1975) reported that dugongs were extinct in the Laccadive islands and the Maldives, citing Snow (1970). Snow's paper does not mention the dugong at either location. The Laccadive (Lakshadweep) Islands are located in the Arabian Sea off the southwest coast of India. There are 36 islands, of which 11 are inhabited. Pandey et al. (2010) conducted interview surveys in 2008 to investigate past records of dugong's occurrence. Twenty-two fishers were interviewed across three villages. Seagrass patches were also surveyed in winter 2008, around Agatti, Bangaram, Kalpetti, Kavaratti and Pareli Islands by boat and their GPS coordinates recorded. Fishers were unaware of dugongs; the boat surveys resulted in no sightings. Husar's (1975) claims that the dugong is extinct in the waters of the Laccadive islands and the Maldives appear to be without substance. There is no record of the dugong occurring in either location.

Apart from Table 5.1, Pakistan and Bangladesh are not considered further in this chapter, even though both are listed as Range States under the Memorandum of Understanding on the Conservation and Management of Dugongs (*Dugong dugon*) and their Habitats throughout their Range (Dugong MOU). Bangladesh is also a Signatory State.

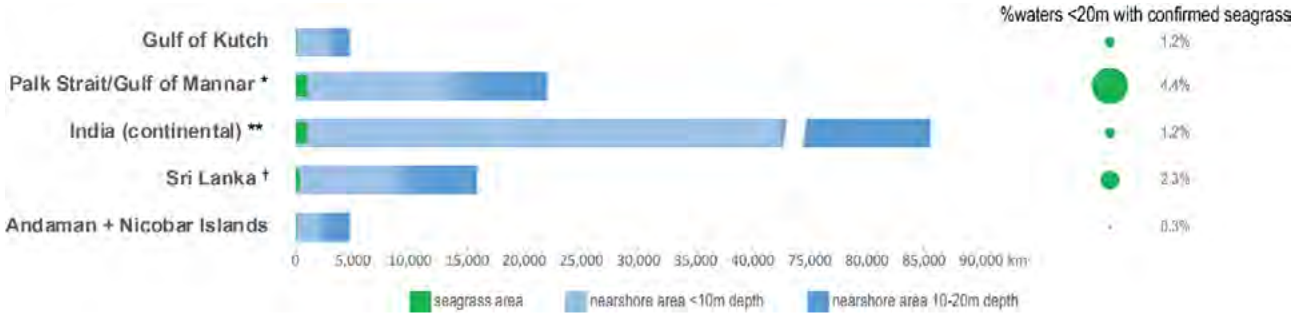
The Gulf of Kutch (Figures 5.1, 5.3) in the Indian state of Gujarat, opens towards the Arabian Sea facing the Gulf of Oman. It is a wedge-shaped embayment around 130 km long and 43 km wide at the mouth with an average depth of 30 m and a maximum depth of 60 m (Anand et al. 2017). There are two physical habitats in the Gulf: (1) the northern coast, which is characterized by mangroves and vast open mudflats, and (2) the southern coast, which supports a range of habitats including seagrass meadows, coral reefs, rocky and sandy shore environments, mudflats and mangroves. (Sivakumar and Nair 2013; Kamboj 2014; Pathan et al. 2020; Johnson et al. 2023; Anand et al. 2024).

The **Gulf of Mannar and Palk Bay** are to the south and north, respectively, of Adam's (or Rama's) Bridge, a narrow peninsular extension of the Indian mainland on the southeast coast of India. These regions are connected to Palk Strait and Gulf of Mannar along the northwest coast of Sri Lanka. Palk Strait, which in places is only about 25 km wide, separates the Tamil Nadu state of India and the Mannar district of Sri Lanka. Palk Bay also connects the Bay of Bengal in the northeast with the Gulf of Mannar in the southwest of Adam's Bridge (Figures 5.1, 5.5).

The **Andaman and Nicobar Islands** in the Bay of Bengal (Figures 5.1, 5.6) support biodiversity of global significance (Myers et al. 2000). These approximately 570 islands are divided into two groups by the Ten-Degree Channel, which is 140 km wide at its narrowest point (Figures 5.1, 5.6). Twenty-six islands in the Andaman group and 12 in the Nicobar group are inhabited (Pandey et al. 2010; D'Souza et al. 2013; Sivakumar and Nair 2013). The Andaman archipelago comprises 78% of the total geographical region and can be divided into North, Middle, South and Little Andaman and Ritchie's Archipelago, 20 km east of Great Andaman Island. The Nicobar archipelago is divided into Car Nicobar, Nancowry Group and Great Nicobar Group. The closest likely mainland dugong habitat to the Andaman and Nicobar Islands is along the Tanintharyi coast of Myanmar (Figure 5.1), where unknown numbers of dugongs occur (Chapter 6). The closest distance between the Andaman Islands and Myanmar is around 295 km, between the Nicobar Islands and Myanmar; approximately 635 km. The closest distance between the Nicobar Islands and Southeast Asia is to Banda Aceh in Indonesia (approximately 210 km).

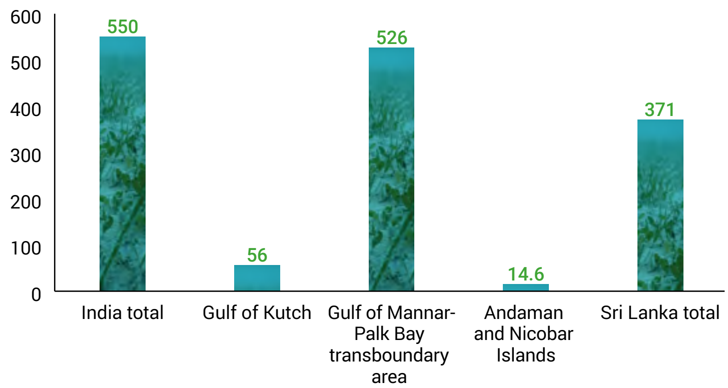
The total area of seagrass in India (Figure 5.2) is estimated with moderate to high confidence to be 1,013 km^2 (Geevarghese et al. 2018; Pathan et al. 2020; Seal et al. 2024). The total area for Sri Lanka

Figure 5.2. Histogram showing the areas of seagrass known with moderate to high confidence in the coastal waters shallower than 20 m for specified locations within the South Asian region. The areas of seagrass are almost certainly underestimates. While not all shallow coastal waters are potential seagrass habitat, the figure indicates: (1) the need to undertake additional seagrass mapping in this region, and (2) that neither the Gulf of Kutch nor the Andaman and Nicobar Islands have sufficient potential habitat to support large dugong populations. Len McKenzie figure; reproduced with permission.



** Includes India and Sri Lanka coasts; ** includes Gulf of Kutch, Gulf of Mannar – Palk Bay region, excludes Andaman and Nicobar Islands; † includes Palk Strait and Gulf of Mannar coasts.*

Seagrass Mapped Area (km²)



Seagrass communities are under-mapped with current estimates likely underestimates.

is estimated to be 371 km^2 (Bandara et al. 2011; Ministry of Mahaweli Development and Environment [MMDE] 2018; Udagedara and Dahanayaka 2020; Suwandhahannadi et al. 2024).

- The Gulf of Kutch supports 56 km^2 of seagrass (Geevarghese et al. 2018; Pathan et al. 2020).
- Most (around 77%) of India's seagrass grows in the state of Tamil Nadu (Geevarghese et al. 2018).
- In the Andaman Islands, the area of seagrass is estimated to be approximately 5.79 km^2 (Geevarghese et al. 2018). The lagoons at Inglis and Henry Lawrence Islands in the Andaman Island Group are reported to sustain dense, diverse seagrass coverage of up to 1.85 km^2 (Geevarghese et al. 2018). The Nicobar Group is estimated to support 8.8 km^2 of seagrass meadows, mainly occurring around Great Nicobar and Car Nicobar Islands (Geevarghese et al. 2018).

5.1.2 Geopolitical and socioeconomic overview

This information is provided as an indication of the challenge for each of the Range States in the region to consider the conservation of dugongs and their habitats in the context of their socioeconomic development needs. Increasing human populations in coastal areas and the associated development adversely affect marine ecosystems, including dugongs and their habitats (Marsh et al. 2011). India has the largest human population of any nation, overtaking China in April 2023 (United Nations Department of Economic and Social Affairs [UNDESA] et al. 2023). Nearly 174 million people (approximately 12% of the total population) live within 50 km of the coast of Indian and Sri Lankan jurisdictions in the dugongs' range (Gujarat, Tamil Nadu and the Union Territory of the Andaman and Nicobar Islands, and the entirety of Sri Lanka); around 93 million within 10 km (approximately 7 % of the total population) (Schiavina et al. 2023). India's population is almost certain to continue to grow for several decades (UNDESA et al. 2023). In 2024, the Indian economy ranked the fifth largest in the world based on nominal Gross Domestic Product (GDP) (Cleartax 2024). Table 5.1 summarizes the Human Development Index and per capita GDP of the countries in the South Asian region.

The Andaman and Nicobar Islands are of immense strategic significance for India, securing the eastern seaboard and providing a geographic link between India and its Southeast Asian neighbours (Das 2011). The geographical isolation of these archipelagos presents serious challenges such as the poaching of marine and forest resources, illegal migration, arms smuggling and natural disasters (Das 2011). The archipelagos are home to some of the most isolated indigenous peoples in the world (Andaman and Nicobar Administration 2023). The Great Andamanese, Jarrawas, Nicobarese, Onges, Sentinalese and Shompen peoples inhabit the Andaman and Nicobar Islands, along with immigrant settler communities from mainland India. The Sentinelese, who live on North Sentinel Island, are probably the world's only surviving Palaeolithic people without contact with any other group or community. All groups hunt wild pig, dugongs, turtles, and fish, etc. for their food requirements (Pandey et al. 2010). Indigenous islanders now account for just 8% of the total population of the Andaman and Nicobar Islands (Directorate of Health Services 2015), and there are protests around further contact with them. This situation has restricted scientific access to their lands and seas (but see Johnson et al. 2023).

Table 5.1. Human Development Index (HDI) status rank and Gross Domestic Product (GDP) per capita rank of the dugong Range States in South Asia. Consistent with the remainder of this chapter, the countries in this table are ordered west to east starting with Pakistan. Although it is uncertain whether the coastal waters of Pakistan and Bangladesh support resident populations of dugongs, both countries have been included in this table as they are listed as Range States under the Dugong MOU. Countries with the highest HDI or GDP have the lowest ranks. 189 countries were ranked for both indices.

Range State	HDI	HDI Rank 2023[i]	GDP per capita rank[ii]
Pakistan	Low	161	129
India	Medium	132	120
Sri Lanka	High	73	97
Bangladesh	Medium	129	121

i 2023 HDI data from https://hdr.undp.org/data-center/country-insights#/ranks (downloaded from the internet January 2024);
ii 2023 per capita GDP from https://www.worldometers.info/gdp/gdp-per-capita/ (downloaded from the internet June 2024).

Approximately 22 million people live in Sri Lanka (UNDESA 2023). Sri Lanka has been facing civil unrest since at least the 1980s (Leatherwood and Reeves 1989), and an economic crisis since 2019 (Hovan George et al. 2022). In August 2021, the Sri Lankan Government declared an economic emergency, in April 2022, the country experienced a double-digit consumer price inflation (CPI) rate of 29.8% (Khandre 2022). Such economic crises are challenging for many sectors including environment and conservation (Rodrigo 2022).

5.1.3 Genetics of dugong populations in South Asia

For an overview of genetics-relevant techniques, definitions, studies and general findings, refer to Chapter 1, particularly Figure 1.2.

No nuclear genetic markers[2] have been used for studies on dugongs from this region.

Jayasankar et al. (2009) and Srinivas et al. (2021) have collectively reported 22 sequences (410 bp or longer) from a portion of the mitochondrial control region from Indian locations (Gulf of Kutch, Gulf of Mannar–Palk Bay region, and the Andaman Islands). These sequences represent seven haplotypes, six of which clearly fall within the West Indian Ocean (WIO) haplogroup (Chapter 1, Figure 1.2) and include one haplotype (shared by three individuals) from the Andaman Islands.

The seventh, haplotype (MK986812) was from a single dugong from the Andaman Islands and was markedly different from those of the WIO haplogroup. This outlying sequence is very similar to that (KJ022719) from a single dugong from the Andaman Sea coast of Thailand (Chapter 6) reported by Bushell (2013) and a short sequence from Sri Lanka (MH704292) derived by Plön et al. (2019) from a bone registered in the National Museum of Scotland in 1836. These three sequences represent

1 All genetic terms are defined in Chapter 1.

a distinct haplogroup, here termed the East Indian Ocean (EIO) haplogroup (Chapter 1, Figure 1.2). In their recently published paper, Furness et al. (2024) named this the EI Clade. Another sequence of known geographical origin from Plön et al. (2019; MH704314) and one from Furness et al. (2024; sample SDG012), both from Belitung, Indonesia, appear to belong here, as does MH704371 (Moreton Bay, Queensland, Australia). The former location seems reasonable, but the latter is puzzling and requires confirmation.

A further four short sequences from Sri Lanka were reported by Plön et al. (2019). Where known, the animals from which these came were sampled in the Gulf of Mannar–Palk Bay region. These four sequences are consistent with two of the haplotypes found in dugongs from adjacent Indian coastal waters (Srinivas et al. 2021) and therefore fall within the WIO haplogroup. Plön et al. (2019) regarded their Sri Lankan sequences as representing a separate sublineage within this haplogroup. But with the more recent addition of sequences from India (Srinivas et al. 2021), almost all sequences from mainland India and Sri Lanka appear to belong to the general WIO haplogroup, within which there is limited overall diversity (Figure 1.2). Furness et al. (2024) stated that the sequence from their sample SDG175 (widespread Australasian haplogroup; Figure 1.2) was from India, but the same sample was from Indonesia according to Plön et al. (2019), a more likely geographical source.

One sequence from Plön et al. (2019) from the Nicobar Islands (MH704374, registered in 1888 in the Natural History Museum, London) was consistent with the widespread Australasian haplogroup (Chapters 9 and 10). However, DNA from the same sample was resequenced by Furness et al. (2024; their sample SDG352) and clearly belongs to the WIO haplogroup.

The presence of location-specific haplotypes in the Gulf of Kutch, the Gulf of Mannar–Palk Bay region and the Andaman Islands led Srinivas et al. (2021) to infer regional differences among these locations. But the small number of samples available and the slight differences among haplotypes require caution in interpreting these results. Similarly, various tests of demographic processes all yielded statistically non-significant results (Srinivas et al. 2021), likely as a consequence of the limited number of samples. The overall impression is similar to that for other regions of the Western Indian Ocean: limited mitochondrial diversity but with some evidence of distinct populations (Furness et al. 2024), probably of relatively recent origin. If nuclear genetic diversity is also very limited, the same warnings about genetic resilience mentioned in Chapter 1 will apply. Any actions or natural phenomena that reduce numbers further or hinder movement and gene flow between locations will risk further genetic erosion.

- Some mitochondrial sequence data are available for dugongs from India (including the Andaman Islands) and Sri Lanka.
- Most of these sequences can be referred to the Western Indian Ocean (WIO) haplogroup, but haplotypes from India differ slightly from those in East Africa.
- A small cluster of sequences (from Sri Lanka, Andaman Islands, Thailand, Indonesia and Queensland, Australia) apparently constitute a separate, previously unrecognized haplogroup, here termed the East Indian Ocean haplogroup.
- There seems to be slight regional genetic differentiation within India.
- Priority should be given to obtaining data from nuclear markers, preferably via whole-genome sequencing, to estimate heterozygosity, levels of inbreeding and population fluctuations in South Asia over time. It would also be desirable to determine whether there is a largely unsampled Eastern Indian Ocean haplogroup, and if so, its distribution.

5.2 Distribution, abundance and trends of dugongs in South Asia

The dugong population of this region apparently occurs in three isolated populations: (1) the Gulf of Kutch; (2) the Gulf of Mannar–Palk Bay region; and (3) the Andaman and Nicobar Islands, each of which is discussed separately below along with consideration of whether the dugong likely occurs in Sri Lanka, external to the Gulf of Mannar–Palk Bay region. If dugongs are resident in Bangladesh, that population would likely be connected to the population in Myanmar (Chapter 6).

5.2.1 Gulf of Kutch

The Gulf of Kutch (Figure 5.3; 22.56° N, 69.54° E) is the only area on the west coast of India currently known to support dugongs. Historically, dugongs have been reported from further south along this coast of India. Jerdon (1894, p.311) reported they were sighted off the south Malabar and

Konkan coasts, as far north as Canara (southern Maharashtra). There have not been any sightings since these records (Jones 1967); past sightings may have been vagrants. This high wave energy coast lacks appropriate conditions for seagrass (Jones 1967) and studies of the extent of seagrass in India such as Geevarghese et al. (2018) and Thangaradjoua and Bhatt (2018) do not mention occurrences of mappable seagrass meadows on the west coast of India outside the Gulf of Kutch. Geevarghese et al. (2018) mention localized seasonal seagrass meadows of *Halophila beccari* on the west coast at Karwar (Karnataka), Malwan and Ratnagiri (Maharashtra). It is unlikely that these seagrass meadows support dugongs, given that they are all at least 600 km from known dugong habitats.

Research in the Gulf of Kutch was initially based on data collected from strandings, dead and captive dugongs (Jones 1967; Frazier and Mundkur 1990). The dugong population was described as probably consisting of 'very stray numbers' (Jones 1959). More recently, strandings (e.g., Singh et al. 2004; Pandey et al. 2010; Hatkar et al. 2023), and fisher interviews (e.g., Singh 2003; Sivakumar and Nair 2013; Anand et al. 2017, 2024; Johnson et al. 2023) have provided important information on dugongs and their habitats in the southwestern Gulf of Kutch.

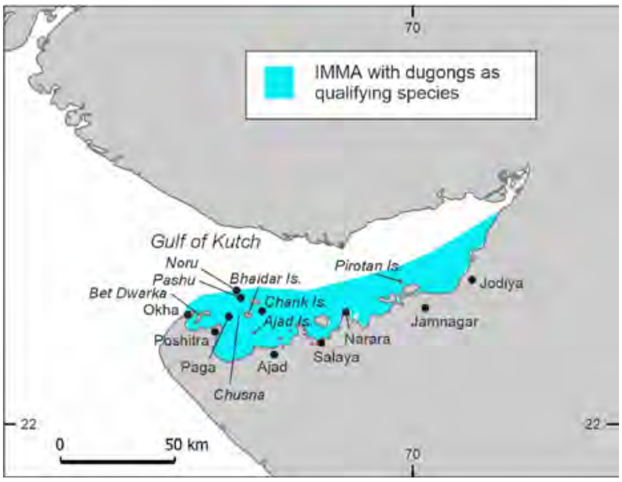
Seagrass mapping has been limited to the southern Gulf of Kutch because fisher survey results suggested this region is the main dugong area (Anand et al. 2017). Pathan et al. (2020) recorded around 39 km^2 of seagrass in the southwestern Gulf of Kutch in a total of 12 meadows (seven intertidal, two midtidal and three subtidal, deepest 3.7 m). Anand (2021, unpublished data) observed a seagrass area of approximately 23 km^2 exclusively within the intertidal zone, including large areas of seagrass observed at Chank, Noru, Bhaidar and Pirotan Islands and Paga Reef. Johnson et al. (2023) report that the southwestern Gulf of Kutch harbours a vast network of interconnected seagrass meadows including more than 10 reef top meadows (Figure 5.4), four vast intertidal meadows and more than five subtidal meadows but do not provide an updated extent. Pathan et al. (2020) recorded *Halodule uninervis, Halophilia ovalis, Halophila beccarii, Halopila decipiens* in the Gulf of Kutch; Anand et al. (2021, unpublished data) also recorded *Halophila ovata. Halodule uninervis* and *Halophila ovalis* were the dominant species.

Hatkar et al. (2023) built on previous work (e.g., Anand et al. 2017; Singh et al. 2004) to compile dugong stranding records for the Gulf of Kutch between 1877 and 2022. They documented 29 carcasses across 11 locations: three dated pre-1900; 12 between 1959 and 1994 and 14 between 2000 and 2018. Most of the stranding records occurred in the southwestern Gulf but carcasses were also found as far east as Sachana (one carcass in 1877) and a stranded skull was located on the northwestern shore at Mandivi in 1893. Most animals died of unknown causes. The leading identifiable cause of death in the Gulf of Kutch at 21% was net entanglement (Hatkar et al. 2023).

Anand et al. (2017) interviewed 723 fishers from 32 villages to obtain information on the distribution of and threats to dugongs in the southern Gulf of Kutch in 2008. Sightings were reported from the following locations (Figure 5.3): Ajad Island (three), Bet Dwarka (11), Chank Island (two), Okha (three), Pirotan Island (two), Poshitra (three), and Salaya (three). Only 7.6% (n=27) of fishers claimed to have seen one or more dugongs in the Gulf of Kutch between the 1980s and January 2008, suggesting that they are very rare in this region.

Parasharya et al. (2023) interviewed 100 locals across a wide age range from nine villages in the southwestern Gulf of Kutch to assess dugong distribution and abundance. Eighteen percent of

Figure 5.3. Geographic context of the Gulf of Kutch showing placenames mentioned in the text. An Important Marine Mammal Area (IMMA) with the dugong as a qualifying species is shown in blue. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



participants confirmed at least one dugong sighting, but respondents lacked awareness of any change in the population, likely due to the dugong's low abundance. Dugong feeding trails (Figure 5.4) were reported from Ajad, Bhaidar, Chank, Narara, Paga and Pirotan (Anand et al. 2024).

Recent scientific evidence of live dugongs in the southwestern Gulf of Kutch includes: (1) dugong feeding trails at several sites (Anand 2012; Pathan 2020; Johnson 2023; Figure 5.4); (2) one opportunistic sighting of a single dugong in 2019 near Bhaidar Island (the first live sighting in over 20 years; Anand et al. 2023, unpublished); and (3) unoccupied aerial vehicle (UAV) footage of a dugong cow-calf pair in 2021-2022 (Johnson et al. 2023).

The 'Gulf of Kutch' has been identified as an IMMA with dugongs listed as one of three qualifying species (IUCN-MMPATF 2021; Figure 5.3). The other two qualifying species are the finless porpoise, *Neophocaena phocaenoides* and the Indian Ocean humpback dolphin, *Sousa plumbea*.

- The Gulf of Kutch supports a small, isolated, resident dugong population. The limited extent of the potential seagrass supporting habitat in the Gulf indicates that it can support only a relatively small dugong population.
- The 'Gulf of Kutch' has been identified as an IMMA with dugongs listed as a qualifying species along with two coastal dolphin species.
- It may be effective and efficient to develop and implement conservation arrangements for all three marine mammals in the Gulf of Kutch, rather than dugongs per se.
- The conservation status of the dugong in the Gulf of Kutch merits assessment as an IUCN 'subpopulation'.

Figure 5.4. Dugong feeding trails at Chepri Reef in the Gulf of Kutch Marine National Park. Sameeha Pathan photograph; reproduced from Johnson et al. (2023) with permission.

5.2.2 Gulf of Mannar–Palk Bay region

5.2.2.1 Historical situation

The importance of dugongs in the Gulf of Mannar–Palk Bay region between India and Sri Lanka (Figure 5.5) has been recognized for more than 160 years (e.g., Tennent 1861; Annandale 1905; Bertram and Bertram 1970 a,b; Jones 1981; Leatherwood and Reeves 1989). This transboundary region, shared by India and Sri Lanka, is currently the most important habitat for seagrasses and dugongs in South Asia (Johnson et al. 2023; Anand et al. 2024; Seal et al. 2024).

Twentieth century accounts indicate that this region must have supported large numbers of dugongs. For example, Annandale (1905) stated:

'…from what I was told by the native fishermen, who possess special nets for the capture of the Dugong, it is rare nowadays for more than one specimen to be taken at a time, whereas formerly, in the Gulf of Manaar [sic], flocks of many hundreds were said to occur.… I was told that as many as sixty were sometimes brought into Kilakarai, a large native port near the northern corner of the Gulf on the Indian shore, in a year; but this number is probably exaggerated.'

Government records suggest that the native fishers may not have been exaggerating. A Sri Lankan government sponsored dugong fishery operated during the British colonial period, with 40-50 dugongs caught each season (Haley 1884). After Sri Lanka gained independence in 1948, the practice continued even though Leatherwood and Reeves (1989) could find no subsequent meaningful estimates of annual catch until the 1950s. Bertram and Bertram (1970 a,b) estimated that 100-150 dugongs were taken per year in the Mannar district of Ceylon [sic] in 1957-1959 based on the catch data of Norris (1960). Leatherwood and Reeves (1989) summarized monthly catches for the years 1953, July 1957–June 1959 based on Norris' data from government inspectors plus a Ceylon [sic] administrative report for 1953. These records indicate a total catch (over the three years) of 387 dugongs. Leatherwood and Reeves (1989) cautioned that these figures may be overestimates because some cetacean meat was marketed as dugong meat.

Jones (1981) estimated that catches on the Indian coast were approximately 150-175 dugongs per year, plus 100-150 per year on the Sri Lankan side. Based on inquires and personal visits, Jones concluded that catches in both countries were decreasing. Nevertheless, Silas and Fernando (1985) reported that more than 250 dugongs were caught and killed between April 1983 and August 1984 in the villages of Kilakarai and Periyapattinam in Tamil Nadu.

Taken together, this information suggests that large numbers of dugongs were harvested from the Gulf of Mannar–Palk Bay region in the twentieth century and that concerns over the status of the dugong in the region have existed for many years.

5.2.2.2 21st Century

The Gulf of Mannar–Palk Bay region supports at least 14 seagrass species (Balaji 2018; Geevarghese et al. 2018; Udagedara and Dahanayaka 2020; Ponde et al. 2021): *Cymodocea rotundata, C. serrulata; Enhalus acoroides; Halophila beccarii, H. decipiens, H. ovalis, H. major, H. minor, H. ovata, H. stipulacea; Halodule uninervis, H. pinifolia; Syringodium isoetifolium* and *Thalassia hemprichii.*

Extensive interview surveys of fishers in both Sri Lanka and India in the early 2000s suggest that the Gulf of Mannar–Palk Bay region now supports a much lower number of dugongs than in the recent past, and that fishers perceive a decline in sightings (Ilangakoon et al. 2008; Sivakumar and Nair 2013; Anand et al. 2015; Silva et al. 2017 a,b; Johnson et al. 2023). Fishers variously attributed the decline to at least one of the following: hunting, disturbance in dugong habitat, bycatch in fishing gear, and destructive fishing practices such as dynamite fishing and trap nets, development projects, and cyclones (see also Section 5.4, Table 5.2).

Johnson et al.'s (2023) exploratory UAV transect surveys of 6.34 km^2 of the inshore waters (maximum 3 km from the coastline) of the Dugong Conservation Reserve in Palk Bay in 2022-23 (Figure 5.5) recorded four dugong sightings, a dugong encounter rate of one per 0.72 km^2.

In 2023, dialogue between India and Sri Lanka was initiated with support from the CMS Dugong MOU Secretariat, with the aim of strengthening joint research and management of dugongs and their habitat in the region (K. Sivakumar personal communication via email to Marsh and Schramm 2024).

The 'Gulf of Mannar and Palk Bay' has been identified as an IMMA (area 20, 663 km^2; Figure 5.5) with the dugong listed as the only qualifying species (IUCN-MMPATF 2022a).

5.2.2.3 Other potential dugong habitats in Sri Lanka

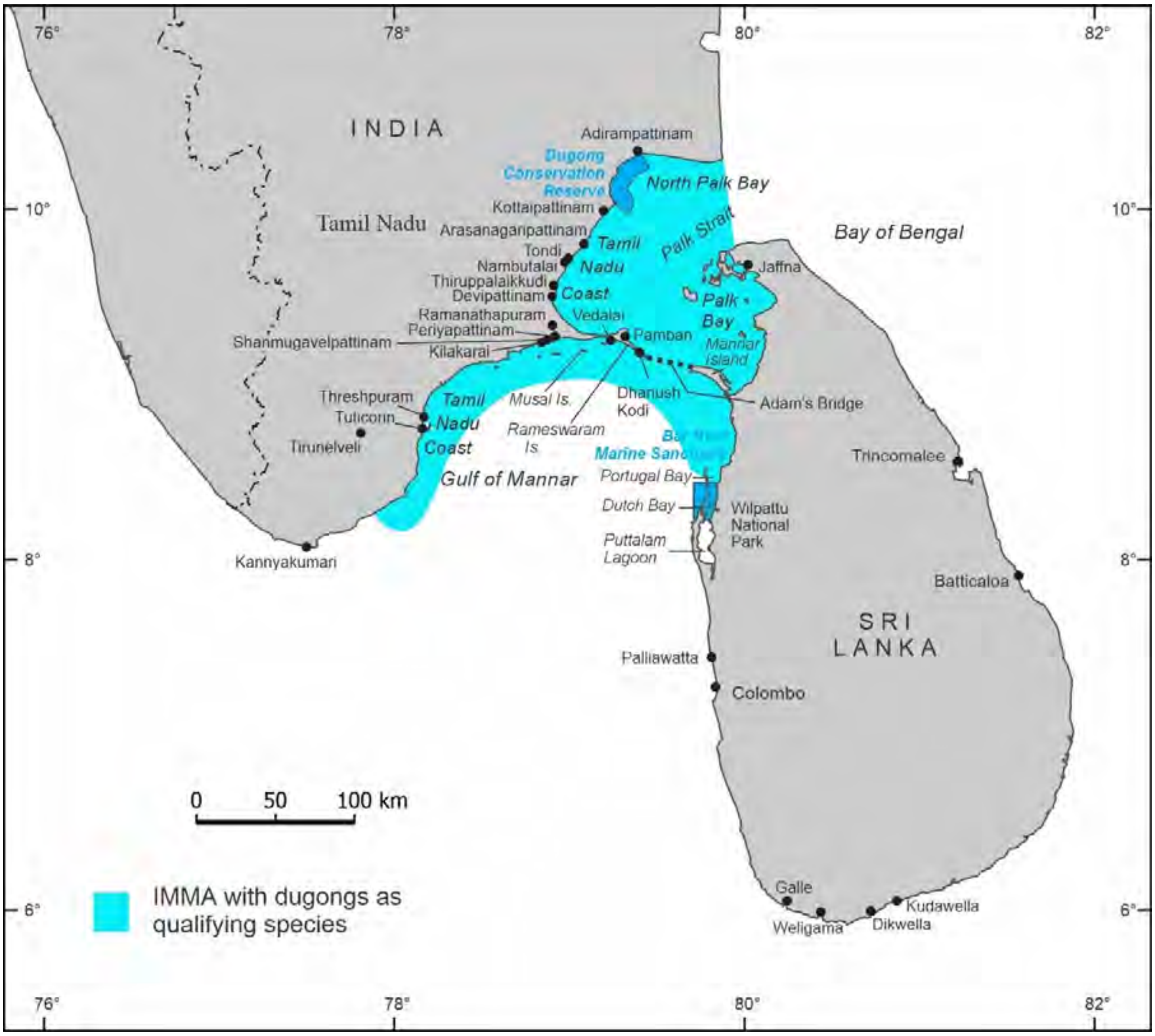
Although Bertram and Bertram (1970 a,b) concluded that dugongs were "virtually absent" from the south coast of Sri Lanka, Leatherwood and Reeves (1989) concluded that:

'Although they have not been collated in any systematic way previously, there appear to be enough bits of information scattered in the literature to demonstrate that dugongs formerly occurred at least sporadically along most of the Sri Lankan coastline where suitable habitat exists (or existed)'.

The records collated by Leatherwood and Reeves suggest that dugongs have occurred at: (1) several locations along the east coast, including near Trincomalee, where Udagdaera and Dahanayaka (2020) found records of seagrass; and (2) at least five locations in the southwest of the Island where carcasses have been recovered including Dikwella, Galle, Weiligama, Kudawella and Palliawatta (Figure 5.5). There is clearly a need to investigate the current situation regarding the distribution of dugongs and their seagrass habitats in Sri Lanka outside the northwestern region.

- The transboundary Gulf of Mannar–Palk Bay region is the most important habitat for seagrasses and dugongs in South Asia.
- The Gulf of Mannar–Palk Bay region apparently now supports a much lower number of dugongs than in the recent past.
- The region has been identified as an IMMA with the dugong as the only qualifying species.
- Procedures need to be developed to enhance the governance arrangements, research findings and community support to improve the management of dugongs and their habitats in the Gulf of Mannar–Palk Bay region, especially the impacts of fisheries interactions on dugongs and seagrasses.
- The current situation regarding the distribution of dugongs and their seagrass habitats in Sri Lanka outside the Gulf of Mannar–Palk Bay region merit investigation.

Figure 5.5. Geographic context of Tamil Nadu (India) and Sri Lanka showing placenames mentioned in the text. The IMMA and protected areas are shown in different shades of blue and are labelled accordingly. Inset: The Gulf of Mannar Biosphere Reserve. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



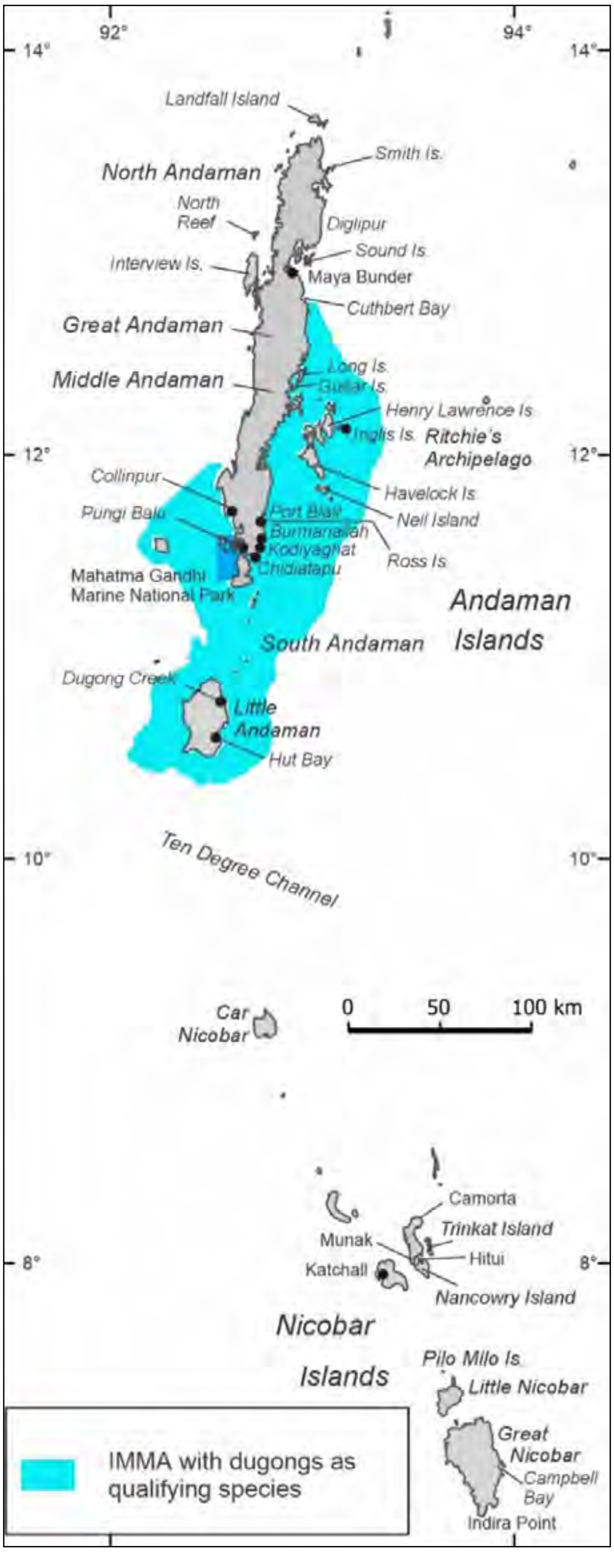
- Dugongs in the overall Tamil Nadu-Sri Lanka region likely qualify for separate IUCN Red List of Threatened Species status assessment as a 'subpopulation'. Such an assessment would require quantitative data on dugong abundance in the region including all of Sri Lanka.

5.2.3 Andaman and Nicobar Islands

Gole et al. (2023) recorded 12 species of seagrass from the genera *Enhalus, Cymodocea, Halodule, Halophila, Thalassia* and *Syringodium* in the Andaman and Nicobar Islands.

Between 1994 and 1997, Das and Dey (1999) surveyed various parts of the Andaman and Nicobar Islands (Figure 5.6) for dugongs using vessel, SCUBA, and snorkel surveys. They also conducted interview surveys, despite some fishers being reluctant to share information due to the illegality of deliberate hunting. Vessel surveys failed to locate any dugongs. Dugong bones were examined on several occasions at the following locations: Camorta, Havelock Island, Hut Bay, Katchall, Maya Bunder and Port Blair (Das and Dey 1999). Fishers and divers reported a total of five dugongs between 1990 and 1994 along the northwest of Camorta Island; another five individuals were sighted near Dugong Creek and Hut Bay; and four animals were sighted in Little Nicobar (Pilo Milo area; northwest) and in the Great Nicobar Islands (Das and Dey 1999; Figure 5.6).

Figure 5.6. Geographic context of the Andaman and Nicobar Islands showing placenames mentioned in the text. An IMMA with the dugong as a qualifying species is shown in blue. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



Groups of five to six dugongs were reported by fishers and divers on at least five occasions between 1990 and 1997; six animals were seen near Landfall Island on a regular basis (Das and Dey 1999); a female dugong was incidentally caught in a net 500 m offshore from Hut Bay. Based on such reports, Das and Dey (1999) concluded that dugong populations in the Andaman and Nicobar Islands were very small and had been declining since the 1950s as evidenced by the sporadic nature of sightings and records of poaching.

D'Souza and Patankar (2009) undertook snorkel and SCUBA surveys around Burmanalla, Camorta, Chidiatapu, Havelock, Interview, Kodiyaghat, Nancowry, Neil, and Trinket Islands, and North Reef (Figure 5.6) between February 2007 and March 2008 to better understand dugong behaviour. Their sites were chosen based on records of seagrass meadows, dugong occurrence and anecdotal evidence from local authorities and islanders. Three male dugongs were sighted during the surveys: one on the eastern side of Havelock Island, one on Neil Island, and the other at Kodiyaghat, South Andaman (Figure 5.6).

On the basis of interview surveys, Pandey et al. (2010, 2012) recorded a total of 81 incidental sightings in the Andaman and Nicobar Islands between 2007 and 2009. Forty-one percent (n=33) of the sightings were in the Little Andaman of the Andaman Group, 15% (n=12) of sightings were reported in the waters of Nancowry Island of the Nicobar Group.

A citizen science program targeting fishers, defence personnel (Indian Navy and Indian Coast Guard), Forest Department staff and the Tribal Protection Police was established in the Andaman Islands in 2017 and extended to the Nicobar Islands in 2021, as part of the Compensatory Afforestation Fund Management and Planning Advisory (CAMPA) Dugong Recovery program of the Ministry of Environment, Forest and Climate Change (MoEFCC) (Johnson et al. 2023). The resultant maps of dugong distribution throughout the islands, which include information from tribal protected areas and defence restricted regions for the first time, identify locations where individual dugongs, pairs and larger groups and carcasses have been reported, and demonstrate that dugongs are more widely distributed than suggested by earlier studies. The respondents reported 63 sightings of small groups of dugongs in the waters of the Andaman Islands. The larger herds of seven to 13 individuals included several calves (Gole et al. 2023).

Under the CAMPA-Dugong recovery programme (CAMPA 2022), the Wildlife Institute of India conducted exploratory surveys for dugongs using an UAV in 2021-22 (Johnson et al. 2023). Sixteen transects were flown in the North Andamans, 36 transects in Chidiatapu, Collinpur, Mahatma Gandhi Marine National Park (MNP) and Pungi Balu, and 30 transects in Ritchie's Archipelago. Dugongs were detected across the North and South Andaman Islands and Ritchie's Archipelago. The surveys yielded encounter rates of one dugong 0.6 km-2 in Ritchie's Archipelago, and 1.85 km^{-2} in Mahatma Gandhi MNP. Small groups of dugongs and calves were reported from the southwestern coast of South Andaman Island and Ritchie's Archipelago (Johnson et al. 2023).

The only quantitative data on dugong population trends in the region are from the occupancy modelling conducted by D'Souza et al. (2013), who estimated that dugong occupancy across the Andaman and Nicobar Islands had declined by 60% over the previous 20 years based on anecdotal historical and current data. They concluded that their modelled estimates of decline were at best conservative because of illegal, unreported and unregulated (IUU) hunting.

The 'Southern Andaman Islands' were recognized as an IMMA in 2022 (IUCN-MMPATF 2022b), and the Nicobar Islands and North Andaman Island are listed as Areas of Interest (AoIs).

- The Andaman and Nicobar Islands support a small, isolated, resident dugong population.
- The limited extent of the potential seagrass supporting habitat in the Andaman and Nicobar Islands means that these islands can support only a relatively small dugong population.
- It may be effective and efficient to develop and implement conservation arrangements for marine megafauna, rather than dugongs per se in this region.
- The 'Southern Andaman Islands' have been identified as an IMMA with dugongs as a qualifying species.
- Dugongs in the Andaman and Nicobar Islands likely qualify for separate IUCN status assessment as a 'subpopulation'.

5.3 Cultural values

As in most other parts of their range (Marsh et al. 2011; Ponnampalam et al. 2022), the cultural significance of dugongs in South Asia is linked to their value as food, medicines and other traditional uses as well as the practice of hunting. Historically, dugongs were harvested in Tamil Nadu and Sri Lanka (Sivakumar and Nair 2013), where their meat has a been a traditional delicacy (Ilangakoon et al. 2008), and by some tribes in the Andaman and Nicobar Islands (Das and Dey 1999). Many medicinal qualities have been attributed to the flesh and bones of the dugong throughout the South Asian region. Dugong meat is believed to possess rejuvenating qualities, and the consumption of meat is thought to cure digestive issues (Nair et al. 1975). The indigenous peoples in the Andaman and Nicobar Islands have been legally exempt from the statutory ban on dugong hunting that has applied in the rest of India under the *Indian Wildlife (Protection) Act 1972* due to the significant totemic and heritage value they place on the dugong (D'Souza et al. 2013).

Cultural practices differed in the three regions in which dugongs occur in South Asia, as outlined below.

5.3.1 Gulf of Kutch

The local name for dugong used by Hindu people in the Gulf of Kutch is *Bai Manas* (woman human), while Muslim fishers refer to dugongs as *Suwar machi* (pig fish) (Frazier and Mundkur 1990). Kacchi locals have several names for the dugong, including *Pranjada, Suwarmachi, Pranjado, Pranj* and *Harundo* (Pandey 2010; Sivakumar and Nair 2013). People in the area used dugong oil as a preservative and conditioner for wooden boats (Frazier and Mundkur 1990), while meat was consumed and believed to have medicinal, rejuvenating, and aphrodisiac properties (Jones 1967). Some fishers extracted oil from dugong fat (Anand et al. 2017).

Fossils of four species of extinct dugongs starting from 42 million years old have been found from the Gulf of Kutch region (Bajpai and Domning 1997; Bajpai et al. 2006; Thewissen and Bajpai 2009).

5.3.2 Tamil Nadu–Sri Lanka

The Sinhala name for dugong is *mudu uru* and the Tamil names are *kadal kanni* (angel of the sea), *kadal pandri, kadalpashu* and *kadalpanni* (sea pig), *orgil* and *avuliya*, the latter referring to the fact that female dugongs feed their calves via mammary glands (Leatherwood and Reeves 1989; Sivakumar 2013; Anand et al. 2015).

Archaeological excavations in Manthai, an ancient seaport in Sri Lanka, revealed fragments of dugong bone dating from 3,000 years BP (C. Deraniyagala personal communication to R. Gunaratna in Leatherwood and Reeves 1989) suggesting that dugongs have been hunted there for thousands of years. Hines (2012) reported that dugong meat has long been a delicacy in Sri Lanka and demand persisted into at least the latter half of the twentieth century (see Section 5.2.2). For example, between 1955 and 1960, dugong meat was a featured dish at Catholic festivals and in the 1980s, it was commonplace for cetacean flesh to be sold as dugong due to the high demand and higher price that dugong meat could command (Leatherwood and Reeves 1989).

Prior to the declaration of the *Wildlife (Protection) Act 1972,* the capture of a dugong had to be announced to the residents of Kilakarai, a coastal town in southern Tamil Nadu (Figure 5.5), by a town crier (Silas and Fernando 1988). It is reported that the demand for dugong meat was once so high that the failure to inform a friend of the availability of the meat was despised and could strain relationships among friends and relatives (Silas and Fernando 1988).

Several dugongs were kept in captivity at the Central Marine Fisheries Research Station, Mandapam Camp, Tamil Nadu from 1955 (Jones 1959, 1967). Most died soon after being taken into captivity, but a male and female were maintained on a diet of seagrass for several years from 1959. Mating behaviour was observed; no calves were born.

5.3.3 Andaman and Nicobar Islands

Dugongs were known as *Pani suvar* or *Jal suvar* (sea pig) by Bangali and Telugu fishermen in the Andaman and Nicobar Islands (Pandey et al. 2010). The Nicobarese and Onge tribes call the dugong *Ena bonya* (Pandey et al. 2010).

Due to the isolation of the indigenous islanders, cultural research in the Andaman and Nicobar Islands has been limited. Das and Dey (1999) reported that the Andamanese, Nicobarese and Onge tribes traditionally hunted dugongs with iron harpoons; members of the Shompen tribe, the indigenous people of the interior of Great Nicobar Island, had no knowledge of dugong hunting, suggesting that the meat was not traded with inland tribes. Onge believed that carrying decorated dugong bones (tusks, ribs, pelvic or pectoral girdles) increased good fortune, especially when hunting (Sivakumar 2013; Sivakumar and Nair 2013). The Onge preserve the skull and lower jawbone of the dugong and keep them above the cooking area, believing that the smell released from the dead dugong would attract animals from the forest or sea, facilitating future hunts (Pandey et al. 2010).

The dugong has been the state animal of the Union Territory of Andaman and Nicobar Islands since 2006.

5.4 Threatening processes

Historically the greatest threat to dugong in the region was direct hunting for meat and other products as discussed in Section 5.2. With the exception of indigenous hunting in the Andaman and Nicobar Islands, hunting has been illegal in Sri Lanka since 1937 and India since 1972. Illegal hunting is extremely difficult to quantify (D'Souza et al. 2013), so it is very challenging to obtain accurate data about its contemporary importance.

Anand et al. (2015, 2017) and Pandey et al. (2012) obtained fishers' views about the relative importance of the major causes of the perceived dugong decline. The results varied by area as summarized below (Table 5.2).

Sivakumar and Nair (2013) used the Dugong MOU Standardized Catch and Bycatch Questionnaire (Pilcher et al. 2017) to interview Indian fishers in Gulf of Kutch, Tamil Nadu and the Andaman and Nicobar Islands. The factors for the decline in dugong numbers in their region identified by the two-thirds of fishers able to comment have many similarities with factors identified in the earlier surveys but emphasise the perceived impact of the 2004 Indian Ocean earthquake and tsunami (Table 5.2).

The various threats to dugongs were prioritized based on a survey done during 2014-15 initiated by Tamil Nadu Forest Department (TNFD) under Tamil Nadu Conservation Biodiversity Greening Project (TBGP)

Table 5.2. Fishers' views regarding the relative importance of the major causes of the perceived dugong decline in Indian waters. The figures are percentage of respondents in each location rounded to the nearest integer.

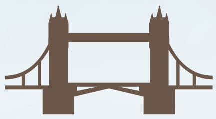
Cause of dugong decline	Anand et al. 2015, 2017; Pandey et al. 2012; surveys conducted in 2008			Sivakumar and Nair (2013)[iv]
	Gulf of Kutch (n=16)	Gulf of Mannar-Palk Bay (n=1242)	Andaman and Nicobar Islands (n=394)	All regions (n=1,616)
Hunting		43%	46%	21%
Fisheries related[i]	75%	48%	17%	33%
Other anthropogenic[ii]	25%	3%		
Tsunami/cyclone		3%	37%	44%
Other natural causes		3[iii]%		3%

i incidental catches, damage to seagrass meadows, noise disturbance
ii pollution
iii includes stingray barb injuries
iv % based on 67% who responded to this question only

Threatening Processes

Negative interactions with small-scale fisheries are the principal cause of dugong mortality and habitat loss in the region

Loss of seagrass is a major problem in all important dugong habitats in the region



Building a shipping canal or bridge between India and Sri Lanka could damage seagrass beds in the Gulf of Mannar-Palk Bay region

Extreme weather events have direct impacts on dugongs through strandings, and indirect impacts from seagrass loss

Apparently low genetic diversity: a significant challenge to population resilience and recovery

The cumulative impacts of these threats make targeted conservation interventions across the region very important, especially habitat protection and the mitigation of human-induced threats.

through Suganthi Devadason Marine Research Institute (TNFD 2016). High priority threats identified were: (1) entanglement with fishing nets (gillnets such as sangili valai, thrirukkai valai, salai valai); (2) poaching for meat; (3) habitat (seagrass) destruction; and (4) propeller injury. The medium priority threats included: (1) pollution (solid waste disposal, sewage, and wastewater disposal from aquaculture farms); (2) sedimentation caused by trawling; and (3) lack of awareness about the importance of dugongs. Lack of capacity to identify dugongs and climate variability were identified as low priority threats.

5.4.1 Hunting and poaching

Even though the data presented in Table 5.2 are somewhat dated and restricted to fishers, it is clear that illegal dugong hunting was likely a major problem in Tamil Nadu and the Andaman and Nicobar Islands, even though its current importance relative to other threats cannot be quantified. Sivakumar and Nair (2013) reported that in the Gulf of Mannar, the rarity and illegality of hunting dugongs have increased the meat's sale value and poaching still occurs (Sivakumar 2013). D'Souza et al. (2013) believed that illegal hunting by non-indigenous groups in the Andaman and Nicobar Islands was significantly underreported and difficult to monitor.

5.4.2 Fishing impacts

Adverse impacts for artisanal fishing on dugongs and their habitats in South Asia range from incidental mortality in gillnets, shark nets and blast fishing, to damage to seagrass from bottom trawling and anchors. Since the introduction of synthetic gillnets in the 1950s, incidental catch has become an increasingly significant threat to dugongs in South Asia and much of the dugong habitat in the Gulf of Mannar is under intensive fishing pressure (Hines 2012). In an email to Marsh in 2024, Edward Patterson advised that 900 vessels with potential to kill dugongs plus 3,100 vessels with potential to damage seagrass, were operating in the Palk Bay - Gulf of Mannar region between India and Sri Lanka.

In the Gulf of Mannar–Palk Bay region, 19 dugongs (14 deceased, five live) were reported as bycaught in shore seine nets between 2016 and 2019 (Balaji and Sekar 2021). The five living dugongs were released by the Thanjavur and Pudukkottai divisions of the TNFD, Wildlife Institute of India, Coastal Security Group (Tamil Nadu Police Department), OMCAR Foundation and local volunteers. A further 26 dead dugongs were reported between April 2021 and March 2023 (V. Balaji personal communication via email to Marsh and Schramm 2024). Twelve years of marine mammal stranding observations in Pudukottai and Thanjavur districts of northern Palk Bay recorded 19 dead dugongs along their coasts, which comprises only 20% of the total coastline length of Palk Bay in India.

Since the introduction of rewards and incentive payments to rescue and release dugongs by MoEFCC's CAMPA Recovery Program and TNFD (Section 5.5.5), 19 live dugongs have been successfully released (Johnson et al. 2023; V. Balaji personal communication via email to Marsh and Schramm 2024). Net entanglement remains a significant problem.

During the civil war in Sri Lanka in 1980s, fishers from Sri Lanka migrated to the Indian coast of Palk Bay and introduced trap nets, which now pose threats to large areas of seagrass habitat. Each fisher typically operates three to six trap nets (V. Balaji personal communication via email to Marsh and Schramm 2024). The routine maintenance of trap nets requires removing seagrasses from inside an area covered by the net. Dugongs also get caught in trap nets, though they are later released (Figure 5.7).

Figure 5.7. Dugong caught in a trap net in Thanjavur District, Palk Bay in May 2023. Vedharajan Balaji (OMCAR) photograph; reproduced with permission.

Since 2023, trawlers from the Coromandel coast of Tamil Nadu have moved further south to Palk Bay, damaging seagrass meadows in the Dugong Conservation Reserve. This change has also created issues between small-scale fishers and trawler operators, who attempt to occupy their fishing grounds (V. Balaji personal communication via email to Marsh and Schramm 2024).

Blast fishing was banned in 1897 under the Indian Fisheries Act but resumed illegally in Palk Bay, and subsequently used to kill dugongs (Silas and Fernando 1985). Blast fishing is no longer practised along the Tamil Nadu coast because the Fisherman Cooperative Society, the State Fisheries Department and Forests Departments are more vigilant in policing the technique (J. Johnson personal communication via email to Marsh and Schramm 2024).

Marine litter from fisheries is already a major threat in the Gulf of Mannar and Palk Strait marine environments (Figure 5.8) and is expected to grow in severity (MARESSOL 2022).

5.4.3 Habitat loss

The loss of seagrass habitat is clearly a major problem in all major dugong habitats in the region. Anand et al.'s (2017) surveys indicate that fishers believe that pollution and trawling are major threats to the health of seagrass meadows in the Gulf of Kutch. Patterson Edward et al. (2019) found bottom trawling to be the most serious threat to

Figure 5.8. Artisanal fishing vessels and beach litter in the Dugong Conservation Reserve, North Palk Bay, Tamil Nadu, India. Swata Iyar photograph; reproduced from Johnson et al. (2023) with permission.

the seagrass meadows at their restoration site in the Gulf of Mannar in India. Das and Dey (1999) also reported habitat loss, which they attributed to land use change and increased boat traffic, to be the primary reason for the declining numbers of dugongs in the Andaman and Nicobar Islands.

5.4.4 Coastal infrastructure

The Gulf of Mannar-Palk Bay dugong population faces the most challenging development pressures in the region. The proposal to build the Sethusamudram shipping canal linking Palk Bay and the Gulf of Mannar between India and Sri Lanka has been met with continuous opposition from environmental and religious groups since its conception in the mid-1800s (Rodriguez 2007). Presently the proposal is dormant, however may be reactivated as the Prime Minister of India and President of Sri Lanka agreed to improve their countries' economic and energy ties by building a land link across Palk Strait (Agence France Presse 2023). The passage is projected to alter the complex marine ecosystems of the region, directly impacting marine megafauna habitat within the Gulf of Mannar–Palk Bay region. Environmental concerns about the proposed land link are likely to include its effects on dugongs and their habitats. Another concern is the proposal to exploit gas and petroleum in the deepwater off the Gulf of Mannar Biosphere Reserve. (*Hindustan Times* March 1 2025).

5.4.5 Extreme weather events and climate change

Extreme weather events have direct impacts on dugongs through strandings, and indirect impacts from seagrass loss, which causes dugongs to move from an affected area, postpone breeding, and mortality due to starvation (Marsh et al. 2022). Fishers' reports indicated that large numbers of dead dugongs were washed ashore after a cyclone in the Gulf of Mannar in 1954 (Ilangakoon et al. 2008). The Andaman and the Nicobar Islands lost approximately 15 km^2 of seagrass between 2004 and 2007, likely due to the 2004 Indian Ocean earthquake and tsunami (Thangaradjou et al. 2010). Table 5.2 suggests that the 2004 tsunami likely caused more significant seagrass loss in the Andaman and Nicobar Islands than the other dugong habitats in India (Pandey et al. 2010). This result can be explained by the proximity of the southern Nicobar Islands to the epicentre of the earthquake that caused the tsunami (Section 5.1.1). Sri Lanka and Tamil Nadu were also severely affected.

5.5 Conservation initiatives

5.5.1 International conventions

All Range States in South Asia are signatories to the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCC), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and are parties to the Convention on Migratory Species of Wild Animals (CMS). India, Sri Lanka, and Bangladesh have signed the Dugong Memorandum of Understanding (Dugong MOU).

5.5.2 National laws

5.5.2.1 India

Dugongs have been granted the highest level of protection under Schedule I of the *Indian Wildlife (Protection) Act, 1972*, which outlaws the hunting, killing and capture of dugongs as well as the buying and selling of meat. These actions are punishable by imprisonment. Scheduled tribes in the Andaman and Nicobar Islands are legally exempt because of the Andaman and Nicobar Islands *Protection of Aboriginal Tribes Regulation (1956)*. Some identified critical habitat for dugongs have been protected as National Parks, Wildlife

Sanctuaries and Conservation Reserves as per the *Wildlife (Protection) Act, 1972*. Other coastal areas with seagrass meadows are managed under the *Environment (Protection) Act, 1986*.

5.5.2.2 Sri Lanka

Dugongs in Sri Lanka are protected under the *Flora and Fauna Protection Ordinance of 1937,* which has since undergone several amendments to enhance the protection of various species, including dugongs. The most recent amendment was in 2022 *(Fauna and Flora Protection (Amendment) Act, No. 7 of 2022)*. Dugongs are also protected against misuse by the *Wildlife Policy of Sri Lanka* and the *Fisheries and Aquatic Resources Act (1996)*. Other relevant legislation incudes: *Marine Pollution Prevention Act No. 59 of 1981; Coast Conservation Act No. 57 of 1981 and Amendment Act No. 64 of 1988; The National Environmental Act No. 48 of 1980* (amended by *Act No. 56 of 12988, No. 53 of 2000*).

Although dugongs are technically protected by these laws, resources for enforcement are often lacking, and illegal actions often occur without punishment (Hines 2012). Twenty-eight percent of the respondents in Silva et al.'s (2017a) focus groups with fishers in the Sri Lankan waters of Palk Bay and the Gulf of Mannar reported that corruption was one of the main causes of the continuation of destructive and illegal fishing methods, plus a lack of law enforcement and negligence of government officials in implementing regulations.

5.5.3 Conservation status

5.5.3.1 India

Dugongs are listed under Schedule I of the *Wildlife (Protection) Act, 1972*. Dugongs are also listed as one of 21 threatened species under the Integrated Development of Wildlife Habitat (IDWH) Programme of India (launched in the 11th plan period 2009) that gives utmost priority for the conservation of species through National Species Recovery Plans. In 2021, the Government of India launched Project Dolphin which also covers the conservation of dugongs and their habitat at the national level.

Dugongs are listed as one of the five Critically Endangered species identified by the MoEFCC for species recovery under the CAMPA scheme, which has funding support of INR 23.58 crore (USD 3.15 million). The CAMPA recovery program was launched in 2016 through the Wildlife Institute of India across the relevant Indian states (Gujarat, Tamil Nadu, and Andaman and Nicobar Islands).

5.5.3.2 Sri Lanka

The Sri Lankan Red List of Threatened Animals mirrors the IUCN Red List of Threatened Species, which categorises the dugong as Vulnerable at a global scale (Marsh and Sobtzick 2019); its status at a national scale has not been evaluated.

5.5.4 Protected areas

5.5.4.1 Gulf of Kutch

The Gulf of Kutch Marine Sanctuary was established in 1980 to conserve marine biodiversity and extended in 1982 when some areas were given increased protection with Marine National Park status. The Marine Sanctuary covers an area of approximately 458 km^2; the MNP an area of 163 km^2. MPAs in India are notified under the *Indian Wildlife (Protection) Act, 1972* and are established as category I and II IUCN protected areas. The MNP and Sanctuary cover mainly intertidal zones along the southern coast of the Gulf, including the coral reefs, mangroves, seagrass meadows, mudflats, islands, and creeks, that support rich marine life including dugongs (IRADe 2017). The region has also been a hub of anthropogenic activities attracting investment in oil, petroleum, shipping, tourism, and salt production, all of which have created tensions between stakeholders regarding the management of the area. A workshop in 2016 recognized that appropriate management of the MNP would require an evidence-based seascape/ landscape approach. Magrota et al. (2020) surveyed artisanal fisher-folk fishing in and around the MNP. Most fishers (ranging from 89% in Bet Dwarka to 100% in Sachana) claimed that they were not aware of many of the management strategies of MNPs but were concerned about the need for better management to help conserve coral reefs and mangroves around these areas. Magrota et al. (2020) did not mention dugongs.

5.5.4.2 Tamil Nadu

The Gulf of Mannar Marine Biosphere Reserve in India was declared in 1989 by the Government of India and was recognized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and Biosphere Programme in 2001. In 1986, the 'core zone' of the reserve was declared by Government of Tamil Nadu as the Gulf of Mannar MNP covering 560 km^2 that included all 21 islands, adjoining coral reefs and seagrass meadows off the coasts of the Ramanathapuram and Tuticorin districts in Tamil Nadu. The launching in 2002 of the collaborative initiative of the Government of India, the Government of Tamil Nadu and the Global Environment Facility

(GEF) United Nations Development Programme (UNDP) on 'Conservation and Sustainable Utilization of Gulf of Mannar Biosphere Reserve's Coastal Biodiversity' brought the community together to take part in the conservation and management along with the authorities of the MNP. The Gulf of Mannar Biosphere Reserve Trust (GoMBRT) was formed to ensure effective coordination and main streaming of biodiversity conservation issues into the productive sector and policy development.

As part of the MoEFCC's Dugong Recovery program, the North Palk Bay region was identified as a critical dugong habitat. In 2019, the Wildlife Institute of India recommended the establishment of a Dugong Conservation Reserve (Sivakumar 2021). In September 2022, the Tamil Nadu government declared an area of around 448 km^2 in the northern part of the Palk Bay as a 'Dugong Conservation Reserve' notified by gazette order *G.O. Ms. No.165, Environment, Climate Change and Forests (FR.5).* The Dugong Conservation Reserve stretches from Adiramapattinam (Thanjavur district) to Amapattinam (Pudukkottai district) extending about 55 kilometres along the coast (Figure 5.5). This reserve is the first established in India specifically to protect dugongs. Figure 5.8 illustrates part of the challenge of implementing effective management in this reserve. The Tamil Nadu Forest Department has called tenders for India's first Dugong Conservation Centre to complement the reserve. An intra-regional workshop titled: 'Developing strategies to support dugong conservation In Palk Bay was held in October 2023 (Torres 2024).

India was added as the sixth participant country in the Seagrass Ecosystem Service Project in January 2024 with the Palk Bay site as the focus of implementation (Dugong MOU Secretariat via email to Marsh and Schramm August 2024).

5.5.4.3 Sri Lanka

Established in 1992, the 310 km^2 Bar Reef MPA is just offshore from the Kalpitiya peninsula (Figure 5.5) and Puttalam lagoon in the Gulf of Mannar, a known dugong habitat.

5.5.4.4 Andaman and Nicobar Islands

One hundred MNPs and Sanctuaries have been established across the Andaman and Nicobar Group of islands (Wildlife Institute of India 2021). The prominent and notable MNPs (Figure 5.6) include:

- **Rani Jhansi MNP** covering 256 km^2 of Ritchie's Archipelago, a regionally important dugong location.
- **Mahatma Gandhi MNP** established in 1983, covering 281 km^2 including 15 uninhabited islands for the conservation of marine life including dugongs.
- The **Greater Nicobar Biosphere Reserve** was established in 2013. The dugong is mentioned in the description of the reserve (UNESCO 2022).

These protected areas have been managed with approved management plans prepared by Andaman Forests Department with inputs from the Wildlife Institute of India.

5.5.5 Other recent conservation initiatives

5.5.5.1 India

- In 2007, the Organization for Marine Conservation Awareness and Research (OMCAR) Foundation was established to improve dugong conservation in northern Palk Bay. The OMCAR Foundation collaborates with fishers, the Forest Department and Wildlife Institute of India for collective conservation efforts including the rescue of dugongs, seagrass acoustic mapping and marine mammal stranding responses. Ecofriendly seagrass restoration methods have been developed (Balaji et al. 2020) and replicated locally and internationally. In 2024, OMCAR shared its seagrass restoration method, which uses an ecofriendly bamboo frame, with stakeholders and NGOs in Trang Province, Thailand through IUCN. OMCAR has held over 470 community awareness events since 2007 and provides educational scholarships to 50 students each year. OMCAR has also established a Marine Conservation Leadership programme, which provides free food and accommodation for young researchers in India to work as interns and learn about seagrass mapping, UAV surveying and conservation.
- In the Andaman Islands, the Directorate of Fisheries banned the use of monofilament nylon nets in 2008 because they are unselective (Advani et al. 2013). Most fishers support the ban, but some villages continue to use these nets despite their ecological consequences.
- Widespread seagrass restoration has been attempted in the Gulf of Mannar region (Patterson Edward et al. 2019).
- The Tamil Nadu Sustainability Harnessing Ocean Resources and Blue Economy (TN-SHORE) project is implemented by the Government of Tamil Nadu through the Tamil Nadu Coastal Restoration Mission with assistance from the

World Bank at the estimated cost of INR 2,000 crores (USD 250 million) across the next five years. An International Dugong Conservation Centre is proposed for Manora (Thanjavur District) in Palk Bay at a cost of INR 90 crores (USD 11.25 million). Large scale restoration of degraded seagrass meadows in the Gulf of Mannar–Palk Bay region is also proposed (Government of Tamil Nadu, Environment, Climate Change and Forest (EC.4) Department G.O. (Ms.) No.11 dated 10.01.2024).

- The Government of India has sanctioned a new project titled 'Tamil Nadu Biodiversity Conservation and Greening Project for Climate Change Response (TBGPCCR) (Phase 2)' funded by the Japan International Cooperation Agency (JICA) with an outlay of INR 920.52 crore (USD 115 million) for implementation over eight years from 2022-23 to 2029-30 (Government of Tamil Nadu 2022). Conservation and management of coastal biodiversity including seagrass and dugongs in the Gulf of Mannar–Palk Bay region is an important component of the project.
- From 2023, the Gulf of Mannar MNP has implemented annual monitoring of dugong habitats (seagrass meadows) in Palk Bay and Gulf of Mannar with 58 permanent monitoring sites (J. Patterson Edward personal communication via email to Marsh and Schramm 2024).
- In 2016, the Wildlife Institute of India launched the Dugong Recovery Program 2016–2025. The recovery program has four major objectives: (1) species conservation and management; (2) habitat conservation and management; (3) participatory management of dugong and their habitats; and (4) capacity building of state forest departments and local communities. The major achievements of this Programme follow (Johnson et al. 2023).

1. **Habitat conservation and management:** Under the CAMPA-Dugong recovery program, the extent of seagrass habitat, quality, and threat intensity in the following 'Critical Dugong Habitats' (CDHs) is being documented as follows:
   - Gujarat: 10 reef meadows, four vast mid-intertidal meadows and more than five subtidal meadows,
   - Tamil Nadu: seagrass cover in the Gulf of Mannar,
   - Andaman and Nicobar group: 66 seagrass meadows,
   - A threat heat map 2016-2025 has been prepared for each key dugong habitat.
2. **Participatory management of dugongs and their habitats:** More than 75,000 people (including fishers and school children) have attended awareness campaigns.
3. **Dugong Volunteer Network:** More than 1,000 people registered as volunteers including fishers, coast guards, marine police, tourist guides, and divers. A flagship Dugong Scholarship Programme provides financial support (INR 500 [USD 6] per month) towards the education of students from fishing backgrounds. These 'Dugong Ambassadors' were established to encourage the participation of the fishing community in dugong conservation. Since the inception of the program in 2017, 398 students in Gujarat, 447 students in Tamil Nadu and 80 students in the Andaman and Nicobar Islands have been awarded the scholarship.
4. **Capacity building of state forests departments and local communities:** Under the CAMPA Dugong Recovery Programme, the Wildlife Institute of India organized a series of Capacity building Programmes for forest staff, fisheries staff, navy personnel, coast guard and marine police of dugong in Indian states (Gujarart, Tamil Nadu and Anadman and Nicobar Islands) to train key stakeholders in dugong conservation and seagrass habitat monitoring:
   a. More than 60 forest staff have been trained in SCUBA diving and underwater monitoring techniques,
   b. 120 forest staff have been trained in drone piloting and aerial monitoring of dugongs and other marine megafauna,
   c. More than 60 Indian forest service officers have been trained in the management of coastal and marine biodiversity, and
   d. Over 500 personnel from Indian coast guard, navy and marine police have been educated about the need for marine biodiversity conservation.
5. **Dugong Day celebrations** were launched as part of an outreach program through social media in 2020 to spread information regarding the importance and the status of the dugong. This initiative has continued annually.
6. **Incentives for the release of bycaught dugongs:** the Wildlife Institute of India introduced monetary incentives for fishers who rescued and released live dugongs. The incentives include a cash award (IND 10,000 [USD 120]), a medal, certificate, and dugong

rescue kit. This scheme has been well received by fishers and is now supported by Forests of Tamil Nadu and the OMCAR Foundation. So far 35 fishers have benefitted from this scheme. In addition, the TNFD now provides IND 5,000 (USD 60.23) as compensation for net damages to fishers.

7. **Marine mammal stranding responses:** the Wildlife Institute of India organized the first 'Marine Mammal Stranding Response Workshop' in Tamil Nadu for forest officers and veterinarians in 2022. Eighteen participants (14 Range Forests officers; four veterinarians) were provided with training in stranding responses for both live and dead marine mammals, sample collection, and necropsy protocols. The Wildlife Institute of India published a *Manual on Marine Mammal Stranding Response* detailing the handling protocols for stranded marine mammals (Sivakumar et al. 2022).

5.5.5.2 Sri Lanka

The USD 622,000 GEF Dugong and Seagrass Conservation Project implemented by the Dugong MOU (2015-2019) focussed on the Sri Lankan coast of the Gulf of Mannar and Palk Bay (Dugong and Seagrass Conservation Project).

Conservation projects were designed to:

1. Raise awareness and respect for dugongs and their seagrass habitat in Sri Lanka,
2. Establish a marine conservation centre in northwest Sri Lanka,
3. Establish dugong and seagrass conservation areas in the Gulf of Mannar–Palk Bay region of Sri Lanka,
4. Provide incentives to local communities for stewardship of coastal habitats.

Although the project did not achieve all its aims, its achievements included:

- Conducting **an awareness campaign** including producing a dugong information booklet, dugong poster and a mini documentary.
- **Promoting alternative livelihoods** by working with selected fishing communities. Interventions were designed to engage the community in non-destructive income avenues. The establishment of small businesses such as: salt packaging, sewing, fishing using legal nets, ornamental fish culture, crab fattening, sea bass culture and batik handicraft were encouraged. Physical resources, coaching and training were provided to key beneficiaries. The program evaluation concluded that the environmental interventions contributed to the overall goal of promoting sustainable human development (UNEP-CMS 2024).

5.6 Research and monitoring initiatives

5.6.1 Current research and monitoring

- **Anand (2021)** assessed the status of dugong and its habitat in the Gulf of Kutch, utilising land and boat-based surveys, walking transects and UAV surveys to map intertidal seagrass meadows. The study has provided information regarding dugong distribution, seagrass species richness and area. Indirect evidence such as dugong feeding trails were also recorded as well as one live sighting of a dugong.
- **The Dugong Recovery Program** (Section 5.5.5.1) includes a comprehensive research program. In 2023, the program involved 19 researchers plus support staff (see Johnson et al. 2023). The work included: (1) seagrass surveys; (2) geospatial analysis of seagrass meadows; (3) ecological surveys for seagrass associated benthic macrofauna and fish species; (4) threat mapping; (5) aerial surveys for dugong population monitoring; and (6) utilising citizen science for understanding dugong distribution.
- Research was conducted between 2015 and 2019 on dugongs and their habitats, in the Sri Lankan waters of the Gulf of Mannar and Palk Bay as part of the **GEF Dugong and Seagrass Conservation Project** (Section 5.5.5.2). The research included: (1) an assessment of what nearshore fisherman and villagers knew about the biological and ecological aspects of the dugong and their attitudes to conservation to provide the background for an awareness campaign (Silva et al. 2017a,b); and (2) seagrass mapping and ecological studies to determine the diversity and abundance of seagrasses in inshore and deeper (subtidal) areas (Pahalawattaarachchi 2018).

5.6.2 Future research

Monitoring the dugong population in South Asia will require repeated standardized surveys with systematic protocols. Although knowledge of the distribution and status of seagrass habitats the Gulf of Mannar–Palk Bay region in Tamil Nadu has considerably improved recently because of investment in research and conservation projects,

Other Priorities for Action

Develop cross-boundary governance arrangements between **India** and **Sri Lanka** for the **Gulf of Mannar- Palk Bay Transboundary region**.
Undertake further targeted research to improve the management of dugong populations and seagrass communities with emphasis on reducing fisheries impacts, climate change and other threats.
Undertake research to determine if dugongs are resident in Sri Lankan waters outside the Palk Bay - Gulf of Mannar- Transboundary region.
Undertake research to determine if dugongs are resident along the **Chittagong coast** of **Bangladesh**.
Prepare applications to IUCN for Gulf of Kutch and Andaman and Nicobar Islands to be listed as threatened subpopulations.
Undertake transboundary surveys to estimate dugong abundance in the Palk Bay-Gulf of Mannar region as a basis for an IUCN subpopulation evaluation

there are still major gaps in the data surrounding dugongs, which need to be addressed with focused research and action planning. The major problem, which has been recognized since at least the 1970s (Jones 1981), is the lack of bilateral coordination of research on the distribution and abundance of this transboundary population.

For the last 50 years, civil unrest in Sri Lanka has been a barrier to bilateral collaboration but the current geopolitical climate seems more promising. Research collaboration between Sri Lanka and India would facilitate the pooling of expertise and resources and provide the evidence base for cooperative management. Well-designed aerial surveys over the whole Gulf of Mannar–Palk Bay region have the potential to improve the current population estimates (Anand et al. 2015) based on reported sightings and enable IUCN Red List of Threatened Species assessment of the 'subpopulation'.

5.7 Regional co-operation

India hosted the first South Asia sub-regional workshop on the Conservation and Management of Dugongs in June 2011, a joint effort by the MoEFCC (then named the Indian Ministry of Environment and Forests), UNEP/CMS Dugong MOU Secretariat, and the Wildlife Institute of India (UNEP-CMS 2011). Policy and conservation management experts attended from India, Pakistan, Sri Lanka and Bangladesh, government agencies and NGOs. The workshop agreed to encourage the governments of Bangladesh, Pakistan, and Sri Lanka to sign the Dugong MOU; Bangladesh signed the MOU in 2013; Sri Lanka in 2012.

The workshop also agreed to develop and deliver a practical and resource efficient strategy to collaborate and implement regional conservation and management initiatives for the conservation of dugongs and their habitats and enhance communication among participating countries and organisations. This commitment does not seem to have been advanced since the meeting despite discussion about holding a second workshop. Another South Asia subregional workshop should be a high priority.

5.8 Regional summary

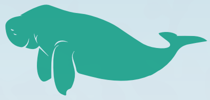
Dugong distribution in the South Asian Region is apparently limited to: (1) the Gulf of Kutch, (2) Gulf of Mannar–Palk Bay (and possibly elsewhere in Sri Lanka), and (3) the Andaman and Nicobar Islands. Known areas of concentration are listed in Table 5.3. Research is required to determine if dugongs are resident in the remainder of Sri Lanka and the Chittagong coast of Bangladesh.

In the Gulf of Kutch and the Andaman and Nicobar Islands, dugong populations are small, and it may be effective and efficient to develop and implement conservation arrangements for all coastal marine mammals, rather than dugongs *per se*.

Table 5.3. Confirmed areas of concentration for dugongs in South Asia.

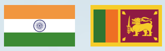
Region	Areas of importance
Gulf of Kutch	Bural Chank Reef (Paga, Pashu, Kharamitha Chusna, Bhaidar, Noru, Chank, Ajad and nearby reefs, between Narara and Pirotan Island
Gulf of Mannar–Palk Bay region	**Gulf of Mannar:** waters between Vedalai and Shanmugavelpattinam (Ramanathapuram District) (coastal length 32 km) **Palk Bay:** waters between Devipattinam and Thamotharapattinam (Ramanathapuram District) (coastal length 58 km) and between Kottaipattinam (Pudukottai District) and Adiramapattinam (Thanjavur District) (coastal length 55 km).
Andaman & Nicobar Islands	**North Andaman:** Landfall Island, Smith Island, Ross Island and Sound Island, Interview Island **Middle Andaman:** Cuthbert Bay, Maya Bunder, Long Island and Guitar Island **South Andaman:** Ritchies Archipelago's (Neil and Havelock Island) Southern portion of South Andaman **Little Andaman:** Eastern coast, from Hut Bay to Dugong Creek. **Nicobar Islands:** Between Nancowry islands (Trinkat Island, Camorta Island, Attahiak, Munak, and Hitui) and Northeast portion of Kachal island (Kapanga) **Great Nicobar Island:** Between the area of Campbell Bay and Indira point.

Confirmed Significant Locations



Gulf of Kutch

Supports a small, isolated, resident dugong population an Important Marine Mammal Area.



Gulf of Mannar and Palk Bay

Transboundary region, shared by **India** and **Sri Lanka**; currently the most important habitat for seagrasses and dugongs in **South Asia** and an Important Marine Mammal Area; apparently now supports a much lower number of dugongs than in the recent past.

Andaman and Nicobar Islands

Supports a small, isolated, resident dugong population. The **'Southern Andaman Islands'** have been identified as an Important Marine Mammal Area

Procedures need to be developed and shared between India and Sri Lanka to enhance the governance arrangements focusing on community participation in conservation and management. Targeted research is required to improve the management of dugong populations and seagrass communities, with particular emphasis on reducing the impacts of fisheries, climate change and other threats to dugongs and seagrass meadows.

The knowledge of the distribution of the dugong and the status of seagrass habitats in Gulf of Mannar–Palk Bay area in Tamil Nadu, India has considerably improved due to recent targeted investment. The declaration of Dugong Conservation Reserve by the Government of Tamil Nadu and the proposed establishment of an International Dugong Conservation Centre in Palk Bay, Tamil Nadu (India) and the new projects with funding support from World Bank (TN-SHORE) and JICA (TBGPCCR–Phase 2) are expected to further improve the knowledge, scientific data collection and conservation measures on the dugong population and their associated seagrass habitat.

The status of dugong populations in South Asia remains data deficient. Each of the Gulf of Kutch; Gulf of Mannar–Palk Bay; and Andaman and Nicobar Islands dugong populations likely qualifies for separate IUCN Red List of Threatened Species assessment as 'subpopulations'. A robust transboundary population estimate would be required for the transboundary Gulf of Mannar–Palk Bay region between India and Sri Lanka.

5.9 References

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Chapter 6

CONTINENTAL SOUTHEAST ASIA

Authored by: Franco Leung, David Blair, Rebecca Chambers, Ellen Hines, Len McKenzie, Vibol Ouk, Louisa Ponnampalam, Serina Rahman, Tint Tun, Long Vu and Helene Marsh

Franco Leung[1], David Blair[1], Rebecca Chambers[2], Ellen Hines[3], Len McKenzie[4], Vibol Ouk[2], Louisa Ponnampalam5, Serina Rahman[6], Tint Tun[7], Long Vu[8], Helene Marsh[1]

[1]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[2]Department of Fisheries Conservation, Ministry of Agriculture, Forestry and Fisheries, Kingdom of Cambodia.
[3]Estuary & Ocean Science Center, School of the Environment San Francisco State University, California, United States of America.
[4]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Cairns, Queensland, Australia.
[5]The MareCet Research Organization, Subang Jaya, Selangor, Malaysia.
[6]Southeast Asian Studies Department, National University of Singapore, Singapore and Kelab Alami, Johor, Malaysia.
[7]Freelance Marine Biologist, Myanmar.
[8]Center for Biodiversity Conservation and Endangered Species (CBES), District 2, Ho Chi Minh City, Viet Nam.

Correspondence to: Helene Marsh helene.marsh@jcu.edu.au.

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Cover image: Dugong fountain in Trang, Thailand. Patrick Lepetit photograph.

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This report was produced on the Bebegu Yumba campus of James Cook University in Townsville, Australia on the lands of the Wulgurukaba and Bindal peoples. We gratefully acknowledge First Nations Custodians of all lands which this report covers. We recognize the deep, lasting connections to Country, and pay respect to Elders past, present and emerging.

Contents

Range/Signatory States

Range States	Signatory States
Myanmar	Yes
Thailand	Yes
Malaysia (Peninsular)	No
Singapore	No
Cambodia	No
Viet Nam	No

Regional findings

The countries considered in this chapter on Continental Southeast Asia include: Malaysia (Peninsular Malaysia only)[1], Kingdom of Cambodia (Cambodia), Kingdom of Thailand (Thailand), Republic of the Union of Myanmar (Myanmar), Republic of Singapore (Singapore) and The Socialist Republic of Viet Nam (Viet Nam)

- Dugongs face significant challenges in this region, primarily from incidental bycatch, habitat loss and degradation. The underlying causes of these threats vary across Range States, but their root causes include inadequate law enforcement, coastal development, and poverty.
- The status of dugongs in this region remains data deficient, despite the efforts by many researchers and NGOs.
- The following globally-important Important Marine Mammal Areas (IMMAs) with the dugong as a qualifying species have been recognized or are in the process of being evaluated: (1) Trang in Thailand (under evaluation); (2) the 'Mersing Archipelago' IMMA, off the eastern coast of Johor in Peninsular Malaysia; (3) the transboundary 'Kien Giang and Kep Archipelago' IMMA, which spans the Kep Province in Cambodia and the Kien Giang Province in Viet Nam; and (4) the 'Côn Đảo' IMMA in Viet Nam.
- The Andaman Sea coast of Thailand and the east coast of Johor in Peninsular Malaysia are the only locations with confirmed populations ranging from tens to hundreds of dugongs. Effective protection of these populations is particularly important.
- Throughout most of the region, dugongs persist in fragmented, relatively small populations in recognized areas of local importance. Thus, it may be more efficient and effective to consider dugong conservation in these locations in the context of the conservation of marine megafauna more generically than to develop specific dugong management plans.
- Increased attention to transboundary management and the conservation of seagrass meadows known to support dugongs would be highly desirable.
- The largest knowledge gaps are: (1) inadequate mapping of seagrass in most countries, particularly Myanmar; (2) lack of quantitative data about most of the dugong populations; (3) lack of understanding of the contemporary transboundary movements of dugongs; (4) the limited understanding of the genetic structure of dugong populations outside Thailand; (5) spatial understanding of the threats posed by fisheries; and (6) understanding the causes of the large-scale seagrass dieback along the Andaman coast of Thailand; (7) the human dimensions of dugong interactions with fisheries and coastal development.
- The dugong population in the in the Côn Đảo Archepelago region of Viet Nam must be at high risk because of its isolation and may merit International Union for Conservation of Nature's (IUCN) Red List of Threatened Species evaluation as a 'subpopulation'[2], depending on the availability of data.

6.1 Regional setting

6.1.1 Geographic overview

This chapter considers the status of the dugong along the approximately 9,630 km coast of Continental Southeast Asia from the coastal border of Bangladesh and Myanmar (20.71° N, 92.37° E) to the coastal border of Viet Nam and China (21.53° N, 108.06° E), as well as the associated offshore islands. From west to east, the region comprises the coastal waters of Myanmar, Thailand, Peninsular Malaysia, Singapore, Cambodia, and Viet Nam (Figures 6.1, 6.3).

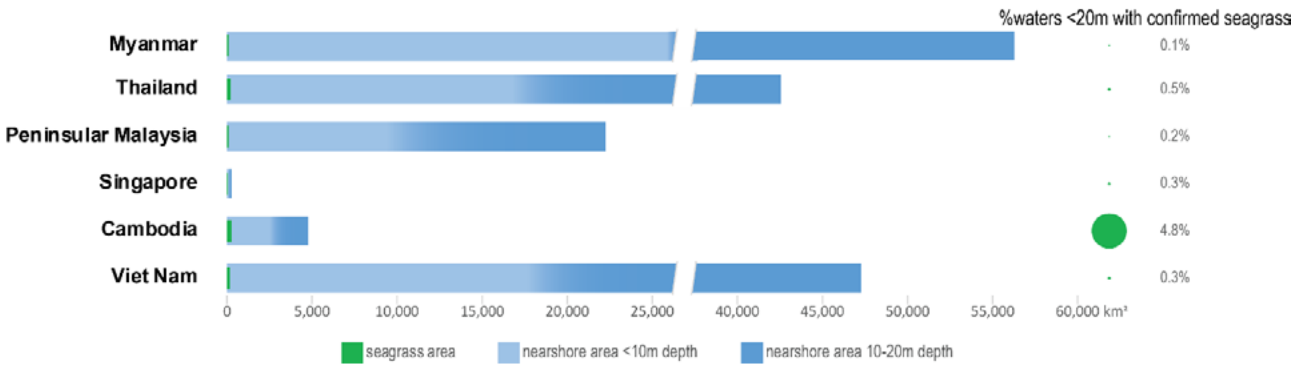
The waters of Continental Southeast Asia are part of the Tropical Indo-Pacific seagrass bioregion (Short et al. 2007). The estimated minimum area of seagrass for each dugong Range State (Figure 6.2) that can be confirmed with moderate to high confidence is as follows (ordered west to east, consistent with the remainder of this chapter): Myanmar 5 km^2 (Beffasti 2008; Novak et al. 2009; Soe-Htun et al. 2015), Thailand 210 km^2 (Gulf coast 122 km^2; Andaman coast 88 km^2) (Supanwanid 2001; Sudo et al 2021; UNEP-WCMC and Short 2021; McKenzie et al. 2023; Department of Marine and Coastal Resources [DMCR] 2024); Peninsular Malaysia 39 km^2

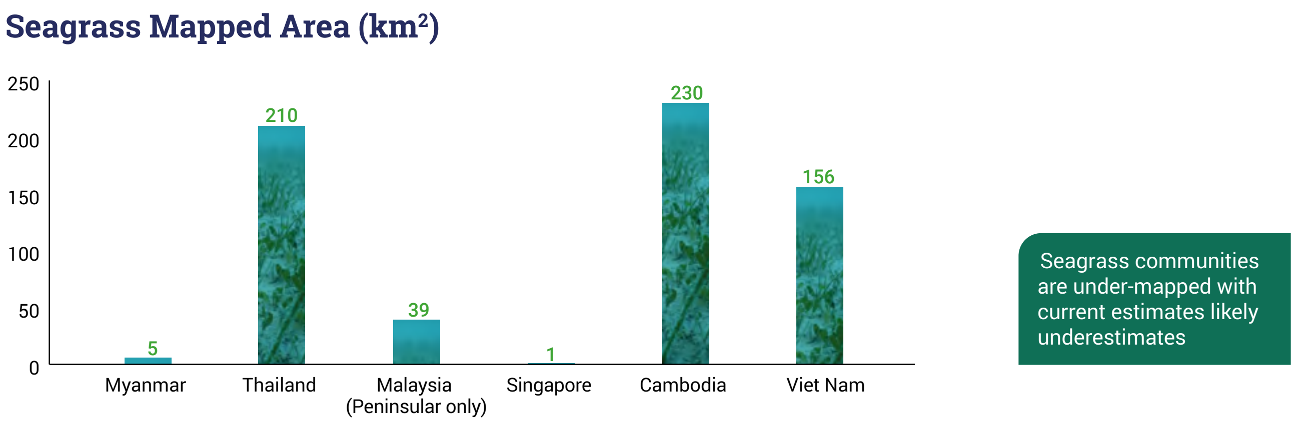
1 East Malaysia is discussed in Chapter 7: Maritime Southeast Asia because it is situated on the island of Borneo.

2 IUCN uses the term 'subpopulation' in the assessment of a regional population. The term 'subpopulation' is used here with reference to IUCN documentation only.

Figure 6.1. Geographic context of Continental Southeast Asia showing placenames mentioned in the text. Dugong Range States are (ordered west to east): Myanmar, Thailand, Malaysia (Peninsular), Singapore, Cambodia and Viet Nam. IMMAs and Marine Parks are shown in blue. Potential IMMAs (known as Areas of Interest [AoIs]) are not shown here as they have not been confirmed but are mentioned in the text. Inset bottom left: Cambodia coast. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

Figure 6.2. Histogram showing the size of known areas of seagrass and coastal waters shallower than 20 m deep for each dugong Range State in the Continental Southeast Asia region. The areas of seagrass are almost certainly underestimates. Len McKenzie figure; reproduced with permission.





(McKenzie and Yoshida 2006; Ooi et al. 2011; Hossain et al. 2015; Ho et al. 2018; Sani and Hashim 2019; Sudo et al. 2021; Heng et al. 2022); Singapore 1 km^2 (Yaakub et al. 2013; McKenzie unpublished data); Cambodia 230 km^2 (Hines et al. 2008; Mangroves for the Future 2013a; Supkong and Bourne 2014; Leng et al. 2014, 2015; Sudo et al. 2021); and Viet Nam 156 km^2 (Nguyen et al. 2022). All areas are rounded to nearest km^2, standard errors are not available. These estimates, particularly for Myanmar, are likely underestimates and do not take account of the condition of the seagrass.

In Continental Southeast Asia, dugongs are scattered throughout the region's shallow coastal and island waters. The westernmost sighting of a dugong in the region was at Man Aung Island (18.79° N, 93.64° E) along the Rakhine coast of Myanmar (Ilangakoon and Tun 2007; Tun and Ilangakoon 2007; Figure 6.1). On the eastern coast, the most northerly sightings have been from the waters near the Hà Cối River (21.23° N, 107.56° E) in the Gulf of Tonkin, Viet Nam (UNEP/CMS 2011).

Dugong abundance in this region generally appears to be low, except for the population in Trang Province on the southern Andaman coast of Thailand (Hines et al. 2005; DMCR 2011, 2018; Figure 6.1). The reasons why the Trang region supports a significant dugong population are not known but is likely to be associated with the size and configuration of the local seagrass meadows.

Most records are based on direct sightings, historical accounts from interviews, bycatch records, strandings, and dugong feeding trails (Supplementary Material in Panyawai and Prathep 2022). Recorded numbers are likely lower than the actual population size due to the few comprehensive surveys with corrections for detection bias, outside the regionally important coastal islands of Libong and Muk in southern Thailand.

6.1.2 Geopolitical and socioeconomic overview

This information (see Table 6.1) is provided as an indication of the challenge for each of the Range States in the region to consider the conservation of dugongs and their habitats in the context of their

Table 6.1. Human Development Index (HDI) status and rank and Gross Domestic Product (GDP) per capita rank of the dugong Range States in Continental Southeast Asia. Consistent with the remainder of this chapter, the countries in this table are ordered west to east starting with Myanmar. Countries with the highest HDI or GDP have the lowest ranks. 189 countries were ranked for both indices.

Range State	HDI	HDI Rank 2023[i]	GDP per capita rank 2023[ii]
Myanmar	Medium	149	138
Thailand	Very High	66	73
Malaysia (whole country)	Very High	62	56
Singapore	Very High	12	2
Cambodia	Medium	146	136
Viet Nam	High	115	101

i 2023 HDI data from https://hdr.undp.org/data-center/country-insights#/ranks (downloaded from the internet January 2024);
ii 2023 per capita GDP from https://www.worldometers.info/gdp/gdp-per-capita/ (downloaded from the internet June 2024).

socioeconomic development needs. The region is populated by around 280 million people, increasing at an average of 0.7% p.a. (United Nations 2022). The Human Development Index (HDI) classifies Cambodia, Myanmar, and Viet Nam as developing countries; Malaysia, Singapore and Thailand as developed countries (World Population Review 2023). Further details are below and in Table 6.1.

Myanmar (Figure 6.1) has a coastline of 2,832 km in the Andaman Sea and borders Bangladesh in the north and Thailand in the south. Myanmar has a medium HDI of 0.585 (ranked 149) and a Gross Domestic Product (GDP) of USD 62.26 billion (World Bank 2022). Approximately 52 million people live in Myanmar (United Nations Development Programme [UNDP] 2022). In recent years, Myanmar has been wracked by civil war (Braun et al. 2023).

Thailand (Figure 6.1) has two disjunct coastlines: (1) 750 km in the Andaman Sea adjoining Myanmar in the north and Peninsular Malaysia in the south; and (2) 1,670 km in the Gulf of Thailand, adjoining Peninsular Malaysia in the south and Cambodia in the north. Thailand has a Very High HDI of 0.800 (ranked 66), a GDP of USD 495.42 billion (World Bank 2022); and a population of approximately 72 million people (UNDP 2022).

Malaysia comprises Peninsular Malaysia, which is considered in this chapter because it is part of Continental Southeast Asia. East Malaysia, which is located on the island of Borneo, is considered in Chapter 7, with the other maritime countries in the region. The 1,972 km coastline of Peninsular Malaysia (Figure 6.1) directly abuts Thailand in the north and Singapore in the south. Malaysia has a Very High HDI of 0.803 (ranked 62) and a GDP of USD 407.03 billion (World Bank 2022). Around 33 million people live in Malaysia (Peninsular and Continental; UNDP 2022).

The 64 islands of **Singapore** border Peninsular Malaysia to the north and Indonesia to the south (Figure 6.3). Singapore's coastline is approximately 193 km. The island nation has a Very High HDI of 0.939 (ranked 12) and a GDP of USD 466.79 billion (World Bank 2022). Approximately 6 million people live in Singapore (UNDP 2022).

The 443 km coastline of **Cambodia** adjoins Thailand in the west and Viet Nam to the east (Figure 6.1, inset). Cambodia has a Medium HDI of 0.593 (ranked 146), a GDP of USD 29.5 billion (World Bank 2022), and a population of around 16 million people (UNDP 2022).

The 3,444 km coastline of **Viet Nam** adjoins Cambodia in the southwest and China in the northeast (Figure 6.1). Viet Nam has a High HDI of 0.703 (ranked 115), a GDP of USD 408.8 billion (World Bank 2022) and a population of approximately 97 million people (UNDP 2022).

6.1.3 Genetics of dugong populations

For an overview of genetics-relevant techniques, definitions, studies and general findings, refer to Chapter 1, particularly Figure 1.2.

Specific genetic studies from this region are available only for the dugong populations in Thailand (Palmer 2004; Bushell 2013; Poommouang et al. 2021, 2022). The Andaman Sea coast of Thailand supports a relatively large number of dugongs, whereas the Gulf of Thailand apparently has only a very small population. These two areas are separated by the Isthmus of Kra and Peninsular Malaysia. The shortest distance by sea between Trang on the Thai Andaman coast and Pattani on the Thai Gulf coast is about 1,900 km.

Marine organisms moving between the Gulf of Thailand and the Thai Andaman coast need to transit through the waters of Singapore, a region now heavily impacted by shipping and other human activities. The only genetic data available for dugongs from Singapore is a single mitochondrial sequence (MH704285)[3] reported by Plön et al. (2019) and derived from material dated 1887 stored in the Bremen Überseemuseum. This sequence belongs to the Western Indian Ocean haplogroup (which has not been recorded from Thailand).

Bushell (2013) and Poommouang et al. (2021) make mitochondrial sequence data (410 bp or longer) from Thailand publicly available. Both publications also analysed microsatellite data and reached slightly differing conclusions. With one exception, all mitochondrial haplotypes from Thailand fall into either the Northeastern haplogroup or the Andaman haplogroup (Chapter 1, Figure 1.2). Dugongs in the Northeastern haplogroup occur along both coasts of Thailand, as well as from Thailand eastwards to Japan and Palau, and south to Indonesia and Ashmore Reef (on the continental shelf of north-west Australia). The Andaman haplogroup is known only from the Andaman Sea coast of Thailand. One sequence reported by Bushell from that coast belongs to the Eastern Indian Ocean haplogroup (Chapter 5).

The Andaman haplogroup may have emerged as a distinct cluster due to its relative isolation in the Andaman Sea when sea-levels were low (see Voris 2000 for maps of the region at, and following, the glacial maximum approximately 17,000 years BP). If so, it is surprising that this haplogroup did not disperse further in post-glacial times, given the distribution of the northeastern haplogroup. The latter could have originated east of the Sunda Shelf but is now widespread around the Sunda region and into the western Pacific. This suggests that the Sunda Barrier (e.g., Crandall et al. 2019) has not greatly affected the distribution of dugongs.

Bushell (2013) noted that comparisons of mitochondrial haplotype and microsatellite data suggested some migration between the Andaman Sea coast and the Gulf of Thailand. The mitochondrial data suggested strong pairwise differentiation among three regions (North Andaman, South Andaman, and Gulf of Thailand) but this was less marked in the microsatellite data, suggestive of male-biased movement and female philopatry. Poommouang et al. (2022), primarily based on microsatellite data, considered that the populations in the Gulf of Thailand and the Andaman coast were genetically distinct.

3 For definitions of genetic terms see Chapter 1.

Bushell (2013) found no strong evidence of a genetic bottleneck, inbreeding, or recent population decline (except possibly in the Gulf of Thailand). Poommouang et al. (2021) reported little evidence of inbreeding and good genetic diversity among 118 Thai dugongs, based on inter-simple sequence repeats (nuclear markers) and mitochondrial sequences. They noted that samples collected in the last decade of the 20th Century collectively exhibited more variation than those collected subsequently, suggestive of recent population decline. A follow-up study using nuclear microsatellite loci from 77 dugongs (Poommouang et al. 2022) indicated some inbreeding in Thai coastal waters.

- Thai dugongs either side of the Isthmus of Kra mainly belong to the Northeastern mitochondrial haplogroup. A large minority of those on the Andaman Sea coast belong to a separate group, here termed the Andaman haplogroup, found nowhere else.
- There remains uncertainty about the extent to which Thai dugongs are genetically separated by the Isthmus of Kra.
- There is some evidence of inbreeding in Thai dugongs.

6.2 Distribution, abundance and trends in Range States

6.2.1 Myanmar

The first recorded likely dugong sighting in Myanmar's waters was reported by the Reverend S. Benjamin in 1853 (Mason and Theobald 1882).

'I have discussed the question as to what animal, the Sanscrit term 'jala hasti', or water elephant, was really applicable, as some scholars have supposed that it may have applied to the now extinct Hippopotamus of the Nurbudda. The conclusion, however, to which I have come is, that the 'jala hasti' really applied to the Dugong.'

The Myanmar coastline can be divided into three regions (ordered north to south): (1) the Rakhine; (2) the (Ayeyarwady) Delta; and (3) Tanintharyi, which includes the Myeik Archipelago (Figure 6.1). Many reports of dugongs in Myanmar come from the Rakhine region based on group discussions and individual interviews with residents of coastal villages, fisheries authorities and fishers from 2005-2007 (Ilangkoon and Tun 2007; Tun and Ilangkoon 2007).

Along the Rakhine coast, interviewees demonstrated knowledge of dugongs and their seagrass habitats, with frequent sightings of small groups of dugongs including cow-calf pairs. Man Aung island was well-known for dugongs, which were frequently sighted during the rainy season (Tun et al. 2010; Figure 6.1). Local fishers around Gwa also reported dugong sightings during the fishing season from September to April but not during the non-fishing season from May to August. Other places where dugongs were reported include the waters of Hmawyone and Shwe ya gyaing and neighbouring villages (Ilangakoon and Tun 2007; Tun and Ilangakoon 2007).

At Hmawyone village on the Rakhine coast, respondents reported that dugongs often bumped their heads against the wooden rudder of anchored artisanal fishing craft destroying the rudder. Fishers using these artisanal craft carried long bamboo poles to push dugongs away from their boats and used iron rudders, to avoid dugong interference. Fishers in Gwa reported that dugongs often followed sea cucumber divers between the surface and the ocean floor (Ilangakoon and Tun 2007).

Hines (2012) interviewed fishers and 'sea gypsies' in the Myeik Archipelago in the Tanintharyi Region in 2007. Interviewees saw only the occasional dugong and researchers found little potential seagrass habitat. Nonetheless, Tun (2012) reported dugong feeding trails amidst dense *Halophila ovalis* patches along the eastern coasts Nyaung Wee Islands near Lampi Island.

Although anecdotal reports of dugong bycatch have been recorded (e.g., Tun and Ilangagoon 2007), dugong strandings and bycatch are considered underreported due to the absence of established reporting mechanisms, and a lack of awareness about the dugong's conservation status among both coastal communities and authorities in Myanmar.

This information indicates that the area of seagrass in Myanmar (5 km^2 as reported by Beffasti 2008; Novak et al. 2009; Soe-Htun et al. 2015), is an underestimate, especially along the Rakhine coast.

- Knowledge of the distribution and abundance of dugongs and their habitats in Myanmar is inadequate. Management, awareness and community participation are weakly developed.

6.2.2 Thailand

Dugongs occur on both the Andaman Sea and Gulf of Thailand coasts (Figure 6.1). These two populations are separated by approximately 1,900 km and there are reported genetic differences between them (see Section 6.1.3).

Aerial surveys in 2017 suggested that there are fewer dugongs in the Gulf of Thailand than in the Andaman Sea (around 30 and 191 individuals sighted (uncorrected counts) respectively) (DMCR 2018). The qualitative difference between the number of dugongs sighted during the surveys in Gulf of Thailand and the Andaman Sea accords with records of 282 strandings from 1962 to February 2008; 71.6% were from the Andaman Sea and 25.8% were from the Gulf. The remaining 2.6% included no information on stranding location (Adulyanukosol et al. 2009).

Panyawai and Prathep (2022) conducted a systematic review of the literature on dugongs in Southeast Asia. They concluded that, in the Andaman Sea, where dugong research has been conducted for several decades (see Table 6.2 in Section 6.7), dugongs are distributed along the coast of the following locations (ordered from the north to south): Ranong (Sai Dam), Phuket Island (Paklok and Chalong Bays), Krabi (Koh Sri Boya and Koh Pu), Phang-nga (Phra Thong and Yao Islands and Phang-nga Bay), Trang (Chao Mai and Muk, Libong, and Sukorn Islands) and Satun (Lidee and Sarai Islands) (Adulyanukosol et al. 1997, 1999; Adulyanukosol 2004; Hines et al. 2005; Nakanishi et al. 2006; DMCR 2018). Uncorrected counts suggest that the dugong population in the coastal waters of Trang Province comprises at least 154 individuals (DMCR 2018), making it one of the largest in Asia (Chapters 5–7). It is also the most comprehensively studied. An AoI with the potential for designation as an IMMA with the dugong as the qualifying species is under evaluation for Trang (IUCN-MMPATF).

Dugongs have been much less studied in the Gulf of Thailand where aerial surveys have been conducted only in specific areas (e.g., ordered west to east: Surat Thani, Nakhon Si Thammarat, Rayong, Chanthaburi and Trat; Figure 6.1). Panyawai and Prathep (2022) report: (1) evidence of live and dead dugongs from provinces such as Chon Buri, Chumphon, and Patt; and (2) that aerial surveys between 2017 and 2019 recorded dugongs off the coast of Rayong (at Paknamprasae), Chonburi (at

Sattahip Bay), Trat (at Mairood and Kood Island), Surat Thani (at Phumriang Bay and Samui Island), and Nakhon Si Thammarat (Tharai Island) (DMCR 2019 a,b).

- Uncorrected counts indicate that the dugong population in the coastal waters of the Andaman coast of Thailand is likely one of the largest in Asia. It is also the most comprehensively studied Asian population.
- An IMMA AoI with the dugong as the qualifying species is under evaluation for Trang.
- There appear to be fewer dugongs living in Thai waters of the Gulf of Thailand than in the Andaman Sea.

6.2.3 Peninsular Malaysia

The dugong was believed to be almost extinct in the waters of Peninsular Malaysia before the late 1990s (Marsh et al. 2002). This assumption was proved incorrect by the response to the 'Si Tenang' dugong calf incident in 1999 (Section 6.3.4). Current knowledge indicates that in Peninsular Malaysia dugongs occur only in the waters of the southern state of Johor. A helicopter survey along the east coast of Johor recorded sightings of 18 dugongs in Pulau Sibu, and nearby Besar and Rawa Islands (Mansor et al. 2000; Marsh et al. 2002). Dugong feeding trails were recorded in a seagrass meadow dominated by *Halophila ovalis* at the mouth of Sungai Boh (Boh River), a small tributary of Sungai Pulai (Pulai River) in Johor Strait (Marsh et al. 2002), as well as at the seagrass meadow of Tanjung Adang, near the estuary of Sungai Pulai where *H. ovalis, H. spinulosa* and *Enhalus acoroides* were present (Zulkifli Poh 2009).

Off the east coast of Johor, Ponnampalam et al. (2015) recorded 93 sightings of dugongs during aerial surveys covering 2,986 km of the Mersing Islands of Besar, Rawa, Seribuat, Sibu and Tinggi across eight days in July 2010. Twenty-four percent (n=22) were cow-calf pairs and the largest group comprised five individuals. The mean encounter rate was 7.04 dugongs hour^{-1} (Ponnampalam et al. 2015). In 2014–2016, line-transect surveys covering 23,790 km over 145 flying hours were conducted primarily over the Sibu-Tinggi Archipelago (Ponnampalam 2017). The surveys yielded 642 sightings of dugongs, of which 24.5% were groups with calves. Group sizes ranged from single individuals to a maximum of 43 animals (mean 1.9 ± 3.6 SD) (Ponnampalam 2017). Most dugongs were sighted in approximately the same areas off the west-southwest of Sibu Tengah Island, as during the 2010 survey (Ponnampalam et al. 2015). Dugongs were also observed in Pulau Tinggi during the 2014–2016 aerial surveys, however no calves were sighted (Ponnampalam 2017). Research conducted by Heng et al. (2022) in 2016–2017 further supported these findings, demonstrating that the main feeding grounds of dugongs in the east coast waters of Johor were concentrated in the mid-section of the subtidal seagrass meadow in Sibu Archipelago, particularly off the west and southwest of Pulau Sibu Tengah. Seagrass mapping indicated that the size of the meadow at the Sibu Archipelago was 12.9 km^2, making it the largest known continuous seagrass meadow in Malaysia (Heng et al. 2022). Eight dugongs, one individual and three groups including a cow-calf pair were sighted during a drone survey covering the northwest and southwest of Pulau Sibu, and the south of Pulau Sibu Tengah in 2017 (Ahmad et al. 2019).

Between 2009 and 2021, five dugongs were found dead in the western Johor (Tebrau) Strait and reported to the Fisheries Department by the fishermen of Mukim Tanjung Kupang (Musa 2021). While there was no indication of cause of death of an adult male dugong found in 2009 (Section 6.4.3), two dugong calves were believed to have drowned in a drift net (2010 and 2016); another two were caught in an illegal trawl net (2019).

Monthly community monitoring of multiple seagrass meadows in the western Johor Strait near the Sungai Pulai estuary between 2018 and 2021 (Kelab Alami 2022) recorded regular dugong feeding trails in several locations (two intertidal meadows and near Merambong Island). This study is not exhaustive given that feeding trails are difficult to monitor in deeper water due to turbidity, high vessel traffic and the known presence of bull sharks and crocodiles. Community monitoring estimated a population of less than six individuals including both adults and juveniles, based on the width of feeding trails.

It is possible that dugongs in this area also use the nearby Singapore Strait where a dead calf was found in 2021. This animal is believed to have been caught in an abandoned fishing net (S. Rahman personal communication via email to Marsh and Schramm 2024).

The Sibu-Tinggi Archipelago off the east coast of Johor, particularly the Sibu Island cluster, is the most significant habitat for dugongs in Peninsular Malaysia (Figure 6.1). In 2019, the area was designated the 'Mersing Archipelago' IMMA (area 1,244 km²), with dugongs as the qualifying species (IUCN-MMPATF 2022c).

Both contemporary and historical dugong studies indicate that the eastern areas (particularly the Mersing Archipelago) off the east coast of Johor, consistently harbor a higher concentration of dugongs compared to the western or southern Johor Straits. L. Ponnampalam (personal communication via email to Marsh, October 2024) considers there are no more than 100 dugongs in the waters of the Mersing Archipelago.

6.2.4 Singapore

The Johor Strait is a narrow water body (approximately 1 km wide at some locations) bound by Peninsular Malaysia to the north and Singapore to the south (Figure 6.3). It is crossed by two bridges: the Johor-Singapore Causeway and the Second Link. The Causeway does not allow water exchange, and thus effectively divides Johor Strait into two separate areas (Ng et al. 2015). The Singapore Strait extends from the southern coast of the main island of Singapore to the Riau Islands in Indonesia and includes 43 islands. Thus, the dugongs in Johor Strait are shared by Malaysia and Singapore; those in the Singapore Strait are shared by Singapore and Indonesia (Figure 6.3).

Figure 6.3. Geographic context of Singapore showing the place names mentioned in the text. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

Singapore is one of the world's largest container ports (World Shipping Council 2019). Ng et al. (2022 a,b) reviewed records of dugongs in this hyper-urbanised environment. They recovered 69 observations of live dugongs and carcasses between 1820 and 2021 and identified eastern Johor Strait as a dugong area of regional importance, especially during the northeast (December to early March) and southwest (June to September) monsoons. Ng et al. (2022 a,b) also found dugong feeding trails along the anthropogenically-disturbed Johor Strait and western Singapore Strait where extensive shoreline modification has occurred (Section 6.4.4). This region is the strongest global example demonstrating that dugongs will continue to use anthropogenically-modified environments (Ng et al. 2022 a,b).

- Dugongs persist in the hyper-urbanized environment of the waters of Singapore, despite the high level of anthropogenic disturbance.
- This region is the strongest global example demonstrating that dugongs will continue to use anthropogenically-modified environments.

6.2.5 Cambodia

Nelson (1999) suggests that dugongs were abundant in Cambodian coastal waters until around 1975. Nonetheless, no scientific data were collected until the 1990s (Tana 1998; Nelson 1999).

In 2004, comprehensive surveys conducted by Hines et al. (2004, 2008), including aerial and boat assessments, failed to detect any dugongs or feeding trails. However, the following studies suggest that dugongs occur along the southeast coast of Cambodia: (1) interview surveys conducted by Beasley et al. (2001); (2) sightings by coastal residents in Kampot and Kep Provinces (Cambodian Marine Mammal Conservation Project [CMMCP] 2023); (3) Hines et al.'s (2004) interviews of residents in fishing villages in Kampot and Kep in 2002 and 2004; and (4) a by-caught dugong in Kampot Province in 2018 (Tubbs et al. 2019) and dugong bycatch reported in the Kep and Kampot trawl fishery between August 2022 and September 2023 (Tubbs et al., 2024).

Since 2017, the CMMCP has interviewed fishers across five communities in Kep province, Bokor City and the Chaornghuon fishing community in Kampot. Data were collected through these interviews, citizen science calendars, land surveys, and boat surveys.

These sources recorded dugong sightings in the Kep Archipelago and along the seagrass meadows and reefs of Kampot in eastern Cambodia. A confirmed dugong sighting was made in Kep (June 2022) and Kampot (January 2023). In June 2023, CMMCP received information about the sale of dugong meat (suspected trawler bycatch) at Kep market (CMMCP 2023). In 2022, CMMCP staff received reports of three dugongs being killed: one was a juvenile stranded in Koh Pho after entanglement and another was a juvenile stranded in October 2020.

In eastern Cambodia, CMMCP respondents identified various potential locations for dugong sightings. While they reported no direct observations of dugongs, local knowledge persists regarding areas where dugongs may occur. This region is close to Phú Quốc Island in Viet Nam (see Section 6.2.6), where dugong hunting and sightings have been documented.

The status of the dugong in Cambodia is data deficient. The lack of regular, comprehensive surveys, and proximity to Thailand and Viet Nam make it challenging to draw definitive conclusions as individual dugongs almost certainly cross the international boundaries. Nevertheless, the relatively large area of seagrass meadows in both western and eastern Cambodia, plus observations of dugongs in the vicinity of these meadows, suggests the potential for dugong habitats in the region (Hines et al. 2008).

The IUCN Marine Mammal Protected Area Task Force (MMPATF) declared the transboundary 'Kien Giang and Kep Archipelago' IMMA, which covers the Kep Province in Cambodia and the Kien Giang Province of in Viet Nam. The dugong is a qualifying species (IUCN-MMPATF 2022b).

- The status of the dugong in Cambodia is data deficient.
- The relatively large area of seagrass meadows in both western and eastern Cambodia, plus observations of dugongs in the vicinity of these meadows, suggests the potential for dugong habitats in the region.
- The IUCN MMPATF declared the transboundary 'Kien Giang and Kep Archipelago' IMMA, which covers the Kep Province in Cambodia and the Kien Giang Province of in Viet Nam, with the dugong as a qualifying species.

6.2.6 Viet Nam

The coastal waters of southern Viet Nam support dugongs in some areas, particularly in the south (Figure 6.1), as evidenced by opportunistic observations over the last 60 years summarized below.

- Even though Perrin et al. (2005) reported that dugongs were present in the north of Hạ Long Bay (Quảng Ninh Province) near the border with China, verified occurrences are now limited to southwestern Viet Nam, especially the Côn Đảo Archipelago and Phú Quốc Island (Van Bree and Gallagher 1977; Cox 2002; Quang et al. 2005; Hines et al. 2008; UNEP/CMS 2011, 2016), where there are persistent reports of small populations.
- Quang et al. (2005) concluded that dugongs were still present in the waters around Phú Quốc Island but that the population had suffered a steep decline since the 1970s because of blast fishing, electric trawls, extensive uncontrolled use of fish corrals and fishing using illegal mesh sizes.
- The marine patrolling team of the Côn Đảo National Park, where dugongs are protected from fishing and development, consistently report opportunistic sightings of dugongs. Unpublished records from the Côn Đảo National Park also include three dugong strandings between 2017 to 2018 (L. Vu personal communication via email to Marsh and Schramm 2024).
- Between 2019 and 2022, the Center for Biodiversity Conservation and Endangered Species (CBES) undertook comprehensive dugong monitoring in Côn Đảo Archipelago (CBES unpublished data 2024). Unfortunately, due to the impacts of COVID-19 pandemic and limited funding, the study had to pause from late 2020 with a brief resumption in 2022. The last recorded data were of six dugong sightings: four from vantage point observations; two from opportunistic boat-based surveys. All sightings were of single animals within Côn Sơn Bay, southeast of Côn Đảo main island. Given the limited number of sightings, the size of dugong population cannot be estimated, though the low encounter rates suggest it is small.
- Dugong feeding trails were exclusively found within Côn Sơn Bay across multiple surveys, indicating year-round utilization of this area by dugongs, especially in the intertidal seagrass bed at Lò Vôi Beach, suggesting the possibility of this area serving as a potential high-density area for the dugong population in the Côn Đảo Archipelago.

- The 'Côn Đảo' region has been declared an IMMA with the dugong as a qualifying species (IUCN-MMPATF 2022a).
- The dugong population in the Côn Đảo Archipelago must be at high risk because of its isolation and may merit IUCN Red List of Threatened Species evaluation as a 'subpopulation' as discussed in Chapter 11.

- The status of the dugong in Viet Nam is data deficient.
- The most important, known areas for dugongs are Côn Đảo Archipelago and Phú Quốc Island.
- The 'Côn Đảo' region has been declared an IMMA with the dugong as a qualifying species.
- The dugong population in the Côn Đảo region must be at high risk because of its isolation and may merit IUCN evaluation as a 'subpopulation', depending on the availability of data.

6.3 Cultural values

Dugongs play an important cultural role in Continental Southeast Asia. The accounts below illustrate similarities and differences between Range States.

6.3.1 Myanmar

Dugongs are known as *Ye wet* (water pig) and *Ye thu ma* (mermaid) in Myanmar (Tun et al. 2010). The Salone people or sea nomads maintain ancient beliefs that connect deceased children with dugong reincarnation. Narratives from the Tanintharyi Region, on the Andaman coast of southern Myanmar (Figure 6.1) describe an animal resembling a dolphin with a pig-like face, a transition from a dolphin to terrestrial pig. This legend is believed to have stemmed from the absence of pigs on isolated islands, leading locals to hypothesize their transformation from dolphins, linked by dugongs.

Dugong parts were used for medicinal purposes: skin and bone were used to treat diarrhoea; blood to remove warts. Some people preserved dried dugong skin and bones for medicinal use. Some locals asserted that dugong meat had a superior taste to pork and advised against consuming dugong meat during pregnancy due to its perceived 'cold' nature (Tun et al. 2010).

An attempt was made to display a dugong at the Yangon Zoological Garden. The dugong known as 'Man Aung Nyunt' was caught from the waters of Man Aung Island in 1966 and transported to Yangon. Seagrasses were also collected from Man Aung Island and sent to Yangon to feed the dugong. 'Man Aung Nyunt' died a few months later.

6.3.2 Thailand

Various names like *Payoon, Moonurn, Moodud, Nguag, Datong,* and *Duyong* have been used to refer to dugongs, each carrying local significance (Adulyanukosol et al. 2010a). Moonam, used in southern regions, was derived from the pinkish meat resembling pork, while in Chanthaburi Province *Moodud* reflects the piggish appearance and feeding behaviour of dugongs (Boonprakob et al. 1983; Adulyanukosol et al. 2010a). The name *Ban Lo Duyong* in Krabi Province originated from the dugong's call, suggesting a history of dugong hunting in the area.

In the village of Ban Chao Mai in Trang Province, there is a legend about how a pregnant wife's craving for seagrass fruits led her husband to gather them daily. Unsatisfied, she ventured into the sea, indulged in the fruits, became trapped in the seagrass leaves, and transformed into a dugong. The husband joined his wife in the sea. The fruits of the seagrass, *Enhalus acoroides,* formerly held cultural significance as a snack (Adulyanukosol et al. 2010a).

Similarly, a legend from Talibong Island (Figure 6.1) linked a woman's transformation into a dugong due to cravings for seagrass (*Enhalus*) fruits, influencing the belief that dugong tears are a powerful love potion (Nateekanjanalarp and Sudara 1994). Along the Andaman coast in southern Thailand and northwestern Peninsular Malaysia, a local song and dance drama known as *Rong Ngeng,* or *Li Ke Pa* featured the coastal community of *Chao Le* or sea gypsies, reflecting the love between a man and a woman, symbolising the affection of a dugong cow for her calf. Sea gypsies believed that dugong tears are potent love potions:

'... I am thinking of the lady, I cannot eat any food because of touching the dugong tears. I cannot eat any food and I am always thinking of you all times.'

The sea gypsies emphasized that the ideal dugong tear for a love potion should come from a calf that has lost its mother, suggesting an understanding of the close relationship between dugong cows and their calves. In more recent years, new songs focusing on dugongs and conservation aim to raise awareness among local communities and the younger generation (Adulyanukosol et al. 2010a).

Cultural beliefs in Thailand attribute aphrodisiac, protective, and anti-rheumatic properties to various dugong body parts, including bones, skin, tears, and tusks. A pair of tusks was valued at THB 10,000 (approximately USD 230) and tusks were openly traded through village officials as reported by Nateekanjanalarp and Sudara (1994).

In Trang, some villagers near Hat Chao Mai National Park formerly used body parts from stranded dugongs, such as teeth and tusks, as aphrodisiacs. This raised conservation concerns, with publicised reports attributing declining dugong numbers to traditional uses. The Department of Fisheries issued warnings against possessing dugong body parts, emphasizing legal consequences, however violations persisted as locals considered dugong meat delicious and adhered to a historical tradition of hunting them. In Trat, one family used dugong oil to treat muscle pain (Adulyanukosol 2002a). Rings made from dugong bone and tusks were found in Krabi Province, with reports of illegal exportation to black markets for use in Chinese medicine by a family in Nua Khlong (Adulyanukosol 2002b).

In the past, coastal villagers consumed meat from dugongs caught incidentally in their fishing gear, believing this practice accorded with their religious beliefs. Rojchanaprasart et al. (2014) suggested that traditional ecological knowledge regarding dugongs directly influences their conservation and encouraged coastal villagers to participate in dugong conservation, supporting their participation in conservation planning as stakeholders in co-management.

An orphaned dugong calf, later nicknamed 'Marium' found by local villagers in the Andaman Sea, was relocated to a sheltered area around Koh Libong in Trang Province in 2019. News of 'Marium', her daily interactions with her carers and the efforts to care for her, featured in news outlets around the world. 'Marium' died in August 2019 from infections resulting from plastic ingestion. Her death sparked outpourings of grief on social media and resulted in the Thai government declaring 17 August as 'National Dugong Day' (Ponnampalam et al. 2022).

Dugongs feature in street sculptures and fountains around the town of Trang, on the Andaman Sea coast (Figure 6.4).

Figure 6.4. Fountain in Trang, Thailand decorated with dugongs. Patrick Lepetit photograph; reproduced with permission, courtesy of the photographer.

6.3.3 Peninsular Malaysia and Singapore

The name dugong is derived from the Malay word *duyong* which means 'mermaid' or 'lady of the sea'. Sir Thomas Stamford Raffles (Raffles 1821), then British Governor of Sumatra, wrote that the Malays considered dugongs to be a symbol of maternal affection because of the care given by a female to her calf, and provided insights into how these strong bonds were exploited when dugongs were hunted:

'During our short possession of Singapore (not more than six months) four of these animals have been taken; but the greatest number is said to be caught during the opposite or northerly monsoon, when the sea is calmest, near the mouth of the Johore river, in the inlet of the sea between Singapore Island and the main. They are usually taken by spearing (at which the natives are particularly dexterous) during the night, when the animals give warning of their approach by the snuffling noise they make at the surface of the water……When they succeed in taking a young one, they feel themselves certain of the mother, who follows it to the margins of the sea, and allows herself to be speared or taken with the greatest ease' (Raffles 1821 p. 345).

This account confirms that dugongs were hunted by the people of the Johor Straits. Dugong meat was described as 'excellent beef' and highly prized by the Malay people at the time. Abraham (1924) reported that dugongs in Singapore's waters were hunted by the indigenous Orang Laut (sea gypsies) using a traditional harpoon called a *tempuling* fitted with a stout line fastened to the harpoon head. The *Orang*

Laut 'played' with the harpooned dugong until it tired and died. The meat of the animal was then sold to Malay and Chinese people.

The Malays considered the 'congealed mucus secretion of the eye-lids' to be a powerful love potion (Gibson-Hill 1950). In Singapore, Raffles (1821) reported that when dugong calves were caught, they had 'a short sharp cry, which they frequently repeat; and it is said they shed tears' (p. 345), which were used as a charm to secure the affections of a prospective lover. While the fishers do not eat the meat, some claim that boiling the bones creates a tonic that is good for one's health (S. Rahman personal communication via email to Marsh and Schramm 2024).

Interviews with the Seletar community in the western Johor Strait, Malaysia (Zulkifli Poh 2009) indicate that the indigenous Seletar people, who once occupied the Johor Strait as sea nomads (the *Orang Laut* mentioned in Abraham [1924]), used to hunt for dugongs for their meat and body parts. As dugong occurrences are incredibly rare in modern times, younger members of the Seletar community do not possess the same cultural connection with dugongs as their elders and know about dugongs only from the tales their elders have shared (Zulkifli Poh 2009).

Throughout much of the 20th century, the dugong was considered to be extinct in the waters of Peninsular Malaysia and Singapore. In 1999, Atan Hussein, a fisherman in Johor accidentally caught a 1.5 m long dugong calf, later nicknamed 'Si Tenang,' in a fishing net. He subsequently kept and cared for 'Si Tenang' in his *kelong*, a wooden offshore platform similar to a fish corral but primarily used for fishing (Sia 2017). Atan kept the dugong in his *kelong* and tended it for six weeks until he was forced to release the animal on the directive of the Fisheries Department. He was very upset when 'Si Tenang' was found dead 48 hours later, followed shortly afterwards by the carcass of an adult female. The event attracted global publicity and comment from the Malaysian Prime Minister and was a catalyst for research on dugongs in Malaysia.

'Gracie', a female dugong, was displayed at Underwater World in Singapore from 1998 to 2014. She was rescued as a suckling calf when her mother drowned in a fishing net in Pulau Ubin, Singapore. She grew very slowly and was very small for her age when she died (Marsh 2022).

6.3.4 Cambodia

Hines et al. (2008) interviewed fishers in Koh Kong (western Cambodia), Kampot and Kep provinces (eastern Cambodia) (Figure 6.1). All respondents from Koh Kong claimed that the dugong had never been hunted, whereas all interviewees in eastern Cambodia reported historical hunting. Dugongs in both areas were still occasionally caught accidentally and fetched a good price in the market. Since the 2006 fisheries law prohibiting catching or selling dugong was foreshadowed in 2004, the fisheries authorities claimed that dugongs caught in nets were released. Nonetheless, Beasley and Davidson (2007) reported that dugongs, which are seen as symbols of good luck, were highly sought after for their meat, internal organs, bones, and tusks, with tusks fetching up to USD 200. Local people used dugong bones as medicine against fevers and to protect livestock from illnesses. The tusks and skull were processed and sold for medicinal use (Beasley et al. 2001; Beasley and Davidson 2007).

Recent reports indicate that the active hunting, killing, and illegal trade of dugongs persist in Cambodia (CMMCP 2023).

6.3.5 Viet Nam

The cultural significance of dugongs in Viet Nam manifests in whale temples, consumption practices and traditional rituals. The whale temples, along the southern and central coastlines, generally known as *Lăng Ông*, serve as repositories of natural history information, particularly marine mammals (Smith et al. 1995, 1997; Vu et al. 2020). McGowen et al. (2021) found dugong skulls in whale temples in Đà Nẵng and Chàm Island (Figure 6.1). No dugong skulls were found in the other whale temples visited by McGowen et al. (2021).

Hines et al. (2008) explored the cultural relevance of dugong meat through interviews. Market sellers in Dương Đông (Phú Quốc Island, Kien Giang Province; Figure 6.1) described the diminishing availability of dugong meat since 1994-1995. At the time of Hines' (2008) survey, the meat was so precious that fishers who caught dugongs no longer sold it in the market, though this may have been due to the regulations put in place to protect dugongs (L. Vu personal communication via email to Marsh and Schramm 2024). Some fishers in nearby Hàm Ninh and Bãi Thơm were continuing to actively catch dugongs with sting ray/shark nets imported from Japan or Korea.

Hines et al. (2008) were told that dugong meat remained a staple in the diets of these communities, with the skin used in a special hot-pot dish. Each part of the dugong was valued: large tusks fetched up to USD 650 when sold for Chinese traditional medicine or tourism; the skin was valued at USD 4 per kg; ear bones USD 6.50 each, and various bone pieces, notably ribs, USD 0.20-0.65. Tusks, bones, and dried bile ducts were used in various medicinal practices.

6.4 Threatening processes

Even though direct hunting has declined over the past decade, dugongs in Continental Southeast Asia are subjected to several threatening processes, most significantly: incidental catch by both small-scale and illegal commercial fishers, rapid development causing habitat loss, and habitat degradation from destructive fishing methods. These threats have root causes such as: rapid population increase, poor education, inadequate law enforcement, marginalization of small-scale fishers, and poverty, albeit with variations in intensity in the various Range States. Singapore is an outlier as explained below.

The interactions between dugongs and small-scale fisheries are the most serious contemporary threat to dugongs globally (Marsh and Sobtzick 2019). Small-scale fisheries are a vital component of livelihoods across the dugong's Range States in Continental Southeast Asia, particularly in rural coastal and island areas (Pomeroy 2012; Teh and Pauly 2018). Thailand and Viet Nam lead in terms of both human population size and fisheries production. Peninsular Malaysia produces a high volume of fisheries products, despite a smaller human population. Myanmar and Cambodia face the greatest economic challenges in this region. Singapore, a small yet affluent nation, plays a substantial regional role through its involvement in commercial fish trade and consumption, and large-scale shipping (Fabinyi et al. 2022).

6.4.1 Myanmar

The demand for dugong meat in Myanmar is relatively weak with only a few locals considering it a delicacy or attributing medicinal properties to body parts (Tun et al. 2010; Section 6.3.1). Direct threats to dugongs in Myanmar are considered to occur at relatively low levels. Occasional opportunistic killing with hand harpoons, primarily localized in areas like Gwa (Figure 6.1), has been reported (Ilangakoon and Tun 2007; Tun and Ilangakoon 2007).

Fishing is the major source of dugong mortality in Myanmar. Although gillnets and set nets pose risks along the Rakhine coast, more destructive methods like explosives and push nets are not used (Ilangakoon and Tun 2007; Hines 2012). However, underreporting of dugong strandings and bycatch presents a significant challenge due to a lack of established reporting mechanisms and limited awareness about dugong conservation among coastal communities and authorities (Hines 2012).

6.4.2 Thailand

The absence of significant reports of deliberate dugong hunting in the past four decades is attributed to the implementation of the *Fisheries Acts of B.E. 2490 (1947)* (Adulyanukosol 1998, 2004; Hines 2012). Small-scale fisheries in Thailand are overshadowed by large-scale commercial fishing (Teh and Pauly 2018), aggravating coastal poverty and depleting fishery resources, making dugongs victims of intense fishing activities, whether trapped by illegal fishing gears or sold for profit if incidentally caught (Hines 2012).

Threatening Processes

Bycatch in artisanal fishing and illegal hunting for body parts are still principal causes of dugong population decline, even though illegal hunting no longer occurs in some Range States

Loss and degradation of coastal seagrass is a major problem in all important dugong habitats in the region.

Extreme events have direct impacts on dugongs through strandings, and indirect impacts from seagrass loss.

The cumulative impacts of fishing mortality and habitat loss make coordinated conservation interventions across the region very important, especially as several Range States have not yet signed the Dugong MOU.

The degradation of mangroves, seagrass meadows, and coral reefs along the Andaman coast is a serious indirect threat to dugongs, driven by overfishing, destructive fishing techniques, and the removal of mangrove forests for shrimp or shellfish farming (Hines 2012; Fabinyi et al. 2022). The potential threat of seagrass community degradation due to global climate change and coastal development further compounds this habitat loss (Khogkhao et al. 2017). The rapid increase in the coastal population intensifies the pressure on natural resources, through activities like tin dredging near the shore and sedimentation from land-based mining, mainly in Phuket, Phangnga, and Ranong provinces (Hines 2012).

In recent years, reports of emaciated and dead dugongs along the Andaman coast of Thailand (Daochai et a. 2024) have been linked to seagrass dieback (Wipatayotin 2024). This ongoing situation is summarized in Text Box 6.1.

TEXT BOX 6.1. The status of seagrass and dugongs along the Andaman Coast of Thailand in January 2025

- In response to government and community concern about the loss of seagrass and increase in the number of dead and emaciated dugongs along the Andaman Coast, WWF Thailand organized and supported a fact-finding mission with the cooperation of the Thai Department of Marine and Coastal Resources (DCMR).
- The Mission Team spent five days on the Andaman Coast in January 2025, bookended by briefing sessions with DCMR in Bangkok. The team inspected the condition of seagrass meadows, was briefed on attempts at seagrass restoration, observed the use of drones to monitor the distribution, abundance and behavior of dugongs at local (bay) scales and met with local experts from universities and DMCR, NGOs and community groups.
- The Mission concluded that the root cause of the recent seagrass loss along the Andaman coast is unknown. The impacting factors are unclear and cumulative, and appear to be:
  - reduced light availability from siltation
  - chronic and diffuse land runoff/river discharge
  - acute and point source human activities, e.g., dredging, reclamation, etc.
  - elevated sea temperatures
  - elevated daytime tidal exposure
  - elevated dissolved nutrients
  - Green turtle herbivory of remaining seagrass shoots.
- Different parts of the Andaman coast had experienced different levels of seagrass loss. The most serious losses were in the coastal water in Trang Province. In contrast, seagrass was in fair to good condition in Krabi, Phang Nga and Phuket Provinces. Dugongs, including a mating pair, were sighted by the Mission Team via DMCR and citizen science drones.
- Dugongs were responding to seagrass dieback along the Andaman coast in a manner similar to that observed in 10 seagrass diebacks recorded in Australia, since the 1970s (Chapter 1). with increased strandings, reduced breeding and moving from the area of dieback as follows.
  - Dugong strandings along the Andaman Coast in 2023-24 averaged 42 per year compared with an average of 20 per year in 2019-22; 40% of dugong strandings were in an emaciated state, especially along the Trang coast (Piyarat Khumraksa DMCR, unpublished data provided to Marsh in January 2025).
  - Calf counts on aerial surveys had declined from 9% in 2020-2023 to 3% in 2024 (calculated by Marsh from DMCR data provided in January 2025)
  - The Mission Team received consistent reports that the dugongs are no longer sighted in the waters of Trang Province.
- The Mission Team was told that there is no evidence of reports of unusual numbers of Green turtles in poor condition or dead, a situation unlike that reported in Australia in association with large-scale seagrass diebacks. This difference is likely due to greater opportunities in Thailand for turtles to feed on shoots of the most persistent seagrass *Enhalus* (which is rare in or absent from several of the locations where seagrass dieback has occurred in Australia) and eat fish in nets.

6.4.3 Peninsular Malaysia

Fishing practices are a major threat to dugongs in Peninsular Malaysia. The risks to dugongs associated with trawling, the most extensively used fishing gear, go beyond immediate mortality due to propeller wounds and gear entanglement, and include substantial habitat damage. In addition, at least two of the 18 recorded dugong deaths from around Sibu and Tinggi since 2014 (all of which were juveniles), had been caught in an illegal longline known locally as *rawai hantu* (Hines et al. 2020).

Hashim et al. (2017) conducted habitat risk assessments on dugongs in Johor. Hines et al. (2020) used the Bycatch Risk Assessment (ByRA) toolkit, based on InVEST open-source models, to identify zones of elevated risk to dugongs from fishing in Johor waters. Hines et al.'s (2020) modelling indicated the following high-risk locations: (1) dugongs in and around Sultan Iskandar Marine Park surrounding Sibu Island from vessels that originated from the mainland pier at Tanjung Leman; (2) near Mersing, a local fishing port, and (3) around Besar Island to the north (Figure 6.1).

In western Johor Strait, several dead dugongs have been reported by the local community of Mukim Tanjung Kupang, Gelang Patah. In 2009, a local fisherman found a 3.1 m adult male dugong washed ashore near Sungai Pok (Pok River). The dugong's face was slashed, a result of the removal of the dugong's tusks 'for good luck'. Locals believe the dugong died of natural or other causes, and that the tusks were removed after death (S. Rahman personal communication via email to Marsh and Schramm 2024).

Kelab Alami, a local community organisation has been monitoring the coastal habitats and endangered species of the western Johor Strait since 2008, combining citizen science, community research and local ecological knowledge. A dead dugong calf was found in 2010 at the Tanjung Adang seagrass meadow, near the Port of Tanjung Pelepas. The calf was believed to have drowned in a fishing net; it was found with blood seeping from its nose. Another calf was found dead floating in the Tanjung Kupang seagrass meadow in 2016 apparently having drowned in a drift net (S. Rahman personal communication via email to Marsh and Schramm 2024). In 2019, an additional two dead calves were found trapped in an illegal trawl net (banned in nearshore waters) that was owned by local villagers. This incident was reported to the Fisheries Department, and the nets seized (S. Rahman personal communication via email to Marsh and Schramm 2024).

Seagrass habitat degradation is further increased by land reclamation and chemical runoff from oil palm plantations (Hashim et al. 2017; Bujang et al. 2018). Coastal development, especially from 1997 to 2014 along the Johor Straits (Figure 6.3), has caused significant changes in dugong habitat conditions (see Bujang et al. 2018), suggesting a close correlation between dugong deaths and anthropogenic disturbance (Hashim et al. 2017).

Although reclamation of a new island (Forest City) in the western Johor Strait resulted in the burial and damage to parts of the Tanjung Kupang seagrass meadow, dugong feeding trails were found in the area throughout the development period. When coastal hydrology was restored by the removal of a sand-bridge, the buried seagrass quickly recovered (S. Rahman personal communication via email to Marsh and Schramm 2024). Feeding trails continued to be observed until unseasonal, extreme weather occurred in 2022-2023, resulting in extensive algal build-up over the seagrass. Seagrass monitoring in 2024 indicated that there are still both adult dugongs and calves feeding in western Johor Strait despite the extensive coastal development (S. Rahman unpublished 2024).

6.4.4 Singapore

Coastal habitat loss in the region has been particularly severe, with Singapore experiencing a significant decrease in its natural coastline length between 1922 and 2011, accompanied by substantial loss of intertidal habitats (Lai et al. 2015). The urbanization of coastal areas and a subsequent surge in anthropogenic uses of sea spaces have been identified as major drivers of dugong population decline (Hines 2012). Land reclamation activities along the Johor and Singapore Straits, dating back to the mid-1800s and intensifying after 1965, have caused extensive reduction in intertidal habitats, including seagrass meadows (Lai et al. 2015).

Ng et al. (2022 a,b) observed peaks in dugong observations coincident with the northeast and southwest monsoons. Distribution patterns of stranded carcasses have been associated with a combination of natural and anthropogenic factors such as seasonality in seagrass abundance, tidal cycles, wind patterns, and vessel traffic. Additionally, the high volume of vessel traffic and shipping activities in Singapore's coastal waters, coupled with the impact of wind or vessel-generated waves and noise on foraging activities, further compounds the challenges faced by dugongs in the Johor and Singapore Straits (Ng et al. 2022 a,b). Ongoing and future reclamation plans for areas along the Pulai and Johor Rivers are expected to exacerbate these losses, posing a significant threat to dugong foraging and calving grounds (Ponnampalam et al. 2022).

6.4.5 Cambodia

Dugongs are directly targeted for their body parts, making them highly endangered in Cambodian waters (Marsh et al. 2002; Hines et al. 2004; Beasley and Davidson 2007; CMMCP 2023). The nets used by small-scale commercial fishers, particularly Spanish mackerel and trawl fishing nets, incidentally catch dugongs (Beasley and Davidson 2007; Tubbs et al., 2019, 2024). This challenge is further compounded by habitat degradation and overfishing, driven by contemporary fishing techniques and the ever-increasing coastal population and poverty (Hines 2012).

Seagrass meadows are under severe threat, especially in areas like Kep, where the meadows are not valued by local people (Marsh et al. 2002; Beasley and Davidson 2007; Hines et al. 2008). The risks are heightened by the expansion of shrimp farms and the mounting pressure from a burgeoning coastal population. The root cause of these environmental harms was reported to be poverty in the early 2010s (Hines 2012).

6.4.6 Viet Nam

Direct hunting of dugongs near Phú Quốc Island (Figure 6.1) was an ongoing threat early this century. Dugongs were hunted for various purposes, including food, medicine, and money (Hines et al. 2008; Hines 2012). Other threats include incidental catch by small-scale and illegal commercial fishers, and the escalating use and degradation of seagrass meadows (Hines et al. 2008; Hines 2012). Kiên Gian Province is home to Phú Quốc Island, a critical location for dugongs in Viet Nam, and boasts 10,880 registered fishing boats and an annual seafood catch exceeding 636,170 tons (Hines et al. 2020). Numbers for Phú Quốc Island alone were unavailable at the time of writing. The intensive use of gillnets and trawling gears, exacerbate the challenges faced by dugongs (Hines et al. 2020).

While seagrasses remain abundant in some regions, their degradation is widespread due to aquaculture and sedimentation, declining water quality, overfishing, and coastal development, especially near Phú Quốc Island (Sudo et al. 2021). Additional problems include sewage discharge into seagrass areas and destructive fishing (Hines 2012). Despite a positive trend in seagrass meadow expansion in certain areas of Viet Nam, a significant decline has been observed in most regions over the past two decades (Sudo et al. 2021).

In the Côn Đảo Archipelago, the management of dugong hunting appears to have been addressed through coordinated efforts involving the patrolling activities of Côn Đảo National Park and various conservation education initiatives by local and international NGOs (L. Vu personal communication via email to Marsh and Schramm 2024). However, the recent surge in coastal development and land acquisition along the beaches in this region pose significant threats to the integrity of all seagrass beds. The construction of six premium resorts, some of which are already built, in Côn Sơn Bay, southeast of the Côn Đảo main island, where the majority of dugong feeding trails have been identified, exacerbates these concerns. Moreover, infrastructure development activities, including road construction and expansion along the coastline of the main island, are contributing to sediment discharge to seagrass beds. Since 2022, the construction of new speed ferry piers in Côn Sơn Bay directly threatens established dugong habitats. The growing popularity of speedboat tours within Côn Sơn Bay also raises the risk of potential boat-dugong collisions, with at least one dugong sighted by CBES displaying evidence of propeller cuts on its body (L. Vu personal communication via email to Marsh and Schramm 2024). The escalating trend of unsustainable tourism further jeopardizes the health of seagrass beds in Côn Đảo, as evidenced by CBES's observations of extensive trash dumping in these critical habitats during seagrass bed surveys. Unlike Phú Quốc, where dugongs can move between seagrass beds, dugongs in the Côn Đảo Archipelago are particularly vulnerable to seagrass loss due to the relatively isolated nature of the archipelago and the absence of alternative habitats nearby. The nearest shoreline lies 80 km west of the islands, and the closest known seagrass meadow is at least 400 km away. These factors underscore the urgent need for comprehensive conservation measures to mitigate the escalating threats facing the dugong population and their habitats in the Côn Đảo Archipelago.

6.5 Conservation initiatives

6.5.1 International conventions

All dugong Range States in Continental Southeast Asia are signatories to the Convention on Biological Diversity, the United Nations Framework Convention on Climate Change, and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). None is a participant in the Convention on Migratory Species of Wild Animals.

Only Myanmar and Thailand have signed the Dugong Memorandum of Understanding (Dugong MOU).

6.5.2 National laws

The information in this section is based on Ezekiel's (2018) review of marine wildlife protection in Association of Southeast Asian Nations (ASEAN) including an evaluation of their strengths and weaknesses.

6.5.2.1 Myanmar

Myanmar has implemented several legal measures that safeguard dugongs including:

- The *2018 Law Relating Conservation of Biodiversity and Protected Areas*, which classifies dugongs as 'Completely Protected Wildlife'.
- The Myanmar *Marine Fisheries Law's Article 23*, a directive that explicitly prohibits activities such as catching, killing, wounding, harassing, storing, transporting, transferring, selling, exporting without permission for whole or part of the dugong and the requirement to release a dugong immediately if it is caught alive (T. Tun personal communication via email to Marsh and Schramm 2023).
- *Animal Health and Development Law No. 17, 1993* (amended 2010), which addresses cruelty to animals, including marine wildlife, in trade.
- The *Notification for Control of Endangered Fish Species* which deems the capture, possession, trade, or export of CITES-listed marine species, including the dugong, to be an offense.

Myanmar prohibits destructive fishing methods, including poisons and explosives, through various laws such as the *2002 Rules, Marine Fisheries Law,* and *Law Relating to the Fishing Rights of Foreign Fishing Vessels*. There are some exemptions from the prohibition on possessing protected wild animals in the *Protection of Wildlife and Conservation of Natural Area Law,* such as the use of body parts as drugs, making the law less effective (Ezekiel 2018).

6.5.2.2 Thailand

The official protection of dugongs in Thailand dates from the *1947 Fishery Act*. The Act prohibits activities such as the possession, capture, entrapment, and destruction of dugongs. The *2015 Royal Ordinance on Fisheries B.E. 2558* replaced the *Fisheries Act* and strategically targets illegal, unreported, and unregulated (IUU) fishing. This ordinance intricately details licensing requirements, control measures, and penalties, emphasizing sustainable fisheries management.

The protection of the dugong under the Fishery Act is reinforced by other laws including:

- The 1992 *Wildlife Preservation and Protection Act,* which lists the dugong as one of the 15 species on Thailand's wildlife reserve list.
- The *2014 Wild Animal Reservation and Protection Act (WARPA) (No. 3) B.E. 2557,* which governs the establishment and management of Wild Animal Sanctuaries and Non-Hunting Wild Animal Areas. This critical legislation has undergone many amendments, with a current draft proposing intensified penalties and expanded protected status, aligning with international obligations, such as CITES.
- The *2015 Promotion of Marine and Coastal Resources Management Act B.E. 2558*, which aims to consolidate marine and coastal management. This act establishes a national committee responsible for formulating policies, management plans, and regulations and grants the authority to establish marine and coastal protected areas, enforcing penalties for violations and ensuring the prevention of severe damage to marine or coastal resources.
- The *2016 Regulation governing the Import, Export and Bringing in-transit of Marine Life B.E. 2559,* which introduced regulations focused on protecting rare marine species by banning the import, export, or transit of specified marine species without a permit.

Although this legal framework reflects Thailand's commitment to marine conservation, effective implementation remains challenging. Ongoing amendments and proposed enhancements, such as increased penalties and extended protected status, signify the intent to address ongoing challenges. The lack of specific bycatch mitigation measures in the Ordinance on Fisheries and ambiguities within WARPA are weaknesses.

6.5.2.3 Peninsular Malaysia

In Peninsular Malaysia, there are numerous laws to preserve marine diversity, including dugongs:

- The *Fisheries Act 1985 (Part 5, Section 27),* and the Fisheries *(Control of Endangered Species of Fish) Regulations (Amendment) 2008,* whereby dugongs are listed as marine endangered species. It is therefore prohibited by law to catch, harass, consume, possess, hunt, trade or export a dugong or any of its body parts. If the dugong has been accidentally caught while fishing and is still alive at the time of capture, it must be

released immediately. If the animal has died, its incidental capture must be reported to the Department of Fisheries Malaysia.
- The *International Trade in Endangered Species Act No. 686 of 2008* is Malaysia's principal CITES-implementing legislation. This act takes precedence over other laws regarding the protection, import, or export of plants and animals. The *International Trade in Endangered Species Act* provides comprehensive protection for CITES-listed species. It prohibits various activities, including the import, export, and possession of scheduled species without the necessary permits. The Act's detailed schedules and appendices ensure up-to-date protection.

In 2011, the Department of Fisheries Malaysia published a Dugong National Plan of Action (NPOA) to serve as a reference and guide for dugong research, conservation, monitoring, and management activities across the country. As of 2024, the NPOA is undergoing an update and will be published as the Dugong NPOA Plan 2 (L. Ponnampalam personal communication via email to Marsh and Schramm 2024). Although Malaysia's national laws reflect its commitment to preserving its rich marine biodiversity, the effectiveness of these laws relies on vigilant enforcement and careful consideration of exemptions.

The fishermen of Pasar Pendekar Laut (Sea Warriors Market, a Fisheries Community Organisation (MyKP), also part of the Kelab Alami initiative) at Sungai Che Manan (Che Manan River) have a sustainable fisheries programme under which they report sightings of endangered species, as well as releasing and reporting any megafauna caught in nets or or longlines. Over the COVID-19 pandemic period, when there was much less vessel traffic in the western Johor Strait, fishermen reported sightings of dugongs near the Tanjung Kupang seagrass meadow, Merambong Island, as well as closer to the Second Link Bridge to Singapore. These sightings were of a cow-calf pair, as well as lone adults. MyKP are currently working to establish a community-led conservation area, in which fishermen are employed as marine rangers to continue and expand on the current sustainable fisheries programme (Rahman 2021). This initiative hopes to bring local stakeholders together to prevent and mitigate damage to the western Johor Strait, with the community leading the way in providing local marine ecological information, monitoring the seascape, and working with scientists and local agencies to protect coastal ecosystems.

6.5.2.4 Singapore

The dugong is protected by four laws in Singapore: (1) the *Endangered Species (Import and Export) Act (2006, revised 2008),* which ratifies Singapore's commitment to CITES, by mandating permits for the import, export, re-export, and introduction from the sea of scheduled species. Penalties for violations are stringently enforced. (2) The *Wild Animals and Birds Act (1965, revised 2000)* regulates the collection, possession, and trade of wildlife within Singapore. (3) The *Animals and Birds Act (1965, revised 2002),* which prevents animal cruelty. (4) The *Fisheries Act (1966, revised 2002),* which controls fishing activities within Singaporean waters and by nationals outside territorial waters.

Singapore's marine wildlife protection laws and the relatively robust ways in which they are enforced are evidence of the nation's commitment to environmental stewardship.

6.5.2.5 Cambodia

Cambodia's legal framework for protecting dugongs and marine resources is comprehensive, incorporating a range of measures to regulate wildlife-related activities. Nonetheless, Cambodia grapples with enforcement and compliance.

- The protection of marine resources including dugongs is underpinned by 2006 legislation, which specifies that it is illegal to catch, sell, buy, or transport them due to their endangered status. This legal framework places responsibility on the Ministry of Agriculture, Forestry, and Fisheries to safeguard and preserve the habitats of dugongs (Hines 2012).
- The dugong is classed as a Critically Endangered Marine Species by the 2009 *Sub-Decree No. 123 2009* (Cambodia, Ministry of Information 2020). Complementing this primary legislation is *Sub-Decree No. 53,* which ratifies Cambodia's commitment to providing protected status for all CITES-listed species. In addition, the Ministry of Agriculture, Forestry and Fisheries promulgated a *Proclamation No. 571 MAFF on the Measures to Protect Endangered Fisheries Resources*.
- Destructive fishing methods are banned by the *Law on Protected Areas and Law on Fisheries.* Requirements for licenses, permits, vessel registration, and logbooks further enhance the comprehensive legal structure governing fishing activities.

Despite the clear legal situation, implementation challenges persist. The absence of measures to mitigate bycatch is a significant weakness, and enforcement powers are vaguely defined by the *Law on Protected Areas*. Dugongs are still being actively hunted and sold (CMMCP personal communication via email to Marsh and Schramm 2023). There is a pressing need for enhanced law enforcement, particularly concerning Cambodian-flagged vessels and national fishing activities extending beyond the exclusive economic zone.

6.5.2.6 Viet Nam

Viet Nam has made proactive efforts to protect marine resources, including dugongs using a complicated legislative process which proliferates implementing regulations for its laws (Ezekiel 2018). Laws passed by the National Assembly are often broad and general, requiring implementation regulations to be effective. Examples are listed below. Ezekiel (2018) provides a comprehensive list.

- The Red Data Book of Viet Nam reinforces the Critically Endangered status of dugongs (UNEP/CMS 2016). A directive explicitly prohibits hunting, transport, or consumption of dugongs.
- *Government Decree No. 160/2013/ND-CP* outlines strict regulations for the exploitation, transfer, trade, or storage of endangered, precious, and rare species prioritized for protection, including dugongs and emphasizes scientific research and biodiversity preservation.
- *Government Decree No. 187/2013/ND-CP* provides a framework for implementing CITES by prohibiting the export of rare and precious wild animals and setting requirements for permits for CITES-listed species.
- The Ministry of Agriculture and Rural Development's *Decision No. 82/2008/QD-BNN* identifies endangered aquatic species, necessitating protection under current legislation.
- *Circular No. 50/2015/TT-BNNPTNT* facilitates the certification of catches, addresses market requirements and contributes to sustainable fisheries management.
- *Ministry of Fisheries Circular No. 02/2006/TT-BTS* serves as a comprehensive guide for implementing *2005 Government Decree No. 59/ND-CP*, aligning with the *2003 Fisheries Law* and regulating production and business conditions for diverse fisheries including: conditions and procedures for obtaining permits for the exploitation of aquatic resources restrictions on permits in closed seasons, no-exploitation areas, or listed entities banned from exploitation. The Circular explicitly bans fishers from using dynamite, electricity, chemicals, and mesh sizes smaller than specified. It also prohibits the exploitation of aquatic resources by fishing vessels or trades banned from operation or operating in specific areas.

While this legal framework is robust, effective implementation remains a concern. There is a need for enhanced law enforcement, especially concerning the International Plan of Action to Prevent, Deter and Eliminate IUU Fishing activities, and ongoing efforts to combat illegal hunting.

6.5.3 Other conservation initiatives

6.5.3.1 Myanmar

- **The Coastal Development and Biodiversity Project** addresses the challenges posed by the anticipated rapid development of coastal areas, driven by increased foreign investment through summarizing available information on coastal biodiversity, identifying key areas, and assessing existing or planned development projects. The initiative seeks to promote responsible and sustainable coastal and infrastructure development, fostering partnerships for a balanced and conservation-oriented approach (Zöckler et al. 2013).
- **The Building Capacity for Community-based Marine Conservation project** comprised community education on dugong conservation including interviews, talks, and environmental education campaigns. The project was conducted along the southern Rakhine and Tanintharyi coasts, and the Myeik Archipelago (Fauna and Flora International [FFI] 2015).
- **Marine Protected Areas (MPA):** 43% of known seagrass meadows are protected in MPAs and Ecologically and Biologically Significant Areas (EBSAs) at the national park level (Sudo et al. 2021). Many surveys and assessments have been conducted recently and researchers are pushing for all seagrass areas to be protected in MPAs or by other means.

6.5.3.2 Thailand

Approximately 20% of Thailand's seagrass meadows are situated within MPAs and EBSAs. However, these areas lack specific protection designations such as Strict Nature Reserve, Wilderness Area, or National Park, and lack specified protection details (Sudo et al. 2021).

- **The SeagrassNet monitoring program** initiated in February 2006 at Haad Chao Mai National Park in Trang Province initially focussed on the Andaman Sea coast before expanding to the Gulf of Thailand. Rattanachot et al. (2018) assessed the impact of seagrass conservation efforts and found an increase of 0.7 hectares in total seagrass area.
- **SEAGONG – Community-Based Seagrass and Dugong Conservation Initiative** empowers coastal communities by co-designing and managing seagrass and dugong conservation areas. Employing participatory methodologies, the project centres on sustainable fisheries, climate change adaptation, and fostering alternative livelihoods. Aligned with Thailand's community-based marine resource management policy, SEAGONG collaborates closely with the Department of Marine and Coastal Resources (DMCR), emphasizing local community engagement in the conservation of mangroves, coral reefs, seagrass, and marine endangered species, including training in seagrass nursery establishment, in situ propagation and dugong population monitoring using sonar and unoccupied aerial vehicles (UAVs). Alternative livelihoods are fostered through market needs assessments, financial planning, and the creation of an eco-guide training program certified by the Tourism Authority of Thailand. The initiative emphasizes communication strategies regarding the vulnerability of seagrass ecosystems to climate change and pollution. By developing complementary business models and integrating eco-tourism, SEAGONG aims to alleviate poverty, reduce fishing pressure, and ensure the long-term sustainability of seagrass and dugong conservation in Thailand (IUCN 2021).
- **Save Andaman Network Foundation (SAN)** is a registered environmental NGO dedicated to preserving the distinctive environment along Thailand's Andaman coastline. Focused on the Katang District of Trang (southern Andaman coast), SAN is the Thai National Partner for the International Climate Initiative (IKI) Seagrass Ecosystem Services (SES) Project. The project operates under the authority of the Department of National Parks. With a commitment to sustainable resource management, community capacity building, and awareness promotion, SAN aims to provide alternative economic opportunities to the fisheries-dependent communities in the region, where a significant portion of the population relies on fisheries for their livelihoods. (Dugong and Seagrass Hub n.d.).
- **Community-Based Seagrass Monitoring and Conservation at Phra Thong Island (Ranong Province, Andaman coast)** aims to document the status of seagrass, enhance local awareness of its importance, and establish a community-based program for long-term monitoring using participatory mapping, conservation area delineation, and workshops on co-management. Educational materials for local resource centres and eco-tourism projects have been developed. Future steps include continued monitoring and documenting the outcomes of proposed initiatives, such as the establishment of a no-take zone (Mangroves for the Future 2013b).

6.5.3.3 Peninsular Malaysia

Fifteen percent of seagrass meadows in Malaysia are located within existing MPAs and EBSAs, mostly protected as Marine Parks (Sudo et al. 2021). Other relevant projects include:

- **Operationalizing the Malaysian 'National Plan of Action for dugongs in Pulau Sibu and Pulau Tinggi', Johor (Project MY1, GEF Dugong and Seagrass Conservation Project):** This project, initiated in 2016, focused on expanding marine parks to include areas with high concentrations of dugongs, sea turtles, and seagrasses. Community training programs emphasized dugongs and the seagrass ecosystem. Key deliverables included the development of a sanctuary, a comprehensive management plan, and the establishment of a strengthened Community Consultative Committee. The project integrated dugong and seagrass conservation into planning processes in Johor and implemented communication and education programs to raise public awareness in the targeted areas.
- **Community understanding and management of dugong and seagrass resources in Johor, Malaysia (Project MY3, Global Environment Facility (GEF) Dugongs and Seagrass Conservation Project):** The MY3 project began in 2016 to assist local communities in understanding the ecological and economic importance of conserving dugongs and seagrass resources, improving local capacity to manage these resources more effectively in harmony with social, cultural, and economic needs. A comprehensive public education campaign was initiated on Tinggi Island, with posters, educational materials, and a dugong-themed storybook, targeting diverse community segments. The campaign focused on educating the public about best practices in dugong and

seagrass management, covering aspects like safe boating, response to stranded dugongs, seagrass habitat protection, and proper waste management. MY3 introduced a six-monthly dugong monitoring program, encouraging community engagement, documenting sightings, and creating a digital map of incidents. Key deliverables included collaborating with local communities and resorts to adopt dugong and seagrass safeguards, building local capacity for seagrass monitoring, and garnering public support for local management measures to protect seagrass and dugongs. The project aimed for at least 60% of the targeted inhabitants to endorse these measures, including reduced boat speeds, appropriate responses to strandings, improved waste management, and the promotion of dugong/seagrass-friendly tourism practices.

- **A multi-pronged approach to overcoming knowledge barriers on the ecology and status of dugongs in Johor: Towards critical habitat protection (Project MY4: GEF Dugong and Seagrass Conservation Project and Pew Marine Fellowship):** Local grassroots marine mammal research and conservation NGO, The MareCet Research Organization (MareCet) undertook several years of multidisciplinary research with local and international collaborators to assess the basic ecology and conservation needs of dugongs in the Sibu-Tinggi Archipelago off the east coast of Johor. Aerial surveys using light aircraft were conducted, along with dugong acoustic surveys, seagrass mapping and research on dugong feeding behaviour, consultations with local community members on the establishment of a Dugong Sanctuary and drafting of the management plan for the proposed Johor Dugong Sanctuary. Following on from the GEF project, MareCet pivoted their efforts on dugong research into the IKI Seagrass Ecosystem Services Project by focusing on protecting the dugong and its seagrass habitat in the Sibu-Tinggi Archipelago using UAVs and researching the biodiversity and seagrass blue carbon stocks in the seagrass meadows of Sibu-Tinggi Archipelago, Setindan Island (at Mersing), and Middle Bank in Penang.

6.5.3.4 Singapore

Seagrass meadows in the waters of Singapore are not protected in MPAs (Sudo et al. 2021; Ng et al. 2022 a,b). Nonetheless, TeamSeaGrass, an NGO, has been actively involved in seagrass conservation since 2007. The project involves the National Biodiversity Centre of National Parks and Seagrass-Watch. About 200 volunteers actively monitor seagrasses along key sites such as Chek Jawa, Pulau Semakau, and Cyrene Reef (Figure 6.3). The project contributes valuable baseline data. Team members engage in outreach efforts, including public exhibitions and talks, to raise awareness of marine biodiversity. Participation is open to individuals aged 19 years and older, regardless of scientific background, and provides with on-the-job training.

6.5.3.5 Cambodia

Only a small proportion of seagrass meadows in Cambodia are included in the categories of strict nature reserve and wilderness and only 13% of the seagrass meadows are covered by the existing MPAs and EBSAs (Sudo et al. 2021). Nonetheless, there are several projects aiming to increase the protection of seagrass meadows as outlined below:

- **Marine Conservation Cambodia (MCC)** is actively addressing the decline in fisheries resources by focusing on alternative livelihoods for coastal communities engaged in illegal and destructive fishing. Through sociodemographic analysis and marine data assessment, MCC identifies solutions for livelihood improvement that have reduced illegal fishing, leading to improved fish diversity and ecosystem health. MCC is piloting marine ranching projects with local communities, combining natural mariculture with sustainable harvest practices, and working to create opportunities for local communities to diversify into marine tourism (CMMCP 2023).
- **Cambodian Marine Mammal Conservation Project (CMMCP)** was launched by MCC in 2017, in collaboration with the Fisheries Administration of the Royal Government of Cambodia. Marine mammal boat, land and citizen science surveys are undertaken regularly in Kep and Kampot provinces to monitor the distributions, behaviors, population trends and threats to coastal marine mammals including dugongs, Irrawaddy dolphins *(Orcaella brevirostris)*, and Indo Pacific humpback dolphins *(Sousa chinensis)*. CMMCP also runs the Marine Mammal Strandings Network which relies on collaborating communities and fishers to report marine mammal fatalities. When a dead dugong is reported, CMMCP staff members will try to obtain information about the health of the specimen and cause of death to identify and monitor threats to marine mammals (CMMCP 2023).

- **Conservation and Anti-Trawling Structures (CANTS):** Marine Conservation Cambodia initiated the deployment of CANTS in Kep province's Marine Fisheries Management Area (MFMA) since the establishment of the region's first MFMA in 2018. These structures, also known as 'blocks,' are designed to encourage water flow, support filter feeder growth, and restore habitats damaged by bottom trawling. Communities in Kep and Kampot have actively participated in constructing and deploying these structures since 2018. The project aims to address the severe impacts of illegal destructive fishing by deploying 47 CANTS and demarcating the boundaries of the MFMA. The CANTS not only act as deterrent to illegal trawling, but also function as artificial reefs and support oyster cultivation, fostering economic opportunities for local communities.
- **The Marine Harvesting Network Project (MHN)** was set up to monitor fishing pressure within the Kep MFMA and to promote and protect small-scale and sustainable fishing practices. Not only can the MHN Project update the government on the status of these fishing activities, but can also help to strategies enforcement, conservation measures, and Marine Protected Area management.
- **The Cambodian Seagrass Conservation Project (CSCP)** aims to conserve, protect, and expand seagrass meadows in Cambodia's coastal waters, benefiting local communities dependent on seagrass-related resources. The project, operating within the MFMA, evaluates habitat destruction and identifies key areas for protection using CANTS. The project involves underwater surveys to monitor seagrass meadow size, species distribution, and abundance, along with carbon sequestration surveys and social assessments, contributing to seagrass-specific management strategies and conservation efforts.
- **Outreach Project (Rolloc Samleng)** provides marine ecology education to local schools in the Kep community. Rolloc Samleng conducts interactive sessions covering various marine topics, using art as a medium to enhance accessibility. Field trips to Koh Ach Seh offer students a firsthand experience of the underwater world, and marine survey techniques, fostering a deeper connection with marine ecosystems.
- **Samaky Organization in collaboration with Khmer Ocean Life** launched the Cambodian Marine Mammal Bycatch and Stranding Network (CMMBSN) in 2024 (El et al., 2024). As part of CMMBSN over 250 community members and eight fisheries officers from across Cambodia's four coastal provinces were trained in stranding and bycatch reporting (El et al., 2024). The Samaky and Khmer Ocean Life partnership also conduct regular marine mammal focused outreach with schools in Kampot province.

6.5.3.6 Viet Nam

Over 50% of Viet Nam's seagrass meadows are found within existing MPAs, but the level of protection is generally unspecified (Sudo et al. 2021). The country's 270,000-hectares of MPA have been approved for biodiversity conservation plans. Nonetheless, seagrasses in Vietnamese MPAs have reduced, a situation attributed to tourism development in the adjacent coastal areas (Tin et al. 2023):

- **Key MPAs** like Ly Son, Nha Trang, and Phu Quoc act as biodiversity conservation centres, playing important roles in resource management and are often used as demonstrated examples for other protected areas in the country (Ngoc 2018). Several alternative livelihood projects have been initiated by government agencies in Viet Nam, such as the Ministry of Agriculture and Rural Development, as well as foreign donors like WWF and DANIDA as a result of these MPAs (Ngoc 2018). Tourism development is a key accompanying strategy in the creation of alternative livelihoods, though in the case of Nha Trang Bay, the industry is yet to bring economic wellbeing to the communities surrounding the MPA (Pham-Do and Pham 2020). Nonetheless, the rise of ecotourism has been a key driver for indirect dugong conservation (Quyet et al. 2022). Supported by substantial infrastructure investments since 2012, ecotourism has not only stabilized the local economy but also fosters social equality, environmental awareness, and the preservation of cultural and natural resources (Prime Minister of Viet Nam 2004).
- **Community Education and Involvement:** Hines et al. (2008) conducted interviews to improve locally based dugong surveys, as well as understanding community perspectives and recommendations for supporting conservation strategies. In addition, various local and international NGOs such as Wildlife at Risk (WAR), WWF, FFI, IUCN Viet Nam have conducted education campaigns to raise awareness on dugong conservation, with focus on the laws

that protect the species and legal consequences of dugong hunting. CBES and Con Dao National Park has formed a dugong and cetacean stranding rescue group in Con Dao (L. Vu personal communication via email to Marsh and Schramm 2024).

6.6 Conservation status

The IUCN classifies the dugong as Vulnerable a global scale (Marsh and Sobztick 2019) but has not made any 'subpopulation'[4] assessments in the Continental Southeast Asian region. The status of the dugong in individual Range States indicates high levels of concern:

- Myanmar: 'Completely Protected Animal'.
- Thailand: Only marine species on the list of 'Preserved species' issued under the *WARPA*;
- Malaysia: Totally protected and listed as a Marine Endangered Species within the *Fisheries (Control of Endangered Species of Fish) Regulations Amendment (2008)* that is contained within the *Fisheries Act 1985.*
- Singapore: 'Critically Endangered' on the Red List of Threatened Animals of Singapore (SG101 2022).
- Cambodia: *'Critical Endangered Marine Species' by Sub-Decree No. 123* (Cambodia, Ministry of Information 2020).
- Viet Nam: 'Critically Endangered' listed in The Red Data Book.

6.7 Research and monitoring

Historical documents, interviews with fishers, boat surveys, feeding trails, aircraft (fixed wing, helicopter, and UAVs) and acoustic surveys have been used to obtain information on distribution, abundance and population trends as outlined in Section 6.2. Section 6.1.3 summarizes the results of the research on dugong genetics. As part of the IKI SES project, researchers at Edith Cowan University undertook assessments of the ecosystems services associated with Blue Carbon (Chapter 1), at sites in Thailand and Peninsular Malaysia, (Lavery et al. 2023 a,b) to determine how these assets might be relevant to policy and provide financial solutions to marine conservation issues.

Table 6.2 summarizes additional research initiatives in the region.

Table 6.2. Research into dugong biology conducted in Continental Southeast Asia and not discussed in this chapter. See also Panyawai and Prathep (2022).

Topic	References
Age determination	Adulyanukosol (1998); Cherdsukjai et al. (2020)
Captive behavior and rearing	Adulyanukosol and Bhatiyasevi (1994); Adulyanukosol (1997); Adulyanukosol et al. (2004)
Elemental composition of dugong tusks	Nganvongpanit et al. (2017)
Feeding behavior and diet	Adulyanukosol and Thongsukdee. (2003); Adulyanukosol et al. (2010b); Tsutsumi et al. (2006); Heng et al. (2022)
Morphological and morphometric studies	Nganvongpanit et al. (2020)
Reproductive behavior	Adulyanukosol et al. (2007); Infantes et al. (2020)
Interactions between dugongs and other organisms (including humans)	Nakaoka and Aioi (1999); Nakaoka et al. (2002); Nakanishi et al. (2006); Rajamani and Marsh (2010); Juraij et al. (2018); Geraldine (2019)
Vocalizations	Ichikawa et al. (2003, 2006, 2009, 2010, 2012); Sakamoto et al. (2005); Shiraki et al. (2009); Tanaka et al. (2017, 2023)

4 'Subpopulation' is the term used by IUCN when making regional assessments of the status of a wide-range species, such as the dugong.

Other Priorities for Action

Investigating the genetics of dugongs across the region, including the extent of gene flow between dugongs in the Andaman Sea and the Gulf of Thailand.

Estimating the size of and trend in of the dugong population in each range state.

Additional seagrass mapping.

Understanding of the contemporary transboundary movements of dugongs.

Effective protection of the dugong populations and their seagrass habitats throughout the region, especially the globally-significant populations on the Andaman coast of Thailand and on the east coast of Johor in Peninsular Malaysia.

Coordinating programs of seagrass restoration, especially along the Andaman coast of Thailand.

Estimating the abundance and isolation of the 'Côn Đảo' dugong population in Viet Nam and the basis for an IUCN subpoulation evaluation

6.8 Regional summary

In the Continental Southeast Asian region, dugongs face significant challenges, primarily from incidental bycatch, habitat loss and degradation. Although instances of direct hunting have diminished in recent years, the remaining threats continue to pose serious risks to dugong survival. Underlying causes of these threats vary across Range States, but are usually related to inadequate law enforcement, coastal development, and poverty. The complex laws in each of the Range States are rarely implemented effectively outside Singapore. Research efforts within Continental Southeast Asia are often limited by funding constraints and a lack of capacity.

The status of dugongs in the region remains data deficient, despite efforts by many researchers and NGOs. Dugongs persist in fragmented, relatively small populations in recognized areas of local importance outlined in the infographic above. The ongoing persistence of the dugong in the region will depend on evidence-based, conservation management of dugongs and their habitats in as many of these areas as possible. The Andaman coast of Thailand and the east coast of Johor in Peninsular Malaysia are the only locations with confirmed populations ranging from tens to hundreds of dugongs. Effective protection of these populations is particularly important.

The largest knowledge gaps are: (1) the inadequate mapping of seagrass in most areas, particularly Myanmar, (2) the lack of quantitative data about most of the dugong populations in the Continental Southeast Asian region, and (3) the lack of understanding of their contemporary transboundary movements.

The extent of gene flow between dugongs in the Andaman Sea and the Gulf of Thailand needs further investigation including in the waters of the Andaman and Nicobar Islands (Chapter 5). A priority should be investigating the genetics of dugongs in the waters of Peninsular Malaysia and Singapore. Extending genetic sampling to other regions of Continental Southeast Asia where dugongs occur has the potential to provide important insights, especially of this work included whole-genome sequencing of individuals from different localities to estimate heterozygosity, levels of inbreeding and population fluctuations in the region over time.

Fishing activity should be mapped throughout the region to enable the threats posed by fishing efforts to be better understood and the significant risks of bycatch reduced. The human dimensions of dugong interactions with fisheries and coastal development should be a high priority. Given the low numbers of dugongs in most parts of the region, it may be more effective to consider the dugong conservation in the context of the conservation of marine megafauna more generically than to develop specific dugong management plans. Increased attention to transboundary management and the conservation of seagrass meadows known to support dugongs is highly desirable.

Confirmed Significant Locations

Myanmar

Myanmar Man Aung Island, Gwa, Thandwe and Shwe Thaung Yan Townships, the Rakhine coast Myeik Archipelago, the Tanintharyi coast

Thailand

Andaman Sea coast: Ranong (Sai Dam), off Phuket Island (at Paklok and Chalong Bays), Krabi (at Koh Sri Boya and Koh Pu), Phang-nga (at Phra Thong Island, Yao Island, and elsewhere in Phang-nga Bay), Trang (at Chao Mai and Muk, Libong, and Sukorn Islands) and Satun (at Lidee and Sarai Islands) Gulf of Thailand coast: Chonburi, Chumphon, and Pattani

Peninsular Malaysia

Mersing Archipelago (especially Sibu Besar, Sibu Tengah, Sibu Kukus and Sibu Hujung Islands, Tinggi Island, Babi Besar Island) Western Johor Strait (especially around Pulai River estuary/Gelang Patah) and eastern Johor Strait (Pasir Gudang, Johor River estuary, Pengerang)

Singapore

Pulau Ubin Island, Changi, Tanjung Chek Jawa, Tekong Island in the eastern Johor Straits of Singapore

Cambodia

Koh Kong Island Kep Archipelago, and coastal area of Kep Province Coastal area of Kampot Province

Viet Nam

Côn Đảo Archipelago Phú Quốc Island

The following globally-important Important Marine Mammal Areas (IMMAs) with the dugong as a qualifying species have been recognized or are in the process of being evaluated:

1. **Trang in Thailand (under evaluation);**
2. **the 'Mersing Archipelago' IMMA, off the eastern coast of Johor in Peninsular Malaysia;**
3. **the transboundary 'Kien Giang and Kep Archipelago' IMMA, which spans the Kep Province in Cambodia and the Kien Giang Province in Viet Nam; and**
4. **the 'Côn Đảo' IMMA in Viet Nam.**

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Chapter 7

MARITIME SOUTHEAST ASIA

Authored by: Timothy Quimpo, Terri Aquino, Lem Aragones, David Blair, Hans de Iongh, Akbar A Digdo, Amanda Hodgson, Saifullah Jaaman, Len McKenzie, Nicolas Pilcher, Louisa Ponnampalam, Leela Rajamani and Helene Marsh

Timothy Quimpo[1], Terri Aquino[2], Lem Aragones[3], David Blair[1], Hans de Iongh[4], Akbar A Digdo[5], Amanda Hodgson[6], Saifullah Jaaman[7], Len McKenzie[8], Nicolas Pilcher[9], Louisa Ponnampalam[10], Leela Rajamani[11], Helene Marsh[1]

[1]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[2]Marine Wildlife Watch of the Philippines, Puerto Princesa City, Palawan, Philippines.
[3]College of Science, University of the Philippines, Diliman, Quezon City, Philippines.
[4]Evolutionary Ecology Group, Department Biology, University of Antwerp, Netherlands and Institute of Environmental Sciences, Leiden University, Netherlands.
[5]YAPEKA, Bogor Utara, Kota Bogor, Jawa Barat, Indonesia.
[6]Centre for Marine Ecological Research, Edith Cowan University, Joondalup, Western Australia, Australia.
[7]Marine Endangered Species (MES) Program, Institute of Oceanography & Environment (INOS), Universiti Malaysia Terengganu (UMT), Malaysia.
[8]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Cairns, Queensland, Australia.
[9]Marine Research Foundation, Taman Khidmat, Kota Kinabalu, Sabah, Malaysia.
[10]IBEC, Universiti Malaysia, Sarawak, Malaysia.
[11]Centre for Marine and Coastal Studies, Universiti Sains Malaysia, Pulau Pinang, Malaysia.

Correspondence to: Helene Marsh helene.marsh@jcu.edu.au.

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Contents

Range/Signatory States

Range States	Signatory States
Indonesia	No
Malaysia (East)	No
Brunei Darussalam	No
Philippines	Yes
Timor Leste	Yes

Regional findings

The countries in Maritime Southeast Asia considered in this chapter include: Brunei Darussalam (Brunei), Democratic Republic of Timor-Leste (Timor-Leste), Republic of Indonesia (Indonesia), Malaysia (East Malaysia only) and Republic of the Philippines (Philippines)

- The dugong populations in Maritime Southeast Asia are fragmented and data deficient because information is largely based on local sightings at a subset of possible habitats.
- Important Marine Mammal Areas (IMMAs) with the dugong as a qualifying species have been declared for the following sites in Indonesia: (1) 'Balikpapan, Adang and Apar Bays' in East Kalimantan; (2) 'Tolitoli' in Central Sulawesi; (3) 'Kaimana' in West Papua; and (4) the 'Eastern Lesser Sunda Islands and Timor Coastal Area'.
- The following areas are under evaluation by the Marine Mammal Protected Areas Taskforce (MMPATF) as IMMAs with the dugong as a qualifying species: (1) 'Brunei Bay' bordered by Brunei, the Malaysian state of Sarawak and the Malaysian Federal Territory of Labuan; and (2) 'Mayo and Pujada Bays' on the Pacific coast of Mindanao in the Philippines.
- It has been assumed that dugong populations are declining in the region because of unsustainable, historical hunting, incidental entanglement in gillnets, destructive fishing, boat collisions and seagrass habitat degradation but there are no quantitative trend data.
- It would be desirable to design and apply survey techniques suitable for both: (1) the spatial scale of the distribution of dugongs and their seagrass habitats, and (2) the local capacity in each Range State.
- The following sequence of surveys could provide important new information for management: (1) fisher surveys to identify dugong areas of local importance and threats to dugongs at the desired governance scale; (2) seasonal 'hotspot surveys' using small drones and eDNA to provide baseline information on dugong distribution and abundance; (3) seagrass surveys using the Seagrass-Watch protocols being applied in the International Climate Initiative (IKI) Seagrass Ecosystem Service (SES) project; (4) focus groups with local experts to identify threats to dugongs and other megafauna and their habitats to inform: (a) a review of the adequacy of existing Marine Protected Areas (MPAs) to protect megafauna, including dugongs and their habitats; and (b) the design of new or modified MPAs to achieve effective conservation management of marine megafauna.
- Especially in Indonesia and the Philippines, there is a mismatch between the spatial scale of marine conservation, which is largely organized at a local level, and strategic planning for dugong conservation, which has been at a national level. Coordinated governance of marine conservation at a regional level could be advantageous.
- Given that most dugong populations are likely small, conservation planning and management may receive more community support if it were organized for megafauna rather than dugongs *per se*.
- At the key location of Brunei Bay on the island of Borneo, international coordination across the state government of Sarawak and the federal territory of Labuan in East Malaysia and the country of Brunei would be highly desirable.

7.1 Regional setting

7.1.1 Geographic overview

This chapter considers the status of dugongs in Maritime Southeast Asia, which includes the following island nations ordered clockwise by their western boundaries: Indonesia, East Malaysia (otherwise known as Malaysian Borneo), Brunei Darussalam (henceforth Brunei), the Philippines, and the Democratic Republic of Timor-Leste (henceforth Timor-Leste) (Figure 7.1). The region has an estimated total coastline length of 94,709 km, 57% of which lies in Indonesia (54,716 km), 38% in the Philippines (36,289 km), approximately 3% in East Malaysia (2,837 km) and less than 1% each in Timor-Leste (706 km) and Brunei (161 km). Although this region represents an estimated 40% of the coastline in the dugong's global range (Marsh et al. 2011), it is unlikely to represent such a high percentage of dugong habitat as the area of shallow sea surrounding each island is generally narrow and the seagrass meadows are restricted to the shallow coastal and reef nearshore areas (Figure 7.2).

The waters of all dugong Range States in Maritime Southeast Asia are in the Indo-Pacific seagrass bioregion, and the estimated seagrass areas known

Figure 7.1. Geographic context of Maritime Southeast Asia showing placenames mentioned in the text. Dugong Range States are (ordered by their western boundaries): Indonesia, East Malaysia, Brunei, Philippines and Timor-Leste. The areas of dugong concentration in Indonesia (2010-2022) identified by Digdo et al. (2024), which are different from IMMAS (see Figures 7.3 and 7.7), are outlined by red boxes (clockwise around the region starting with the southernmost box): Nusa Tenggara Timur, Kepulauan Bangka-Belitung, Kepulauan Riau, Sulawesi Tengah, Sulawesi Utara – Minahasa Utara, Sulawesi Utara – Sangihe, Papua Barat. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

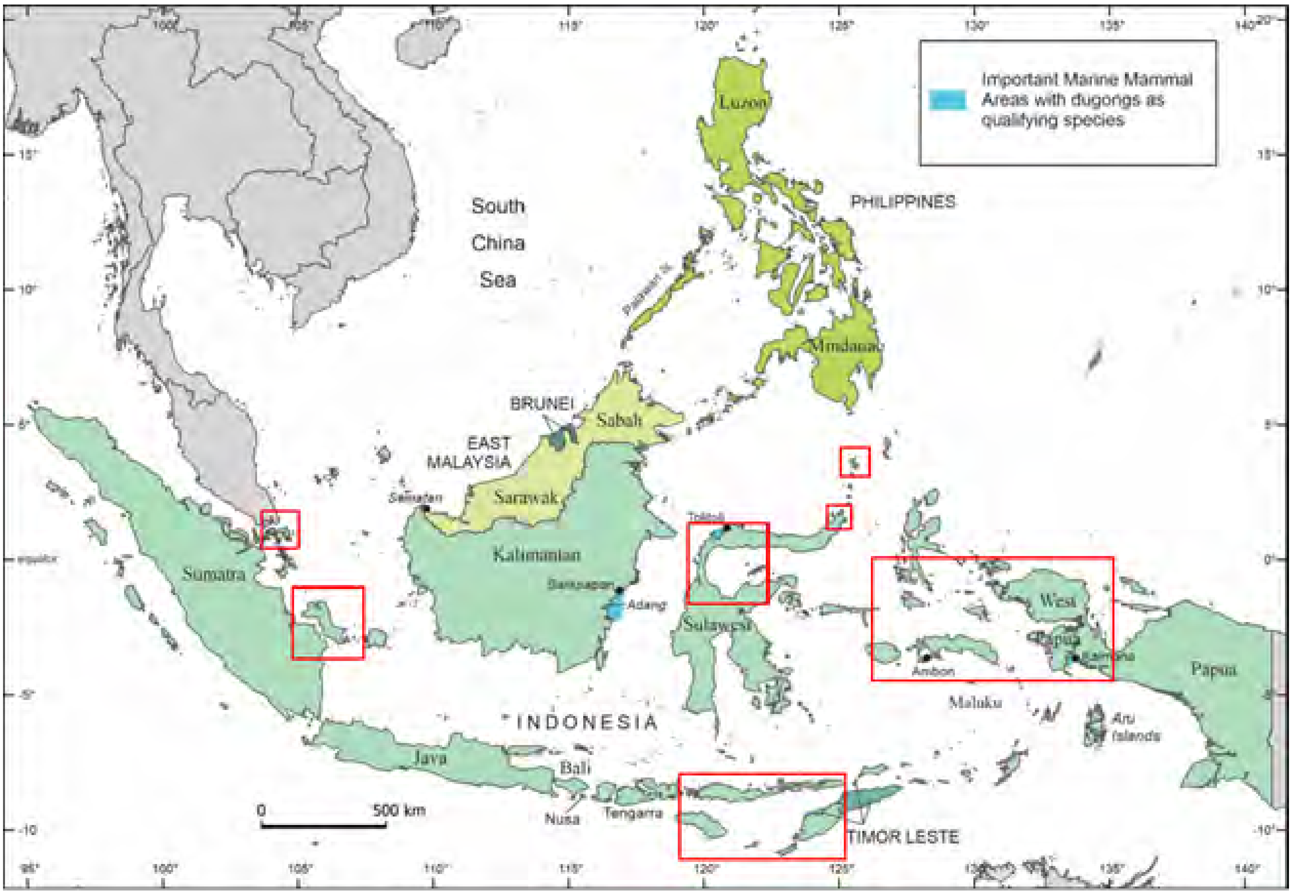
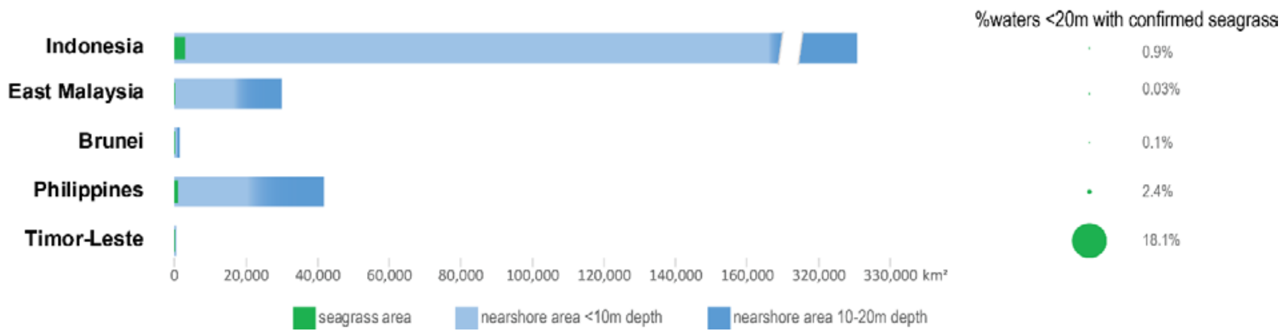
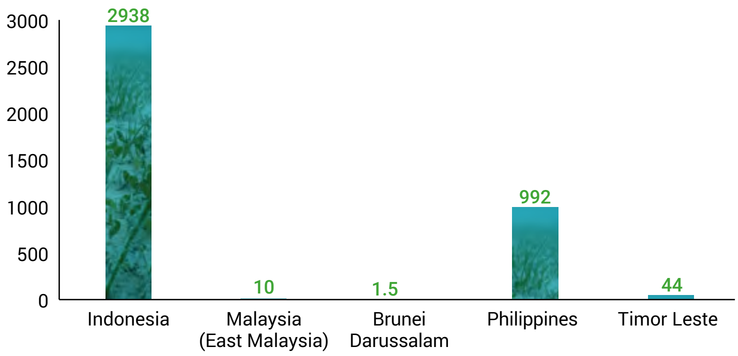


Figure 7.2. Histogram showing the known areas of seagrass and coastal waters to 20 m deep for each dugong Range State in the Maritime Southeast Asia region. The areas of seagrass are almost certainly underestimates and do not include reef associated seagrasses, for which only predicted estimates are available. Len McKenzie figure; reproduced with permission.



with moderate to high confidence (Figure 7.2) are as follows (countries are ordered by their western boundaries, consistent with this chapter): Indonesia 2,938 km^2 (Bonnet 2016; Sjafrie et al. 2018; Sudo et al. 2021; McKenzie et al. 2023), East Malaysia 10 km^2 (Jaaman et al. 2011; Hossain et al. 2015 a,b, 2016; Rajamani and Marsh 2015), Philippines 992 km^2 (Samonte-Tan et al. 2007; Fortes 2008; Tamondong et al. 2013; Japitana and Bermoy 2015; Sudo et al. 2021; McKenzie et al. 2023), and Timor-Leste

Seagrass Mapped Area (km²)



Seagrass communities are under-mapped with current estimates likely underestimates

44 km^2 (Boggs et al. 2012; Joyce 2013; McKenzie et al. 2023). Lamit et al. (2017) roughly estimated the area of seagrass in Brunei to be 1.5 km^2 however no seagrass polygon maps were available at the time of writing (McKenzie et al. 2020). Recent estimates from the Allen Coral Atlas (2020) predict the spatial extent of reef-associated seagrass meadows to be 5,584 km^2 in Indonesia and 1,988 km^2 in the Philippines. These areas have not been included in the above totals because they are predictions only, indicating the critical need for further seagrass mapping efforts within these countries.

The dugong populations in Maritime Southeast Asia are fragmented. Their status is data deficient (Marsh et al. 2011) because information is largely based on local sightings at a subset of possible habitats as outlined in the country reports below. It has been assumed that dugong populations are declining in the region as a result of unsustainable, historical hunting, incidental entanglement, destructive fishing (Aragones et al. 2017, 2022, 2024), coastal development, boat collisions and seagrass habitat degradation (Persoon et al. 1996; Jaaman et al. 2008 a,b, 2009; Johnson et al. 2023) but there are no quantitative trend data.

Indonesia encompasses over 17,500 islands and is the largest archipelago in the world to form a single country. Indonesia consists of five main islands or parts of islands (ordered west to east): Sumatra, Java, Kalimantan, Sulawesi, and Papua; two major archipelagos (Nusa Tenggara and Maluku) and 60 smaller archipelagos (McDivitt et al. 2023; (Figure 7.1).

East Malaysia is situated on the northern part of the island of Borneo and separated from Peninsular Malaysia by approximately 640 km of the South China Sea (Lockard et al. 2023). East Malaysia is bordered by Kalimantan in Indonesia to the south and surrounds the land border of Brunei, an independent Sultanate. East Malaysia consists of the states of Sabah and Sarawak and the Federal Territory of Labuan (Figures 7.1, 7.3, 7.4).

Brunei is divided into two disconnected segments by the Malaysian State of Sarawak, with the larger of the two segments comprising three districts (Belait, Tutong, and Brunei-Muara), bordering the South China Sea to the north and to a small extent Brunei Bay to the northeast (Figures 7.1, 7.4). The smaller segment comprising the Temburong District, lies between Lawas and Limbang (Malaysia) and is bordered only by the semi-enclosed Brunei Bay (Figure 7.4).

The **Philippines** is an archipelago of more than 7,000 islands and islets lying about 800 km off the coast of Viet Nam. The large islands can be grouped as follows: (1) the Luzon group in the north and west, consisting of Luzon, Mindoro, and Palawan; (2) the Visayas group in the centre; consisting of Bohol, Cebu, Leyte, Masbate, Negros, Panay, and Samar; and (3) Mindanao in the south (Figures 7.3, 7.5).

Timor-Leste (East Timor) is located in the eastern Lesser Sunda Islands. The nation occupies the eastern half of the island of Timor, the small nearby islands of Atauro (Kambing) and Jaco, and the enclave of Ambeno, including the town of Pante Makasar, on the northwestern coast of Timor (Britannica 2023a; Figures 7.1, 7.3).

7.1.2. Geopolitical and socioeconomic overview

This information (Table 7.1) is provided as an indication of the challenge for each of the Range States in the region to consider the conservation of dugongs and their habitats in the context of their socioeconomic development needs. Economic development in the countries of Maritime Southeast Asia has increased within the past 25 years, but the

Table 7.1. Human Development Index (HDI) status rank and Gross Domestic Product (GDP) per capita rank of the dugong Range States in Maritime Southeast Asia. Consistent with the remainder of this chapter, the countries in this table are ordered clockwise by their western boundaries starting with Indonesia. Countries with the highest HDI or GDP have the lowest ranks. 189 countries were ranked for both indices.

Range State	HDI	HDI Rank 2023[i]	GDP per capita rank[ii]
Indonesia	High	114	96
Malaysia	Very High	62	56
Brunei	Very High	51	11
Philippines	Medium	116	114
Timor-Leste	Medium	140	139

i 2023 HDI data from https://hdr.undp.org/data-center/country-insights#/ranks (downloaded from the internet January 2024);
ii 2022 per capita GDP from https://www.worldometers.info/gdp/gdp-per-capita/ (downloaded from the internet June 2024).

extent of this development varies by country (Yeung 2022) as summarized below.

Indonesia, the world's fourth most populous country (Yeung 2022), has a High HDI of 0.705 (ranked 114), a GDP of USD 1.3 trillion (World Bank 2022), and a population of around 273 million (United Nations Development Programme [UNDP] 2022). **Malaysia** (Peninsular and East combined) has a Very High HDI of 0.803 and a GDP of USD 407 billion (World Bank 2022). Around 6 million people live in East Malaysia (Britannica 2023b). **Brunei** has a Very High HDI of 0.829, a GDP of USD 16.7 billion (World Bank 2022), and a population of approximately 455,000 people (UNDP 2022). **The Philippines** has a Medium HDI of 0.699, a GDP of USD 404.3 billion (World Bank 2022), and a population of around 113 million (UNDP 2022). **Timor-Leste** has a Medium HDI of 0.607, a GDP of USD 3.2 billion and a population of approximately 1.3 million people (UNDP 2022).

7.1.3 Genetics of dugong populations

For an overview of genetics-relevant techniques, definitions, studies and general findings, refer to Chapter 1, particularly Figure 1.2.

No genetic studies have focused on dugongs from this region. The only data are several mitochondrial partial control region sequences of varying lengths reported by Tikel (1997); Blair et al. (2014), Plön et al. (2019) and Furness et al. (2024).

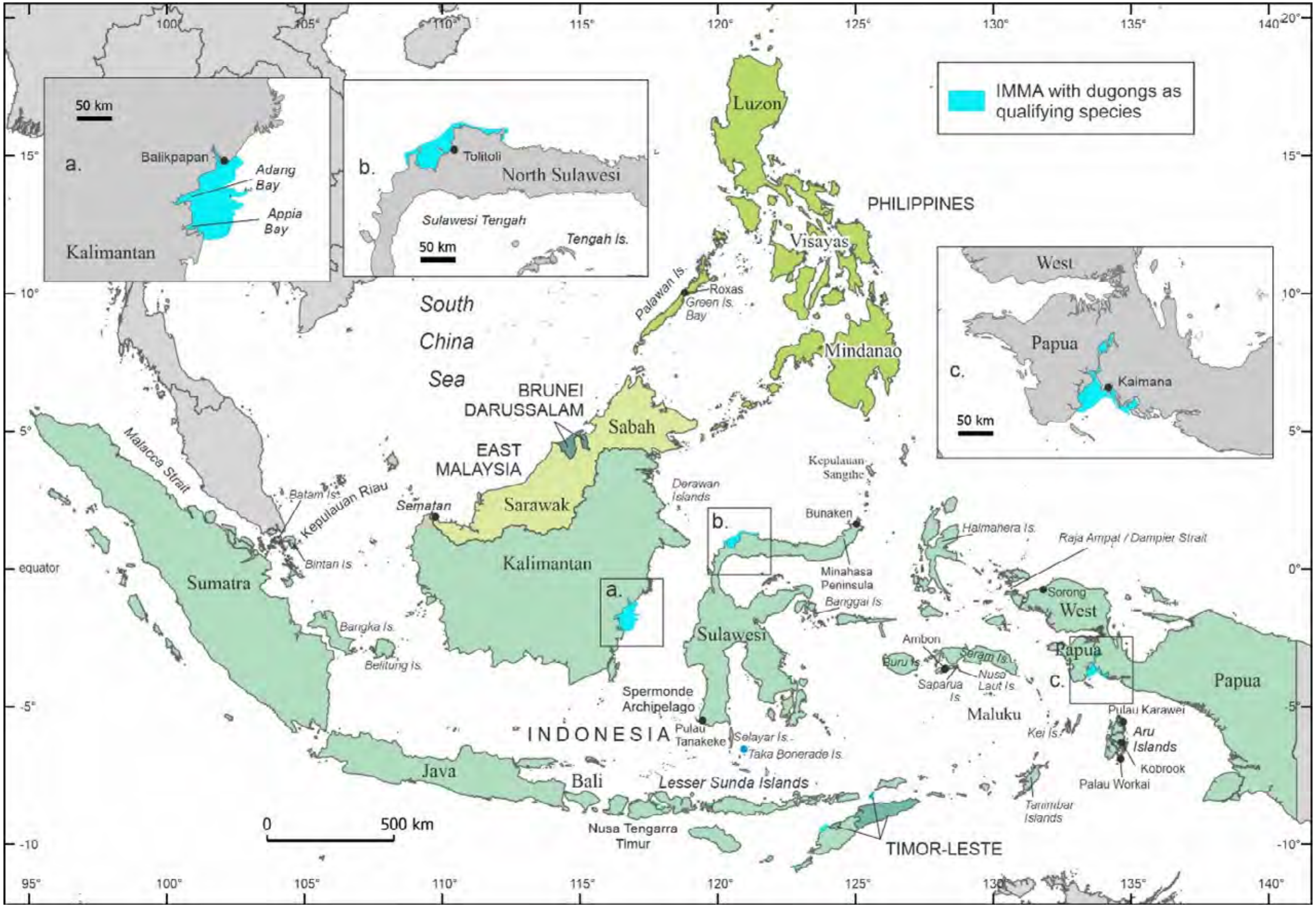
One principal haplogroup spans Maritime Southeast Asia and regions peripheral to it. This is the 'northeastern haplogroup', as depicted in Chapter 1, Figure 1.2, which includes several sequences (410 bp) from East Malaysia (n=1, Kuala Prayi, Sabah), Indonesia (n=2, Ambon, Maluku, eastern Indonesia) and the Philippines (n=1, Taytay, Palawan). These haplotypes are quite similar to one another, but geographically well separated. Shorter sequences reported by Plön et al. (2019) also belong within this haplogroup. These are from Sorong, West Papua (Figure 7.3), and Rote Island, East Nusa Tenggara (Figure 7.7). They are also similar to haplotypes within the northeastern haplogroup from localities external to the Maritime Southeast Asia region: Okinawa (Japan, Chapter 8); Ashmore Reef (Australia, Chapter 10); Thailand (both Andaman Sea coast and Gulf of Thailand, [Chapter 6]) and Palau (Chapter 9). Very recently, Furness et al. (2024) reported a further four sequences in this haplogroup, all from islands of eastern Indonesia.

The East Indian Ocean haplogroup is represented in the region by one of Plön et al.'s sequences (MH704314) and another reported by Furness et al. (2024: their SDG012). Both were from Belitung Island, located between southern Sumatra and Kalimantan, Indonesia.

Surprisingly, the Australasian widespread haplogroup remains almost completely undetected in the region. To date, the only possible example (MH704315) is from Plön et al. (2019) from an unknown locality in the 'Indian Archipelago', likely Indonesia, and a single sequence from Furness et al. (2024; their SDG006) from the Aru Islands.

That one haplogroup, the northeastern haplogroup, spans this entire region and extends beyond it is unexpected given the size of the region, its complex marine biogeography (e.g., Carpenter et al. 2011; Crandall et al. 2019) and its history of sea level changes (Voris 2000; Ludt and Rocha 2015). It is also surprising given the example of genetic subdivision at smaller scales in Australian waters (Chapter 10). However, sampling remains very limited and data from nuclear genetic markers are not yet available. Our ignorance of dugong population-genetic structure in this region is near total.

Figure 7.3. Geographic context of Maritime Southeast Asia showing Indonesian IMMAs with the dugong as a qualifying species mentioned in the text. IMMAs are shown in blue. Insets: (a) 'Balikpapan, Adang and Apar Bays' in East Kalimantan; (b) 'Tolitoli' in Central Sulawesi; (c) 'Kaimana' in West Papua. The 'Eastern Lesser Sunda Islands and Timor Coastal Area' IMMA is illustrated in Figure 7.7. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



- The only genetic data for dugongs from Maritime Southeast Asia consists of several mitochondrial partial control region sequences. Almost all of these belong to the northeastern haplogroup.
- The impression is of relatively limited diversity in the region, but the genetic sampling is too inadequate for conclusions to be drawn.
- Increased sampling is required. In particular, whole-genome data for a few individuals would greatly increase our understanding of dugong populations in the region.

7.2 Distribution, abundance and trends in Range States

7.2.1 Indonesia

The first written record of a dugong occurrence in Indonesia was made in 1712 by Samuel Falours, a Dutchman employed by the United East Indies Company (Hines 2012). He described a juvenile dugong being kept for four days in a bathtub in Ambon (Pietsch 1991).

Contemporary data on dugong distribution and abundance are largely limited to anecdotal information supplemented by local-scale sightings and records obtained using a variety of techniques as summarized in Table 7.2. There are few data from aerial surveys. In central Maluku, de Iongh et al. (1995a) observed 17 dugongs during an aerial survey across the islands of Ambon, Haruku, Saparua and Nusa Laut in 1990. As part of the IKI SES project, YAPEKA conducted drone surveys off the western side of North Minahasa where fisher surveys had suggested dugong presence, however no dugongs were recorded (A. Hodgson personal communication via email to Marsh and Schramm 2024). Interestingly, the Dugong MOU Standardized Catch and Bycatch Questionnaire data has indicated numerous dugongs in the area, as well as around Sangihe Island (N. Pilcher personal communication via email to Marsh and Schramm 2024).

In addition, Digdo et al. (2024) developed a database of 1,033 dugong sighting and stranding records for the Indonesian archipelago between 2010 and 2022. The database comprises 337 incidental reports documented via the internet, news, and social media and 696 cases based on publications and grey literature and includes records for 24 of the 37 Indonesian provinces. There were more than 50 reported sightings from each of five provinces (Sulawesi Utara, Kepulauan Bangka Belitung, Sulawesi Tengah, Nusa Tenggara Timur and Kepulauan Riau; Figures 7.1, 7.3). Sulawesi Utara and Kepulauan Bangka Belitung had more than 100 reported sightings.

Digdo et al. (2024) identified six main clusters of dugong sightings: four around small island groups surrounding the Banda Sea and two approximately 1,000 km to the northwest between South Sumatra and the Malacca Straits (Figure 7.1). Sightings were mostly associated with known areas of seagrass. However, surprisingly few dugong sightings were reported from a large area of seagrass along the Indian Ocean coast of Sumatra or from the Indian Ocean coast of Central and West Java. Mortality records were highest in the Kepulauan Bangka Belitung and Kepulauan Riau Archipelagos on the northwest side of the Java Sea.

Collectively, this information suggests that: (1) dugongs occur in all the major geographic regions of Indonesia; (2) local populations are small and fragmented; (3) there is a lack of systematically acquired information or quantitative data about the distribution and abundance of dugongs in Indonesia; and (4) an absence of robust data about trends. This situation is a major gap in our understanding of the global status of the dugong, given the vast extent of known and potential seagrass habitat in Indonesia. Previous estimates of dugong population size (e.g., 1,000–10,000; Marsh et al. 2011) are guesses.

As detailed in the IMMA e-Atlas, IMMAs with the dugong as a qualifying species have been declared for the following sites in Indonesia (Figure 7.3): (1) 'Balikpapan, Adang and Apar Bays' in East Kalimantan (International Union for Conservation of Nature [IUCN]-MMPATF 2022a); (2) 'Tolitoli' in Central Sulawesi (IUCN-MMPATF 2022d), where the IMMA boundary overlaps a Convention on Biological Diversity – Ecological or Biological Significant Area (EBSA); (3) 'Kaimana' in West Papua (IUCN-MMPATF 2022c), which is part of the Raja Ampat MPA network and Bird's Head Seascape; and (4) the 'Eastern Lesser Sunda Islands and Timor Coastal Area' (IUCN-MMPATF 2022b), which includes 25 locations where dugongs have been sighted within the coastal areas of Sabu Islands, Rote Islands, Eastern Flores and Timor Island. This IMMA shares a border with Timor-Leste and northern Australia. In addition, a candidate IMMA with the dugong as a qualifying species is under consideration in the 'Raja Ampat and Dampier Strait' region of West Papua (IUCN-MMPATF).

Table 7.2. Summary of information on the distribution and abundance of dugongs in Indonesia. This table does not include the unpublished locations in Digdo et al. (2024) that are based on dugong sighting and stranding records for the Indonesian archipelago between 2010 and 2022.

Geographical region	Methods	Locations where there is evidence of dugong presence	References
Sumatra	Anecdotal information from 1975-2017 Bangka Island: Interviews (135 local informants aged 20-50 2017); sightings from the Agency for Marine and Fisheries of Bangka Belitung Islands Province, local newspapers and publications (1976-2014)	Riau and Belitung Islands Bangka Island:20 records (22 dugongs) 56% from Central Bangka Island District, 25% from South Bangka, 13% from Bangka District and 6% from Pangkalpinang City; older records limited to Bangka, South Bangka and West Bangka; and all new records from Bangka Island's east. 82% of recorded dead dugongs (50% entangled in gillnets, 41% stranded and 9% in sero (traditional barrier trap net)	Hendrokusumo et al. (1979); Marsh et al. (2002); Syafutra et al. (2018); Panyawai and Prathep (2022)
Java	Anecdotal information	Ujung Kulon National Park, along Cilegon and Labuhan coasts, south of Cilacap, Segara Anakan, southeast of Blambangan, Banten Bay	Hendrokusumo et al. (1979); de Iongh et al. (1997); Marsh et al. (2002); Panyawai and Prathep (2022)
Kalimantan	Vessel surveys	Balikpapan Bay: 15 dugongs sighted during vessel surveys in the early 2000s, maximum herd size of three	de Iongh (2005); de Iongh et al. (2007); Panyawai and Prathep (2022)
Nusa Tenggara (Lesser Sunda Islands)	Anecdotal information; fisher interviews Rote Island, Solor-Alor Islands 2004	Bali, Lembata, Mali, Nusa Tenggara Timur, Rote Island, Solor-Alor Islands	Marsh et al. (2002); Mustika (2006); de Iongh et al. (2009a); Lee and Nijiman (2015); Sirimorok and Asfriyanto (2020); Plaimo et al. (2021); Panyawai and Prathep (2022)
Sulawesi	Anecdotal information	North Sulawesi; Central Sulawesi: Lingayan Island, Tolitoli; South Sulawesi: Togean (Tongian), Banggai, Spermonde (where the dugong may be extinct), Taka Bone Rate/Selayar, and Tanakeke Islands, Wakatobi National Park	Moore et al. (2017); Cullen-Unsworth et al. (2018); Marimba et al. (2019); Satyaningtijas et al. (2020); Sondita et al. (2020); Panyawai and Prathep (2022)
Maluku Islands	Anecdotal information from 1976; local scale shoreline aerial surveys Lease Islands 1990, 1992; strandings	Lease Islands, Buano Island, Aru Tenggara. Aerial surveys recorded 22-37 individuals; pregnant dugong caught by local fishers at East Halmahera 2011; in 2016, two carcasses found stranded at Morotai Island; two dugongs captured as tourist attraction at Kokoya Island, released by the Ministry of Marine Affairs and fisheries, March 2016	Allen et al. (1976); de Iongh et al. (1995 a,b); Persoon et al. (1996); Marsh et al. (2002); Utami et al. (2018); Panyawai and Prathep (2022)
Papua	Anecdotal information (sightings and strandings) from 1976; shoreline aerial surveys 1981, 2008	Bird's Head Seascape, Papua Barat. 14 dugongs recorded during 1981 aerial survey along coasts of Teluk Wondama, Roon Island, and Mioswaar Islands; 2008 aerial survey recorded 24 dugongs around Raja Ampat Islands; local fisher Kiat village, West Fafka trapped dugong as tourist attraction	Allen et al. (1976); Marsh et al. (2002); de Iongh et al. (2009a); Mangubhai et al. (2012); Utami et al. (2018); Panyawai and Prathep (2022)

- Dugongs occur in all the major coastal regions of Indonesia.
- Local populations are small and fragmented.
- There is a lack of robust, quantitative data about the distribution and abundance of dugongs in Indonesia, and an absence of robust data about trends.
- This situation is a major gap in our understanding of the global status of the dugong, given the vast extent of known and potential seagrass habitat in Indonesia.
- IMMAs with the dugong as a qualifying species have been declared for the following sites in Indonesia: (1) 'Balikpapan, Adang and Apar Bays' in East Kalimantan; (2)'Tolitoli' in Central Sulawesi; (3) 'Kaimana' in West Papua; and (4) 'Eastern Lesser Sunda Islands and Timor Coastal Area'.

7.2.2 East Malaysia

Jaaman et al. (2009) conducted 753 interviews in the 16 districts along the coastline of Sabah between March 1997 and December 2004, and 358 interviews across 15 districts in Sarawak between November 1998 and October 2000. Fishers reported sighting dugongs in Lawas and Limbang (northern Sarawak) and two respondents in Sematan (southern Sarawak) reported dugongs near the Kalimantan (Indonesian) border on multiple occasions (Jaaman et al. 2009). All districts in Sabah (n=16) recorded incidental bycatch of dugongs; in Sarawak; only respondents in the northern region reported incidentally catching dugongs (Jaaman et al. 2009).

Rajamani and Marsh (2010) conducted aerial surveys in 2003 and 2005–2006 along approximately 1,448 km of Sabah's coastline to identify areas of dugong abundance at a regional scale. A total of 53 dugongs (including nine calves) were observed. The largest numbers of individuals were sighted around Labuan Island followed by Sandakan Bay (n=8), Brunei Bay (n=6), Jambongan Island and Kudat (each with three individuals sighted; Rajamani and Marsh 2010).

In Brunei Bay and Lawas, Sarawak (Figure 7.4), dugongs were sighted feeding and swimming slowly during each of the local-scale, aerial surveys conducted by Jaaman et al. (2001) and Jaaman and Lah-Anyi (2003). Sightings included a cow-calf pair. The mean group size was 2.4 dugongs, and the maximum group size was eight (S. Jaaman personal communication via email to Marsh and Schramm 2024). Results of these surveys suggested that there is a small breeding population of dugongs in Lawas waters. Feeding trails in seagrass beds have also been sighted regularly during seagrass monitoring conducted periodically in the area (S. Jaaman personal communication via email to Marsh and Schramm 2024).

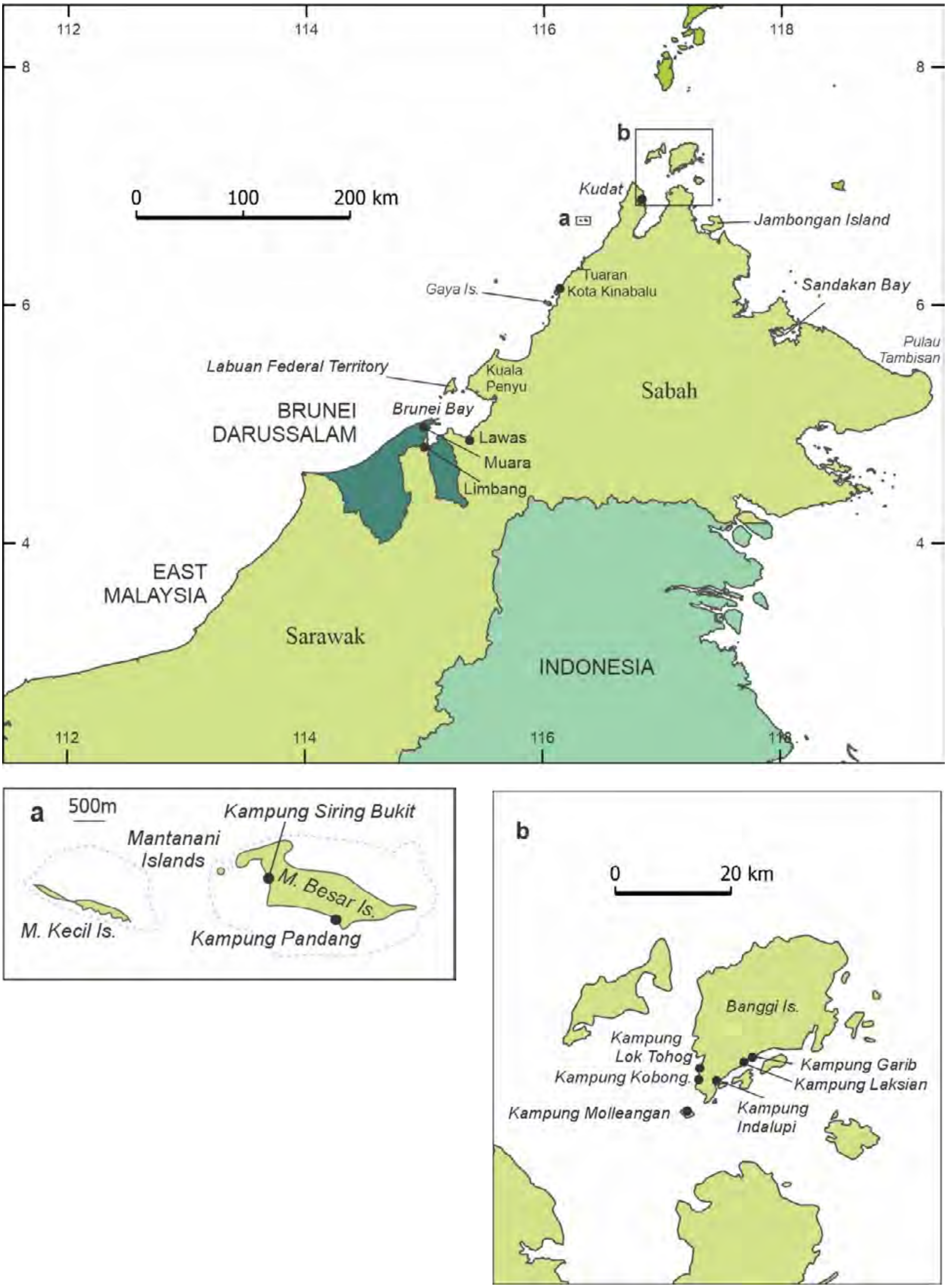
Rajamani and Marsh (2010) conducted focus groups and interviews with fishers at Banggi Island and Mantanani Island in 2002 (Figure 7.4) to identify habitats at a local scale. Ten groups and 13 individual fishers were interviewed in September 2002 at Banggi Island at the following locations: Kampung Garib, Kampung Indalupi, Kampung Kaligau, Kampung Kobong, Kampung Laksian, Kampung Lok Tohog and Kampung Molleangan. Rajamani and Marsh (2010) also interviewed nine groups and two individuals in February 2002 in the villages of Kampung Pandang and Kampung Siring Bukit on Mantanani Island. All interviewees at Banggi Island had observed dugongs. Sightings were rare with 48% of fishers having observed a dugong only once in 2001; the remainder had not seen any that year. Sightings were most often of one adult (58%) or a cow-calf pair (31%). On Mantanani Island, 91% of fishers had observed dugongs including nine sightings of individuals, two strandings and two incidental catches.

Rajamani and Marsh (2010) developed a community monitoring program at Mantanani and Banggi Islands. Many of the reports were of a single, adult male dugong that frequently interacted with people on Mantanani Island including the villagers' children, Mantanani resort staff and tourists. This animal has not been seen since 2007. These observations also suggested that at least five dugongs were resident or transient at Mantanani Island between 2001 and 2003 and that three adult dugongs and a cow-calf pair were observed in the Banggi Island region in 2002. In 2001, at Banggi Island, one incidental capture and one hunting incident were recorded.

A rapid assessment interview survey protocol (Moore et al. 2010) was deployed among 2,170 respondents from 161 coastal communities in 2007 (Pilcher et al. 2008). Seventeen dugong interactions with small scale fisheries in the preceding year were recorded. Ten of the 17 interactions involved gillnets, one dugong was caught in a trawl net, and one was reportedly entangled in a hook and line.

Dugongs have also been recorded in Gaya Island, Kuala Penyu, Labuan, Pulau Manukan and Tuaran (Jaaman and Lah-anyi 2003; Rajamani 2009); coastal waters near Kota Kinabalu (Jaaman 2000;

Figure 7.4. Geographic context of northern East Malaysia (Sarawak and Sabah) and Brunei showing placenames mentioned in the text. Insets: (a) Mantanani Islands; (b) Banggi Island. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



Jaaman and Lah-Anyi, 2003; N. Pilcher personal communication via email to Marsh and Schramm 2024); and Pulau Tambisan (Dolar et al. 1997; Marsh et al. 2002).

Taken together, these results indicated that dugong populations in East Malaysia are small and clumped, and urgently require management intervention at local scales in the regionally important dugong habitats identified by the various surveys.

- The dugong is widely distributed in East Malaysia in small, clumped populations.
- The status of East Malaysian dugong populations is data deficient.
- Management interventions are required at local scales at regionally important habitats, including Brunei Bay, Labuan Island, coastal waters close to Kota Kinabalu, Gaya Island, Kudat, Banggi Island, Mantanani Island, Jambongan Island, Sandakan Bay, and Pulau Tambisan.

7.2.3 Brunei

Brunei Bay, an important dugong habitat (Rajamani and Marsh 2010), is bordered by Brunei to the southwest, the Malaysian state of Sarawak to the southeast, and the Malaysian Federal Territory of Labuan to the north. Thus, these jurisdictions share a dugong population (Panyawai and Prathep 2022). Four confirmed sightings of dugongs, including three live sightings and one dead animal were reported by UNEP and CMS (2015). Three such incidents have been in the Muara area of Brunei (Figure 7.4). A 1.75 m dugong found entangled in fishing nets was later released by divers from the Fisheries Department (Wong and Ahmad 1996).

'Brunei Bay' is an Area of Interest (AoI) with the potential for designation as an IMMA, for which the dugong is a qualifying species (IUCN-MMPATF).

- Brunei Bay is important dugong habitat that is bordered by Brunei, the Malaysian state of Sarawak and the Malaysian Federal Territory of Labuan.
- It would be advantageous for surrounding jurisdictions (i.e., East Malaysia) to collaborate in the management of threats to dugongs and other marine megafauna in Brunei Bay.
- 'Brunei Bay' is an AoI with the dugong as a qualifying species (IUCN-MMPATF).

7.2.4 Philippines

Historically, dugongs were believed to have occurred throughout the waters of the Philippines, across the three main island groups of Luzon, Mindanao and Visayas (Figure 7.5), however, dugong populations are now fragmented (Nishiwaki and Marsh 1985; Kataoka et al. 1995; Panyawai and Prathep 2022).

Dugongs have been sighted in Mindoro off the southwest coast of Luzon (Baltazar and Yaptinchay 1998) and at several sites in the Palawan Islands group (Aragones 1994; Hines 2012; Poonian and Lopez 2016); and Negros Occidental (de la Paz et al. 2021) in the Western Visayas region. In Mindanao, dugongs have been sighted in northern Mindanao (Marsh et al. 2002) and Davao (Mizuno et al. 2017; Abreo et al. 2018; Figure 7.5).

An AoI with the dugong as a qualifying species is under consideration in neighboring 'Mayo and Pujada Bays' on the Pacific coast of Mindanao (IUCN-MMPATF).

Field surveys of dugong populations in the Philippines are sparse, with most information obtained from interviews and strandings (Aragones 1994; Aragones et al. 2010; de la Paz et al. 2021; Molina 2023). Aragones (1994) developed and applied a technique using simultaneous land-based surveys to identify important dugong habitats around the island of Calauit in Northern Busuanga, Palawan. Molina (2023) extended this technique in 2019 to 32 monitoring stations (most operated by local indigenous peoples) in the Calamian Island group (Figure 7.6), along with surveys of local fishers. The combined techniques enabled important dugong habitats to be identified in the island group and demonstrated that the location is an important dugong area in Palawan with calf sightings indicating a reproducing population.

In April 2023, Community Centred Conservation (C3) Philippines, in collaboration with the indigenous Tagbanua people used small drones to document 25 individual dugongs in the Calauit Island area. The project was conducted under the Seagrass Ecosystem Services Project, implemented by CMS Abu Dhabi under the Dugong MOU with financial support from the International Climate Initiative (IKI). The flight paths, designed by technical partners from Murdoch University, Australia, were planned to cover known dugong feeding grounds, as identified by the Tagbanua community (https://www.dugongseagrass.org/news/drone-survey).

Figure 7.5. Map of the Philippines showing placenames mentioned in the text. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

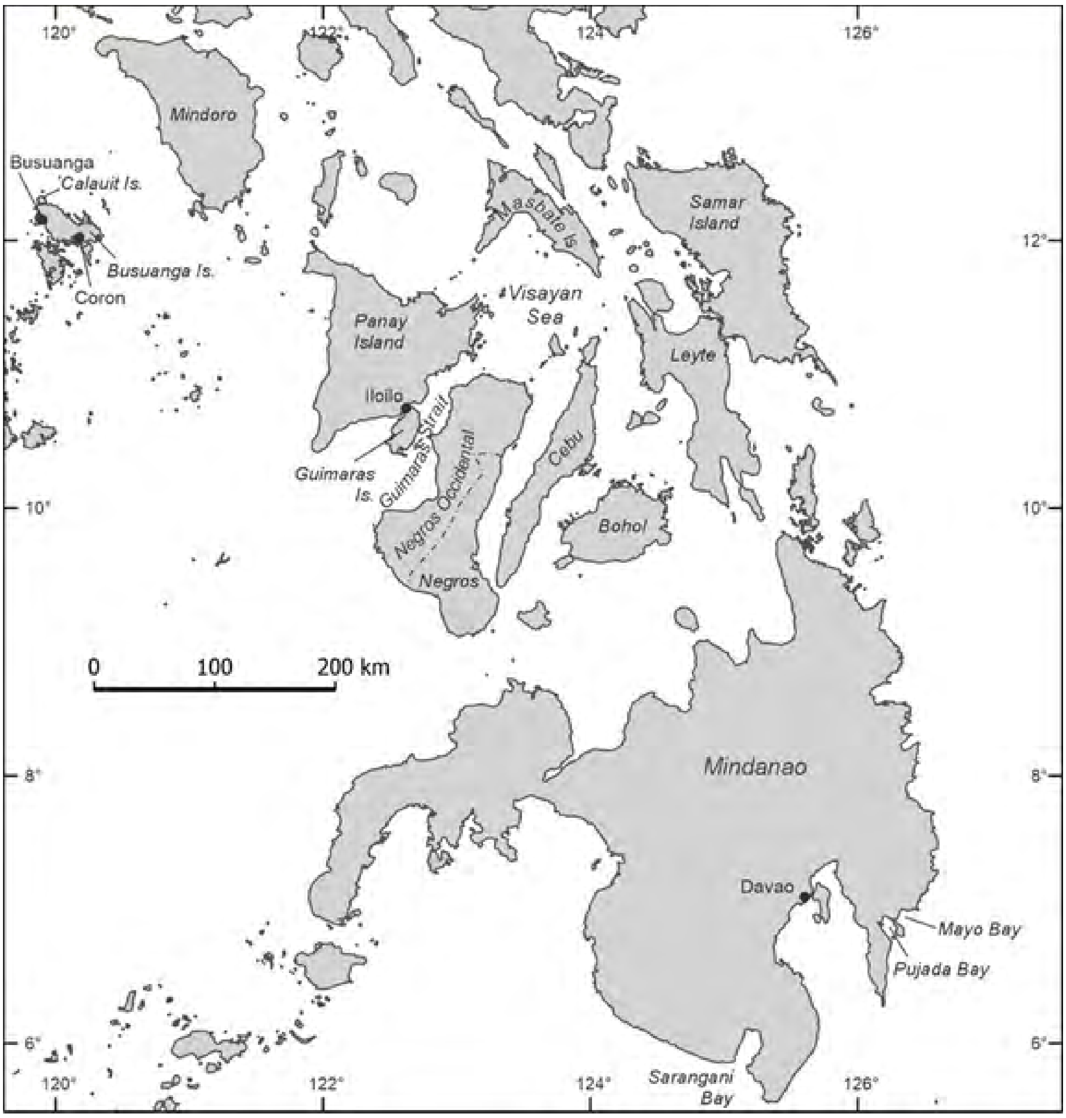
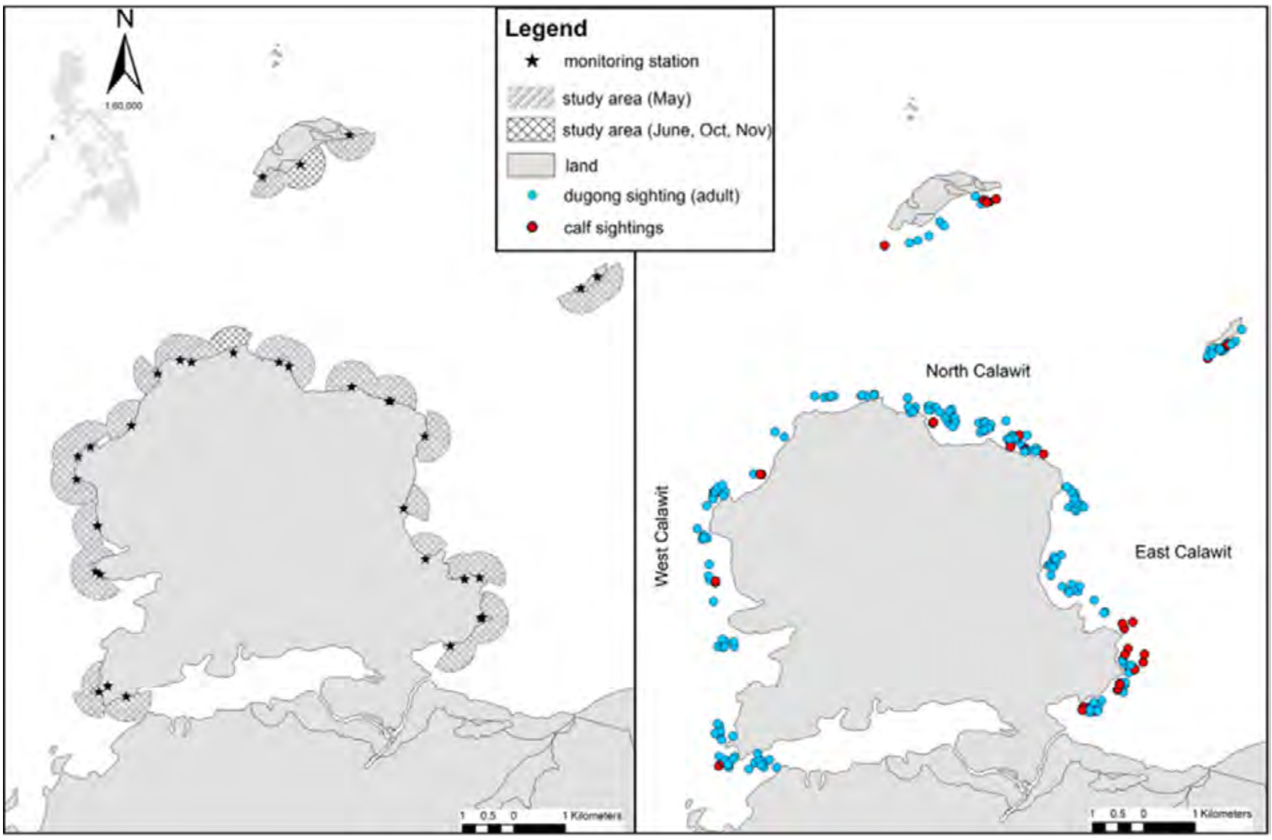


Figure 7.6. Map of Calauit (Calawit) Island north Palawan, Philippines showing the land-based, citizen science, method of recording dugong sightings for vantage points on a high island. Left figure shows simultaneous monitoring stations and the viewing area covered from each vantage point; right figure shows dugong sightings in 2019 based on simultaneous land-based surveys in May, June, October and November 2019. Reproduced from Molina (2024) with permission.



Within the Calamian Islands, dugongs are known to feed in Busuanga and Coron and have shown strong fidelity to at least one feeding site that has become a tourist destination (T. Aquino personal communication via email to Marsh and Schramm 2024). Dugongs are also known to occur around the island of Guimaras and the Panay Island in the Visayas (Figure 7.5). All fishers interviewed by Dolar et al. (2005) reported sightings of and/or encounters with dugongs. Dugong presence was further validated by feeding trails found in the area during the study.

Dugongs have also been reported off Roxas and Puerto Princesa as a result of the Dugong MOU Standardized Catch and Bycatch Questionnaire surveys used during the IKI SES project (N. Pilcher personal communication via email to Marsh and Schramm 2024).

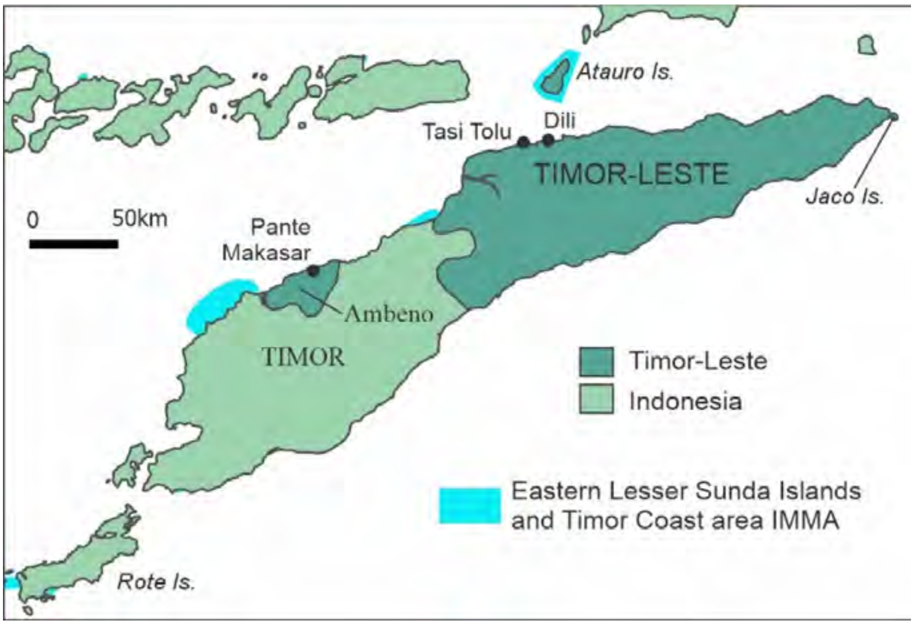
In early June 2024, four dugongs including one calf were sighted in Sarangani Bay (Esquire Philippines 2024). Strandings, mostly of dead dugongs, have been recorded across the three main island groups (Aragones et al. 2010, 2024; de la Paz et al. 2021). Dugong populations in the Philippines are presumed to be decreasing (Aquino et al. 2012; Al-Asif et al. 2022), but the data to support or refute this presumption are limited.

- Historically dugongs were believed to have occurred throughout the coastal waters of the Philippines, however, their populations are now fragmented and data deficient.

7.2.5 Timor-Leste

Inferences about dugong abundance in Timor-Leste (Figure 7.7) are largely based on anecdotal sightings. Dethmers et al. (2009) conducted monthly shoreline marine megafauna surveys along the Timor-Leste coastline from April to November in 2008. Dugong sightings were relatively rare; individuals were recorded in June (n=1) and November (n=5). Anecdotal sightings of dugongs have been reported throughout the north of the island both East of Dili and at popular dive sites west of Dili, and from Atauro Island (McKenzie and Yoshida 2019). A resident animal 'Douglas' frequented Roda Reef, Tasi

Figure 7.7. Geographic context of Timor-Leste with placenames mentioned in the text. The 'Eastern Lesser Sunda Islands and Timor Coastal Area' IMMA is coloured blue. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



Tolu and Dili Rock East and was often sighted by divers. Other popular dive sites for dugong sightings are Pertamina Pier in Dili and Secret Garden (east of Dili). In 2017, a small juvenile dugong was reported to be accompanying 'Douglas'. It is unknown whether 'Douglas' is a female, and the juvenile was her calf (McKenzie and Yoshida 2019) or if 'Douglas' is alive at the time of writing (June 2024).

Inferences about dugong abundance in Timor-Leste are largely based on anecdotal sightings, which have been reported throughout the north of the island both East of Dilli and at popular dive sites west of Dili, and from Atauro Island.

- The 'Eastern Lesser Sunda Islands and Timor Coastal Area' IMMA would benefit from cross-jurisdictional management involving Indonesia, Timor-Leste and Australia.

7.3 Cultural values

7.3.1 Indonesia

In some areas of Indonesia, dugongs are considered sacred and are valued and protected, while in other areas they are hunted and exploited for the perceived magical and aphrodisiac properties of their bones, teeth, tusks and gall bladder (Dugong and Seagrass Hub n.d.a). James Fox (personal communication to Mustika 2006) claimed that the people of the island of Roti considered the dugongs to be a female human and dead dugongs were buried formally in dugong cemeteries.

In the Aru Islands, dugong meat was sold at a local market in 1998 for USD 1 per kg (Marsh et al. 2002). During a survey of tourist stores in Southern Bali in June 2013, Lee and Nijman (2015) recorded over 130 dugong parts, including bones and teeth but also many carved items and some derivatives. The most common items were cigarette pipes usually carved from dugong ribs, and decorative carvings from bone and teeth. Lee and Nijman (2015) reported that dugong carvings cost USD 1,500–3,000 and were used for decorations. Some carvings made of dugong teeth were believed to ward off bad luck (Syafutra et al. 2018). Additionally, dugong tears were extracted from entangled or trapped individuals and used as love potions (Syafutra et al. 2018).

Moore et al. (2017) compiled and evaluated data and information (mostly unpublished) on the distribution, exploitation and community perceptions of dugongs in the Banggai, Spermonde, Taka Bonerate/Selayar, Tanakeke and Togean Islands of Sulawesi. They found that: (1) some small island communities in Sulawesi have dugong princess (*putri duyung*) legends; (2) many fishing communities consider dugong meat superior to beef and see it as a welcome change from fish; and (3) certain body parts and secretions attract a high price, such as dugong tears.

7.3.2 East Malaysia

Dugong hunting may have been practised as early as the 1600s, with dugong exploitation related to: (1) the consumption of their meat, which was considered a delicacy and typically eaten during special occasions such as weddings; and (2) the perceived medicinal properties of dugong oil and ground bones. Other dugong body parts (e.g., bones, ribs, tears, teeth and tusks) were made into carvings, decorations, and/or love potions (Marsh et al. 2002; Rajamani et al. 2006). In the early 2000s, some locals still believed and practiced traditional medicine, using dugong body parts (Jaaman 2000, 2004; Jaaman and Lah-Anyi 2002, 2003; Jaaman et al. 2000, 2001). More recent studies do not provide updates on whether these practices continue. Ubian and Bajau communities in Sabah use dugong tusk and bone for treatment of asthma, back pain, and shock (Rajamani et al. 2006). Dugong tears were believed to be used as an attractant to members of the opposite sex (Rajamani et al. 2006). Similar practices and beliefs have been recorded in Sarawak. Nonetheless, some find dugongs to be inedible as they believe dugongs are reincarnations of a cursed pregnant woman.

In Banggi and Kudat, dugongs were often trapped in fishing nets such as *pukat udang* (prawn nets), *kelong* (fish traps) and *pukat Rantau tenggelam* and *tanasi* (gillnets) (Rajamani et al. 2006). Traditionally, the Bajau Pelauh people of Sabah hunted dugongs for marriage dowries and as a symbol of manhood. Typically, dugongs were hunted at night with a sail/rowboat in Sabah, with three-to-five-inch portions of dugong meat sold at USD 1.30 in the market and whole dugongs sold at USD 25-100 depending on size (Marsh et al. 2002).

7.3.3 Brunei

Dugong hunting is likely to have occurred because of the high quality of dugong meat and locals believing that dugong body parts (e.g., bones, tears, tusks) have medicinal properties (Rajamani et al. 2006). Dugongs were hunted using harpoons, javelins, nets, and dynamite in some areas (Jaaman et al. 1999; Marsh et al. 2002).

7.3.4 Philippines

The *Duyong* (dugong) *Cave* is an archeological site located on the isolated southwest coast of Palawan Island, close to the extensive Tabon Cave complex. Fox (1970) describes how more than 5,000 dugong bones were found scattered on the surface and subsurface levels of the cave. He considered these bones to be ritual offerings at an important neolithic burial site, which was used over several thousand years from approximately 7,000 to 4,600 years BP.

Historically, dugongs were hunted in the Philippines, with spears and dynamite (Kataoka et al. 1995; Marsh et al. 2002). Dugong hunting was usually for consumption, and some fishers believed that parts of their skeletal, digestive, reproductive, and integumentary systems could be used as medicine (Marsh et al. 2002).

7.3.5 Timor-Leste

Hunting dugongs is now uncommon in Timor-Leste (Dugong and Seagrass Hub n.d.b) because it is believed that they are sacred animals that act as mediums of their ancestors when they are called on for help (McWilliam 2007).

7.4 Threatening processes

Hunting, incidental entanglement, and degradation of seagrass meadows are the major threats to dugongs in Maritime Southeast Asia (Marsh et al. 2002; Hines 2012; Pilcher et al. 2017; Al-Asif et al. 2022; Johnson et al. 2023). The cumulative impacts of these threats are considered likely to have exacerbated the decline of naturally fragmented dugong populations (Jaaman et al. 2008 a,b; 2009; Rajamani and Marsh 2010) but contemporary estimates of the magnitude of these threats are not available.

Some examples of these threats are considered below.

7.4.1 Hunting (past and present)

Dugong hunting is now prohibited in all Range States in Maritime Southeast Asia, apart from exemptions for some traditional peoples. For example, some traditional customary communities in Indonesia have distinct ways of living in remote or secluded places, and continue their hunter-gather traditions under customary (mostly unwritten) laws. Mulyani (2023) documents the laws applying to such groups. Her book is silent on the matter of hunting of marine mammals.

The examples below indicate that hunting by many groups outside traditional customary communities has been substantial in the recent past. In addition, laws are often inadequately enforced, with dugong poachers rarely punished significantly (Jaaman et al. 2008a). Dugongs were intentionally hunted in Indonesia using illegal blast and cyanide methods

Threatening Processes

Bycatch in artisanal fishing gears and blast fishing, seems to be the principal cause of direct mortality to dugongs, although there are few data for most of the region.

Although much less than in the past, illegal hunting for dugong body parts is still a key concern.

Loss and degradation of coastal seagrass is a major threat to important dugong habitats in the region due to mariculture waste, deforestation, siltation, coastal development, dredging, recreation and climate change.

Collision with vessels especially in ferry lanes is an unquantified cause of dugong mortality.

The cumulative impacts of fishing mortality and habitat loss make coordinated conservation interventions across the region very important, especially as several Range States have not yet signed the Dugong MOU.

(Marsh 2002). An estimated 80–200 dugongs were killed in Kobroor, eastern Aru, Maluku in 1979; 20-40 individuals in 1989 (Marsh et al. 2002). Compost (1980) estimated that the annual dugong catch from the main fishing areas of Aru ranged from 545–1,020 individuals in the late 1970s and noted that dugongs were "still quite common" there. Brasseur and de Jong (1991; cited in Moss and Van der Wal 1998) reported that 59–90 dugongs were caught in east Aru in 1989, and that catch numbers dropped to 29–36 dugongs in 1990. Their estimates were obtained by interviewing people from 14 villages between Pulau Karawei and Pulau Workai, which constitutes almost a third of the east Aru coast.

Jaaman et al. (2008a) used interviews to determine the nature and magnitude of directed catches of marine mammals in Sabah, East Malaysia. Between March 1997 and December 2004, they interviewed 1,186 fishers, village heads and/or knowledgeable villagers along the coastline. A total of 231 hunters caught dugongs and 49 hunted both dugongs and dolphins. The magnitude of dugong catches was similar throughout Sabah, but less in Sarawak. Harpoons or spears were the main hunting gear. An estimated 796 dugongs were reported to be taken annually with an average catch of 2.8 dugongs (95% CI = 2.47-3.21) per hunter. Most hunters had stopped hunting by the 1980s and only 32 (11%) said they still hunt dolphins or dugongs, at least occasionally or opportunistically during fishing trips at the time of those interviews. Such rates of dugong removal were almost certainly unsustainable (Jaaman et al. 2008a; Johnson et al. 2023) and are likely to have contributed to the disappearance of dugongs from some locations (Marsh et al. 2002; Poommouang et al. 2021).

7.4.2 Fisheries interactions

While dugongs may no longer be hunted directly, incidental entanglement in nets or mariculture lines in nearshore waters is a serious but poorly documented threat that typically results in mortality due to drowning (Dolar et al. 2005; Rajamani et al. 2006; de Iongh et al. 2008; Jaaman et al. 2009, 2017; Marsh et al. 2011; Pilcher et al. 2017; Syafutra et al. 2018; Hines et al. 2020; Panyawai and Prathep 2022).

In Indonesia, a study on the exploitation of dugongs during 1979 and 1980 reported that 550–1,000 dugongs were caught each year using Taiwanese nets originally set for sharks in eight areas in the Moluccas (de Iongh and Wenno 1992). Today, in 2024, most incidental entanglements are in gillnets (Syafutra et al. 2018) and/or fish weirs (Marsh et al. 2002). Individual animals are reportedly released back to the wild if alive (Utami et al. 2018) and consumed if dead (Syafutra et al. 2018).

Jaaman et al. (2009) conducted 753 interviews of fishers in the 16 districts along the coastline of Sabah between March 1997 and December 2004, and 358 interviews across 15 districts in Sarawak between November 1998 and October 2000. Incidental bycatch of dugongs was reported from all 16 districts in Sabah and the northern region of Sarawak by gillnets, trawlers and fish stakes. Jaaman et al. (2009) estimated that 479 dugongs (95% CI = 434-528) were bycaught every year in Sabah and 14 (95% CI = 2-30) in Sarawak, and concluded that bycatch rates, particularly in gillnets, may be unsustainably high. However, no dugong catches were seen during their observer trips. There is clearly significant dissonance between these bycatch estimates, and the dugong sightings reported in Section 7.2.2. Between 1996 and 2001, dugongs were the most recorded marine mammals stranded in East Malaysia (Jaaman et al. 2009).

In the Philippines, four of 119 dugong strandings (8%) were categorized as incidental entanglements. Seventy-seven percent (n=92) of those strandings were deceased dugongs but were not properly assessed for bycatch. All had good body condition and could have possibly been victims of entanglement or fisheries interactions (Aragones et al. 2017, 2024; L. Aragones personal communication via email to Marsh and Schramm 2024).

7.4.3 Blast fishing

Destructive fishing techniques such as blast fishing are still used throughout much of Maritime Southeast Asia. Of the 119 dugong strandings Aragones et al. (2017) recorded in the Philippines between 2005 and 2016, 10 individuals were assessed as victims of blasting. Two dugongs were still alive when stranded but eventually died.

Illegal blast fishing is still prevalent in parts of Sabah and appears to be a major cause of dugong mortality (L. Rajamani personal communication via email to Marsh and Schramm 2024). Fishers opportunistically kill dugongs with this technique if they are spotted while fishing. When dugongs are caught, they are either consumed locally or sold to merchants on other islands near Banggi or in the Philippines, where dugong meat is considered a delicacy, particularly for special occasions such as wedding feasts (Rajamani et al. 2006).

7.4.4 Seagrass degradation

Dugong populations are threatened by declining seagrass habitats globally (Johnson et al. 2023, although it is not known if and where seagrass habitat is limiting given the reduction in population size in most parts of the dugong's range. In densely populated coastal areas, a combination of mariculture waste, deforestation, siltation, incidental and destructive fishing, reclamation, development, dredging, and recreation degrades seagrass habitats (Marsh et al. 2002; Waycott et al. 2009). In the Philippines, major threats to dugongs include pollution due to coastal developments such as resorts in the Palawan islands (Hines 2012).

7.4.5 Vessel strikes

Collisions in boat channels or seagrass habitats can injure and/or kill dugongs (Plaimo et al. 2021; Meidina et al. 2023). However, the magnitude of this threat has not been quantified in Maritime Southeast Asia. There is some concern regarding a projected tourism increase in areas around Calauit Island due to the presence of dugongs (see Section 7.2.4. Philippines). Dive centers in the Calamian Islands offer dugong tours, thereby increasing vessel traffic in known dugong habitats and the potential for dugong-vessel interactions.

7.5 Conservation initiatives

7.5.1 International conventions

All dugong Range States in Maritime Southeast Asia are signatories to the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change (UNFCC). Only the Philippines is a party to the Convention on the Conservation of Migratory Species of Wild Animals (CMS); the Philippines and Timor-Leste are both signatories to the Memorandum of Understanding on the Conservation and Management of Dugongs and their Habitats throughout their Range (Dugong MOU). All Range States except Timor-Leste are contracting parties to Convention of International Trade in Endangered Species (CITES).

7.5.2 National laws

7.5.2.1 Indonesia

Sahri et al. (2020) and Nugraha et al. (2024) critically reviewed the legal framework and current institutional arrangements for the protection of marine mammals in Indonesia. Five international conventions, 28 Indonesian national regulations, and 16 provincial regulations on marine spatial planning were relevant, although some of these, for example the membership of the International Whaling Commission, apply to cetaceans only. Sahri et al. (2020) and Nugraha et al. (2024) identified three phases in the development of the legal framework regarding marine mammal governance: 1970s (species-centred approach), 1990s (site-based approach), and current (wider marine management approach). Despite these regulations, Sahri et al. (2020) conclude that the practical actions required by these regulations are still unclear and protection gaps exist, rendering conservation efforts less effective. Missing elements in conservation strategies developed to 2023 include a code of conduct for marine mammal watching tourism, standards for aquaria, and the legal basis for marine mammal stranding network and underwater noise pollution. Sahri et al. (2020) suggests establishing a mechanism for cross-institutional coordination for more effective marine mammal protection in Indonesia. Indonesia becoming a party to the Convention on the Conservation of Migratory Species of Wild Animals would be an important step.

Dugongs are protected under *Article 33(3) of the 1945 Constitution*, which protects all species within the land and water resources of Indonesia (UNEP and CMS 2015). Dugongs are also protected through the *Conservation of Flora and Fauna Act No. 7 of 1999* under which they are listed as protected fauna. This legislation emphasizes the management of protected species through research and monitoring wild populations, the rehabilitation and protection of wild individuals and the protection of their habitats from threats.

The outdated Indonesian Wildlife Trade Law (*Indonesian Natural Resources and Ecosystem Conservation Act Number 5 1990*) has recently been strengthened (Eryan 2024, and personal communication via email to Marsh 2024). One of the first convictions under the revised law included three pipes made from dugong tusks seized in 2024 in Palembang, South Sumatra (Yulisman 2024).

The Ministry of Marine Affairs and Fisheries (MMAF) also protects dugongs and seagrass habitats through the management of six marine national parks: Thousand Islands, Karimum Jawa, Bunaken, Wakatobi, Taka Bonerate and Cendrawasih Bay. In addition, local management of marine parks in Batu Angus, Aru Islands, Togian and Kupang Bay also protects dugongs and their seagrass habitats (Marsh et al. 2002). Management plans and the establishment of MPA networks have also been drafted for Bali, Komodo, Alor, Kaimana, Raja Ampat and Derawan. Strategies include spatial expansions of individual MPAs or linking numerous small MPAs into MPA networks (UNEP and CMS 2015).

With increasing reports of marine mammal strandings, the Indonesian government created a national Standard Operational Procedure (SOP) for assisting stranded marine mammals. The SOP was created by organizations including the MMAF, the Indonesia Institute of Science, Jakarta Animal Aid Network, Yayasan Konservasi RASI, World Wildlife Fund Indonesia, Conservation International Indonesia, and APEX Environmental (UNEP and CMS 2015). This SOP outlines procedures for handling live or disoriented marine mammals, together with disposal and postmortem investigation of dead individuals. Conservation and education campaigns have been conducted at various schools and fishing villages to improve knowledge on monitoring, conservation, policies, stranding procedures for marine mammals, and proper waste disposal and recycling to reduce seagrass degradation.

de Iongh et al. (2009 a,b) prepared a 'National Conservation Strategy and Action Plan for the Dugong in Indonesia' in partnership with the Centre for Oceanography in Jakarta. The Action Plan included a dugong database (de Iongh 2016). It is not known if this strategic plan was implemented. An action plan to conserve marine mammals for 2018–2022 was launched by the Indonesian government through enactment of *MMAF Decree No.79/2018*. Sahri et al. (2020) describe this plan as a comprehensive, structured, and detailed document that includes implementation and enforcement mechanisms: (i) research on ecological and socioeconomic cultural aspects, (ii) building a database and information system, (iii) reduction of the mortality rates from fishing and vessel strikes, (iv) identification and protection of critical habitats (e.g., migration corridors) as conservation areas, (v) regulation and modelling the potential economic value of marine mammal, (vi) capacity building and strategic partnership for registration of strandings, and (vii) regulation of the negative effects of noise and coastal development.

7.5.2.2 East Malaysia

Dugongs are protected from trade and hunting in Malaysia under the *Fisheries Act 1985; Fisheries Regulations 1999; Wildlife Protection Ordinance 1998 (Sarawak);* and *Wildlife Conservation Enactment 1997 (Sabah)* (Marsh et al. 2002). In 2011, Malaysia prepared a 'National Plan of Action for Conservation and Management of Dugong', which was being updated as of 2020 (Dugong and Seagrass Hub n.d.b). An update was not available at the time of writing (June 2024).

7.5.2.3 Brunei

Dugongs are listed under the protected species *Wildlife Protection Act 1978*, a law focused on the conservation and management of biodiversity (UNEP and CMS 2015). Dugongs are also protected from hunting, disturbance, harassment, selling and disposal through the *Fisheries Order 2009 of the Department of Fisheries*.

7.5.2.4 Philippines

The dugong was the first marine mammal to be protected by Philippine laws (Marsh et al. 2002). The Department of Environment and Natural Resources (DENR) have enacted several laws to prohibit and penalize catching, selling, purchasing, possessing, transporting, and exporting dugongs (Marsh et al. 2002; Perrin et al. 2005). DENR *Administrative Order 55 and 48, Wildlife Act of the Philippines (Republic Act No. 9147), Department Administrative Order 2004-15*, and *Fisheries Code Act 8550* (and its amended version *RA 10654*) protect dugongs in the Philippines, where they are included in the list of endangered, threatened, vulnerable, indeterminate, and insufficiently known species of wild birds, mammals, and reptiles (Marsh et al. 2002; UNEP and CMS 2015). Under these laws, trade of dugongs is prohibited and penalized, except for research. Regulatory permits under *Administrative Order 96* and *Executive Order 247* are required to extract dugongs or their tissues for research. Additionally, dugongs situated in MPAs throughout the Philippines are safeguarded from hunting through *Republic Act 7586*. There are also local resolutions in Palawan (a site with the highest sightings of dugongs) by the Palawan Council for Sustainable Development (*03-216, 04-226, 10-413*) that identify dugongs as Critically Endangered and requiring protection (UNEP and CMS 2015).

Research to assess the current population status of dugongs, information dissemination to educate the public about dugongs and their conservation, and training to protect and aid entangled, captured or stranded dugongs have been enacted regionally through *Administrative Order 55*. Several agencies have participated in the conservation of dugongs: DENR, the Pawikan Conservation Project (PCP), Protected Areas and Wildlife Bureau (PAWB; now the Biodiversity Management Bureau [BMB]), World Wildlife Fund (WWF) Philippines, Crocodile Farming Institute (CFI), Wildlife Refuge and Rescue Centre (WRRC; now the Palawan Wildlife Rescue and Conservation Centre [PWRCC]), Palawan Marine Mammal Rescue Society (PMMRS), Mindanao Environment Forum (MEF), Siliman University, Southeast Asian Fisheries Development Center, and the University of the Philippines, Diliman (Marsh et al. 2002; UNEP and CMS 2015). The Philippine Marine Mammal Stranding Network Inc (PMMSN) and the Marine Mammal Research and Conservation Laboratory of the University of the Philippines, Institute of Environmental Science and Meteorology (UP IESM) through the *Bureau of Fisheries and Aquatic Resources (BFAR) Fisheries Office Order 313* (series of 2019) provide technical assistance for bycatch monitoring.

Researchers at UP IESM together with the Biodiversity Management Bureau of the Department of Environment and Natural Resources developed an 'Action Plan for Dugongs in the Philippines' in 2017. The resultant plan, which has been renamed a 'Conservation Action Plan for the Philippines (2020-2030)' is still awaiting formal approval by the DENR Secretary, but some key activities identified in the plan (e.g., conservation awareness programs and research) have already been initiated by local stakeholders in some areas.

Marine Wildlife Watch of the Philippines (MWWP) collaborates with DENR on dugong conservation activities and has conducted several local dugong projects in the recent past (T. Aquino personal communication via email to Marsh and Schramm 2024).

7.5.2.5 Timor-Leste

Dugongs are protected in Timor-Leste through the 'National Biodiversity and Strategy Action Plan' (NBSAP) and the *Marine Protected Species Act* (Dugong and Seagrass Hub n.d.c). The NBSAP described the importance of seagrass beds as habitats for dugongs and other associated taxa like fish and invertebrates. Other laws or management plans that aim to conserve biodiversity in general are the 'National Strategic Development Plan of Timor-Leste (2011-2030)', the 'National Adaptation Program of Action on Climate Change (December 2010)', the 'National Action Program to Combat Land Degradation', and the *Biodiversity Decree Law* (Dugong and Seagrass Hub n.d.c) In addition to these nation-wide management plans and laws, dugongs are also protected within large MPAs (e.g., Nino Konis Santana National Park; da Silva 2021), or managed locally using traditional laws (e.g., *Tara Bandu*; Dugong and Seagrass Hub n.d.c).

7.5.3 Conservation status

The IUCN has listed the dugong as a Vulnerable species globally (Marsh and Sobtzick 2019). The dugong is listed as Critically Endangered in the Philippines based on Section 2 (List of Threatened Wildlife and their Categories) of *DENR Administrative Order No. 2004-15* (Molina 2023) and Endangered in Timor-Leste under the *Marine Protected Species Act* (Dugong and Seagrass Hub n.d.c).

No information about the domestic status of the dugong in Indonesia, Malaysia, and Brunei was available.

7.6 Research and monitoring activities

7.6.1 Overview

Research on dugongs across Maritime Southeast Asia has focused on determining their distribution and relative abundance at key localities within each Range State, together with some limited research on their biology, ecology, behavior, and threats (Marsh et al. 2002; Hines 2012). These investigations have been conducted by a large number and variety of institutions including local and international universities, government agencies and non-government organizations (NGOs), but have not been coordinated within or between Range States. The participating institutions are listed in Appendix 7.1 in Online Supplementary Material. (https://www.cms.int/dugong/en/publication/global-assessment-dugong-status-and-conservation-needs)

7.6.2 Research methods used to date

Much of the research on dugongs in Maritime Southeast Asia has used four methods: (1) interviews and focus groups involving fishers, (2) catch and/or stranding reports, (3) aerial surveys using occupied aircraft and (4) small scale unoccupied aerial vehicle (UAV), or drone surveys. However, not all these methods have been used in every Range State. For example, aerial surveys have been conducted at a broad scale only in East Malaysia (Rajamani and Marsh 2010) and at a local scale in the Lease Islands in Indonesia (de Iongh et al. 1995a). Aragones (1994) and Molina (2023) used land-based surveys in the inshore waters of the Calauit Island group in the Philippines (Figure 7.6). Research in Brunei, Philippines and Timor-Leste, has predominantly used interviews and reports of dugong sightings, catch and strandings (e.g., Jaaman et al. 2008 a,b; Panyawai and Prathep 2022). These differences in survey methods and extent have precluded meaningful comparisons of dugong distribution and relative abundance across this region.

Jaya Ancol Oceanarium in Jakarta kept dugongs in captivity for many years from 1984 (Syah 2001). Some animals were used for research: trialling attachment for satellite transmitters (Marsh and Rathbun 1990); gut passage rate (Lanyon and Marsh 1995); blood parameters (Syah 2001); and water turnover (Lanyon et al. 2006). The Oceanarium no longer houses dugongs.

de Iongh et al. (1997, 1998, 2008) studied the behavior of dugongs and tracked the movements of four animals for between 41- and 285-days using satellite transmitters. Home ranges varied between 4.1 km^2 and 43.4 km^2 (de Iongh et al. 1998). Each animal showed the individualistic patterns of movement that are characteristic of dugongs in other parts of their range (Deutsch et al. 2022). de Iongh (2005), de Iongh et al. (2007) and Budiarsa et al. (2021) studied the interactions between dugongs and intertidal seagrass habitats in Indonesia.

The 'Conservation of biodiversity, seagrass ecosystems and their services – safeguarding food security and resilience in vulnerable coastal communities in a changing climate' project has been managed by the Secretariat of the Memorandum of Understanding on the Conservation and Management of Dugongs and their Habitats throughout their Range of the Convention on the Conservation of Migratory Species of Wild Animals (CMS Dugong MOU) and funded by the German Federal Government's IKI. This project aimed to deliver site-specific assessments of seagrass health and threats, and to evaluate the ecosystem services seagrass provides. Project sites

Other Priorities for Action

- Estimating the distribution, size of and trend in the dugong population in each range state, using techniques appropriate to its geography and local capacity.
- Additional seagrass mapping using the Seagrass-Watch Protocols developed and applied in the IKI SES project.
- Developing effective governance at appropriate spatial scales, especially in Indonesia and the Philippines.
- Effective protection of the dugong populations and their seagrass habitats throughout the region.
- Understanding of the contemporary transboundary movements of dugongs.
- Developing transboundary arrangements for conserving dugongs and their habitats in Brunei Bay.
- Investigating the genetics of dugongs across the region.

and areas of interest in Maritime Southeast Asia were northern Minahasa, Indonesia; Ulugan Bay, Palawan, Philippines; Green Island Bay and Roxas, Palawan, Philippines and Hera Bay, Timor-Leste. Site-specific community-participatory methodological tools for seagrass assessment were developed and modified and included the following approaches:

- Drop cameras: used to collect photo quadrats at mapping points, positioned using a restricted random sampling design.
- Field validation data: used to create maps within specific areas of interest.
- PlanetScope Dove imagery: used to create spatially explicit seagrass maps using field validation point data and machine learning.

For each site, a map package was made available on open access Map Viewer and included: a survey spot check layer of field validation points; extent map of seagrass presence; a raster/polygon layer of interpolated seagrass abundance (% cover) and a polygon layer of seagrass communities (McKenzie et al. 2023). Some results from this work (McKenzie et al. 2023) are:

- Between January and June 2023, 2.42 km^2 of seagrass were mapped in Northern Minahasa, North Sulawesi Indonesia. Average seagrass abundance was 30.3 ± 1.2 %[1] cover. Most communities were on fringing reefs. Nine seagrass species were recognized. The meadows were largely dominated by *Enhalus acaroides* and *Thalassia hemprichii.*
- Between October 2022 and April 2023, 3.33 km^2 of seagrass were mapped within Ulugan Bay, Palawan, Philippines. Average seagrass abundance was 23.0 ± 2.3 %[1] with a mosaic of seven seagrass community types, predominantly in fringing reef habitats, dominated by *Enhalus acaroides* and *Thalassia hemprichii.*
- Between November 2022 and March 2023, 2.48 km^2 of seagrass was mapped at Hera Bay, Timor-Leste. Average seagrass abundance was estimated to be 36.9 ± 2.1%[1], and mostly occurred on fringing reefs dominated by *Enhalus acaroides* and *Thalassia hemprichii.*

The project successfully implemented a new collaborative approach to shallow water seagrass mapping, which has been widely shared with local stakeholders and scientists. The approach has the capacity to contribute to the globally standardized seagrass assessment, which is required throughout much of the dugong's range (see Chapter 11).

The Coral Triangle Initiative (CTI), a multilateral partnership between Indonesia, Malaysia, Philippines, Timor-Leste, Papua New Guinea, and Solomon Islands aims to protect marine resources (including dugongs) within the biodiverse region. CTI has recently been using citizen science in dugong population monitoring in the Lease Islands (Coral Triangle Center 2023).

As part of the IKI SES project, researchers at Edith Cowan University undertook assessments of the ecosystems services associated with Blue Carbon (Chapter 1), at sites in Indonesia and the Philippines (Lavery et al. 2023 a,b) to determine how these assets might be relevant to policy and provide financial solutions to marine conservation issues.

7.7 Regional summary

The coastal waters of Maritime Southeast Asia support numerous, fragmented dugong habitats, however, estimates of dugong populations and their status in the region are few and not strictly comparable (Marsh et al. 2011), despite the large number of institutions that have been involved in dugong conservation research in each county (Section 7.6.1). This is a situation that will be challenging to rectify for reasons of governance and geography as well as funding, which tends to be short-term and project based. For example, the IKI SES project has provided for capacity building in several dugong Range States to allow local NGOs to conduct surveys using small drones, however, ongoing support and funding for these surveys is not guaranteed from any source and may not be forthcoming.

As explained in Section 7.1.1, the length of coastline for each Range State, especially in Indonesia and the Philippines is vast, the shallow sea surrounding the islands is generally narrow, individual seagrass beds are small and fragmented, and without considerable information on the genetic structure of the dugong population it will be difficult to justify IUCN Red List of Threatened Species listings at the regional level (see guidelines prepared by IUCN Regional Applications Reference Group; IUCN 2012). In addition, especially in Indonesia and the Philippines, there is a mismatch

1 McKenzie et al. (2023) is silent as to whether these intervals refer to Standard Errors or Standard Deviations.

Confirmed Significant Locations

Indonesia

Sumatra: Bangka Island, Bintan Island, Batam Island

Eastern Kalimantan: Balikpapan Bay, Adang and Appia Bays Derawan Islands

Central Sulawesi: Tolitoli

North Sulawesi: Bunaken, Minahasa Utara, Kepulauan Sangihe

Lesser Sunda Islands: Eastern Lesser Sunda Islands and Timor Coast Area including 25 locations in the coastal areas of Sabu Islands, Rote Islands, Eastern Flores and Timor Island

West Papua: Kaimana in Raja Amput Protected Areas MPA network and Bird's Head Seascape

Moluccas Province: Lease Islands, Seram Island, Kei Islands, Buru, Halmahera, Tanimbar, Aru Islands

Southwest Papua: Raja Ampat and Dampier Strait region

East Malaysia and Brunei

Sarawak: Brunei Bay, Labuan Island, coastal waters close to Kota Kinabulu, Gaya Island, Kudat,

Sabah: Banggi Island, Mantanani Island,

Brunei: Jambongan Island, Sandakan Bay, and Pulau Tambisa

Philippines

Mindanao: Mayo and Pujada Bays, Sarangani Bay

Visayas: Guimaras Island, Guimaras Strait, Iloilo, Panay Island, Negros Occidental

Palawan: Calauit Island, Busuanga Island, Busuanga-Coron area, Green Island Bay, Roxas

Timor-Leste

East of Dili, West of Dili, Atauro Island, Roda Reef, TasiTolu

between the spatial scale of marine conservation, which has largely been organized at the local scale, and strategic planning for dugong conservation, generally organized at the national level (see Section 7.5.2). Coordinated governance at a regional level could be advantageous.

In Indonesia, the MMAF has six regional offices "Balai Pengelolaan Sumberdaya Pesisir dan Laut" (BPSPL, the Coastal and Marine Resource Management Offices), which manage several provinces within their territories. Regional action plans subsidiary to the national plans could be organized. Similarly, in the Philippines, regional plans for each of the main island groups: Luzon, Visayas, and Mindanao could advance the conservation management of dugongs. Planning may receive more community support if it were organized for megafauna rather than dugongs *per se*. At the key location of Brunei Bay (Section 7.2.3), international coordination across the East Malaysian state government of Sarawak, the federal territory of Labuan in East Malaysia, and the country of Brunei would be highly desirable.

Once governance arrangements for the conservation of megafauna and their habitats are established at appropriate spatial scales, it would be desirable to design and apply survey techniques suitable for: (1) the spatial scale of the distribution of dugongs and their seagrass habitats, and (2) local capacity in each Range State. For example, a sequence of: (1) the Dugong MOU Standardized Catch and Bycatch Questionnaire surveys to identify dugong areas of local importance and threats to dugongs (Pilcher et al. 2017) at the desired governance scale, (2) seasonal 'hotspot surveys' using small drones and eDNA to provide baseline information on dugong distribution and abundance, (3) seagrass surveys using the Seagrass-Watch protocols being developed and applied in the IKI SES project, and (4) focus groups with local experts to identify threats to dugongs and other megafauna and their habitats, could inform: (a) a review of the adequacy of existing MPAs to protect megafauna, including dugongs and their habitats; and (b) the design of new or modified MPAs to achieve effective conservation management of marine megafauna.

7.8 References

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Chapter 8

EAST ASIA

Authored by: Helene Marsh, David Blair, Toshio Kasuya, Songhai Li, Mingli Lin, Len McKenzie, Hiroyuki Ozawa, Yoshihito Wakai, Linda Wong, Hideki Yoshikawa and Luisa Schramm

Helene Marsh[1], David Blair[1], Toshio Kasuya[2], Songhai Li[3], Mingli Lin[3], Len McKenzie[4], Hiroyuki Ozawa[5], Yoshihito Wakai[6], Linda Wong[7], Hideki Yoshikawa[8], Luisa Schramm[9]

[1]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[2]5-30-32-3, Nagayama, Tama, Tokyo, Japan.
[3]Marine Mammal and Marine Bioacoustics Laboratory, Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences, Beijing, China.
[4]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Cairns, Queensland, Australia.
[5]Okinawa Prefecture Environment Science Centre Kyoduka, Urasoe-City, Okinawa, Japan.
[6]Toba Aquarium, Toba, Mie, Japan.
[7]China Biodiversity Conservation and Green Development Foundation, Chengming Building, Xizhimen, Beijing, China.
[8]Save the Dugong Campaign Centre, Chiyoda Building, Nakama Office Tukudohatiman, Shinjuku, Tokyo, Japan.
[9]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Townsville, Queensland, Australia.

Correspondence to: Helene Marsh helene.marsh@jcu.edu.au.

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Cover image: Activists using the dugong as a symbol of their protest against the construction of the Futenma Replacement Facility in Henoko-Ōura Bay, Japan. Taro Hosokawa photograph.

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This report was produced on the Bebegu Yumba campus of James Cook University in Townsville, Australia on the lands of the Wulgurukaba and Bindal peoples. We gratefully acknowledge First Nations Custodians of all lands which this report covers. We recognize the deep, lasting connections to Country, and pay respect to Elders past, present and emerging.

Contents

Range/Signatory States

Range States	Signatory States
China? (Vietnamese-Chinese border to the northern border of the Fujian Province including offshore islands)	No
Japan (Nansei Islands)	No

Only one dugong has been seen in Chinese waters over the last several decades. The size of the population in Japanese waters is critically low.

Regional findings

Countries considered in East Asia include: 日本 (Japan) and People's Republic of China (China)

- Dugongs are in critically low numbers in the coastal waters of China (Viet Nam-China border to the northern border of the Fujian Province including offshore islands) and Japan (waters of the Nansei Islands).
- It is extremely unlikely that dugongs will recover in this region given the low likelihood of dugongs migrating into the area, successful captive breeding programmes, or translocating dugongs into the region from elsewhere.
- The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species formally classified the Nansei 'subpopulation'[1] as Critically Endangered in 2019. An assessment for the Chinese 'subpopulation' would almost certainly reach the same conclusion.
- Given this situation, interventions designed to protect coastal marine megafauna more generically in China as part of its Ecological Conservation Redline strategy, may be more successful than dugong-specific interventions.
- Some segments of the Japanese public consider the remaining dugong population in Japanese waters to be very important, a situation that could be harnessed to address the threats to megafauna in the Nansei Islands region more generically.

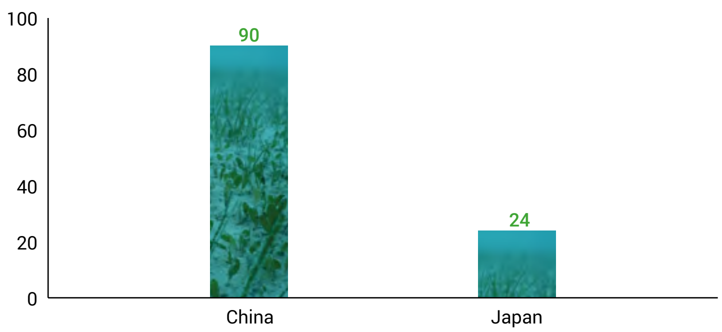
8.1 Regional setting

8.1.1 Geographic overview

This chapter considers the status of the dugong along the ~ 12,025 km coast of East Asia, north of the Vietnamese-Chinese border (21.53° N, 108.06° E) to the northern border of the Fujian Province (27.17° N, 120.43° E), the Chinese coastal islands of Hainan and Taiwan (Figure 8.1) and the offshore Nansei Islands (also known as Ryukyu Islands, Southwest Islands, Nansei-Shoto, Ryukyu-ko or Ryukyu Arc) in Japan (Figure 8.2). The Nansei Islands form an almost 1,300 km long arc between Kyushu and the island of Yonaguni about 150 km northeast of Taiwan Island, China. Within the Nansei Islands, the northern limit of the dugong's historical distribution was probably around the Amami Island group (Carter et al. 1946; Nishiwaki et al. 1979).

This region is the northern boundary of the dugong's range in the Pacific Ocean and is part of the Tropical Indo-Pacific seagrass bioregion (Short et al. 2007). Estimates of the area of seagrass in the region are variable, but all indicate that extensive seagrass meadows are unlikely to occur. The estimated seagrass area with moderate to high confidence for southern China is 158 km^2, with around 26 km^2 occurring along the mainland; most (~ 16 km^2) in Guangdong province (Huang et al. 2006; Zheng et al. 2013; Jiang et al. 2020), 9 km^2 in Guangxi, and the least (0.1 km^2) in Hong Kong (Fong 1999; Kwok et al. 2005). Approximately 64 km^2 of seagrass meadows occur in the sheltered bays and nearshore habitats surrounding Hainan Island (Huang et al. 2006; Zheng

Seagrass Mapped Area (km^2)



Seagrass communities are under-mapped with current estimates likely underestimates

1 IUCN uses the term 'subpopulation' in the assessment of a regional population. The term 'subpopulation' is used here with reference to IUCN documentation only.

Figure 8.1. Geographic context of the historic range of the dugong in China showing placenames mentioned in the text. Kenting National Park is shown in blue. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

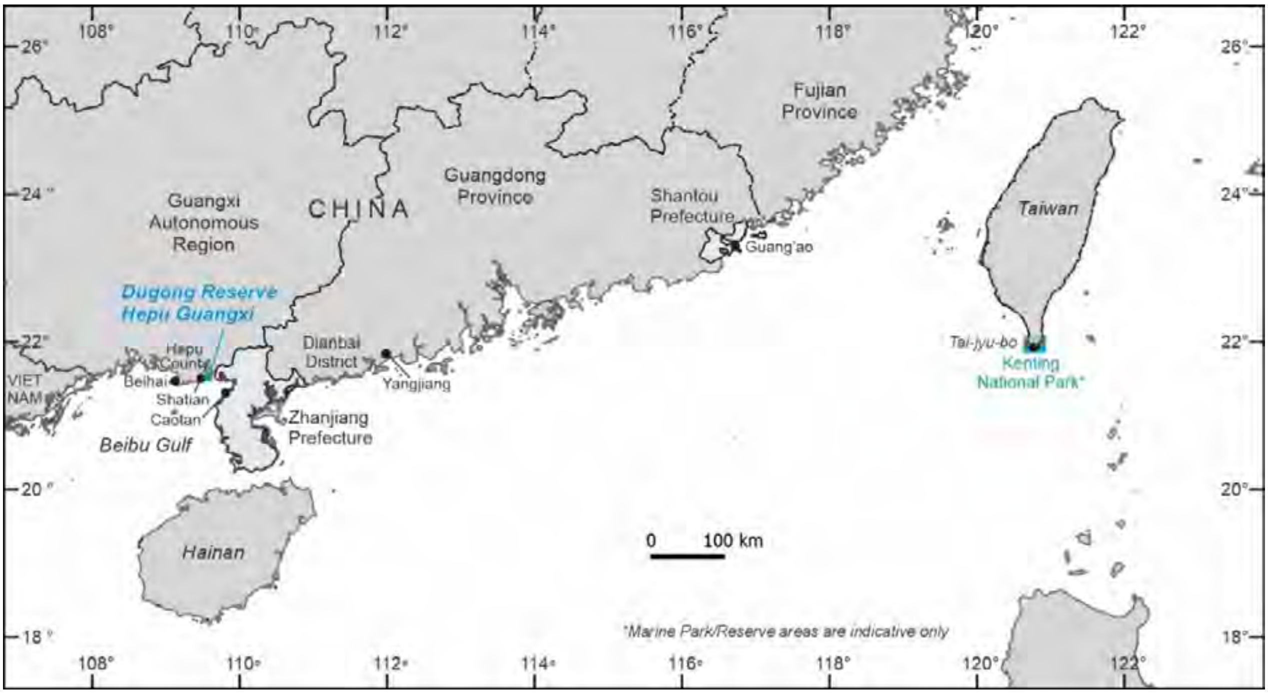
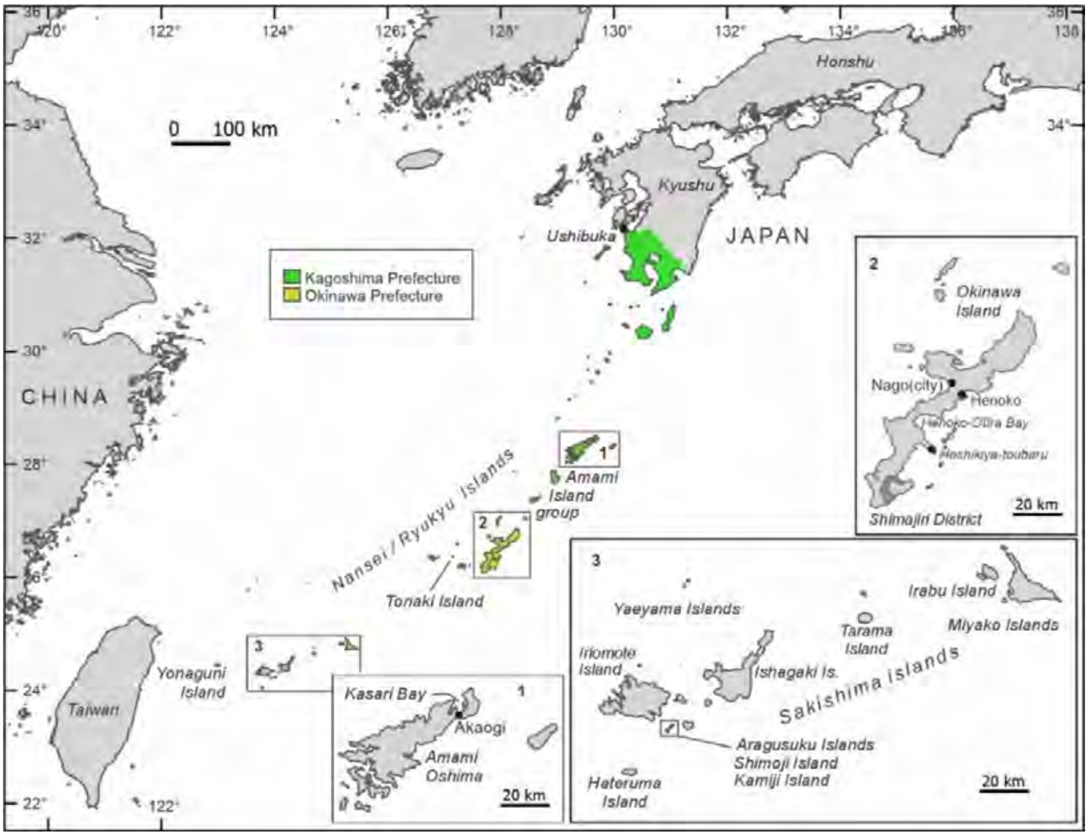


Figure 8.2. Geographic context of the dugong's range in Japan showing placenames mentioned in the text. Insets: (1) Amami Oshima; (2) Okinawa Islands; and (3) Sakishima Islands (Miyako Island Group and Yaeyama Island Group). The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



et al. 2013; Jiang et al. 2017), and the largest area of seagrass (68 km^2) occurs in the waters surrounding Taiwan Island (Sudo et al. 2021).

Sudo et al. (2021) estimated approximately 24 km^2 of seagrass meadows for the Nansei (Ryukyu) Islands in Japan, based on scientific papers and reports from 2000–2020.

There is consensus that the extant dugong population in East Asia is extremely small. In 2019, the IUCN's Red List of Threatened Species classified the Nansei 'subpopulation' as Critically Endangered (Brownell et al. 2019). The Chinese 'subpopulation' has not yet been assessed by IUCN. Brownell et al. (2019) concluded that the dugong was extinct in the coastal waters of the Chinese island of Taiwan, noting that there is some doubt as to whether these waters ever supported a viable population (see Section 8.2.1 below). Lin et al. (2022a), claimed that the dugong was functionally extinct in China and suggested that its regional status there should be reassessed as 'Critically Endangered (possibly extinct)'. However, the IUCN (2012) requirements for assessment as Extinct have not been fulfilled as discussed in Section 8.5.2.1

8.1.2 Geopolitical and socioeconomic overview

This information (Table 8.1) is provided as an indication of the challenge for each of the Range States in the region to consider the conservation of dugongs and their habitats in the context of their socioeconomic development needs. China is a major economy, a G20 country, the third largest country in the world by area, and the world's second most populous nation. It has the world's second largest Gross Domestic Product (GDP; United Nations Department of Economic and Social Affairs [UNDESA] 2023) and a High Human Development Index (HDI) of 0.768 (ranked 79; UNDESA 2023). China has a population of 1.426 billion people (UNDESA 2023), and 162.3 million people live within 50 km of the coast in the dugong's historic range in China; 81 million within 10 km (Schiavina et al. 2023; Chapter 11, Figure 11.2).

China is divided into more than 30 administrative regions; including the following regions in the dugong's historic range: Fujian, Guangdong, Guangxi, Hainan, Hong Kong, Macao, and Taiwan.

Japan is a G7 country with the world's fourth largest GDP (https://www.worldometers.info/gdp/gdp-by-country/#google_vignette) and a Very High HDI of 0.925 (ranked 19) (Table 8.1). Approximately 1.48 million people live within 10 km of the coastline in the dugong's historic range in Japan (Chapter 11, Figure 11.2).

Table 8.1. Human Development Index (HDI) status rank and Gross Domestic Product (GDP) per capita rank of the dugong Range States in East Asia. Consistent with the remainder of this chapter, the countries in this table are ordered west to east starting with China. Countries with the highest HDI or GDP have the lowest ranks. 189 countries were ranked for both indices.

Range State	HDI	HDI Rank 2023[i]	GDP per capita rank[ii]
China	High	79	72
Japan	Very High	19	38

i 2023 HDI data from https://hdr.undp.org/data-center/country-insights#/ranks (downloaded from the internet January 2024);

ii 2023 per capita GDP from https://www.worldometers.info/gdp/gdp-per-capita/ (downloaded from the internet June 2024).

The Nansei Islands have an ethnically distinctive indigenous population and language, and the differences between this region and the rest of Japan continue to play a significant role in the relationship between the people of Okinawa and the Japanese central government (Palz 2023). Historically, the Ryukyu Kingdom ruled the islands, however, the monarchy was abolished in 1879, resulting in the formation of Okinawa Prefecture. The 27-year American occupation of Okinawa after World War II further maintained the region's distinction from the main Japanese islands (Welch et al. 2010). The northern half of the Nansei Islands, including Amami Island, is under the administration of Kagoshima Prefecture, the southern half; Okinawa Prefecture (Figure 8.2).

8.1.3 Genetics of dugong populations

For an overview of genetics-relevant techniques, definitions, studies and general findings, refer to Chapter 1, particularly Figure 1.2.

The only genetics data in this region come from Okinawa. Blair et al. (2014) reported two sequences[2] from this population that represent two haplotypes within the northeastern haplogroup (Chapter 1, Figure 1.2). One of the haplotypes was similar to a sequence from Palawan in the Philippines, about

2 Definitions of genetic terms used in this report are provided in Chapter 1

2,000 km distant. The mitochondrial haplotype extracted from the whole-genome data reported by Tian et al. (2023) differed slightly from the other two, representing a third Okinawan haplotype (data not shown). It is interesting that each of three dugongs sampled from Okinawa should have a different haplotype (at least three different female individuals). This suggests greater past diversity and perhaps a rapid decline in recent times (within a dugong's typical life span).

The Okinawan population has been regarded as distinct, with little opportunity to exchange genes with other populations (Kayanne et al. 2022). Certainly, analyses based on the whole-genome data from a single Okinawan dugong (Tian et al. 2023) place it far from Australian dugongs.

Tian et al. (2023) inferred demographic parameters from the Okinawan genome, which had features reflecting long-term and continuing population decline, extensive inbreeding, and reduction in heterozygosity. All of these features are likely to be observed in a Critically Endangered population.

- Genetic data are extremely limited from the East Asian region. Three mitochondrial haplotypes place dugongs from Okinawa within the northeastern haplogroup.
- Data from a whole-genome study indicate demographic parameters consistent with a Critically Endangered population.

8.2 Distribution, abundance and trends in Range States

8.2.1 China

8.2.1.1 *Fujian, Guangdong, Guangxi, Hainan, Hong Kong and Macao*

Hines (2012) reports that Allen (1938) claimed that the earliest report of a dugong in Chinese waters was made by Dutch explorers travelling between Nanyang and Guangzhou in the mid-seventeenth century.

Lin et al. (2022a) reviewed all available historical data covering the past distribution of dugongs in Chinese waters from the twentieth century onwards. The following is a summary of these records, supplemented by information complied by the China Biodiversity Conservation and Green Development Foundation (CBCGDF; J. Zhou, L. Wong, S. Ma and Y. Xu personal communication via email to Marsh and Schramm 2023):

- 42 records from Guangxi: several field observations for the Beibu Gulf in 1935 (Hines 2012); and 41 observations from Beihai:
  - Hunting: 11 records totalling 244 dugongs 1955-1984 (Shou 1958; Wang and Sun 1986; Wang et al. 2007); these records include 28 animals captured for research in 1976, all of which died.
  - Bycatch: six records of six dugongs 1996-2000 (Wang et al. 2007; Zhou et al. 2003).
  - Strandings: eight records of 11 dugongs 1978-2000 (Wang and Sun 1986; Wang et al. 2007).
  - Field observations/surveys: 16 records of 37 dugongs 1935-2004 (Hines 2012; Wang et al. 2007).
- Four records for Guangdong Province between 1972–1999 (two strandings [Wang and Sun 1986]; and two bycatch [Zhou et al. 2003]); and
- 11 observations from Hainan Province: seven hunting records of a total of 30 dugongs between 1954-1986 (Wang and Sun 1986; Wang et al. 2007); two records of bycatch (each of one dugong in 1983 and 1986; Zhou et al. 2003; Wang et al. 2007); one field sighting in 2000 (Zhou et al. 2003) and one stranded dugong in 2008 (Wang et al. 2010). In 1976, a total of 28 live dugongs were captured with assistance from the Fisheries Bureau of the Guangxi, the Fisheries Bureau of Hepu County, and the Marine Combat Brigade of Shatian Commune, and transported to ponds for scientific research on the artificial breeding of dugongs (Gu 1980). Unfortunately, all died.

Although several vessel surveys for dugongs in Chinese waters were conducted between 1962 and 2004 (Wang and Sun 1986; Zhou et al. 2003; Wang et al. 2007), there are no verified field observations or aerial surveys after 2000. Thus, any conclusions about population size must be tentative. Wang and Sun (1986) concluded that dugongs: (1) were mostly found along the coast of Guangxi and western Guangdong, rarely along the coasts of Dianbai and Yangjiang Counties, Guangdong; (2) in the waters of Hainan Island were found only on the west coast; (3) were not found off the southeast coast of Guangdong; and (4) that the northern limit of their distribution was southern Taiwan.

Lin et al. (2022a) conducted a large-scale interview survey of 788 marine resource users across Guangxi, Guangdong, Hainan and Fujian in 2019. Twelve percent of respondents (n=91) recognized a picture of a dugong, but only 5% (n=37) reported past sightings with a mean last-sighting date in the late 1990s. Only three respondents reported sightings since 2014 (previous five years) including one sighting near the dugong reserve in Caotan, western Zhanjiang Prefecture (western Guangdong), and two sightings in the Guang'ao Port Area of Shantou Prefecture (eastern Guangdong), an area with no historical dugong records.

In their report to the Third Southeast Asian Marine Mammals Symposium (SEAMAM III), Zhao et al. (2015) concluded that 'dugongs have been extirpated from Chinese waters for years'. Lin et al. (2022a) acknowledged the possibility that a few surviving dugongs in Chinese coastal waters might have been undetected by the respondents to their surveys but concluded that: (1) dugongs were likely functionally extinct in China; and (2) recovery is unlikely with the continuing deterioration of coastal ecosystems. They concluded that hunting, combined with the degradation of seagrass meadows and accidental entanglement, contributed to the rapid collapse of China's dugong population, and recommended that the status of the dugong in Chinese waters be formally assessed.

Brownell et al. (2019) concluded that dugongs no longer occur off Taiwan, with the last recorded stranding in 1986. The last sightings from the southern tip of Taiwan (now Kenting National Park) were in the 1950s and 1960s (Zhou 2004). Wang et al. (2015) claimed that previous reports of the presence of dugongs in Taiwanese waters could be traced back to a single confirmed specimen that was reportedly captured near the village of Tai-jyu-bo (21.94° N, 120.75° E) in '1931 or 1932'. This specimen was reported by Hirasaka (1932, 1934), who included photographs of the (adult) skull, which was found in garbage by an official and offered to him for investigation. The fisherman, who told Hirasaka about the dugong, stated that it was captured in the early spring of 1931 and that its stomach contained algae and marine crabs. Hirasaka (1932, 1934) also stated that a young male and an adult male were reportedly captured in 1931 in separate incidents at Haikau, a port near Koshun (which is not far from Tai-jyu-bo), but no specimens were examined. Hirasaka (1934) reports anecdotal information of two or more dugongs in the vicinity of the first capture. Hirasaka's evidence suggests that Wang et al.'s claim that all reports could be traced to a single animal is likely incorrect. Aoki et al. (1938) describe a female dugong carcass in the National Taiwan Museum, Taipei. It was captured off Camiguin Island, Babuyan Islands, Philippines on 25 March 1937.

The Kuroshio Current travels from Luzon Island in the Philippines (where dugongs are present; see Chapter 7), north along the eastern coast of Taiwan, where the continental shelf is narrow and seagrass habitat was not reported by Liu (2013) or Sudo et al. (2021). Thus, these records of dugongs in Taiwan may be extralimital rather than evidence of a past population. If a population had been present, it is likely to have been been extremely small.

Nonetheless, on March 28 2025, a dugong was caught in a fishing net in waters 800m off Fenniaolin fishing port in Yilan (~24,8°N), in northeast Taiwan and released alive (Jeng Ming-shiou (鄭明修), executive director of Academia Sinica's Biodiversity Research Center personal communication to Central News Agency (CNA), the national news agency of the Republic of China). Media photographs seen by Marsh suggest the animal was an immature male. On April 29 2025, a dugong with two scars similar to those photographed on this animal was photographed off Kumejima Island near Okinawa Island Japan, more than 600 km from the the release point (kaisou-n@crux.ocn.ne.jp email to Marsh 30 April 2025).

- If the dugong still exists in Chinese waters, its numbers must be extremely low, and the population is unlikely to recover.

8.2.2 Japan

Dugong bones have been found in more than 100 archaeological sites throughout the Nansei Islands (Welch et al. 2010), indicating that dugongs were hunted from as early as 6,000 years ago (Early Jōmon period). Welch et al. (2010) report that 'these sites are distributed across the archipelago: five sites in the Amami Islands Group, eight sites in the Miyako Island Group, 86 sites in the Okinawa Island Group, and 12 sites in the Yaeyama Island Group'. In addition, bones have been found at two sites on mainland Japan: one on Kyushu and one on Honshu (Figure 8.2).

The most northern, confirmed, modern records of the dugong are considered to be extralimital. In September 2002, an adult dugong was taken in fishing gear, off Ushibuka (32° N, 130° E), Kyushu (Yamamuro et al. 2004). Another was captured in a set net off the west coast of Kyushu in October 2002. A few days after, another was stranded nearby (Ogura et al. 2005).

During the time of the Ryukyu Kingdom (1429–1879) '*the people of Shimoji and Kamiji* (the two islands that make up Aragusuku Island; Figure 2.2) *were* *exclusively allowed to hunt'* (Welch et al. 2010). Dugongs were hunted with nets and the meat was used to pay taxes to the Kingdom between 1637 and 1879 (Ohama 1971). After the Ryukyu Dynasty was integrated into Japan in 1879, dugongs began to be harvested commercially. Harvest statistics from 1894–1916 showed that 327 dugongs were caught during this period near the Yaeyama, Miyako, and Okinawa Island Groups (Uni 2003). There are no data from 1916 until after World War II, when dugongs were killed incidentally in association with dynamite (blast) fishing until 1972, even though the practice was prohibited after 1948 (Uni 2003; Shirakihara et al. 2007; Kayanne et al. 2022).

Kayanne et al. (2022, their Supplementary Material Table 1) summarized data on known dugong mortalities reported in local newspaper articles from 1960-2020 as follows: (1) four dugongs were reported as hunted for sale in 1960, 1965 and 1967; (2) a dead dugong was found in 1987 near Amami and Miyako Islands (Yaeyama Island Group); (3) from 1979–2004, a local newspaper reported that 14 dugongs including six calves were found dead on Okinawa Island: seven were caught in gill or fixed nets (another four were released alive or kept in an aquarium) and seven dead animals were found stranded; (4) a pregnant female was caught in a fixed net in 1995. Bycatch continued until at least 2000 but Kayanne et al. (2022) found no records of bycatch deaths since then.

Dugongs were believed to have been eliminated from the waters of several islands (e.g., the Miyako Island Group by 1965 and around the Yaeyama Island Group by 1967 [Kasuya et al. 2000]), but there have been occasional sightings in the Yaeyama Island Group since that time. Since the 1970s, confirmed sightings and specimens of dugongs have mainly been from the waters around Okinawa Island, where survey effort has been concentrated. There have also been occasional sightings outside the Okinawa region (Brownell et al. 2019; Kayanne et al. 2022).

Aerial surveys for dugongs have been conducted since 1997 largely in response to concerns over the impacts of the military base to be constructed in Henoko-Ōura Bay on Okinawa. In 1998-99, ten dugongs were observed during transect aerial surveys around Miyako, Okinawa and Yaeyama Island Groups: all were sighted during the 837 km flown in 1998; no dugongs were observed around Iriomote, Ishigaki, Tarama and the Miyako Islands in the 310 km flown in 1999 (Shirakihara et al. 2007). In 1999, an airline helicopter sighted six dugongs along the east coast of Okinawa Island (Dugong Network Okinawa 2000). Defence Agency surveys covered dugong habitats around Okinawa Island once a month from 2007–2009, and four times a year since 2009. Up to five dugongs were sighted in a single survey in 2003 (Brownell et al. 2019). From 2007, a maximum of three dugongs (each individually recognizable) had been sighted in a single survey (Brownell et al. 2019). One of these animals died in March 2019 from a stingray barb, presumably while bottom feeding (Japanese Ministry of the Environment 2019); the other known individuals have not been seen in recent years.

There have been occasional dugong sightings outside the Okinawa region. Ogura et al. (2005) reported four sightings from Kasari Bay, Amami-Oshima from the early 2000s, presumably including a dugong reported from Akaogi in Kasari Bay, Amami-Oshima in September 2002. Other incidental sightings have been reported from Tarama Island (Miyako Island Group) from June 2013; Iriomote Island (Yaeyama Island Group) from 2013 to 2014 (Natural Park Foundation 2019); and Tonaki Island, 58 km southwest of Okinawa from July 2017 (Okinawa Prefectural Government 2019); Hateruma Island (Yaeyama Island Group) from August 2018 (Natural Park Foundation 2019). The most recent survey conducted by the Okinawa Prefectural Government (Japanese Ministry of the Environment 2024) reported dugong feeding trails in the Sakishima Islands (Yaeyama and Miyako Island Groups), including Irabu, Iriomote and Kuruma Islands and live sightings in Amamioshima Island and the Sakishima Islands. No feeding trails or live sightings were reported for Okinawa Island.

The dugong population of the Nansei Islands has been under serious threat of local extinction since the 1990s (Uchida 1994; Kasuya and Brownell 2001). A scientifically valid estimate of its size is not available, but numbers are certainly very low (Brownell et al. 2019; Kasuya and Hosokawa 2021; Kayanne et al. 2022). Brownell et al. (2019) estimated the population to be less than ten animals.

Even though the population of dugongs in the region is likely to be extremely small, recent reports of sounds, feeding and photographs of feeding trails at three locations around Okinawa and six locations in the Sakishima Islands indicate that dugongs are not yet extinct there (Figure 8.2 inset 3; Japanese Ministry of the Environment 2019, 2020, 2021, 2022, 2023, 2024; Okinawa Prefectural Government 2019, 2022, 2023; Palz 2023). Dugong faeces have been confirmed by DNA testing of stools found in two locations: (1) about 2 km south of the military base construction site in Henoko-Ōura Bay on Okinawa Island in 2022; and (2) around Irabu Island (in the Sakishima Islands where dugong feeding trails have also been seen; Figure 8.2 inset 3; Okinawa Prefectural Government 2023; Ozawa et al. 2024). As noted in Section 8.2.1 in April 29 2025, a dugong was photographed off Kumejima Island near Okinawa Island (kaisou-n@crux.ocn.ne.jp email to Marsh 30 April 2025).

- The number of dugongs in Japanese waters is almost certainly extremely small but the species persists in the Nansei Islands region.

8.3 Cultural values

8.3.1 China

Historically China was a largely inland, agrarian society (He et al. 2014) in contrast to the maritime society of the Nansei Islands in Japan. We found no academic account of the dugong's values in Chinese culture. Linda Wong (personal communication via email to Marsh and Schramm 2023) advised that historical records described dugongs as 'mermaids' unique to the South China Sea, and that there are legends of dugong tears turning into pearls and using dugong fat for long lasting burning. The stories narrated in Ren Fang's *Shuyiji* ('Ancient tales of strange matters'; Fang [1647]), which dates from the Southern Song period (1127-1279) recount tales of immortals, deities, strange beasts and spirits, including a man named Zha Dao who encountered a fish during his maritime journey. Fang (1647) described this as: 'A woman appeared on the sea, wearing a red gown and with dishevelled hair.' It is uncertain whether this account refers to a dugong.

8.3.2 Japan

Welch et al. (2010) consulted more than 400 sources in their comprehensive research on the dugong in Okinawa's maritime culture. These sources include evidence of dugong bones found in more than 100 archaeological sites throughout the Ryukyu Islands. These deposits are evidence of dugong consumption but the importance and meaning to the people utilising them is unclear. Nonetheless, the Heshikiya-Toubaru Site on the eastern side of central Okinawa includes dugong bone artefacts that were probably used for personal adornments including hairpins, rings, and bracelets in the Late to Final Jōmon period (2,470 – 500 BC), plus 'butterfly' shaped ornaments that may have been used as amulets (Welch et al. 2010; Palz 2023).

Until the Gusuku period (12th–15th century), arrow heads were made of dugong and cow bones, presumably because metal had to be imported from mainland Japan (Welch et al. 2010; Palz 2023). During this time, local lords (*aji*) began to use dice made from dugong bones for playing games. In the Ryukyu Kingdom (1429-1879), dugong meat was a precious resource and if caught, dugongs had to be offered to the king. Dugong meat was not only considered delicious, but it was also alleged to possess medicinal qualities; consuming the meat promised everlasting youth and longevity (*furō chōju* 不老長寿) and assisted women in childbirth and subsequent recovery (Welch et al. 2010; Palz 2023).

The dugong still features in the songs and legends of the people of the Nansei Islands (Welch et al. 2010; Ikeda and Mukai 2012; Palz 2023). Dugong skulls can still be seen atop stone walls at some of the 'sacred groves' (*Utaki*) on the Aragusuku Islands (Marsh personal observation 1999; Welch et al. 2010; T. Kasuya personal communication via email to Marsh 2023; Palz 2023).

Toba Aquarium has held dugongs in captivity since the 1970s and the sole remaining animal, 'Serena', has resided at the Aquarium for more than 30 years (Marsh et al. 2022). 'Serena' is the symbol of the

Figure 8.3. Activists using the dugong as a symbol of their protest against the construction of the Futenma Replacement Facility in Henoko-Ōura Bay. The occasion was a meeting between the Prime Minister of Japan and the Nago Mayor at the Nago Civic Hall in Nago City, Okinawa Prefecture on May 4, 2010. Taro Hosokawa photograph; reproduced with permission.

aquarium and attracts large numbers of Japanese visitors each year.

Palz (2023) studied the role of the dugong in the environmental activism response to the proposed construction of the Futenma Replacement Facility in Henoko–Ōura Bay, Okinawa, by the Japanese government for the US military (see references in Palz 2023 for details of the activism). Palz concluded that the dugong had become a symbol of the protest against the new base; a symbol of resistance that directly influenced the collective human experience of the construction site due to its status as a Critically Endangered species, a Japanese Natural Monument (see Section 8.5.2.2), and an animal with cultural meaning for the people of Okinawa.

8.4 Threatening processes

Historically East Asia probably supported hundreds, rather than thousands, of dugongs because of the relatively small areas of seagrass habitat compared with locations such as the Arabian Gulf (Chapter 4) or Australia (Chapter 10). This situation would have limited the level of sustainable dugong hunting for food, as evidenced by the histories of dugong exploitation in the region outlined in Section 8.2. In recent years, especially in China, major pressures have likely come from the loss of seagrass resulting from human development in coastal areas and incidental capture in fishing nets. Climate change is likely to exacerbate this already precarious situation.

The current threats to dugongs in the region are listed below:

8.4.1 Threats to dugong survivorship

- Incidental capture in fishing gear (e.g., gillnets and set nets). For example in the Nansei Islands of Japan in 2022, 450 gillnet vessels, (448 more than 5 tonnes), 70 set net vessels (64 more than 5 tonnes) and local unlicensed gillnet vessels fished in 24 "common fishery right" areas totaling 4,057 km^2 (https://www.msil.go.jp/msil/Htm/TopWindow.html, downloaded from the internet by Hideki Yoshikawa October 2024).
- Entanglement in marine debris.
- Hunting and direct fishing: historically legal, currently illegal.
- Vessel strike.
- Extreme natural events (e.g., storm surges and tsunamis).
- Possible demographic stochasticity due to the extremely low population size.

8.4.2 Threats to dugong fecundity due to habitat loss, fragmentation and modification

- Habitat damage caused by human settlements in the coastal zone and associated riverine systems, infrastructure developments (including the Futenma Military Base Replacement Facility on Okinawa, Japan), shipping, trawling, destructive fishing.
- Degradation of seagrass habitat, including from untreated sewage disposal, coastal dredging and reclamation, inshore commercial trawling, declining water quality due to land clearing and resultant erosion.
- Extreme weather and climate change impacts on seagrass communities (e.g., extreme tropical storms, marine heatwaves).
- Pollution (e.g., oil spills, heavy metal loads and plastics).

Threatening Processes

Dugong mortality resulting from incidental capture in fishing gear (e.g., gillnets and set nets), entanglement in marine debris, illegal hunting and direct fishing, vessel strike, extreme natural events (e.g., storm surges and tsunamis).

Habitat damage caused by destructive fishing, coastal development and pollution.

Possible demographic stochasticity due to the extremely low population sizes.

8.5 Conservation initiatives

8.5.1 International conventions

Both China and Japan are parties to the Ramsar Convention, Convention on Biological Diversity, the Convention on International Trade in Endangered Species (CITES), and the United Nations Framework Convention on Climate Change. None of these treaties provides any real protection for the dugongs in East Asian waters. Both China and Japan are listed as non-party states to the Convention on Migratory Species of Wild Animals (CMS). Neither country is a signatory to the associated Dugong Memorandum of Understanding (Dugong MOU).

8.5.2 National Laws

8.5.2.1 China

Li et al. (2023) list 16 pieces of legislation and regulation relevant for marine megafauna conservation in China's coastal ecosystems. Dugongs were given Class I protected species status in 1988, with a ban on hunting (National People's Congress of the People's Republic of China 2022).

Lin et al. (2022a) claimed that the dugong is functionally extinct in China. The IUCN (2012) considers a taxon to be extinct when '*there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.*' Thus Lin et al.'s (2022a) assessment has no formal status as the IUCN requirements for extinction have not been fulfilled.

8.5.2.2 Japan

There is some uncertainty as to whether the dugong was nominated as a natural monument before World War II under Japanese domestic law. Nonetheless, the dugong was so designated in January 1955 under the *1954 Ryukyu Government Law for the Protection of Cultural Properties*. After the U.S. returned Okinawa to Japan in 1972, the government placed the dugong on their list of Natural Monuments (Welch et al. 2010). This designation may have been for biodiversity conservation rather than cultural reasons although this is uncertain.

Kasuya and Miyazaki (1997) informally classified the population in Okinawan waters using the IUCN Red List of Threatened Species criteria as Critically Endangered. This informal assessment was subsequently confirmed by Shirakihara et al. (2007). The Japanese Ministry of Environment designated the Japanese dugong as Critically Endangered in their 2007 Red Data Book (Japanese Ministry of the Environment 2014) and have not altered the status since (Kayanne et al. 2022). In 2019, the IUCN formally classified the Nansei 'subpopulation' of the dugong as Critically Endangered under criteria C and D1, on the basis of its very small population size, and evidence of past and continuing observed decline (Brownell et al. 2019).

Okinawa dugongs have also been protected by the *Fisheries Resources Protection Act* since 1993 (Kasuya et al. 2000) and by the *Wildlife Protection and Hunting Management Law* since 2003 (Mammal Society of Japan 2023).

As Brownell et al. (2019) point out, the current legislation and associated protections restrict direct killing but do not regulate incidental kills or habitat alteration, which are currently the most serious threats. Although each fisher must be licensed to operate legally in the small type set net and gillnet fisheries, a license holder is entitled to fish across a wide area. The Ministry of Environment and the Fisheries Agency have made independent efforts to develop techniques to detect a dugong entering a net and safely release a dugong from a net (T. Hosokawa personal communication via email to Marsh 2019). However, the efficacy of such techniques is impossible to determine because dugong numbers are low, making the capture of a dugong in a net a rare (but very serious) event.

8.5.3 Other conservation initiatives

8.5.3.1 China

A dugong reserve in Hepu, Guangxi, was established in 1986 and given national reserve status in 1992. However, sightings in China were already rare by then, indicating that this action was too late to be effective (Lin et al. 2022b).

8.5.3.2 Japan

There are several nationally managed Marine Protected Zones (MPZs) in the Nansei Islands, which are regulated by Japan's Ministry of Environment. Conservation targets there focus mainly on coral reefs, and there is a lack of dedicated areas for seagrass protection (Komatsu and Aoki 2020).

Many MPZs are small, and several are designated as *Ordinary Zones*, where regulation is lenient (Takahashi and Kimura 2004). Regulation can sometimes be restrictive for local economies and incompatible for social contexts of the communities surrounding the MPZs (Kakuma 2007). The *Natural Park Law (1957)* in Japan does not restrict fishing gear in MPZs, nor does it regulate habitat degradation (Ikeda and Mukai 2012). This reduces the efficacy of the protected area, especially in the case of dugong conservation.

There are also numerous community based MPZs in the Nansei Islands. These are sometimes operated by local dive shops (Shah et al. 2019) or fisheries agencies, such as the Yaeyama Fishery Cooperative, which began resource management in the late 1990s and has since established four MPZs (Komatsu and Aoki 2020). Many of these community led MPZs focus on enhancing fishery resources, often by targeting protection of certain species for economic benefit (Shah et al. 2019).

These areas are important for facilitating community participation from local fishers and other stakeholders associated with the marine environment. Cox et al. (2010) found that community led MPZs are better at encouraging local participation and compliance, and often have longer lasting effects than nationally managed Marine Protected Zones.

8.6 Research and monitoring initiatives

In China, the CBCGDF has become a partner of the CMS (CMS 2016), and as of August 2024 its Dugong Task Force is in the process of implementing a three-year work strategy.

With support from the Dugong MOU Secretariat and the US Marine Mammal Commission, the IUCN Sirenia Specialist Group (2019) developed a Japanese Dugong Research Plan to guide future research and monitoring by the Japanese Government, Okinawa Prefecture and NGOs. This plan outlines multiple approaches to determine if any dugongs remain in Japanese waters because the numbers are so low that any single approach is unlikely to be sufficient. The initiatives include: (1) fisher surveys; (2) a smartphone app to encourage the reporting of sightings; (3) using eDNA to confirm the presence of dugongs; (4) passive acoustic observations of dugong; (5) raising public awareness through a mapping dugongs project; and (6) investigating the status of seagrass meadows in the Nansei Islands Region. In the event of dugongs being detected, the plan envisaged a workshop with key stakeholders to design conservation initiatives. To date, this workshop has not been held, despite the evidence that dugongs are not yet extinct in this region (Section 8.2.2). Nonetheless, some of these suggestions have been implemented resulting in evidence that dugongs are not extinct in the islands (Section 8.2.2).

8.7 Regional summary

Dugong populations in East Asia are in a critical condition. It is extremely unlikely that dugongs will recover in this region given: (1) the extremely poor prospects of natural immigration into the area, (2) captive breeding programmes, or (3) the translocation of dugongs into the region from elsewhere.

It is likely that all marine megafauna in Chinese coastal waters are impacted by similar threats to varying degrees. Given the few, if any, remaining dugongs, interventions designed to protect coastal marine megafauna more generically may be more successful than dugong-specific interventions. As Li et al. (2023) point out, although megafauna profoundly affect the functioning of coastal ecosystems, they are often neglected

Other Priorities for Action

- Fully implement the IUCN Sirenia Specialist Groups (2019) Japanese Dugong Research Plan.
- Conduct further seagrass mapping.
- Design and implement interventions to protect coastal marine megafauna and their habitats.
- Submit subpopulation evaluation for China to IUCN

in conservation schemes. China has recently developed an Ecological Conservation Redline strategy, which includes protecting 30% of coastal waters and 35% of coastlines (He et al. 2018), suggesting that the time is right for a coordinated approach to marine megafauna conservation as a core component of this initiative.

The imperilled situation of the dugong in Japan has been recognized both internationally and nationally by its Critically Endangered status as explained above. Numbers are certainly very low, and recovery will be a formidable challenge. Much of the recent and considerable interest in dugong conservation in Japan has been driven by its status as the symbol of opposition to the proposed transfer of the US Marine Corps Air Station Futemna to Heneko-Ōura Bay (see Section 8.2.2 and Figures 8.2, 8.3). The military base is now under construction. As Brownell et al. (2019) point out, '*the current legislation and associated protection only restrict direct killing and do not regulate incidental kills or habitat alteration, both of which threaten the continued existence of dugongs in Okinawan waters*'. Nonetheless, the Okinawan public considers the remaining dugong population in the waters of the Nansei Islands to be very important. Palz (2023) concludes this view has not diminished since the construction started. This influence could be harnessed to transfer attention to the dugongs that might still be living in the waters of the Nansei region and their habitats.

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Chapter 9

PACIFIC ISLANDS

Authored by: Linda Hernandez Duran, David Blair, Chelsea Brown, Christophe Cleguer, Claire Garrigue, Mia Glover, Mélanie Hamel, Len McKenzie, Luisa Schramm, Christina Shaw and Helene Marsh

Linda Hernandez Duran[1], Chelsea Brown[2], David Blair[3], Christophe Cleguer[4], Claire Garrigue[5], Mia Glover[2,6], Mélanie Hamel[4], Len McKenzie[7], Luisa Schramm[4], Christina Shaw[8], Helene Marsh[3]

[1]College of Science and Engineering, James Cook University, Cairns, Queensland, Australia.
[2]WAVES, Lyons, Colorado, United States of America.
[3]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[4]Centre for Tropical Water and Aquatic Ecosystem Research TropWATER, James Cook University, Townsville, Queensland, Australia.
[5]IRD UMR ENTROPIE (Université de la Nouvelle-Calédonie, Institut de Recherche pour le Développement, Université de La Réunion, IFREMER, Centre National de Recherche Scientifique) Nouméa, New Caledonia.
[6]College of Arts, Humanities, and Social Sciences, University of Denver, Colorado, United States of America.
[7]Centre for Tropical Water and Aquatic Ecosystem Research TropWATER, James Cook University, Cairns, Queensland, Australia.
[8]Vanuatu Environmental Science Society (VESS), Port-Vila, Vanuatu.

Correspondence to: Helene Marsh helene.marsh@jcu.edu.au.

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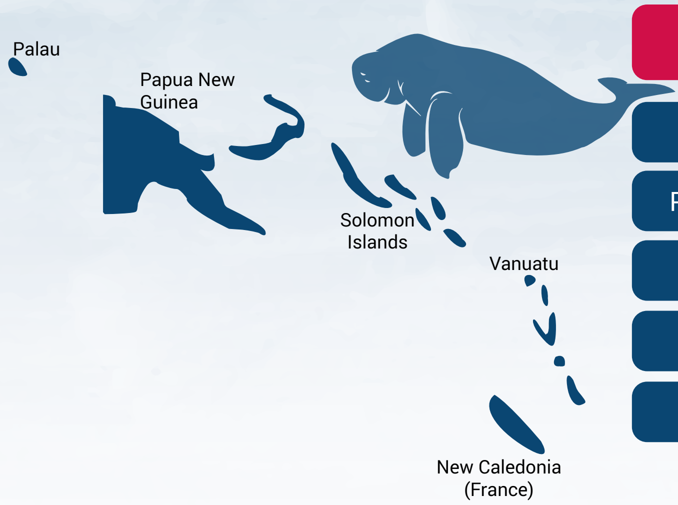
Contents

Range/Signatory States



Range States	Signatory States
Palau	Yes
Papua New Guinea	Yes
Solomon Islands	Yes
Vanuatu	Yes
New Caledonia (France)	Yes

Regional findings

The countries considered in this chapter include the following Pacific Islands: Independent State of Papua New Guinea (Papua New Guinea), New Caledonia (Semi-autonomous Territory of France), Republic of Palau (Palau), Republic of Vanuatu (Vanuatu) and Solomon Islands (Solomon Islands)

- Dugongs persist in locations of local importance in all the Pacific Island Range States considered in this chapter.
- Information on dugong habitats, abundance and conservation status is limited outside New Caledonia, especially for Papua New Guinea (PNG) and the Solomon Islands. Lack of capacity and funding are the main drivers for this persistent gap in investment in research and monitoring. Designing and implementing survey techniques appropriate to Palau, PNG and Vanuatu to monitor the status of dugongs in each of these Range States should be a high priority.
- The Palau dugong population is not only the most isolated dugong population in the world but appears to have very low genetic diversity.
- The 'Southern Shelf Waters and Reef Edge of Palau' Important Marine Mammal Area (IMMA) was established in 2021 with the dugong as the sole qualifying species.
- The Palau 'subpopulation'[1] may be eligible for the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species listing.
- The 'Main Solomon Islands' IMMA encompasses the coastal and offshore waters of the main group of Solomon Islands. The dugong is believed to be widely distributed within the IMMA and is one of the qualifying species.
- The status and size of the dugong population in Vanuatu is unknown. It is likely that the population is small, fragmented and widely distributed among the islands.
- IUCN listed the New Caledonia 'subpopulation' as Endangered in 2022. This 'subpopulation' appears to have very low genetic diversity.
- The dugong is explicitly cited as an attribute of the Outstanding Universal Value (OUV) in the Lagoons of New Caledonia World Heritage property.
- The 'New Caledonian Lagoons and Shelf Waters' IMMA was listed in 2021, with the dugong as a qualifying species.
- An important priority should be to build on the history of regional cooperation to develop a program of coordinated research on and monitoring of the distribution and abundance of dugongs and their seagrass habitats across the region, using techniques that are appropriate to the capacity of each Range State, but which would enable cross-country comparisons.
- Once this foundational work has been established, consideration should be given to understanding the connectivity between dugongs at locations within the region using modern genetics and tracking techniques, especially as genetic diversity appears to be very low for dugongs in both Palau and New Caledonia.

1 IUCN uses the term 'subpopulation' in the assessment of a regional population. The term 'subpopulation' is used here with reference to IUCN documentation only.

9.1 Regional setting

9.1.1 Geographic overview

This chapter summarizes the status of dugong populations across the Pacific Islands from Palau (7.51° N, 134.58° E) to New Caledonia (20.90° S, 165.62° E). The Pacific Islands are clustered into three distinct ethnogeographic regions: Micronesia (Palau east to the Tungaru [Gilbert Islands of Kiribati], north to Enen Kio [Wake Island] and the Northern Mariana Islands); Melanesia (Papua New Guinea east to Viti [Fiji] and south to Norfolk Island); and Polynesia (Hawai'i south to Aotearoa [New Zealand], east to Rapa Nui [Easter Island]). There is no evidence of dugongs occurring in Polynesia and the Polynesian islands are not considered further here.

Within the Pacific region, dugongs are reported from the following Range States (ordered north to south): in Micronesia: Republic of Palau (henceforth Palau); in Melanesia: Independent State of Papua New Guinea (henceforth PNG), the Solomon Islands, Republic of Vanuatu (henceforth Vanuatu), and New Caledonia (Department of France) (Figure 9.1). The Range States in the Pacific Islands have a total coastline length of 17,361 km. These countries are mostly surrounded by narrow areas of shallow water with barrier and fringing reefs (Figure 9.2). This is a very different situation from the habitats of the Australian dugong populations, which are characterized by extensive areas of continental shelf (Cleguer et al. 2024).

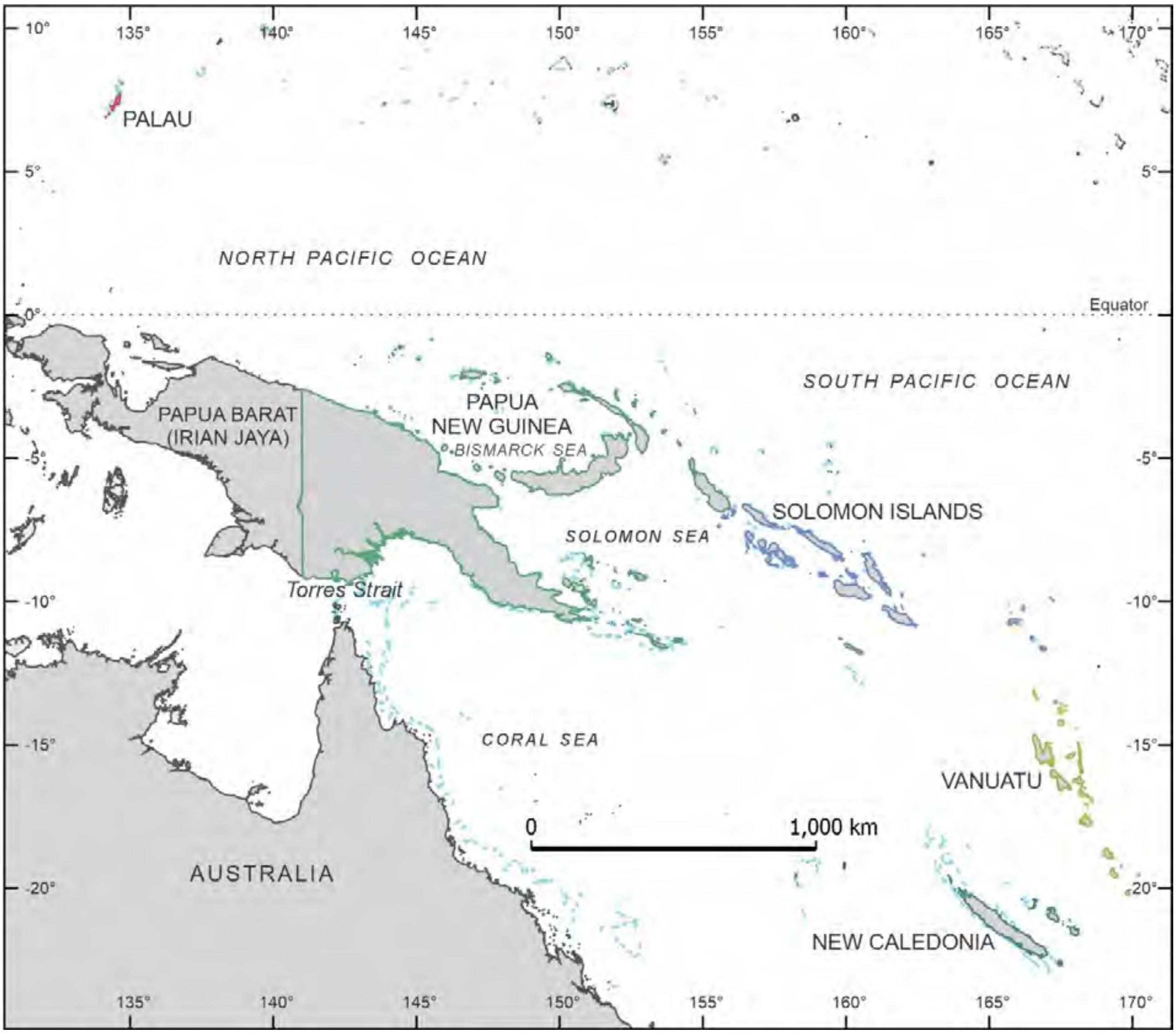
Throughout the Pacific Island region, dugong populations are fragmented and at risk of local extinction, posing significant challenges to their long-term viability (Marsh 2017; Pilcher et al. 2017; Cleguer et al. 2020a; Hamel et al. 2022). Summary details are presented below:

- **Palau** in southwest Micronesia (Figure 9.3), has a 1,519 km coastline comprised of approximately 700 islands and islets surrounded by a barrier and fringing reef complex forming a vast lagoon spanning over 1,200 km² (Wabnitz et al. 2018; Andrew et al. 2019). Palau is approximately 860 km northeast of Indonesia, approximately 900 km east of the Philippines and approximately 450 km southwest of Yap (Micronesia). The Palau dugong population is the world's most isolated (Marsh et al. 2011; Marsh and Sobtzick 2019).
- There are very few records of dugongs from the waters of the Micronesian Islands of Yap (Buden and Haglelgam 2010) and Guam (Nishiwaki et al. 1979; Eldredge 2003). There is no evidence of a resident dugong population in Yap or Guam and the very few dugongs recorded there are believed to be vagrants (Buden and Haglelgam 2010).
- **PNG**, the largest Pacific Island country by area (World Bank 2022c), shares the island of New Guinea with the Indonesian province of West Papua (Chapter 7). PNG has a coastline of 5,152 km and adjoins Australia to the south and the Solomon Islands to the east (Figure 9.4). Dugongs are scattered along the entire mainland coast as well as its outer islands (Hudson 1976; Ligon and Hudson 1977). Dugongs in the Western Province of PNG are part of the Torres Strait population considered in Chapter 10.
- The **Solomon Islands** (Figure 9.5) has a coastline of 5,313 km and consists of two volcanic island chains: six major islands, plus 1,000 outer islands and atolls. The dugong population is widely distributed, but crucial aspects regarding population structure, size and ecology remain unknown (WorldFish 2018; Al-Asif et al. 2022)
- **Vanuatu** comprises 83 islands, has 3,123 km of coastline, and is the eastern limit of dugong distribution in the Pacific (Marsh et al. 2002; McKenzie et al. 2021a). It is approximately 150 km south of the nearest island in the Solomons. There are few details about the dugong population.
- **New Caledonia** is separated from the large Australian dugong populations (Chapter 10) by a minimum of 1,230 km of deep oceanic waters to the west. The archipelago of Vanuatu is separated from New Caledonia by a 350 km stretch of open water to the east (Garrigue et al. 2022). New Caledonia has a total coastline length of 2,254 km and is divided into three Provinces: The Southern, Northern, and Loyalty Islands Provinces (hereafter referred to as Province Sud, Province Nord and Iles Loyauté, respectively). Both Province Sud and Province Nord are located on the main island of Grande Terre (Figure 9.7). New Caledonia supports the largest known dugong population in the region considered in this chapter (Cleguer et al. 2017).
- In 2018, a dugong washed ashore on the eastern coast of Viti Levu, Fiji (Hill-Lewenilovo et al. 2019). Fiji is separated from the nearest established dugong population in Vanuatu by 600 km of deep, open ocean. Although dugongs possess the capacity for such extensive travel, movements over such distances are relatively rare and are usually undertaken by sole, vagrant individuals (Deutsch et al. 2022). The animal reported in 2018 is considered vagrant and Fiji is not discussed further here.

Dugongs are seagrass community specialists (Marsh et al. 2011, 2018). Seagrass ecosystems contribute significantly to the quality of life of the region's people in material and non-material ways (McKenzie et al. 2021a). The scarcity of seagrass, especially eastward across the Pacific, limits the range of the dugong (Secretariat of the Pacific Regional Environment Programme [SPREP] 2013). Despite the restricted area of seagrass habitat, the Pacific region exhibits a high diversity of seagrass species (McKenzie et al. 2021b). Along with Indonesia, Malaysia, the Philippines and Timor Leste, PNG and the Solomon Islands lie within the Coral Triangle (CT), a biodiverse marine ecoregion in the western Pacific Ocean, where up to 19 seagrass species are found (Al-Asif et al. 2022). Twelve species of seagrass can be found in New Caledonia alone, including six genera on which dugongs are known to feed (Andréfouët et al. 2021).

Seagrass habitats in the Pacific region primarily occur in shallow waters (less than 10 m deep) in five major habitat types: estuaries, bays and lagoons, fringing reefs, barrier reefs, and deep waters. The estimated extent of seagrass in the Pacific Island Countries and Territories (PICTs) is 1,446 km^2, approximately 84% of which is in Melanesia; approximately 10% in Micronesia (McKenzie et al. 2020, 2021b). Summary details follow; see also Figure 9.2.

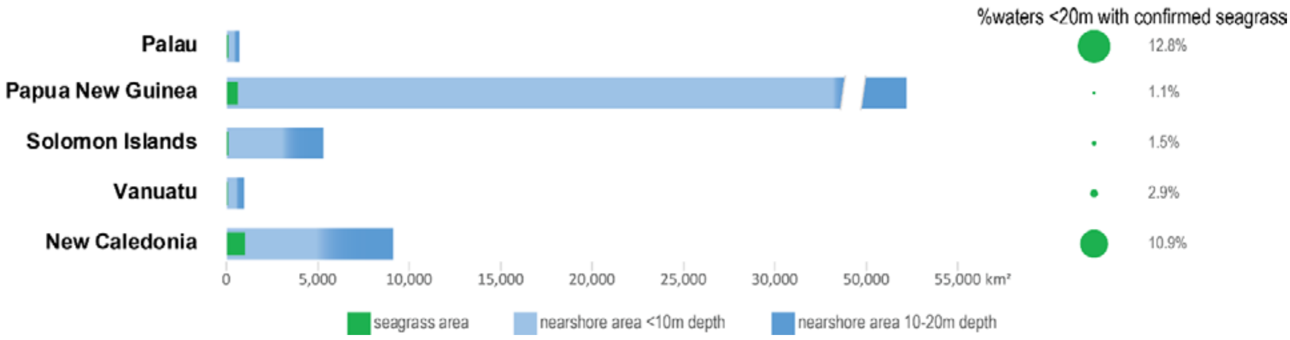
Figure 9.1. Geographic context of the dugong Range States (coloured outlines) in the Pacific Islands region. Dugong Range States, ordered north to south, have colored coastlines in the above map as follows: Palau (red), PNG (green), Solomon Islands (purple), Vanuatu (lime green) and New Caledonia (blue). Coral reefs are shown in light blue dashed lines. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.

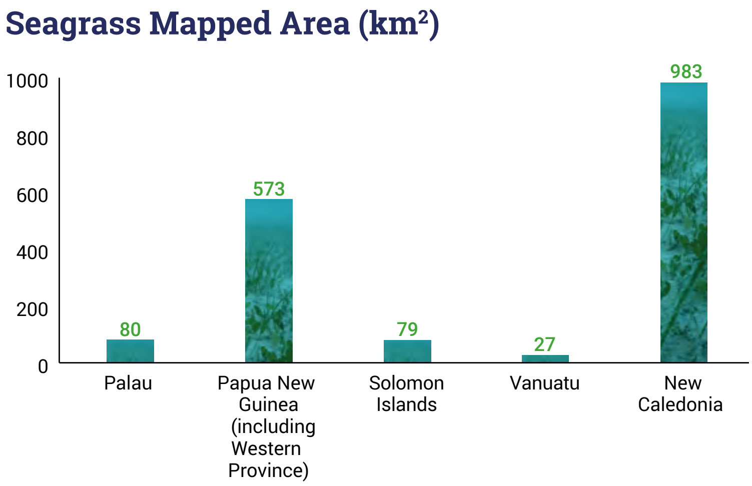


Palau's seagrass is concentrated around intertidal sand flats along the east coast of the main island of Babeldaob, to the sandy shallows of the Rock Islands (Figure 9.3), with the most extensive area (7 km^2) in the north of Peleliu Island (McKenzie et al. 2021b). Palau's seagrass meadows span approximately 80 km^2 and are in protected lagoons, inshore waters, exposed fringing reef flats, and shallow, sheltered subtidal meadows (McKenzie et al. 2021b).

Thirteen species of seagrass have been identified in **PNG** (McKenzie et al. 2021b). Seagrass is mostly concentrated in the southern part of the country. The area of seagrass is less in the eastern regions where meadows occur in sheltered bays, on the protected side of barrier reefs, and on the western side of islands (McKenzie et al. 2021b). Noteworthy seagrass locations include: Manus Island (Seeadler Harbour), New Ireland, Port Moresby, Milne Bay province, Kavieng, Madang, Morobe, Rabaul, Kimbe, Western Province, and offshore islands such as Lihir Island and Mussau Island (McKenzie et al. 2021b). The overall extent of seagrass is estimated to be approximately 573 km^2 (Carter et al. 2023; Skewes et al. 2003; L. McKenzie, unpublished data), however, large areas of potential seagrass supporting habitat remain unmapped (McKenzie et al. 2021b).

Figure 9.2. Histogram showing the known areas of seagrass and coastal waters up to 20 m depth for each dugong Range State in the Pacific Islands region. The areas of seagrass are almost certainly underestimates. Len McKenzie figure; reproduced with permission.





Seagrass communities are under-mapped with current estimates likely underestimates

In the **Solomon Islands**, ten species of seagrass have been recorded across the following locations: Roviana Lagoon (Western Province), Lau Lagoon, Small Malaita (Malaita Province), Tatamba (Isabel Province), Fauro Island, and Wagina Island (Choiseul Province) (McKenzie et al. 2006; McKenzie et al. 2021). *Enhalus acoroides* and *Thalassia hemprichii* are the dominant species throughout the Solomon Islands. The overall area of seagrass totals an estimated 79 km^2 with just over half occurring in Malaita Province (McKenzie et al. 2021b).

In **Vanuatu**, seagrass is restricted to narrow fringing reefs, sheltered lagoons, bays, and inlets (McKenzie et al. 2021b)information on seagrass distribution, biogeography, and status remains largely absent from the scientific literature. We confirm 16 seagrass species occur across 17 of the 22 PICTs with the highest number in Melanesia, followed by Micronesia and Polynesia respectively. The greatest diversity of seagrass occurs in Papua New Guinea (13 species over an area of approximately 27 km^2 (Allen Coral Atlas 2020). Twelve seagrass species have been identified (McKenzie et al. 2021b).

In **New Caledonia**, the total area of seagrass is estimated to be 983 km^2 (942 km^2 in shallow waters, an estimated 41 km^2 in turbid estuaries and an unknown extent in waters deeper than 10 m). Twelve seagrass species have been reported (Andréfouët et al. 2021; McKenzie et al. 2021b). Most of the shallow seagrass can be found around Balabio, Moindou, Cap Goulvain and North Koné in estuaries, channels, reefs and lagoons (Andréfouët et al. 2021; McKenzie et al. 2021b). Aerial surveys and telemetry tracking conducted on the west coast of Grande Terre have provided insights suggesting the existence of regions with high dugong density (Cleguer et al. 2015) and/or areas extensively utilized by tracked dugongs (Figure 4.8 in Cleguer 2015; Cleguer et al. 2020a). These areas likely feature both shallow and deeper water (deeper than 10 m) seagrasses but were not mapped as of June 2024. Comprehensive mapping, particularly on the reef/sandy flat lagoon zones located between the inshore intertidal habitats and the barrier reef encompassing Cap Goulvain, Koné, Ouano, and the lagoon in front of the capital city of Nouméa would likely increase the total area of seagrass present in New Caledonia.

9.1.2 Geopolitical and socioeconomic overview

This information is provided as an indication of the challenge for each of the Range States in the region to consider the conservation of dugongs and their habitats in the context of their socioeconomic development needs. The Pacific Islands in the dugong's range have an estimated combined human population of approximately 10.8 million people (United Nations, Department of Economic and Social Affairs [UNDESA] 2022 a,b). These nations possess significant natural resources and remarkable linguistic and cultural diversity. Fifty-two percent of people living in dugong Range States in this region reside within 10 km of the coast; 93% excluding PNG (Andrew et al. 2019). They face challenges such as geographical isolation, high local human population densities, and extreme vulnerability to the effects of climate change. These nations are among the world's most susceptible to many natural disasters due to their proximity to underwater fault boundaries and reliance on the ocean (Andrew et al. 2019). These challenges are expected to intensify with climate change, profoundly affecting coastal and marine habitats and those dependent on them (Andrew et al. 2019; Johnson et al. 2023).

The region's vulnerability to natural disasters presents formidable constraints to development, including the economic growth required to provide social services, infrastructure and employment for their young populations, at least half of which are aged under 23. China's growing engagement in the Pacific has seen an influx of new international partners and increased access to much-needed finance for Pacific Island countries (Clare 2022).

Palau has a High Human Development Index (HDI) of 0.767 (ranked 80), a gross domestic product (GDP) of USD 218 million and a population of approximately 18,000 (World Bank 2022b). The nation relies on its marine resources, which include both subsistence and commercial fisheries, as well as tourism, all of which contribute significantly to its GDP and employment (Wabnitz et al. 2018). Palau has actively pursued conservation initiatives to safeguard marine resources, promote ecotourism, and ensure sustainable revenue generation since 1992 (Wabnitz et al. 2018). In 2009, Palau was the first country in the world to ban commercial fishing of sharks in its Exclusive Economic zone (EEZ) in favour of dive tourism (Ward-Paige and Worm 2017). Further, in 2023, it became the first country to ratify the Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (United Nations Treaty Collection 2023).

PNG has a HDI of 0.558 (ranked 156), a GDP of USD 30.63 billion and a 2022 population of approximately 10.1 million (World Bank 2022c). Since the 1970s, mining has not only dominated the nation's economy, but has also long been criticised for its negative environmental and social impacts (Yamarak and Parton 2023). As a developing country (UNDESA 2022a), PNG is faced with challenges in delivering sustainable livelihoods. Large-scale mining investment allegedly brings employment opportunities, infrastructure development and more advanced education and health services (Yamarak and Parton 2023). Nonetheless, many local communities experience the opposite, with mining investments benefiting only a minority (Yamarak and Parton 2023).

The marine resources in PNG are essential for the economic well-being of rural, coastal areas. However, the growing coastal population has led to an increase in subsistence and small-scale fishing, posing a severe threat to the sustainability of coastal fish stocks (Asian Development Bank 2014). Unsustainable fishing methods and inadequate conservation efforts have raised significant concerns (Asian Development Bank 2014). Excessive extraction has led to the rapid disappearance of mangrove forests, particularly in the Gulf of Papua, worsening environmental challenges in the region (Asian Development Bank 2014). The porous international boundaries between PNG, Australia, and Indonesia have intensified these issues, which are expected to be further exacerbated by climate change (Stoeckl et al. 2018).

The **Solomon Islands** has a HDI of 0.564 (ranked 155), a GDP of USD 1.6 billion and a fast-growing population of approximately 724,000 (World Bank 2022d). The islands are rich in timber, which contributes 20% to domestic revenue and over 70% of exports. Timber resources have been over-exploited and are facing depletion. Fisheries, an important source of revenue and employment, now comprises 12% of exports (World Trade Organization 2009). Exploitable mineral resources remain largely undeveloped as low value-added commodity production. The country has a history of internal unrest driven by lingering ethnic conflict and a perceived unequal distribution of resources.

These tensions erupted into riots in the capital Honiara in November 2021, from which the country is still recovering (United Nations Committee for Development Policy [UNCDP] 2023a).

Vanuatu has a HDI of 0.607 (ranked 140), a GDP of USD 983 million and a population of around 327,000 (World Bank 2022e). Tourism is Vanuatu's main source of income, and the country's economy has suffered greatly in recent years from the combined effects of the COVID-19 pandemic and tropical cyclone Harold in 2020 (UNCDP 2023b).

New Caledonia is an overseas territory of France. France has a Very High HDI of 0.903 (ranked 23); a separate HDI is not available for New Caledonia. New Caledonia had a GDP of USD 10.07 billion and a population of approximately 277,000 (World Bank 2022a). New Caledonia is a major nickel exporter and has been a luxury eco-tourism destination. It receives considerable aid from France (Central Intelligence Agency [CIA] 2023). The Nouméa Accord of 1998 was designed to remedy the disadvantages of the indigenous Kanak population and foster a supportive relationship between the Kanak and French settlers (Blaise 2017). Negotiations between the French state, separatists, and loyalists are ongoing over the institutional future of the territory

Table 9.1. Human Development Index (HDI) status and rank and Gross Domestic Product (GDP) per capita rank of the countries of the Pacific Islands region. Consistent with the remainder of this chapter, the countries in this table are ordered north to south, west to east starting with Palau. Countries with the highest HDI or GDP have the lowest ranks. 189 countries were ranked for both indices. N.A. = Not Available.

Range State	HDI status	HDI rank 2023[i]	GDP per capita rank[ii]
Palau	High	80	N.A.
PNG	Medium	156	142
Solomon Islands	Medium	155	159
Vanuatu	Medium	140	152
New Caledonia[iii]	Very High	23	N.A. (France: 25)

i 2023 HDI data https://hdr.undp.org/data-center/country-insights#/ranks (downloaded from the internet January 2024).
ii 2023 per capita GDP https://www.worldometers.info/gdp/gdp-per-capita/ (downloaded from the internet June 2024).
iii France's 2023 HDI data is used as New Caledonia is a Non-Self-Governing Territory of France. A separate HDI for New Caledonia could not be found.

post-Accord. The territory had been beset by political uncertainty for several years. The situation in 2024 was particularly volatile (Firmin 2024).

9.1.3 Genetics of dugong populations

For an overview of techniques, definitions, relevant genetic studies and general findings on dugong population genetics, refer to Chapter 1, particularly Figure 1.2.

The only study with a specific focus on genetics in the region was conducted in New Caledonia (Garrigue et al. 2022). This study identified New Caledonia dugongs as distinct from all other dugong populations, including those in eastern Australia. The 55 dugongs sampled in New Caledonia exhibited very little diversity in their mitochondrial control-region sequences[2]: 53 of these shared the same haplotype, which belonged to the widespread haplogroup found around the coast of Australia (Chapter 1, Figure 1.2). The remaining two dugongs possessed haplotypes differing at a single site from the common haplotype (Garrigue et al. 2022). Similar low genetic diversity was noted based on microsatellite data (Oremus et al. 2015). The New Caledonia dugongs have very low values for numbers of alleles, observed heterozygosity and allelic richness, compared to Australian populations (Oremus et al. 2015). There is no evidence of inbreeding among New Caledonian dugongs, but some evidence of a genetic bottleneck (Oremus et al. 2015).

Available data suggest that the present-day population of dugongs in New Caledonia arose from a very small, relatively recent founder event (Garrigue et al. 2022). Habitat suitable for dugongs would have been non-existent or limited at the last glacial maximum, around 20,000 years ago (Ludt and Rocha 2014), suggesting post-glacial dispersal to New Caledonia from elsewhere. This could have been via the Melanesian Island Arc: short mitochondrial sequences from a dugong from Vanuatu and one from Solomon Islands were compatible with the common New Caledonian haplotype (Oremus et al. 2011, 2015; Garrigue et al. 2022). Another possibility is direct colonisation from the central part of the Queensland coast (Oremus et al. 2015), requiring an open water crossing of at least 1,330 km, which seems less likely.

2 All genetic terms are defined in Chapter 1.

Little is known about the genetic structure of dugong populations in PNG. It is very likely that dugongs along most of the southern coast might belong to the same populations as those in northern Australia (Torres Strait, Gulf of Carpentaria and Northern Territory). Those Australian populations belong to the widespread Australasian haplogroup (except in Torres Strait, where the restricted Australian haplogroup is also present; see Chapter 10. Some shorter sequences from specimens collected around 1912 from the northern half of present-day PNG, were reported by Plön et al. (2019). Three of these, belonging to the Australasian widespread haplogroup (Chapter 10), were from New Britain Island. A further two sequences belonging to this haplogroup were from unspecified localities but are likely also from the same area. Interestingly, one specimen (MH704269) from the Berlin Museum für Naturkunde and reported as from New Ireland, belongs to the Western Indian Ocean haplogroup (Chapters 2-5), and therefore represents the easternmost occurrence of this haplogroup. As mentioned in Chapter 7, the only sequence from western New Guinea Island (Indonesia), belonged to the northeastern haplogroup (See Plön et al. 2019).

Like New Caledonia, Palau in the tropical Western Pacific, at the periphery of the dugong's range. The usual expectation is that populations at peripheral locations will exhibit limited genetic diversity. Certainly, that is the case for both New Caledonia and Palau. Seven mitochondrial partial control region sequences are available from Palau. The samples were from salvaged animals found dead or dying in waters around Palau between 2003 and 2013. All sequences are identical to GenBank accession EU835816 and belong to the northeastern haplogroup (Chapter 1, Figure 1.2). This haplotype differs at only one site from one of the common haplotypes found on both sides of the Isthmus of Kra (Thailand), about 4,000 km from Palau (Chapter 6).

- New Caledonia is the only country in the region where any substantial genetic study has been carried out. All individuals belong to the Australasian widespread haplogroup.
- Both mitochondrial and nuclear genetic data indicate that dugongs in New Caledonia have a very narrow genetic base.
- Palau dugongs sampled to date all share the same mitochondrial haplotype, suggesting very limited genetic diversity there.

9.2 Dugong distribution, abundance and trends in Range States

9.2.1 Palau

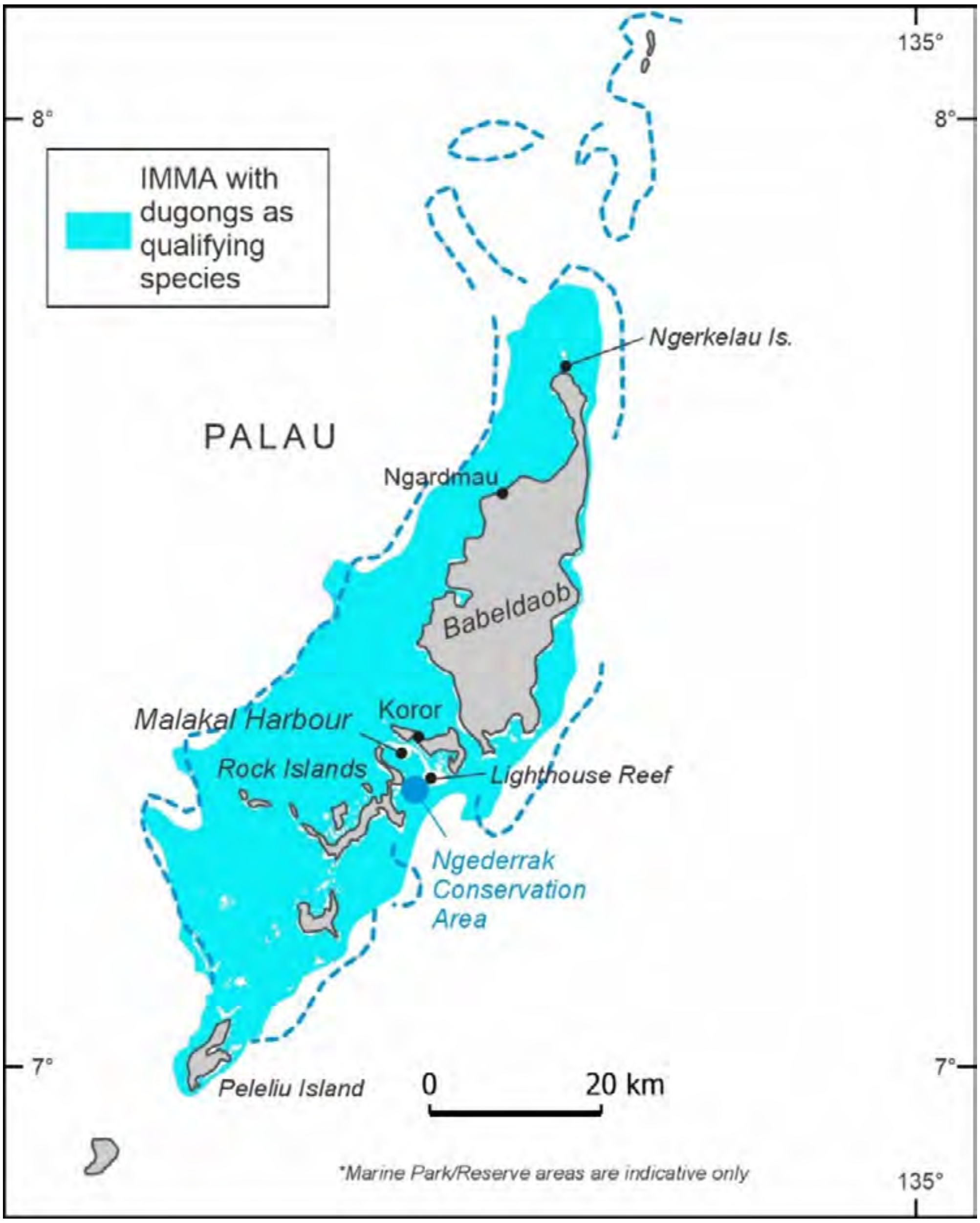
Information regarding the ecology and status of the dugong population is limited (Glover 2023) and compromised by the inconsistency and inadequacy of the survey techniques used as summarized below. Thus, none of these surveys can be used to estimate the overall population size or trends of dugongs in Palauan waters (Figure 9.3), despite considerable investment over nearly 50 years.

In a series of shoreline aerial surveys between 1977 and 2007, sections of Palauan waters were surveyed for dugongs (Brownell et al. 1981; Rathbun et al. 1988; Marsh et al. 1995; Marino et al. 2008). Each of these four surveys sighted a total of between 26 and 38 dugongs. Shoreline surveys such as these underestimate dugong abundance because they do not cover all seagrass habitat.

Aerial surveys flown between September 2009 and March 2011 covered an estimated area of 292 km^2 in and around Malakal Harbor (Coral Reef Research Foundation [CRRF] 2012). A total of 912 dugongs were recorded during 192 flights over 140 days. Many of these records would have been resightings. Thus, it is certain that 912 is an overestimate of the dugong population in Palau (CRRF 2012). The highest numbers of sightings were around the following sites: 43% (n=396) offshore Ngederrak, 24% (n=220) in west Malakal Harbor, and 21% (n=187) in the Ngederrak Conservation Area (CRRF 2012). The Report of Pacific Islands Regional Dugong and Seagrass Conservation (Dugong and Seagrass Conservation Project 2018) noted the uncertainty in the size of the Palauan dugong population, estimating it to be approximately 50 to 100 individuals.

Extensive drone flights (n=134) totalling a flight distance of 539 km over Ngederrak and Lighthouse Reefs (Figure 9.3) in 2018/2019 recorded 521 dugong sightings (Jaiteh et al. 2020) including likely recounts. Seventy-seven percent of the flights (n=103) were flown in the Ngederrak Marine Protected Area (MPA); the remaining 21% (n=31) were flown in adjacent areas including Lighthouse Reef and Malakal Harbor. Only 2% (n=9) of the dugong sightings were recorded in the flights

Figure 9.3. Geographic context of Palau with placenames mentioned in the text. Coral reefs are shown in dashed blue lines. The 'Southern Shelf Waters and Slope Edge of Palau' IMMA is shown in solid blue. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



outside the MPA (Jaiteh et al. 2020). The largest observed herd included 59 dugongs; the average group size was seven (Jaiteh et al. 2020).

The 'Southern Shelf Waters and Reef Edge of Palau' IMMA was established in 2021 with the dugong as the sole qualifying species (IUCN-MMPATF 2021d). The Palau dugong 'subpopulation'[1] may qualify for listing under the IUCN's Red List of Threatened Species under Criterion C or D due to its geographic isolation and small population size.

- Palau supports a small, isolated population of dugongs, which may qualify for IUCN's Red List of Threatened Species listing as a separate 'subpopulation'1.
- Despite considerable investment over 50 years, information regarding the status of the dugong in Palauan waters is insufficient to estimate the overall population size or trends, because of the inadequacies and inconsistencies in survey design.

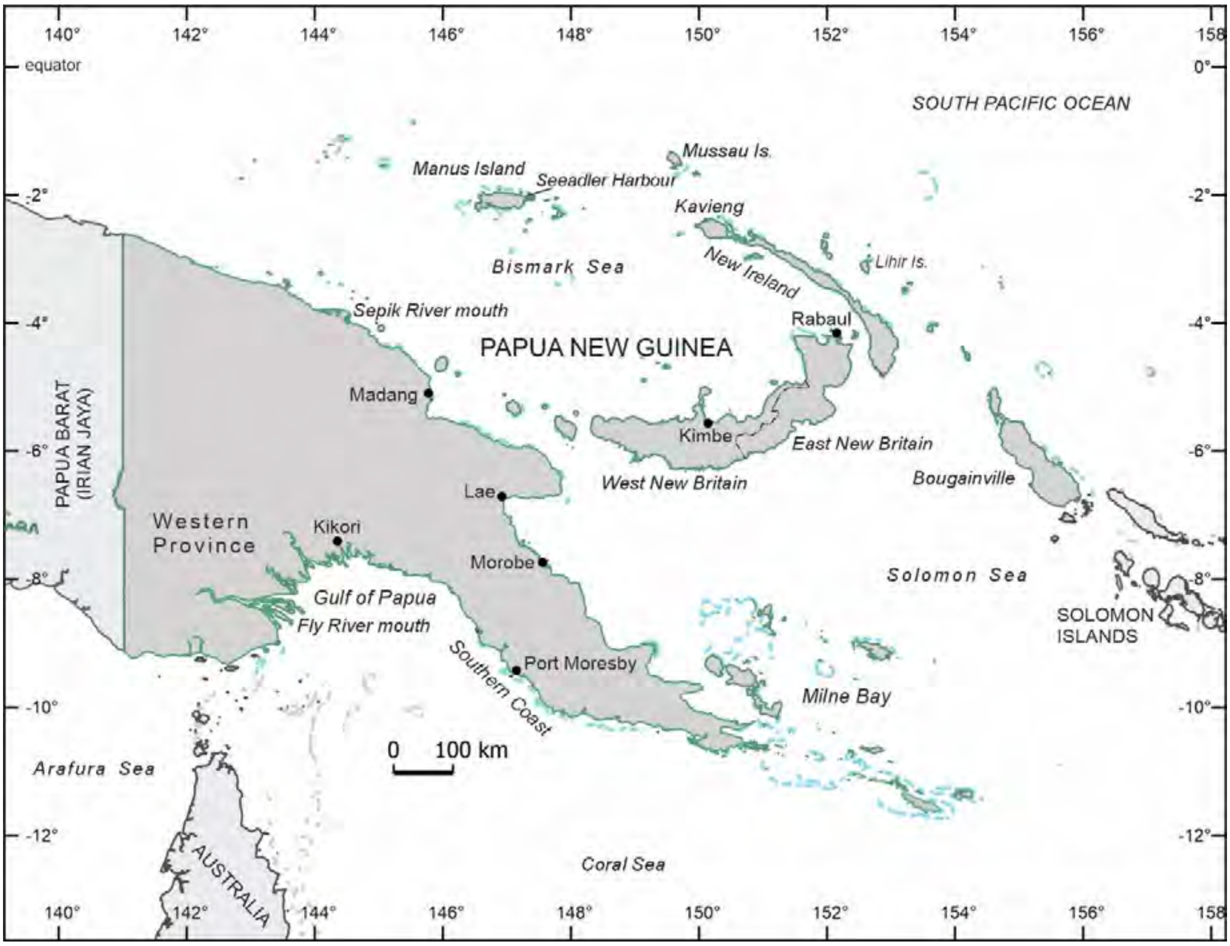
- The 'Southern Shelf Waters and Reef Edge of Palau' IMMA was established in 2021 with the dugong as the sole qualifying species.

9.2.2 Papua New Guinea (PNG)

Dugongs occur in many coastal locations throughout PNG (Figure 9.4), including Torres Strait, which is considered in Chapter 10. A postal survey conducted by Ligon and Hudson (1977) from 1973 to 1977 reported dugong sightings: (1) along the northern coast from the border with Papua Barat (West Papua) to the Sepik River mouth; (2) around Madang and from the Fly River mouth southwest to the southern border with West Papua; and (3) the islands of Manus and West New Britain. In April 1975, Ligon and Hudson (1977) also sighted 186 dugongs (14 calves) in a shoreline aerial survey along approximately 1,200 km of PNG coast including: (1) the Daru-Warrior Reef area in Torres Strait; (2) the south-Eastern Papuan coast; (3) the Lae area; (4) the northwest coast of West New Britain Province; and (4) the northwest coast. Fifty-six percent of sightings were of solitary animals or small groups; the only large groups (28 and 39 animals) were on the Warrior Reef in Torres Strait (see Chapter 10). Ligon and Hudson (1977) concluded that their sightings were an underestimate of dugong numbers.

Bass (2010) conducted an interview survey in Manus and Bougainville in 2008. In Manus, interviews conducted in 13 locations reported. Sightings totalling 64 adult dugongs and 18 calves in the first three months of 2008. Respondents collectively reported a total of 187 adults and 48 calves since 2005, with respondents estimating having seen a total of 952 dugongs since 2003, which must have included many resightings of individual dugongs. In Bougainville, interviews conducted in 25 locations across five survey areas from January to February 2008 reported 20 adults and 10 calves. Overall, from 2007 to 2008, 37 adults and 17 calves were reported. Significant numbers of dugongs were reported from various locations in both Manus and Bougainville provinces.

Figure 9.4. Geographic context of Papua New Guinea (PNG) (outlined in green) with locations mentioned in the main text. PNG coral reefs are shown in blue. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



Beasley and Mavea (2019) conducted interview surveys with the local community and fishers in the Kikori Delta region; the respondents indicated that dugongs occurred there. However, no dugongs were observed during the vessel surveys that the authors carried out between December 2013 and February 2015.

Despite these surveys, the overall size of or trends in the dugong population of PNG cannot be estimated because there have been no comprehensive surveys of coastal waters using appropriate techniques.

The PNG dugong population allegedly began to decline in the late 1970s due to the establishment of the barramundi and lobster fisheries, which brought monofilament gillnets to the country (Kare 1995). However, this has not been confirmed.

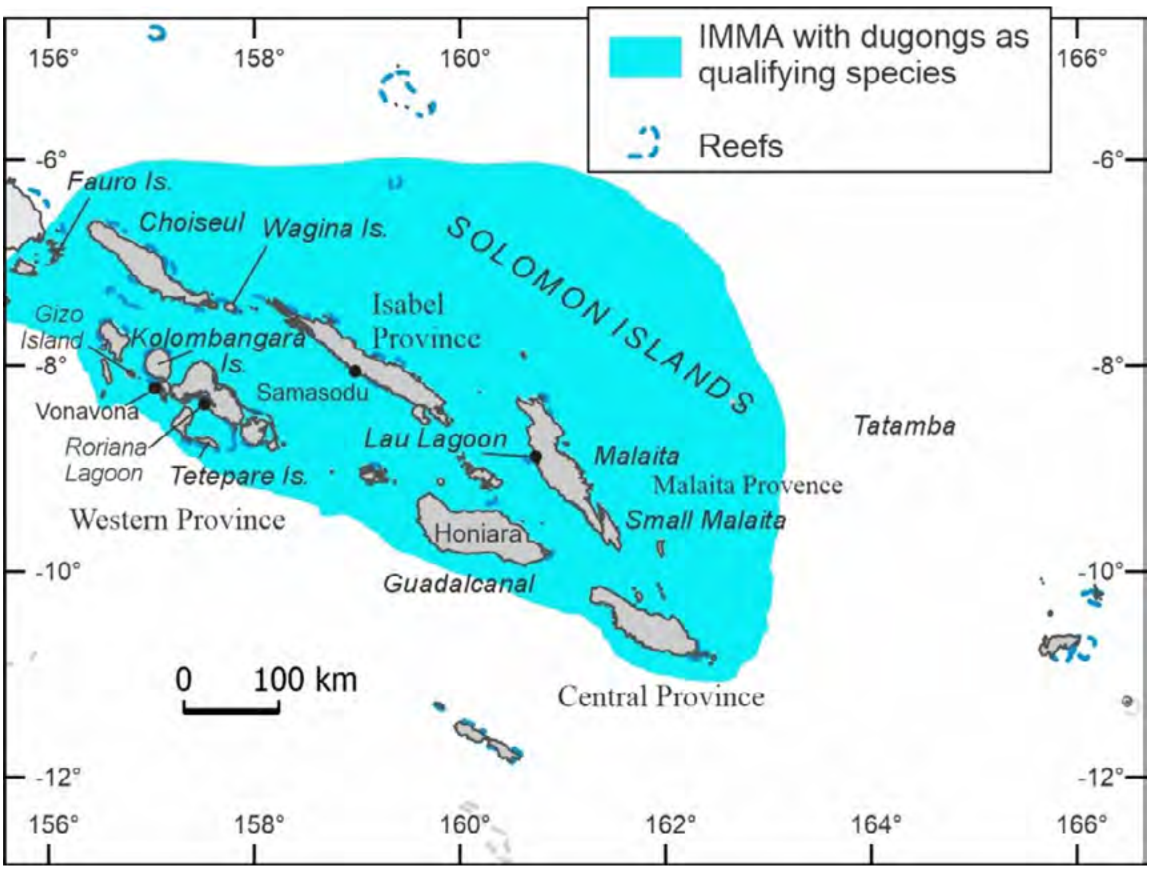
Excluding Torres Strait (Chapter 10), the only IMMA in PNG waters relevant to dugongs is the 'Kikori Delta' IMMA. Although the dugong is not listed as a qualifying species, it contributes to the marine mammal diversity of this IMMA (IUCN-MMPATF 2021a).

- Information regarding the status of the dugong in the waters of PNG is insufficient to estimate its distribution, population size or trends.
- It is likely that dugongs are widely distributed in the coastal waters of PNG.

9.2.3 Solomon Islands

Bass (2010) used interview surveys to obtain basic information on the distribution of dugongs in the Solomon Islands (Figure 9.5). They conducted 98 interviews across 19 villages in six provinces between January and February 2009. A total of 300 dugong sightings (248 adults; 52 calves) were reported in the 12 months prior to the survey (Bass 2010). Western Province had the highest percentage of sightings (29%, n= 87), followed by Malaita (27%, n=82), Isabel (23%, n=69), Guadalcanal (10%, n=30), Choiseul (8%, n=24) and Central Province (2.6%, n=8). Fifty-one sightings were reported from Lau lagoon alone (Malaita Province), 38 along the Samasodu coast (Isabel Province), 30 in northeast Malaita (Malaita Province), and 37 in Honiara (Guadalcanal Province).

Figure 9.5. Geographic context of the Solomon Islands with locations mentioned in the text. The 'Main Solomon Islands' IMMA is shown in blue. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



Bass (2010) also reported on sightings over the 10 years prior to 2009. Malaita had the most sightings (32%, n=237), followed by Isabel (24%, n=175), Western (21%, n=157), Guadalcanal (14%, n=101), Central Province (6%, n=46) and Choiseul (4%, n=26) (Bass 2010). These results suggest that dugongs are widely distributed in the Solomons but cannot be used to estimate abundance or population trends because there have been no comprehensive surveys of coastal waters using appropriate techniques.

A project conducted by the Global Environment Facility (GEF) that aimed to mitigate threats to dugong populations and their seagrass habitats in the Solomon Islands is considered in Section 9.5.3.

The 'Main Solomon Islands' IMMA encompasses the coastal and offshore waters of the main group of Solomon Islands. Dugongs are believed to be widely distributed within the IMMA and are one of the qualifying species (IUCN-MMPATF 2021b).

- Information regarding the status of the dugong in the waters of the Solomon Islands is insufficient to estimate its distribution, population size or trends.
- Dugongs are widely distributed throughout the Solomon Islands.

9.2.4 Vanuatu

The size and status of the fragmented dugong population in Vanuatu (Figure 9.6) are unknown (SPREP 2011; Dugong and Seagrass Conservation Project 2018). To date, only one (shoreline) aerial survey (in October 1987) has been carried has been conducted in an attempt to assess the distribution, abundance, cultural importance, and threats faced by dugongs in Vanuatu (Chambers et al. 1989). Only 11 dugongs were sighted: five individual animals, two cow-calf pairs, and one pair of adults. Chambers et al. (1989) concluded that small groups of dugongs occurred in coastal waters from Aneityum in the south to the Torres Islands in the north, an assessment that accords with the findings of the 2016-17 questionnaire discussed below (Figure 9.6).

The Vanuatu Environmental Science Society (VESS) used the Dugong MOU Standardized Catch and Bycatch Questionnaire to survey fishers over 32 islands across Vanuatu's six provinces in 2016-2017 (Shaw 2017). Five hundred and thirty-seven people were interviewed with most (65%) aged between 25 and 50. Thirty-two percent of respondents reported sighting dugongs every month in the previous year though most agreed that numbers are low, with 27% estimating that only a single dugong lived close to their village and 47% estimating just two (Shaw 2017). Twenty dugong areas of local importance were identified based on these reports: five in each of the provinces of Shefa and Torba, three in Malampa, two in Sanma, and one in Tafea (Shaw 2017). Dugongs congregate in clear waters around Maskelyne Island. Groups of ten or more animals are frequently seen and are a focus for snorkelling tourism (Sethric Philip, email to Marsh, August 2025).

The Vanuatu Archipelago is an Area of Interest (AoI) for potential designation as an IMMA with the dugong listed as an important species (IUCN-MMPATF).

Section 9.5.3 includes information about the Global Environment Facility (GEF) project in Vanuatu.

- The status and size of the dugong population in Vanuatu is unknown.
- It is likely that the population is small, fragmented and widely distributed among the islands.

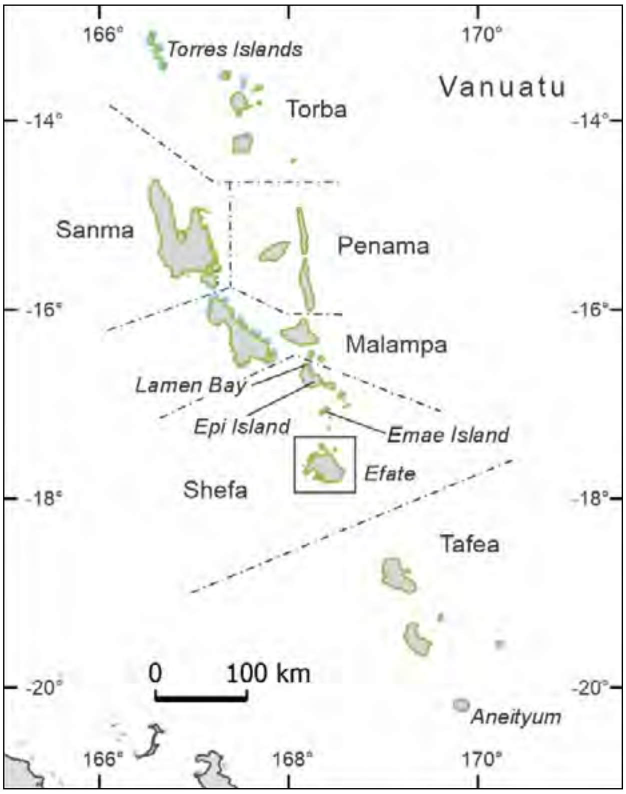
9.2.5 New Caledonia

Most of the information on the distribution and relative abundance of dugongs in New Caledonia (Figure 9.7) comes from six standardized, large-scale aerial surveys conducted between 2003 and 2018 and based on the techniques developed in Australia, including the correction for detection biases (Chapter 10).

The 2003 survey covered 18,128 km^2 across all the lagoons surrounding the main island of Grande Terre, from Iles Bélep in the north, to the Ile des Pins in the south (Garrigue et al. 2008) (Figure 9.7). Iles Loyauté were not surveyed in 2003 due to a lack of evidence of substantial numbers of dugongs in that area (Garrigue et al. 2008). Locals subsequently reported two individuals in 2015, one in Lifou and the other in Ouvéa (Cleguer and Garrigue 2018). Hamel et al. (2022) concluded that the number of dugongs in the Iles Loyauté was likely to be small.

Dugong abundance estimates from all these aerial surveys were originally corrected for availability and perception biases using the *Pollock Method* (Garrigue et al. 2008, 2009; Cleguer et al. 2017). These estimates were revised by Hagihara et al. (2018) using their method, which is considered superior to the *Pollock Method*, because it accounts for differences in the detectability of dugongs based on water depth as explained in Chapter 1. The *Hagihara Method* estimates are provided below.

Figure 9.6. Geographic context of the islands of Vanuatu (left) and Efate Island (right, see box in left figure) with placenames mentioned in the text. The Maskalyne Islands are a remote cluster of islands in the Malampa region. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



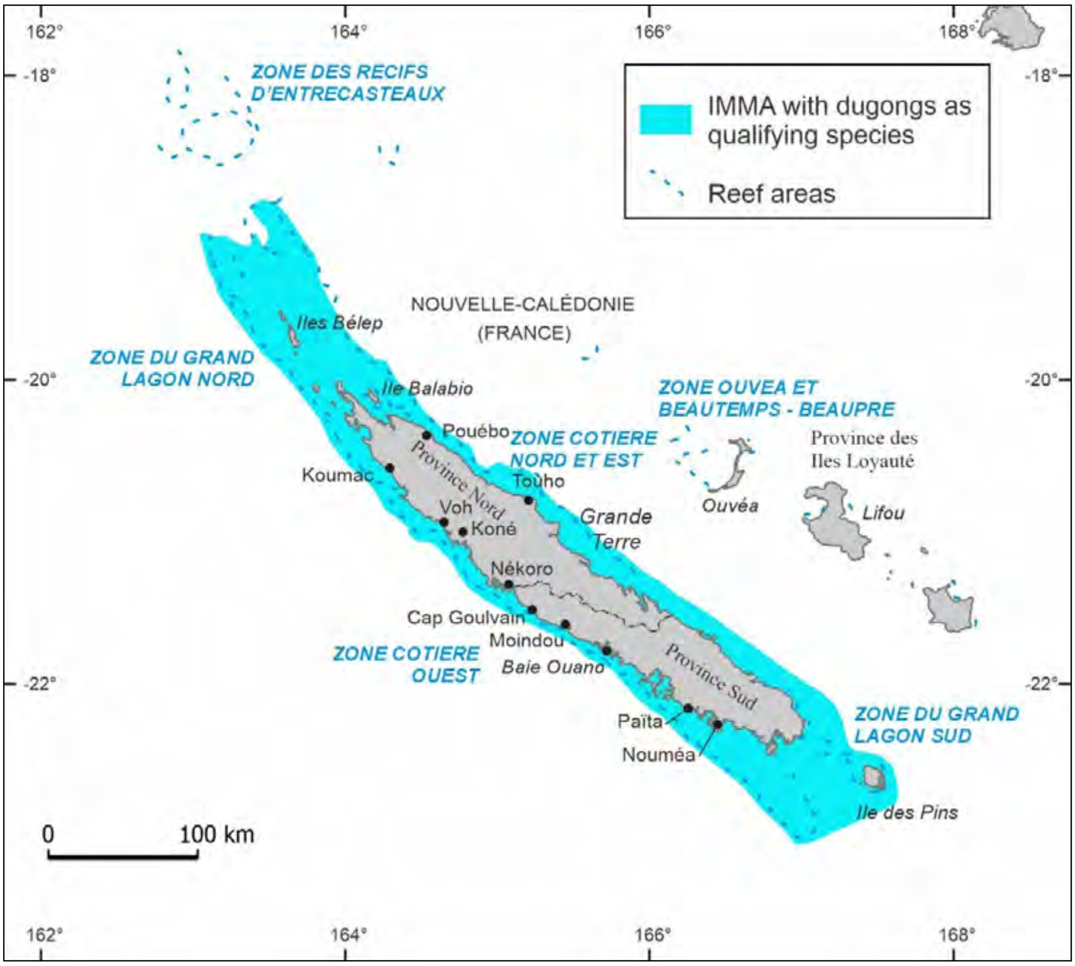
Three hundred and twenty-three dugongs (including 37 calves) were sighted in the 2003 survey: 125 dugongs on transects, 29 dugongs outside the transect, and 169 dugongs during transit flights (Garrigue et al. 2008). The estimated population of dugongs based on the 2003 survey was 1,588 ± SE 407 individuals (*Hagihara Method*). Garrigue et al. (2009) repeated the 2003 survey between January and March 2008 with the aim of investigating seasonal variations in dugong distribution and abundance. The population estimate was 426 ± SE 134 individuals (*Hagihara Method*), much lower than the 2003 estimate, and a concerning result.

Four aerial surveys were subsequently flown in June and November 2011 and 2012 (Cleguer et al. 2017) with a view to: (1) understanding the differences between the 2003 and 2008 surveys, and (2) exploring seasonal variations in dugong distribution and numbers. These surveys produced estimates ranging between 545 ± SE 157 and 1,166 ± SE 293 individuals (Cleguer et al. 2017; Hagihara et al. 2018). It is unclear whether the difference in population size between the six surveys are a result of effects of variation in environmental conditions, dugong behaviour, sampling bias, or real changes in the size of the New Caledonian dugong population (Cleguer et al. 2017). While the population appeared stable between 2008 and 2012 (Cleguer et al. 2017), new estimates are needed to evaluate the current abundance of dugongs. The mean proportion of calves observed increased from 7.4% in June 2003 to 18.0% in June 2011, before decreasing to 4.7% in November 2012 (Cleguer et al. 2017).

For the first time in New Caledonia, an aerial imagery survey was trialled in 2018 to: (1) detect dugongs using a semi-automated imagery processing approach (using Artificial Intelligence [AI] and manual reviews of images) and (2) estimate their abundance (Duclos et al. 2019). Differences in the survey design and data analysis hampered the comparison of the imagery survey with previous observer-based aerial surveys. At the time of writing (June 2024), New Caledonia was overdue for a standardized survey to help assess trends in its dugong population (Hamel et al. 2022).

Dugong distribution in New Caledonia reflects the distribution and composition of seagrass meadows on the western coasts of the islands (Cleguer et al. 2020a; Derville et al. 2022), Ouano and Noumea. The movements of the tracked dugongs varied among individuals and all except one animal undertook

Figure 9.7. Geographic context of New Caledonia with placenames mentioned in the text. The 'New Caledonian Lagoons and Shelf Waters' IMMA is shown in blue. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



large-scale movements (>15 km; mean [±SE] 37.7 ± 5.2 km). Cleguer et al. (2015) developed a spatial model of dugong distribution and relative abundance in Grande Terre based on the data collected between 2003 and 2012 (Garrigue et al. 2008, 2009, 2011, 2012; see Cleguer et al. 2017). Areas of high dugong relative density were situated: (1) on the west coast including areas near Koumac, north of Voh, near and south of Nékoro, Moindou, and between Nouméa and Païta, and (2) on the north-east coast between Pouébo and Touho (Cleguer et al. 2015; Figure 9.7). Cap Goulvain, which supports an intertidal seagrass meadow of 17 km^2 (Cleguer et al. 2020a), was identified as an area with a very high dugong relative density, making it the most important location for dugongs in New Caledonia (Cleguer et al. 2015). A retrospective spatial analysis of the network of MPAs as of 2015, combined with dugong distribution data, suggested that the species had benefited from a modest level of protection afforded by MPAs (Cleguer et al. 2015).

The 'New Caledonian Lagoons and Shelf Waters' IMMA was listed in 2021 with dugongs as a qualifying species (IUCN-MMPATF 2021c). IUCN listed the New Caledonia 'subpopulation'[1] as Endangered in 2022 (Hamel et al. 2022). The dugong population is explicitly cited as an attribute of the OUV in the 'Lagoons of New Caledonia' World Heritage property.

- Most of the information on the distribution and relative abundance of dugongs in New Caledonia comes from six dedicated standardized aerial surveys conducted between 2003 and 2012.
- All population estimates have been corrected for detection biases. They surveys suggest that New Caledonian waters support several hundred dugongs.
- The 'New Caledonian Lagoons and Shelf Waters' IMMA was listed in 2021 with dugongs as a qualifying species.

- IUCN listed the New Caledonia 'subpopulation'[1] as Endangered in 2022.
- The dugong is explicitly cited as an attribute of the OUV in the 'Lagoons of New Caledonia' World Heritage property.

9.3 Cultural values

Dugongs are of great importance to many Pacific Islanders and are an essential element of their maritime culture (Dobbs et al. 2012). Dugongs are often featured in paintings, carvings, and other artefacts. Islanders once valued the dugong as an important food source used: (1) during the initiation of village chiefs, (2) a totem that maintains many cultural practices, and for the (3) development of the personal identity as hunters (Glover 2023). Additionally, dugong body parts are used for making traditional items like drums, spoons, scrapers, and necklaces (Ingram et al. 2022; Glover 2023).

The Palauan word for dugong is '*Mesekiu*' (Johannes 1981). Palauans have long caught dugongs for consumption and traditional use (Glover 2023). Traditionally, dugong meat was reserved for chiefs of the highest rank. Hunting tenure was controlled by chiefs, who often limited harvesting of dugongs and marine turtles (Putney 2008). Dugong vertebrae were worn as bracelets by high-ranking Palauan men, who sometimes broke their hands in the process of donning them (Glover 2023; Figure 9.8).

Today, dugong meat is seldom consumed by Solomon Islanders on Gizo and Kolombangara islands (Figure 9.5) due to their practice of the Seventh Day Adventist religion, which typically follows a strictly plant-based diet. Nonetheless, Gilbertese people residing on the islands do not share the same beliefs and are reported to actively hunt dugongs (Bass 2010). Islanders residing in the Central Province of the Solomon Islands consider the species sacred and do not consume its meat due to the belief that a pregnant woman once committed suicide by jumping from a cliff and was reincarnated as a dugong with a newborn calf (Bass 2010).

Traditional use of dugongs in Vanuatu was not mentioned in the report of the Vanuatu Dugong MOU Standardized Catch and Bycatch Questionnaire 2015-17 (Shaw 2017), which reported the results of interviews with 252 people.

In the Melanesian community of New Caledonia, the dugong is considered to share a common ancestor

Figure 9.8. Dugong vertebrae worn as a bracelet by a high-ranking Palauan man. Juergen Freund photograph; ©Juergen Freund/naturepl.com.

with humans (Dupont 2015). It has historically been used in various traditional ceremonies, such as marriages or funerals of important people and traditional customary purposes such as yam feasts (Garrigue et al. 2008). In the Hoot ma Waap customary area in Province Nord, a dugong was required for celebrations marking the wedding or death of a chief or their first brother, as well as the inauguration of a new chief (Garrigue et al. 2008). Dugong hunting is now restricted in New Caledonia by statutory regulations, which prohibit hunting in the Province Sud and require special permits to be issued by the Environment Departments in Province Nord and Province des Iles Loyauté (Resolution 68 dated 25 June 1963; Province Nord 2008, Province Sud 2009). Such harvest permits can be issued for Melanesian customary ceremonies in the Provinces Nord and Iles Loyauté. However, none has been issued since 2003 (Resolution 68 dated 25 June 1963; Province Nord 2008, Province Sud 2009).

9.4 Threatening processes

Beyond New Caledonia, there is a notable gap in the identification and quantification of the threats faced by dugongs in the Pacific region. This deficiency is exacerbated by inconsistent research, survey, and monitoring methods and initiatives (SPREP 2011).

Another challenge is the limited development of public awareness and educational programs, especially in PNG and the Solomon Islands. There is a shortage of local expertise and leadership in marine species research and conservation management. The absence of effective management and prioritisation mechanisms compounds the issue. For example, Cleguer et al. (2015) developed a spatially explicit model of dugong distribution and relative density in New Caledonia based on the 10-year time series of aerial surveys (see Section 9.2.5). The model demonstrated that most (74%) of the areas of high dugong density were not protected by MPAs because information on dugong distribution had not been available at the time of their design and therefore not considered.

Hendriks and Baird (2022) categorised threats to dugongs in the Pacific Islands into two types: those that cause direct dugong mortality, and indirect threats that result in dugong habitat loss or degradation, which in turn, negatively affect fecundity. As dugongs are long-lived, slow breeding mammals, threats to mortality and are likely to be more serious than threats to fecundity (Marsh et al. 2011).

Some examples of the threats identified by Hendriks and Baird (2022) are considered below. The impacts of these threats are cumulative and spatially variable across the region, but the overall lack of information precludes precise identification of impacted localities, except as identified below.

9.4.1 Direct threats to dugong mortality

Harvesting for food, medicine, artefacts, and trade: Dugongs have long been sought for their meat, oil, skin, bones, and teeth in the Pacific Islands region (Marsh et al. 2002). Hunting for these byproducts is likely to still be a key threat, especially given the low numbers and unknown status of dugong populations in most areas. For most countries, it is unknown whether the level of harvest is sustainable, and there is concern about the increased use of outboard motors and gillnets to capture dugongs (SPREP 2011).

Despite strict national laws prohibiting dugong capture, an average of five individuals is allegedly lost each year due to poaching and vessel strikes in Palau, with unreported incidents likely causing additional losses. There are reports of hunters being paid up to USD 2,000 to illegally catch and kill dugongs for traditional uses (Glover 2023).

In the Solomon Islands, dugong hunting occurs within the Kiribati community of the Western Province, although it does not represent a primary food source (SPREP 2011). Reports of targeted dugong hunting for selling meat emerged in early 2017, particularly in Gizo, Western Province. In contrast, other communities, such as those in Lau Lagoon and West Guadalcanal, consider dugongs

Threatening Processess

By-catch in artisanal fishing gears, especially gillnets and including blast fishing seems to be the principal cause of direct mortality to dugongs, although there are few data for most of the region.

Harvesting for food, medicine, artefacts, and trade despite strict national laws in some Range States.

Loss and degradation of coastal seagrass is a major threat to important dugong habitats in the region due to: coastal development, including reclamation,agricultural and urban pollution, climate change and extreme events.

Collision with vessels in urban areas is an unquantified cause of dugong mortality.

Cyclones, storms, earthquakes, tsunamis can destroy or degrade seagrass meadows . Damage from extreme events is expected to worsen with climate change.

Apparently low genetic diversity in dugongs from Palau and New Caledonia is a significant challenge to population resilience and recovery.

sacred, prohibiting their capture or consumption (Bass 2010; WorldFish 2018). In August 2018, activities such as fishing, retention, possession, purchase, and selling of dugongs were prohibited in the Solomon Islands and made punishable by a substantial fine, imprisonment, or both under the *Fisheries Management (Prohibited Activities) Regulations 2018 (L.N. No. 61 of 2018).*

Although the laws and regulations outlined in Section 9.5.2.5 prohibit fishing for dugongs in New Caledonia, poaching persists. Thirteen percent of dugongs stranded between 1991 and 2022 showed traces of poaching, and evidence of several cases of poaching were discovered further inland (Garrigue et al. 2023; see Hamel et al. 2022 for summary and references).

Bycatch and destructive fishing methods: Incidental drowning of dugongs caught in fishing nets is now considered to be the predominant threat to dugongs in some Pacific Range States because many traditional fishing methods throughout the Pacific have been replaced by contemporary methods, resulting in negative impacts on Pacific marine ecosystems (Kare 1995; Bass 2010; Glover 2023). In Palau, customary fishing methods such as spearfishing and the *ruul* (leaf sweep; a communal method of fishing involving the use of coconut palm leaves woven together to form a barrier), have been replaced by trawling and longline fishing (Glover 2023). During World War II, dynamite (blast) fishing was introduced to feed military personnel. The practice has since been banned, though there are still reports of the method being used illegally (Glover 2023).

Shaw (2017) reported the results of a rapid assessment survey in Vanuatu based on the Dugong MOU Standardized Catch and Bycatch Questionnaire (Pilcher et al. 2017). In total, 537 interviews were conducted over a total of 32 islands, spanning each of the six provinces. Most people reported no catch of dugongs. Eighty-seven percent of people thought no one in their village caught dugongs and only 9% of people thought people in other villages did. In the year prior to the survey, seven people reported catching one to two dugongs. In the previous five years, only four people reported catching one to two dugongs and one admitted to catching over 10. In their lifetimes, only 14 fishers report catching one or two dugongs, one fisher 3-10 dugongs and two fishers catching more than 10 dugongs. These figures include bycatch, but it is unknown what percentage is bycatch or whether it is consumed.

Vessel-strike: Occasional deaths of dugongs from collisions with boats have been reported on the west coast of New Caledonia in urban areas such as Nouméa (Province Sud), Voh and Koné (Province Nord; ESCAL and A2EP 2011) and confirmed from postmortem examination of stranded carcasses (Garrigue et al. 2023). Between 1991 and 2022, collisions with boats were the cause of 11% of dugong strandings (for which causes could be determined, i.e., n=9 of 26; Garrigue et al. 2023). The growth of the tourism industry and associated boating activities may aggravate this risk. Although entanglements in fishing gear was recognized as the cause of death of only 3% of the strandings, this percentage is almost certainly an underestimate, as it is much more difficult to confirm this cause of death than death from vessel strike (Marsh personal observation 2024).

9.4.2 Indirect threats to dugongs

Because of their dependence on seagrass communities (Marsh et al. 2018), dugongs are vulnerable to habitat loss (Chapter 1). There are numerous causes of habitat loss as evidenced by the examples below:

- **Coastal development, including reclamation:** Development and reclamation activities increase sedimentation and turbidity in coastal waters where seagrasses are found. Sedimentation and turbidity not only smother seagrasses, but also reduce the amount of light reaching them, resulting in the degradation of seagrasses and a reduction in their density and productivity (Short et al. 2018).
- **Agricultural pollution:** Nutrient and herbicide runoff from agricultural activities present a potential risk to seagrass habitats and increased sedimentation from poorly managed land practices are cause for concern. Sedimentation, nutrient enrichment from land runoff, and increased turbidity intensify the degradation of seagrass meadows, resulting in a reduction of seagrass density and productivity (Short et al. 2018; Al-Asif et al. 2022).
- **Extreme weather events:** Cyclones and storms can destroy or degrade seagrass meadows. An earthquake and tsunami event in 2010 negatively impacted seagrass cover and diversity in Tetepare Island, Western Province, Solomon Islands (Moseby et al. 2020).
- **Non-agricultural pollution:** The deterioration of water quality by sewage, pollutant discharge, the presence of macro and microplastics, and agricultural activities, poses a direct impact on

seagrass communities (Unsworth and Cullen 2010; McKenzie et al. 2020; Johnson et al. 2023). In addition, expanding coastal mining industries pose indirect threats by affecting key locations crucial for dugong survival (David et al. 2010; Cleguer et al. 2015).

- **Climate change:** Human induced climate change is anticipated to result in changes in the availability, production, species composition and distribution of the seagrass communities on which dugongs depend (Marsh et al. 2022). These changes will exacerbate the ongoing loss of seagrass caused by anthropogenic pressures in the coastal zone (Waycott et al. 2009). Notwithstanding, the Pacific Islands region appears to a global 'bright spot' for seagrasses, where pressures remain relatively low and seagrass more resilient than in most other areas (McKenzie et al. 2021). The most relevant unknown is how climate-induced changes in seagrass community composition will affect dugong food quality, biomass, and preferred feeding locations and how in turn, this will affect dugong fecundity and the capacity for calves to learn from their mothers (Marsh et al. 2022).

9.5 Conservation initiatives

9.5.1 International conventions

All dugong Range States in the Pacific Islands are Parties to the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC), and Signatory States to the Memorandum of Understanding on the Conservation and Management of Dugongs *(Dugong dugon*) and their Habitats throughout their Range (Dugong MOU). France and Palau are Parties to the Convention on the Conservation of Migratory Species of Wild Animals (CMS). France, Palau, PNG, the Solomon Islands and Vanuatu are Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Commitment to the conservation of marine mammals, including dugongs, has been ongoing since SPREP was established in 1993. SPREP has developed a series of regional action plans for marine species including the dugong. SPREP's Dugong Action Plan was last updated in 2022 (Hendriks and Baird 2022).

9.5.2 National laws

9.5.2.1 Palau

In 2010, Palau broadened its commitment to marine conservation by extending protection within its Exclusive Economy Zone (EEZ) to encompass all marine mammals, including dugongs. In the same year, the Marine Division within the Department of Environment and Conservation collaborated with the Coral Triangle Initiative (CTI) to implement dugong conservation through the Marine National Action Plan (SPREP 2011). A 2012-2013 dugong awareness campaign built on the successes of an initial 2010-2011 campaign, to amplify local community awareness regarding the challenges faced by Palau's dugong population, and to enhance understanding of dugong biology and ecology for more effective management (CRRF 2012).

In 2015, Palau designated 80% of its marine EEZ as a National Marine Sanctuary, with the remaining 20% reserved for domestic fisheries (Wabnitz et al. 2018). To support the objectives of this commitment and the Pew Charitable Trusts' Palau Ocean Legacy project, Palau has been applying the Palau Pristine Paradise Environmental Fee (PPEF) to all international airline tickets. This fee contributes to ongoing efforts aimed at preserving the country's marine ecosystems and upholding its commitment to sustainable conservation practices.

The protection of dugong habitat is now a state responsibility in Palau as coastal waters are under state jurisdiction. At the time of writing (August 2024) three states were in the process of passing laws to protect dugong habitat in north Babeldaob. Ngarchelong State had adopted Land Use and Marine Spatial regulations that protect dugong habitat at three sites covering over 50% of their seagrass areas and flat reef as a dugong feeding zone, Ngaraard State has similarly designated two areas that await final approval to become law. A bill to protect dugong habitat in Ngardmau State is being considered by their parliament (J. Beouch [Ebiil Soc Inc.] personal communication via email to Marsh August 2024).

9.5.2.2 Papua New Guinea (PNG)

In 1976, the dugong received official recognition as a 'national animal' under the *Fauna (Protection and Control) Act*, limiting capture to traditional purposes, such as feasts using traditional methods, which require a permit. The law strictly prohibited any commercial exploitation of dugongs. Two years later, in 1978, amendments were made to the legislation, specifically prohibiting the capture of young dugongs and cows with calves in protected areas under the following: *Fauna (Protection and Control) Crown Island Wildlife Sanctuary Rules 1978; Fauna (Protection and Control) Mojirau Wildlife Management Area Rules 1978; Fauna (Protection and Control) Ranba Wildlife Sanctuary Rules 1978; Fauna (Protection and Control) Sawataitai Wildlife Management Area Rules 1978*).

9.5.2.3 Solomon Islands

Dugongs are subject to regulations enforced by the Ministry of Fisheries and Marine Resources. They are officially recognized as protected mammals under the *Fisheries Management (Prohibited Activities) Regulation 2018*. Additionally, the national law on *Wildlife Protection and Management* categorises dugongs as a 'Prohibited Species', prohibiting any trade in the species (WorldFish 2018).

Tetepare Island is the largest uninhabited island in the South Pacific. The Tetepare Descendants' Association (TDA) plays a crucial role in the management and protection of Tetepare's natural resources, employing community-based monitoring of marine species, including dugongs (Dugong and Seagrass Conservation Project 2018).

9.5.2.4 Vanuatu

In Vanuatu, the dugong is protected by the Vanuatu Whale Sanctuary, established through the *Fisheries Act No. 55 of 2005*. The Act prohibits the possession, capture, trade or restriction of movement of any marine mammal within the Vanuatu Whale Sanctuary. Possession of marine mammal parts or products taken from the Sanctuary is also prohibited. These crimes are punishable by a fine of up to VUV 50,000,000 (approximately USD 413,700), imprisonment of up to 2 years, or both. Vanuatu further solidified its commitment to dugong conservation by implementing a national Dugong Action Plan (SPREP 2011).

9.5.2.5 New Caledonia

In 1963, New Caledonia enacted *Resolution 68* (Province Nord 2008; Province Sud 2009), which affords protection to marine mammals (Garrigue et al. 2008). This resolution allows dugong hunting only under special permits. Each of the three Provinces in New Caledonia has independent environmental codes. For example, in Province Sud, Deliberation *03-2004/ APS of 2004* strictly prohibits dugong hunting, with no special permits granted, even for customary purposes. In Province Nord, Deliberation *23-2001/ APN, 85-2001/BPN* and Deliberation *243-2006/APN* allow dugong hunting under special circumstances. In Province Iles Loyauté, the dugong is protected under *Resolution 68*.

Between 2010 and 2015, a collaborative National Dugong Action Plan (hereafter DAP) was implemented. The DAP committee was coordinated by the French MPA Agency and included local environmental managers from Province Nord, Province Sud and Provinces des Iles Loyauté, the French and New Caledonian governments, and non-governmental organisations (NGOs) such as WWF New Caledonia and Operation Cétacés. A second action plan, led by the New Caledonian Biodiversity Agency (ANCB – Agence néo-Calédonienne de la Biodiversité; previously named the Conservatory for Natural Landscapes [CEN - Conservatoire des Espaces Naturels] from 2013 to 2016), aimed to enhance the governance for addressing critical issues like dugong poaching and bycatch in New Caledonia. This plan also focused on advancing the understanding of dugong ecology to strengthen protective measures, assess the population's status, and evaluate the effectiveness of conservation efforts. Under this plan, a project was launched in 2018 to gather cultural knowledge about the species from seaside indigenous peoples. The plan was to be reviewed in 2024 with a third action plan set to be launched for 2025-2030.

Six marine sites surrounding the main island in New Caledonia and representing the main diversity of coral reefs and associated ecosystems across the territory were listed on the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage List in 2008 as a serial nomination (UNESCO 2023); the dugong population is explicitly cited as an attribute of the OUV of this serial World Heritage property.

9.5.3 Other conservation initiatives

The Pacific Islands have made progress in implementing national action plans to undertake conservation programs, managing, and protecting marine and coastal ecosystems. There is ongoing activity in terms of securing funding and facilitating communication between various entities, researchers, and local communities as outlined below.

Members of SPREP in the Pacific region (including all dugong Range States) declared 2011 'the Pacific Year of the Dugong'. The primary objectives of this initiative were to increase awareness regarding fishing activities, minimise dugong mortality resulting from human activities, improve information dissemination, advocate for sustainable management practices, and establish partnerships while securing resources to actively support dugong conservation in the region (SPREP 2011).

The Palau Coral Reef Research Foundation launched a dugong awareness campaign, 'I Love Mesekiu' in 2010-2011, engaging in a variety of outreach activities, such as the distribution of educational materials to all schools in Palau, newspaper press releases to increase awareness of illegal poaching, erection of dugong statues and carvings in the capitol building, among others (CRRF 2012).

Both the Solomon Islands and PNG are part of the Coral Triangle Initiative (CTI), which aims to conserve and sustainably manage marine resources within the Coral Triangle region. In 2013, the PNG Liquefied Natural Gas (LNG) Community Investment Program conducted a comprehensive assessment of dolphins and dugongs (locally known as *Pidu*) in the Kikori Delta region of southwestern PNG. Subsequently, additional funding was allocated to establish a scholarship program, facilitating the pursuit of higher education by selected PNG nationals at the University of Papua New Guinea or James Cook University, Australia (Beasley and Mavea 2019). This ongoing project focuses on the conservation of inshore dolphins and dugongs in the Kikori Delta, working with local communities. NGOs such as Conservation International, The Nature Conservancy, the Wildlife Conservation Society, and WWF contribute significantly to PNG's marine conservation initiatives (Asian Development Bank 2014). Additionally, the PNG Department of Conservation, along with the Government of the Solomon Islands, has invested resources in understanding the ecology and environment associated with seagrass meadows.

Supported by the GEF, the Mohammed bin Zayed Species Conservation Fund, the United Nations Environment Program (UNEP), and the Dugong MOU, the 2014-2018 GEF Dugong and Seagrass Conservation Project (GEF Project) focused on mitigating both direct and indirect threats to dugong populations and their seagrass habitats in eight countries including the Solomon Islands and Vanuatu (Dugong and Seagrass Conservation Project n.d. a,b; SPREP 2014).

The GEF Project worked with VESS to undertake two projects from 2015 to 2019: (1) improve policies for dugongs and seagrasses in Vanuatu through research and awareness raising, and (2) create a national facilitating committee for the GEF Project. Maps generated using data collected through questionnaires and expert elicitation identified 20 locations where dugongs were considered locally important. VESS created two documents to aid in education and outreach: (1) guidelines for Interacting with dugongs and, (2) a code of conduct for tourism operators interacting with dugongs (Dugong and Seagrass Conservation Project n.d. b).

In the Solomon Islands, the GEF Project funded seven projects, working with numerous stakeholders. The projects included strengthening provincial and national capacity for project implementation by establishing a National Facilitating Committee to support the government and issuing a National Dugong and Seagrass Conservation Strategy for reference of implementing partners and stakeholders. Programs were established to promote habitat preservation through alternative livelihoods such as aluminium recycling in Gizo and *Spirulina* cultivation, as well as awareness and educational campaigns in Northwest Vonavona Lagoon. The project committed to mapping critical seagrass fisheries habitats in Lau Lagoon in partnership with WorldFish (Dugong and Seagrass Conservation Project n.d. a). No reports on the outcomes of these projects were available as of March 2024.

Provinces Sud and Nord of New Caledonia declared a territory-wide 'Year of the Dugong' between May 2023 and May 2024. A workshop made it possible to reflect on public policies that could be implemented to facilitate the conservation of dugongs. An artistic competition as well as a 'Dugong Day' were organized offering games, exhibitions and conferences. A training package on what to do in the event of a stranding made it possible to train 117 people (firefighters, nature rangers, police, veterinarians, volunteers) (Province Sud 2023).

9.5.3.1 Traditional laws

In Palau, village councils oversee the management of land and sea (Glover 2023). In the past, it was reported that traditional leadership was transparent and all laws pertaining to marine resources were followed without question (Putney 2008). Law-making power now resides with the central government, however traditional knowledge is becoming increasingly integrated into conservation strategies and decision-making to aid conservation (Glover 2023).

9.5.4 Conservation status

Although its assessments of conservation status are usually conducted at a global scale, IUCN allows assessments of isolated regional 'subpopulations' for wide-range species with a heterogeneous regional status such as the dugong. The global dugong population is currently listed as Vulnerable on the IUCN Red List of Threatened Species (Marsh and Sobtzick 2019), but the New Caledonian dugong 'subpopulation' was listed as Endangered in 2022 (Hamel et al. 2023). The 'subpopulation' qualified for listing as Endangered under criterion C2a(ii) due to the number of mature individuals being believed to be below 2,500 and in continuous decline, and more than 95% of the 'subpopulation' being estimated to occur at a single location: the lagoons within the barrier reef surrounding Grande Terre. The New Caledonian 'subpopulation' was also eligible for listing as Vulnerable under criterion B (VU B2ab(v)) and criterion D (VU D1). Criterion B was supported by the following evidence: (1) the Area of Occupancy is less than 2,000 km²; (2) more than 90% of the region's mature individuals occur at a single location; and (3) there is evidence of continuing decline in the number of mature individuals. An estimation of less than 1,000 mature individuals supported the eligibility for listing under Criterion D. Currently, there are insufficient data to assess the eligibility of this dugong subpopulation under criteria A or E.

The status of the other dugong 'subpopulations' in the Pacific Islands region has not been assessed by IUCN. However, the Palau 'subpopulation' is likely to be eligible for regional listing under Criterion C or D due to its isolation and small population size.

9.5.4. Seagrass status

All seagrass species in the Pacific Island Countries and Territories (PICTs) are listed as 'Least Concern' on the IUCN Red List of Threatened Species, and the global status of only 13% of PICT species are listed as 'decreasing', with the majority (69%) 'stable' and the remainder 'unknown' (McKenzie et al. 2021).

9.6 Research and monitoring initiatives

Much of the research and monitoring initiatives on dugongs and their seagrasses habitats to date have been conducted in New Caledonia, and there is a considerable gap in other Pacific countries. Lack of research capacity and funding are the main drivers for the persisting gap in research and monitoring in other Pacific Island nations.

9.6.1. Distribution and abundance of dugongs and their habitats

As outlined in Section 9.2. diverse survey methods, such as aerial surveys using occupied aircraft (Garrigue et al. 2008, 2009; Cleguer et al. 2017), unoccupied aerial vehicle (UAV) surveys (CRRF 2012), and satellite tracking (Cleguer et al. 2020 a,b) have been used to understand dugong distribution, status, abundance, and behaviour in New Caledonia. A large knowledge gap remains in other Pacific Island nations. Complementing these methods, questionnaires administered to fishers, locals, and indigenous communities have been employed to document dugong distribution as outlined in Section 9.2. This multifaceted approach has enabled the assessment of habitat and protection on marine mammal densities (Heudier et al. 2023). Additionally, innovative tools such as deep learning using film available on social media and video surveys in New Caledonia have contributed to the detection of rare megafauna species in the field (Mannocci et al. 2022; Heudier et al. 2023). Obtaining large numbers of images to train such models is a major challenge for rare and elusive species because field video surveys provide few sightings. Scientists designed a method that takes advantage of videos accumulated on social media for training deep-learning models to detect rare megafauna species in the field. They trained convolutional neural networks (CNNs. Telemetry tracking and systematic aerial surveys have been integrated to provide information about the dugong's use of space (Derville et al. 2022), and the spatio-temporal habitat use dynamics of the dugong Additional survey tools that could be implemented include camera-mounted occupied aircraft, GPS satellite tags, and fine-scale dive profiles (see Chapter 1).

9.6.2 Dugong habitat use

Satellite tracking studies on dugong movements in the waters of Grande Terre, New Caledonia, suggest that dugongs remain within the lagoons, utilising their full width, from close to the shore to the back reef (Cleguer 2015; Cleguer et al. 2020a; Derville et al. 2022).

Cleguer et al. (2024) conducted extensive local-scale surveys (n=62) over Cap Goulvain in New Caledonia using an ultralight aircraft from February 2012 to August 2013 to investigate how dugongs in New Caledonia used a high conservation value coral-reef lagoon system during different seasons and tides to support local management. The surveys were conducted fortnightly over 18 months in different seasons and at different tides.

Temperature loggers and existing local footage of dugong herding behaviour were used to study the habitat use and behaviour of the animals in the area. The researchers found that more dugongs were sighted in the waters of Cap Goulvain during the cool season than during the warm season. As tides restricted access to the intertidal seagrass meadows and during the cool season, more dugongs were sighted in the warmer waters of the fore reef shelf outside the lagoon. Dugongs were resting in large aggregations during their use of this non-seagrass habitat. The study emphasized the importance of non-seagrass habitats for dugongs in spatially restricted coral reef environments as well as the importance of considering outer lagoon habitats as key dugong management areas. This study also adds to evidence of behavioural thermoregulation in dugongs from other areas at the high –latitude limits to their range.

9.6.3 Seagrass mapping

Although mapping seagrass areas in the Pacific Islands poses challenges, it is very important for conservation planning given the data required for spatial models such as MaxEnt (Jayathilake and Costello 2018). However, the integration of diverse technologies (e.g., satellite sensors, UAVs, remote sensing platforms, and acoustic tools) enhances mapping accuracy in both shallow and deep waters. In New Caledonia, seagrass distribution has been part of mapping projects since 2004, incorporating various datasets. Andréfouët et al. (2021) applied a multi-scale hierarchical framework, providing insights for conservation and management decisions concerning seagrass beds and marine megafauna like dugongs.

Seagrass inventories and community maps have been developed in New Caledonia since 1984, applying a multiscale hierarchical framework Nonetheless, the condition of seagrass in New Caledonia is not monitored regularly. A regional analysis conducted by McKenzie et al. (2021) at one site in New Caledonia did not reveal any specific trends. To address this gap, a workshop organized by the French Initiative for Coral Reefs (IFRECOR) took place in 2022 in New Caledonia to establish indicators for future seagrass monitoring (Conservatoire d'espaces naturels Nouvelle-Calédonie 2023; IRD 2022). In 2024, a project will focus on developing indicators and a sampling plan (C. Garrigue personal communication via email to Marsh 2024).

9.6.4 Dugong feeding ecology

Thibault et al. (2024) used carbon and nitrogen stable isotope values in dugong skin to make a preliminary assessment of the feeding ecology of dugongs in New Caledonia. The feeding niche of calves overlapped with that of females, presumably reflecting the long period of maternal care. Differences between adult male and female dugongs suggest sex differences in foraging with females consuming a wider variety of foods than males. Pregnant females may minimize their energy expenditure by focusing their foraging efforts in smaller areas and using a wider range of food resources.

Other Priorities for Action

- Designing and implementing survey techniques appropriate to Palau, PNG and Vanuatu to establish and monitor the status of the dugong in each of these range states.
- Engaging local communities in each range state in nearshore resource management and the curbing of destructive practices to enhance the resilience of seagrass ecosystems.
- Empowering communities in each range state to facilitate the development of culturally-sensitive solutions to support conservation efforts.
- Strengthening legislation to specifically address both direct and indirect impacts on the ecosystem at regional and national levels within each range state.
- Prioritising genetic research on samples from Palau and New Caledonia, where mitochondrial diversity is low.
- Assessing the conservation status of the Palau 'subpopulation' for IUCN.

9.6.5 Additional research techniques that may be applicable

An important priority should be to develop a program of coordinated research on the distribution and abundance of dugongs and their seagrass habitats across the Pacific Islands using techniques that are appropriate to the capacity of each country, but which would enable cross-country comparisons. Once this foundational research has been completed, consideration should be given to understanding the connectivity between dugongs at locations within the region using modern genetics and tracking techniques.

9.7 Regional co-operation

The foundations for regional co-operation are well-developed. SPREP spans 21 Pacific Island Member countries and territories, including Palau, PNG, the Solomon Islands, Vanuatu and New Caledonia. SPREP provides assistance protecting and improving the regional environment to ensure sustainable development for present and future generations. SPREP has launched several campaigns to spread awareness of dugongs and their seagrass habitats across the Pacific, as outlined in Section 9.5.3.

The Pacific Islands Regional Dugong and Seagrass workshops organized by the Dugong and Seagrass Conservation Project (2018) and supported by GEF have also been instrumental in advancing plans and discussions on dugong and seagrass conservation in the Pacific Islands region. Participants from four dugong Range States—Palau, the Solomon Islands, Vanuatu and New Caledonia–have engaged in reporting on the status of dugong and seagrass, discussing initiatives to address threats at both national and regional levels, strategizing the survival of dugong and seagrass ecosystems. Key focal points in these workshops have included the importance of long-term community engagement, where community needs are considered at both national and regional levels. Additionally, the workshops have emphasized the essential role of government and international support, as well as the participation of various stakeholders, in structuring MPAs (Cleguer et al. 2015; Glover 2023). As highlighted by Glover (2023), Traditional Ecological Knowledge of fishing methods and dugong populations is crucial for implementing successful monitoring and management. This knowledge has proven to be pivotal in informing sustainable management of marine resources for the future.

9.8 Regional summary

In the Pacific Islands region, dugongs persist in locations of local importance (Table 9.2), necessitating active engagement with communities and government initiatives to protect them within these areas (Marsh et al. 2002; WorldFish 2018). The commitment to regional protection and action plans has the potential to address dugong population declines and the uncertainties surrounding the sustainability of traditional harvests. It is crucial to utilize a multi-faceted approach which will provide alternatives that minimise all sources of anthropogenic mortality to ensure the survival of dugong populations (Glover 2023).

The following initiatives would enhance the conservation of dugongs and their habitats:

- Designing and implementing survey techniques appropriate to Palau, PNG and Vanuatu to monitor the status of the dugong in each of these Range States.
- Engaging local communities in nearshore resource management and the curbing of destructive practices to enhance the resilience of seagrass ecosystems.
- Empowering communities to facilitate the development of culturally-sensitive solutions to support conservation efforts.
- Strengthening legislation to specifically address both direct and indirect impacts on the ecosystem at regional and national levels within each Range State.
- Prioritizing genetic research on samples from Palau and New Caledonia, where mitochondrial diversity is low.
- Assessing the conservation status of the Palau ‘subpopulation’ for IUCN.
- Increasing efforts in data deficient areas, especially PNG, the Solomon Islands, and Vanuatu, to inform national and regional conservation strategies.

Areas of local importance for dugongs in the Pacific Islands

Palau

Malakal Harbour

Ngardmau Bay

Offshore from Ngerkeklau Island

Koror

Rock Islands

Ngederrak

PNG

Southern coast (for Torres Strait see Chapter 10)

Manus Island

West New Britain

Bougainville

Solomon Islands

Western Province

Malaita

Isabel

Guadalcanal

Choiseul

Central Province

Lau Lagoon

Vanuatu

Shefa (Port Villa Harbour, Mele Bay, Pango, Erakor, Eratap, Havannah Harbour, northern Efafe, northwest Epi, Lamen Bay and Emae Island

Torba

Malampa

Sanma

Tafea

Torres Islands

New Caledonia

Cap Goulvain

West coast areas near Koumac, north of Voh, near and South of Nekoro, Moindou, and between Nouméa and Paita

North-east coast: between Pouebo and Touho

The following areas in the **Pacific Islands** have been declared Important Marine Mammal Areas (IMMAS) with the dugong as a qualifying species:

- Southern Shelf Waters and Slope Edge of Palau IMMA
- Main Solomon Islands IMMA
- New Caledonian Lagoons and Shelf Waters'IMMA

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Chapter 10

AUSTRALIA

Authored by: Helene Marsh, David Blair, Christophe Cleguer, Rachel Groom, Amanda Hodgson, Marlee Hutton, Janet Lanyon, Len McKenzie, Ian McNiven and Holly Raudino

Helene Marsh[1], David Blair[1], Christophe Cleguer[2], Rachel Groom[3,4], Amanda Hodgson[5], Marlee Hutton[6], Janet Lanyon[7], Len McKenzie[8], Ian McNiven[9], Holly Raudino[10]

[1]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[2]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Townsville, Queensland, Australia.
[3]Northern Institute, Charles Darwin University, Darwin, Northern Territory, Australia.
[4]ARC CoE for Indigenous and Environmental Histories and Futures, James Cook University, Townsville, Queensland, Australia.
[5]Centre for Marine Ecological Research, Edith Cowan University, Joondalup, Western Australia, Australia.
[6]Kimberley Land Council, Broome, Western Australia, Australia.
[7]School of the Environment, The University of Queensland, Brisbane, Australia.
[8]Centre for Tropical Water and Aquatic Research TropWATER, James Cook University, Cairns, Queensland, Australia.
[9]Monash Indigenous Studies Centre, Monash University, Melbourne, Victoria, Australia.
[10]Department of Biodiversity, Conservation and Attractions, Perth, Western Australia, Australia.

Correspondence to: Helene Marsh helene.marsh@jcu.edu.au.

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Cover image: A dhangal (dugong) charm for harnessing good luck on a dugong hunt collected on Tudu Island in Torres Strait by Alfred Cort Haddon in 1888. British Museum photograph.

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Contents

Range/Signatory States

Range State	Signatory State
Australia (north of latitude 28°)	Yes

Regional findings

The country considered here is the Commonwealth of Australia including the states of Queensland, Northern Territory and Western Australia from Shark Bay north.

- Australia is the most important location for dugongs and their seagrass habitats in the world. The vast areas of shallow continental shelf in northern Australia provide extensive areas of seagrass supporting habitat. The human population density of most of this region is very low.
- The total estimated dugong population is approximately 166,000 ± SE 21,500 animals. The total area of seagrass estimated with moderate to high certainty in the dugong's Australian range is approximately 57,500 km^2, including 24,076 km^2 in waters more than 15 m deep offshore from the urban coast of the Great Barrier Reef World Heritage Area (GBRWHA). This offshore area has not been surveyed for dugongs.
- The dugong is a Matter of National Environmental Significance (MNES) under national law and receives protection under the laws of all relevant jurisdictions in their Australian range.
- Ten Important Marine Mammal Areas (IMMAs) with dugongs as a qualifying species are recognized in Australian coastal waters: five in Queensland, one straddling Queensland and Northern Territory waters, and four in Western Australia. Dugongs in most of these IMMAs receive some statutory protection under marine park and/or fisheries legislation.
- The dugong population is explicitly recognized as an attribute of the Outstanding Universal Value (OUV) in both the Great Barrier Reef (GBR) and the Shark Bay World Heritage Areas.
- The results of the large-scale aerial surveys that have been conducted over dugong habitats in Australia since the 1980s suggest that dugong conservation status varies regionally within Australian coastal waters from increasing along the remote coast of the GBR World Heritage Area, stable along the Gulf of Carpentaria coast of the Northern Territory and Shark Bay World Heritage Area, declining along the urban coast of the GBRWHA, and uncertain in most other parts of their Australian range.
- Confidence in these assessments varies because of regional and temporal differences in survey recency, frequency, and methodological approach. Much of the dugong's range in Western Australia and the Northern Territory has been surveyed only once and key areas have not been surveyed for more than ten years including: Torres Strait, which supports the largest dugong population, the Gulf of Carpentaria coast of Queensland, and the Pilbara coast of Western Australia.
- With further information, the isolated and remote dugong 'subpopulation'[1] of the Ashmore Reef-Sahul Bank region in Australian waters situated between the northwest coast of Western Australia and the island of Rote, Indonesia may be a candidate for an International Union for Conservation of Nature's (IUCN) Red List of Threatened Species regional listing.
- Dugong hunting by Traditional Owners (Aboriginal or Torres Strait Islander individuals or groups who have a traditional or historical connection, attachment, and/or relationship to an area of land or sea) is legal under Australian Law.
- The process of integrating seagrass data, aerial survey data and Traditional Ecological Knowledge (TEK) to identify the probability of dugong occurrence in Kimberley coastal waters should be explored with Traditional Owners for possible application in other areas.
- Extreme weather events (cyclones, floods, and marine heatwaves) have been the most significant threats to dugongs in their Australian range for at least the last 30 years. Loss of the seagrasses eaten by dugongs results in dugong life history changes including an increase in mortality, especially neonatal and early juvenile mortality, and a decrease in fecundity. In such circumstances, some dugongs undertake temporary emigration, presumably seeking locations where seagrass has not been lost.
- As a very highly developed country, Australia has the potential to conduct research and develop monitoring techniques that inform dugong conservation globally. A high proportion of modern dugong research has been conducted in Australia.
- The development of a national Wildlife Conservation Plan could enable a more

1 IUCN uses the term 'subpopulation' in the assessment of a regional population. The term 'subpopulation' is used here with reference to IUCN documentation only.

systematic and prioritized approach to research and monitoring than that observed to date. The Biologically Important Areas being identified by the Australian Government could be a focus of this plan.

10.1 Regional setting

10.1.1 Geographic overview

This chapter considers the status of the dugong around the approximately 36,000 km coastline (including major offshore islands) of northern Australia between Moreton Bay (27.09° S, 152.92° E) in the east and Shark Bay (25.8° S, 113.3° E), in the west. The area of interest includes Torres Strait or Zenadth Kes, which lies between Cape York, the northern most point of the Australian mainland (10.69° S, 142.53° E) and the coastline of Western Province in Papua New Guinea (PNG; Figure 10.1). The dugongs in Torres Strait waters under PNG jurisdiction are considered here rather than in Chapter 9, because the dugong population of Torres Strait is a transboundary stock between Australia, PNG and West Papua.

The dugong's range in the Australian region spans 18° of latitude, around 40° of longitude and includes coastal waters in the following Australian marine bioregions: Temperate East Marine (Queensland waters only), GBR (which includes Torres Strait), North, and North-West (Figure 10.1). These bioregions have been recognized as the basis of large-scale marine planning in Australia, under the *Environmental Protection and Biodiversity Conservation Act, Commonwealth 1999 (EPBC Act).*

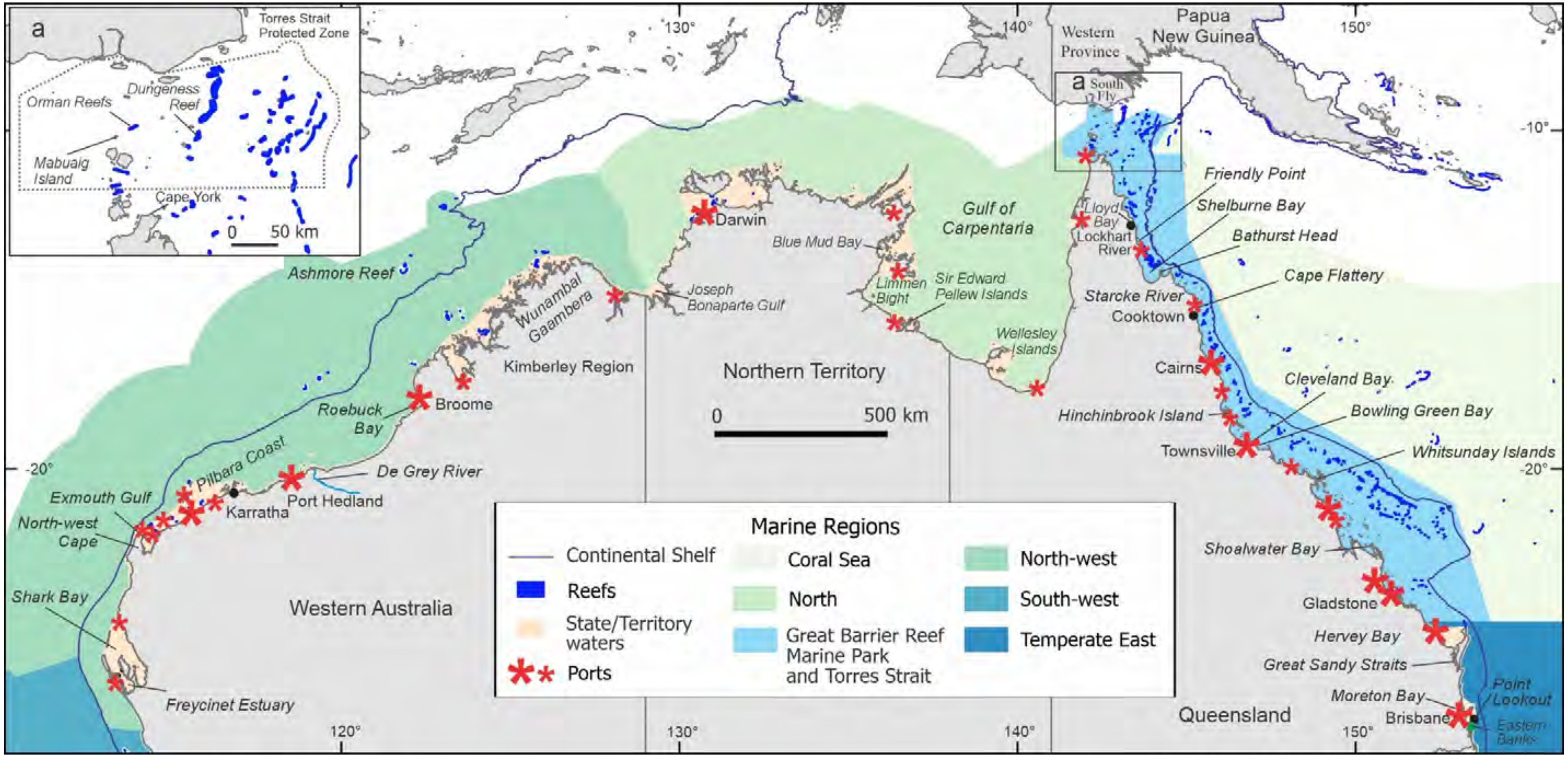
The continental shelf of northern Australia is extensive (Figure 10.1), and its shallow waters support an estimated 57,498 km^2 of seagrass communities known with moderate to high confidence (Figure 10.2; Astill et al. 2011; Hurley and Ng 2017; Del Deo 2020; McKenzie et al. 2020; Carter et al. 2021; Carter et al. 2023; Lucieer et al. 2023). These seagrass communities are all in the Tropical Indo-Pacific seagrass bioregion defined by Short et al. (2007)[2]. The largest areas of seagrass occur in the Torres Strait and along the east coast of Queensland, where sparse *Halophila* meadows are scattered across the seabed down to 76 m. These sparse meadows cover approximately 65% of the total seagrass area (Table 1 in McKenzie et al. 2020; Carter et al. 2021; Carter et al. 2023).

The dugong's winter range spans the entire coastal waters of Queensland and the Northern Territory, and from Shark Bay north in Western Australia (Figure 10.1). Allen et al. (2004) summarized evidence from archaeology, strandings, shark net captures, and anecdotal sightings that confirmed that dugongs also occasionally occurs in New South Wales (NSW) coastal waters in the Austral summer. The NSW coast is characterized by high wave-energy, sandy beaches and the strong south-west flowing East Australian current. Most seagrass occurs in the calmer waters of estuaries, bays, and coastal lakes (MacReadie et al. 2018). The total area of seagrass in the 46 estuaries from Port Stephens in the south to the Queensland border in the north is estimated to be around 61 km^2 (Creese et al. 2009; Lucieer et al. 2023); most seagrass meadows are small (less than 0.05 km^2). In Moreton Bay in Queensland, the southern limit of the dugongs' confirmed winter range on the east coast, some dugongs undertake thermoregulatory movements in winter to the warmer oceanic waters outside that Bay (Marsh and Sinclair 1989a; Lanyon 2003; Preen 1992; Zeh et al. 2018). Thus, winter water temperatures are likely to be too cold for dugongs to be present in NSW year-round (Marsh and Cleguer 2024). In Western Australia, there is anecdotal evidence of a few dugongs occurring south of Shark Bay in summer (A. Gleiss and H. Raudino personal communication by email to Marsh in 2024) and scientific evidence of dugongs undertaking seasonal movements within Shark Bay for thermoregulation as summarized by Deutsch et al. (2022).

The dugong's Australian range supports 20 species of seagrass (excluding *Ruppia maritima*, which is a brackish water species that also grows in freshwater). Dugongs apparently consume all but three of these species (*Posidonia angustifolia, Posidonia australis,* and *Posidonia coriacea*) (Marsh et al. 2018). There is no evidence of dugongs eating any species of *Posidonia*. Apart from *Amphibolis antartica*, most other species that occur in the dugong's range in Australia are widely distributed or common in the Tropical Indo-Pacific seagrass bioregion. *P. angustifolia, P. australis*, and *P. coriacea* are all endemic to southern Australia (Waycott et al. 2014), and mostly occur outside the dugong's range. *Halophila tricostata* (Kuo et al. 1993) and *Cymodocea angustata* (McMillan et al. 1983) are endemic to northern Australia, where the number of

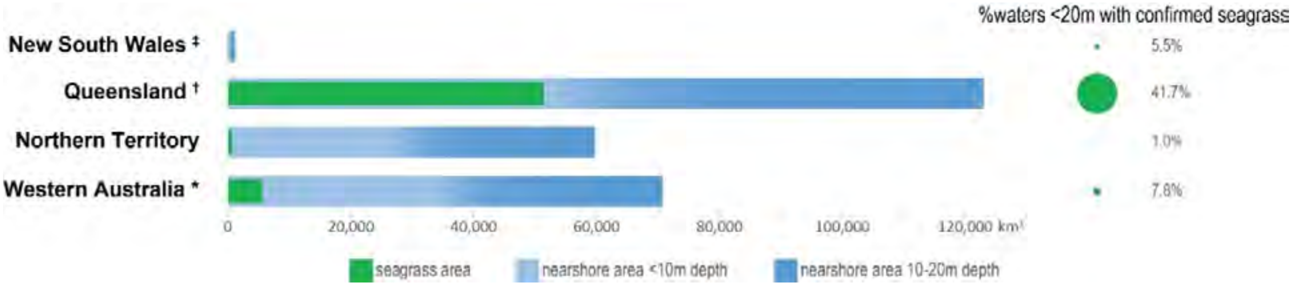
2 The Tropical Indo-Pacific seagrass bioregion as defined by Short et al. (2007) extends from East Africa, South Asia, and tropical Australia to the eastern Pacific. This bioregion is not marked on Figure 10.1 because it extends beyond Australian jurisdiction.

Figure 10.1. The geographic setting of the dugong's range in Australia showing placenames mentioned in the text, major and subsidiary ports, the Australian marine bioregions and the 200 m contour line. Top left inset map: Torres Strait. The northern boundary of the Protected Zone in Torres Strait follows the jurisdictional boundary between Australia and PNG. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



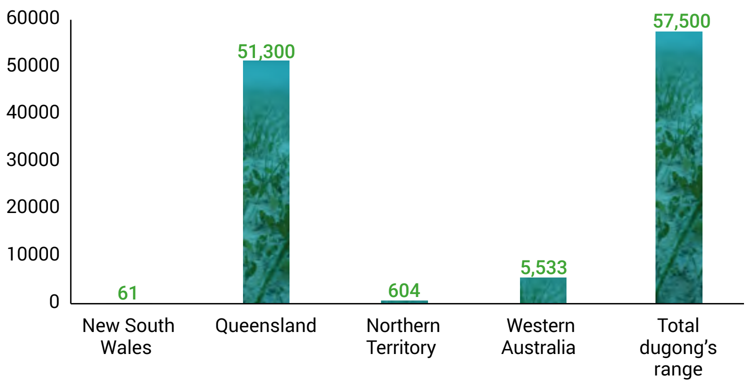
The 200 m depth contour was generated from GEBCO - The general Bathymetric Chart of the Oceans. GEBCO Compilation Group (2023) GEBCO 2023 Grid (doi:10.5285/f98b053b-0cbc-6c23-e053-6c86abc0af7b).

Figure 10.2. Histogram showing the areas of seagrass known with moderate to high confidence in the coastal waters shallower than 20 m deep for specified locations within the Australian region. The areas of seagrass are almost certainly underestimates, especially in the Northern Territory and Western Australia. While not all shallow coastal waters are potential seagrass habitat, this figure indicates: (1) the need to undertake additional seagrass mapping in this region; and (2) that NSW waters could not support a large dugong population, even if the water was warm enough for dugongs to overwinter there. Len McKenzie figure; reproduced with permission.



* Shark Bay north, † includes Torres Strait, ‡ Port Stephens north

Seagrass Mapped Area (km²)



Seagrass communities are under-mapped with current estimates likely underestimates

seagrass species varies with latitude and subregion. For example, Moreton Bay at the eastern end of the dugong's winter range supports seven species (Maxwell et al. 2019), the GBR supports 15 species (Coles et al. 2015), and Shark Bay, Western Australia, 12 species including three temperate species (*A. antarctica, P. australias* and *P. coriacea*) (Strydom et al. 2020).

10.1.2 Geopolitical and socioeconomic overview

Politically, Australia is a federation of six states and two territories. Most of northern Australia is sparsely populated (Chapter 11, Figure 11.2). A high percentage of the human population adjacent to the range of the dugong occurs in relatively few urban centres, such as Brisbane (approximately 2.6 million), Gold Coast (approximately 620,000 people), and Sunshine Coast (approximately 370,000), all of which are in southeast Queensland (SEQ); Townsville (approximately 205,000) and Cairns (approximately 164,000), both of which are in northern Queensland; and Darwin (approximately 171,000), in the Northern Territory (Population Australia 2024).

The South Fly region of Western Province in PNG, the area bordering northern Torres Strait, had a human population of approximately 84,500 in 2021, 37% (approximately 31,000) of which live in coastal regions (National Statistics Office 2021).

Australia has a Very High Human Development Index (HDI; 0.951, ranked 5/189; United Nations Development Programme [UNDP] 2022) and its per capita Gross Domestic Product (GDP) ranks 17/189 (World Bank 2022). In contrast, PNG's HDI is 0.558 (ranked 151/189) and its per capita GDP is ranked 104/189. McGillivray (see Busilacchi et al. 2018) calculated the HDI for Western Province to be 0.260 in 2007, making it one of the poorest areas in the world. In contrast, the mostly Indigenous inhabitants of Australian Torres Strait, had an estimated HDI of 0.735 in 2011 (Butler et al. 2012), which is close to Yap and Biddle's (2010) calculation of 0.737 for

Indigenous Australians as a whole. Thus, there are marked differences between the socio-economic circumstances of: (1) the Australian and Paua New Guinean Indigenous peoples of Torres Strait; and (2) Indigenous and non-Indigenous Australians.

The Torres Strait Treaty, which was signed in 1978 and came into effect in 1985, provides the framework for Australia and PNG to collaboratively manage the Torres Strait region, including the dugong population. Western Torres Strait also borders the coastal waters of West Papua, a province of Indonesia (Chapter 8). The framework for regional cooperation is discussed in Section 10.7.

10.1.3 Genetics of dugongs in Australia

For an overview of genetics-relevant techniques, definitions, studies and general findings, refer to Chapter 1, particularly Figure 1.2.

The Australian region has been the focus of more genetic studies on dugongs than anywhere else. These have cast light on aspects of the dugong's evolution, distribution, and biology.

The earliest genetic work in the region was the PhD thesis by Tikel (1997), largely superseded by work reported in the thesis by McDonald (2005) and published in Blair et al. (2014). Phylogeography and population-genetic inferences based on mitochondrial sequence data (410 bp of partial control region) were the emphases of these works. The presence and spatial distribution of two principal mitochondrial haplogroups in Australian waters were reported (Chapter 1, Figure 1.2): the 'restricted' haplogroup found only along the east coast of Queensland (and one report of an example in the Arabian Gulf by Tikel 1997) and the 'widespread' haplogroup occurring throughout the dugong's range in Australia but rare in southeast Queensland. The widespread haplogroup is also the only haplogroup in New Caledonia (Chapter 9) and is present around the island of New Guinea, eastern Indonesia and possibly further afield (Figure 1.2).

These two haplogroups have strongly contrasting features. Despite many individual dugongs belonging to the restricted haplogroup being included in the network (n=445; Figure 1.2), this group has much less haplotypic and nucleotide diversity[3] than the widespread haplogroup (n=296). In Australia, the restricted haplogroup has been reported only once from west of Torres Strait (Figure 1.2). Baker (2012), in an unpublished thesis, provided additional shorter (319 bp) mitochondrial sequences from bone samples held in the Museum of Tropical Queensland, almost all originating form Queensland waters. The sequences are available in GenBank with accession numbers PP331257-PP331356. Twenty of the samples were from the Gulf of Carpentaria and all belonged to the widespread lineage, further evidence of the geographical limits of the restricted haplogroup. Another feature of the restricted haplogroup is the significant genetic differentiation between its representatives in the Torres Strait region versus those in southern Queensland (Blair et al. 2014; McGowan et al. 2023). It is also remarkable that along the approximately 800 km of coastline extending north from the Whitsunday Islands to Starcke River, the restricted haplogroup is greatly under-represented, despite being slightly in the majority in the Torres Strait to the north (Blair et al. 2014; McGowan et al. 2023). Baker (2012) sequenced 72 additional samples, dating back to the 1970s, from this stretch of coast. The restricted haplogroup was represented by only 16 sequences between the Whitsundays and Starke River, as well as further north to Lockhart River, about 300 km from Torres Strait (Figure 10.1). All seven of the sequences reported by Plön et al. (2019) from this coast belonged to the widespread haplogroup.

Explanations of the distribution and structure of the restricted haplogroup have been proposed. Due to low sea-levels for much of the last 400,000 years, Torres Strait has only occasionally been open to transit by marine organisms (Wilson 2013; Ludt and Rocha 2015). The only tropical sea route between the east and west coasts of Australia when Torres Strait is closed is via the north side of the island of New Guinea (see Figure 1. 3). Presumably the restricted haplogroup arose in isolation east of Torres Strait. During glacial maxima, members of this haplogroup probably retreated to local refugia and experienced genetic bottlenecks (Blair et al. 2014; McGowan et al. 2023). Tian et al. (2024), using whole-genome data, inferred a considerable reduction in the effective population size of dugongs in eastern Australia around the time of the last glacial maximum and a similar finding was presented by Baker et al. (2024). Further divergence into northern and southern sub-groups (from northern and southern refugia) during such times of separation might explain the observed structure within the restricted haplogroup.

3 All genetic terms are defined in Chapter 1.

In contrast to the restricted haplogroup, the widespread haplogroup is represented across the entire Australian range of the dugong but is very rare in southeast Queensland. It is possible that there were no representatives of this haplogroup on the east coast of Queensland until the most recent opening of the Torres Strait 8,000 – 9,000 years ago. Subsequent dispersal along the east coast would have failed to establish a major presence in the southern-most dugong habitats in Queensland.

If the above scenarios are correct, questions that arise include: (a) Why did members of the restricted haplogroup not undertake post-glacial dispersal to become common in coastal waters between the Whitsunday Islands and Lockhart River? (b) Why did members of the widespread haplogroup fail to establish in the southernmost dugong habitats in Queensland? Given that mitochondria are maternally inherited, thus tracking only the movements of females, the patterns observed might indicate a high degree of female philopatry. This raises further questions, such as 'why did representatives of the widespread haplogroup become the majority along the mid-north Queensland coast?' There is no immediately obvious answer.

A third haplogroup has been found in Australian waters (Blair et al. 2014). Two representatives of the northeastern haplogroup were reported from Ashmore Reef on the Sahul Shelf (Section 10.2.4.2), sympatric with representatives of the widespread haplogroup. Ashmore Reef is closer to Indonesia (approximately 150 km) than to mainland Australia (approximately 350 km) (Director of National Parks 2018).

Mitochondrial sequence data, as well as nuclear microsatellite (biparentally inherited) data have been used to explore levels of gene flow in Queensland waters. Genetic structure and isolation by distance along the entire east coast of Queensland (extending over 18 degrees of latitude from Moreton Bay to Torres Strait) have been inferred by all relevant genetic studies (Blair et al. 2014; McCarthy 2018; McGowan et al. 2023; Tian et al. 2024). McGowan et al. (2023) used mitochondrial sequences from 639 dugongs, 22 nuclear microsatellite loci and over 10,000 nuclear Single Nucleotide Polymorphism (SNP) loci (for a subset of animals), which all confirmed the isolation-by-distance pattern along the Queensland coast as well as a marked "genetic break" in the vicinity of the Whitsunday Islands. Both to the south and the north of the Whitsundays, further subdivision could be identified (McGowan et al. 2023). Tian et al. (2024) generated over 16 million SNP loci from whole-genome sequence data for 99 Queensland dugongs. After filtering the SNPs and appropriate analysis, they corroborated the existence of the genetic break near the Whitsunday Islands and dated this at about 10,200 years ago. Suggested reasons for this break include patchy distribution of deep-water seagrasses and/or local current regimes in the Whitsunday Islands inhibiting travel by dugongs through the area in either direction (McGowan et al. 2023). Another possibility, hinted at by Tian et al. (2024), is that local evolutionary adaptations either side of the Whitsunday Islands might have discouraged breeding movements.

At a smaller, but still substantial, geographical scale, two studies have used microsatellites to investigate gene flow and movement between four shallow bay complexes with large dugong populations along the approximately 600 km of coastline in southern and central Queensland: Moreton Bay, Great Sandy Straits, Hervey Bay and Shoalwater Bay. Seddon et al. (2014) genotyped 1293 dugongs at 24 microsatellite loci. They also sequenced a portion of the control region of the mitochondrial genome for a subset of animals. Both types of data indicated a significant departure from random mating expectations in pairwise comparisons among all four bays. A clustering approach showed that the dugongs could be assigned to two major population groups, one confined to Moreton Bay (the southernmost extent of the dugong's winter range in Australia), and the other spread among the three other bays. Moreton Bay is separated from the bays further north by around 200 km of coastline with few seagrass meadows (e.g., Maroochy and Noosa River estuaries, approximately 0.1 km^2 and approximately 2 km^2 seagrass, respectively). Movement of individuals between bays was inferred, with an estimate of 4–5% of individuals moving per generation between Moreton Bay and the major bays to its north. This amount of movement was not sufficient to produce genetic homogeneity (panmixia).

Cope et al. (2015) used pedigrees to investigate contemporary movements between the above bays by analysing 24 microsatellite loci to identify parent-offspring relationships among 1,002 dugongs, many of which had been physically sampled more than once. In their relatively short-term study[4], physical recaptures of an animal in different locations were

4 Compared to dugong generation length of 22-25 years; Marsh and Sobtzick (2019)

rare (six cases), whereas capture of genetically identified offspring in locations different from their parents was more common (about 30% of cases), providing evidence of inter-generational dispersal. Cope et al. (2015) compared their real-life data with modelled expectations to reach estimates of 1-3% of animals moving between locations per year. However, physical (demographic) dispersal is not the same as effective genetic dispersal: individuals may not breed in their new location, which might help to explain the genetic distinction maintained among the studied bays (Cope et al. 2015).

Microsatellite data can also provide some indications of levels of inbreeding, estimates of population size and some other parameters. Seddon et al. (2014) inferred low levels of inbreeding for dugongs in southern Queensland, and low levels of relatedness within each bay.

The overall picture from studies in Australia is of a degree of local philopatry with relatively limited dispersal, at least by females. Evidence for male-biased dispersal in Australia is equivocal. The failure of the widespread mitochondrial haplogroup to have a substantial presence as far south as Moreton Bay, and the split within the restricted haplogroup mentioned above, might indicate little movement with subsequent breeding by female dugongs but indicates nothing about male-mediated gene flow. Satellite tracking of dugongs has not indicated any difference between movement by either sex (Sheppard et al. 2006). However, both the number of animals tracked and the duration of tracking of individual animals is probably too small for definitive conclusions (Deutsch et al. 2022). McDonald (2005) found preliminary evidence of male-biased dispersal. Seddon et al. (2014) did not find any evidence of male-biased dispersal in the southern Queensland populations, whereas Cope et al. (2015) found some support for this behaviour in the same populations based on pedigree analysis.

Evidence of changes in dugong population size in Australian waters through time has been presented by Blair et al. (2014), McCarthy (2018), Tian et al. (2024) and Baker et al. (2024). Based on mitochondrial sequence data, Blair et al. (2014) inferred a recent (effectively post-glacial) population increase in the widespread haplogroup, but little change in the restricted haplogroup. Both Tian et al. (2024) and Baker (2024) used data from one or more whole genomes. The latter used data from a single dugong of the restricted haplogroup sampled in Moreton Bay. This indicated a decline in numbers as sea levels fell after the previous interglacial period (which ended around 115,000 years ago) and the consequent reduction in suitable habitat. There was also evidence of some past, but not current, inbreeding. Tian et al (2024) presented very similar findings based on several genomes originating in nine Australian locations, mostly in Queensland. In all cases, there was an inferred reduction in population size as sea levels fell and some increase after the last glacial maximum. The level of inbreeding appeared to be low, and not recent.

At a more local and short-term level, McCarthy (2018) investigated potential changes in genetic diversity in the Cleveland Bay dugong population (Townsville) by comparing dugongs sampled 50 years apart, during which time there had been significant mortality due to cyclone Althea in 1971 (Heinsohn and Spain 1974) and incidental capture in shark nets (Marsh et al. 2005). Mitochondrial DNA sequences from dugongs that had died in the years 1969 to 1981 were compared to those from individuals that had died more recently (1999-2015). Despite the absence of some rare haplotypes in the second time period, the haplotype and nucleotide diversity measures remained constant between the two time periods, possibly a consequence of the short time span investigated relative to the 22–25-year generation length of a dugong (Marsh and Sobtzick 2019).

Tian et al. (2024) considered their sampled Australian dugong populations to be in good genetic health in terms of genetic diversity, population size and low levels of inbreeding. The current data can act as baseline information against which future changes in Australia can be judged. It is unclear whether the same baseline can be applied to other geographical regions where dugongs occur. Ideas for further genetics research are outlined in Section 10.6.6.

As explained in Chapter 1, genetics should not be the sole basis for determining the scale of management because demographic dispersal is not the same as effective genetic dispersal. Individuals may undertake temporary emigration across the boundaries of genetically distinct areas, especially when seagrass is lost due to extreme weather events. Such animals are likely to be in poor condition (Chapter 1) and may be unlikely to breed in their new location. This is an important topic that merits further investigation.

- The most detailed genetic studies of dugongs globally have been on populations in Queensland waters.
- This research has revealed a complex phylogeographic history that remains to be fully interpreted and explained. The two principal mitochondrial haplogroups in Australia (widespread and restricted) seem to have had different evolutionary and demographic histories.
- Australian dugong populations appear to be in good genetic health in terms of genetic diversity, population size and low levels of inbreeding. There is some evidence of male-based dispersal and female philopatry.
- Genetics should not be the sole basis for determining the scale of management because genetic dispersal is not the same as demographic dispersal. Individuals may move across the boundaries of genetically distinct areas, especially when seagrass is lost due to extreme weather events but may not breed in their new location. This is an important topic that merits further investigation.

10.2 Dugong distribution, abundance and trends

At the spatial scale of northern Australia, dugongs are the most abundant marine mammal in coastal waters (Marsh et al. 2011). Unlike much of the remainder of their range, aerial surveys covering tens of thousands of square kilometres are appropriate for studying dugong abundance, distribution and trends in the Australian region as a result of the spatial scale of their range and their relatively large population. Most of the information presented here comes from standardized strip transect aerial surveys using trained observers, that have been conducted since the 1980s (see Cleguer and Marsh 2023 for a complete list of surveys and links to the relevant references). One of the outputs from these surveys has been the identification of areas of high dugong density, which has served as the basis for conservation management planning, as explained in Section 10.5.

The extent of the large-scale dugong aerial surveys (Figures 10.3-10.11) has largely been determined by jurisdictional boundaries and does not reflect the genetic information outlined in Section 10.1.3. The design of the surveys has remained relatively constant over time and essentially reflects the approach pioneered by Marsh and Sinclair (1989b; *Marsh and Sinclair Method*).

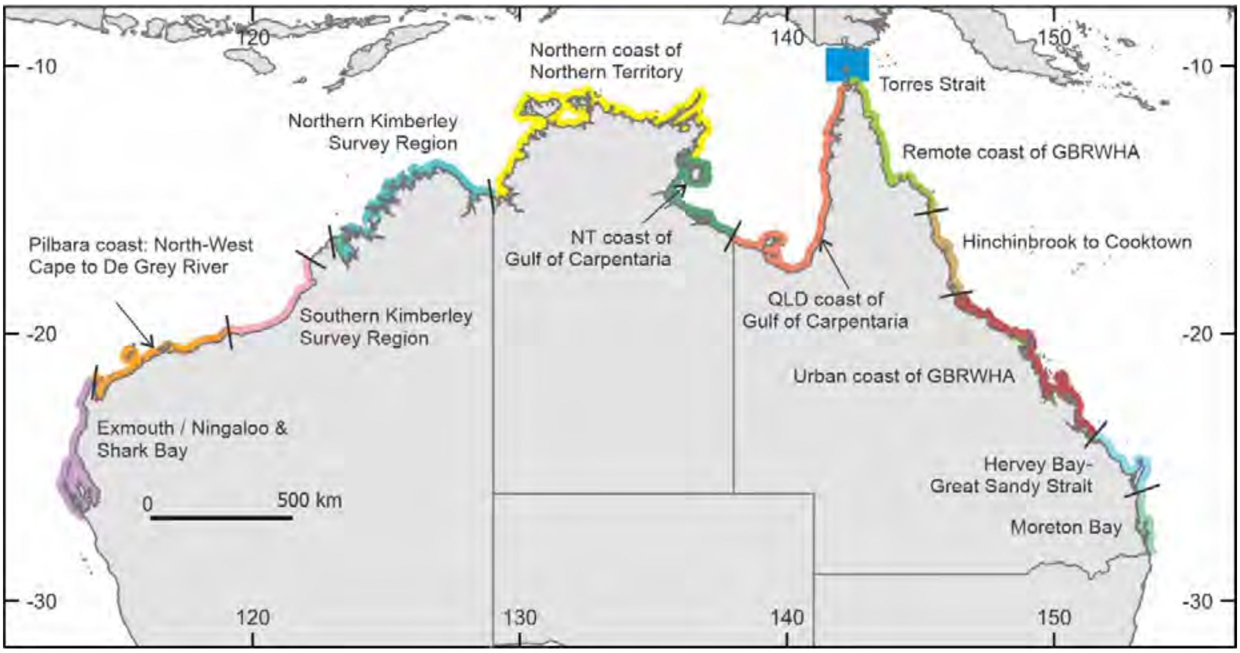
Survey frequency has been variable. Using frequentist power analyses, Marsh and Saalfeld (1989) recommended that each survey be repeated at five-year intervals, an aspirational schedule that was supported by the additional analyses in Marsh et al. (2019), but rarely achieved, even in the GBR region, where it has been the policy of the Great Barrier Reef Marine Park Authority (GBRMPA).

The process for compensating for availability bias (dugongs that are present in the survey transect but not available to observers, usually because of water turbidity), has developed over time (Marsh and Sinclair 1989b (henceforth *Marsh and Sinclair Method*); Pollock et al. 2006 (henceforth *Pollock Method*), Hagihara et al. 2014, 2018 (henceforth *Hagihara Method*)). Consequently, the results of sequential surveys of the same region are not always comparable without reanalysis, which is not possible for earlier surveys because some of the data required for the *Pollock* and *Hagihara Methods* have been collected only since c.2000 and the quality of historical, bathymetric and tidal data is not always adequate. The *Hagihara Method,* which attempts to address the effect of water depth on availability bias, is likely to provide the most accurate estimates to date. However, the effect of correcting for depth-specific detection probability depends on the depth profile and is much greater in areas where dugongs are mostly distributed over extensive deeper water seagrasses (Hagihara et al. 2018) than in areas where dugongs occur only in shallow waters.

The most robust method of detecting trends is the N-mixture Bayesian model technique developed by Rankin and Marsh (2020), which has been applied to surveys conducted on the east coast of Queensland (Marsh et al. 2020; Cleguer et al. 2023, 2024). This method integrates various sources of statistical uncertainty and variation, such as stochastically imputing undetected dugongs resulting from availability and perception biases, and thus is considered superior to frequentist statistics.

The remainder of this section provides an overview of the most recent results for the large-scale surveys for each of the various survey regions across the dugong's range in northern Australia from east to west (Figure 10.3). The method of correcting for availability bias is specified in each case.

Figure 10.3. The spatial scale of each of the large-scale dugong aerial surveys across northern Australia. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



10.2.1 Temperate East Marine Region

10.2.1.1 Moreton Bay survey region

Moreton Bay, at the southern end of the dugong's winter range in Eastern Australia, supports the largest dugong population close to a major city (Brisbane; human population of 2.6M). The surface sediments in Moreton Bay are subject to terrestrial runoff (Grinham et al. 2024) including micro-plastic pollution (Okoffo et al. 2024), exacerbated by floods from the rivers that drain into the bay.

Dugongs have been important to the local First Nations peoples for at least 2,000 years (McPhee 2017) and were seen by the English explorer Matthew Flinders in 1799 (Bryden et al. 1998), who mistook them for seals. The region has been a focus of modern dugong science since Heinsohn et al. (1978) reported the 'discovery of a large population off Brisbane' and this population is now the most intensively studied dugong population in the world (Lanyon et al. 2019).

Moreton Bay supports an estimated 298 km^2 of seagrass (Lucieer et al. 2023; McKenzie et al. 2020) including 88.7 km^2 on the Eastern Banks (Roelfsema et al. 2014), the area that supports most of the dugongs (Lanyon et al. 2019; Figure 10.4).

Lanyon et al. (2002, 2019) have genetically tagged dugongs in Moreton Bay since 2001 as part of Lanyon's comprehensive, longitudinal study of the population. As of 2024, more than 800 individual dugongs had been gene-tagged in Moreton Bay as part of this program (Lanyon unpublished data 2024), indicating that at least that number of animals used the bay during the period 2001-2024. This number must be greater than the number estimated to be in the bay during a single aerial survey.

Cleguer et al. (2023) surveyed Moreton Bay in November-December 2022 using the standard aerial survey design that has been used there since the 1980s. The surveys provide snapshot estimates of the relative abundance of dugongs in the bay at the time of each survey. Moreton Bay is challenging to survey because unlike most other areas in Australia, a large proportion of the dugong population typically occurs in large groups in late spring/summer, when most surveys have been conducted (see O'Shea et al. 2022 for discussion of dugong group size). These large groups significantly influence estimates of dugong population size and density estimates in Moreton Bay but can be inadvertently missed as a result of transect placement.

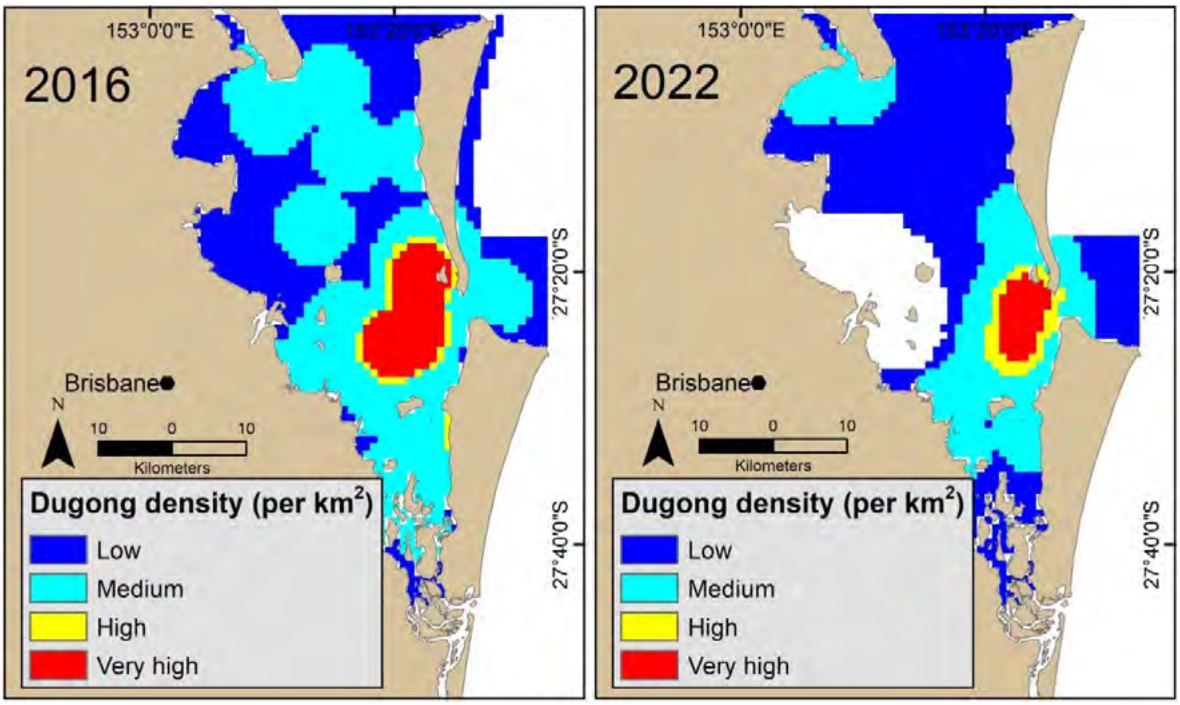
Cleguer et al.'s (2023) dugong population estimate for Moreton Bay in December 2022 was 400 ± SE 116 using the *Hagihara Method*, lower than the earlier estimates reanalysed using that method: 453 ± SE 97 in 2005; 696 ± SE 106 in 2011; and 601 ± SE 80 in 2016 (see Appendix 10 in Cleguer et al. 2023 for details). The estimated number of dugongs around the Eastern Banks (Figure 10.4) was similar in 2022 to previous survey years, but there was a decrease in the number of sightings in the southern bay preventing the calculation of a meaningful abundance estimate for that area. Some of the decrease in the estimated dugong numbers in Moreton Bay in 2022 could be attributable to a failure to detect additional large herds over the Eastern Banks during the transect sampling. However, like past surveys, the survey was conducted around the peak of high tide (when a larger number of dugongs is likely to be present over the shallow Eastern Banks) in excellent weather conditions (low to no wind), and the survey crew checked for additional large herds by flying high over the area after completing the transects (Cleguer unpublished data 2024). The 2022 survey sighted only one herd of 51 dugongs, which is fewer than the five herds (totalling 177 dugongs) detected in 2016, the three herds (totalling 391 dugongs) detected in 2011, and the four herds (totalling 216 dugongs) in 2005.

Despite multiple attempts to survey the area in the vicinity of Brisbane city (blank area in the 2022 survey year panel in Figure 10.4), Cleguer et al. (2023) did not receive permission from Air Traffic Control to conduct the survey. Although this area historically does not support many dugongs, some of the variations in dugong estimates found in the 2022 survey could potentially be explained by an increased use of this area by dugongs. The confirmation of the presence of a relatively large seagrass meadow in Waterloo Bay by Udy et al. (2023, see Figures 9, 10, 11 in their report) supports this possibility.

The dugong population density as a function of transect length was estimated to be 0.274 dugongs km^{-1} ± SE 0.030 in 2022, 30% lower than the 2016 survey, reinforcing a shallow downward trend in density since 2005, estimated to be -1.2% per year using the Bayesian approach (Cleguer et al. 2023). The probability of decline was 0.72 suggesting only weak confidence in a declining trend, and that a zero-trend could not be dismissed.

Despite the evidence of genetic structuring of the dugong population in southeast Queensland, temporary emigration of dugongs from Moreton Bay cannot be ruled out as an explanation for the lower numbers seen in 2022. Cleguer et al.'s (2023) survey, which extended over approximately 10 degrees of latitude along the southern half of the east Queensland coast, did not identify a destination for any such emigration. However, if displaced animals moved to several different bays in Queensland and/

Figure 10.4. Spatially explicit models of dugong density per unit area in Moreton Bay using data from aerial surveys conducted in November 2016 and December 2022. Dugong density estimations were based on the *Hagihara Method and* classified as Low (0 dugongs per km^2); Medium (0-0.5 dugongs per km^2); High (0.5-1 dugongs per km^2), and Very High (more than 1 dugongs per km^2). The Eastern Banks approximates the 2016 high density area. The area in the vicinity of the city of Brisbane could not be surveyed in 2022 so the model did not cover this area, which is in white. Reproduced from Cleguer et al. (2023) with permission.



or northern NSW, these small increases in dugong numbers would not have been detected by the surveys.

Seagrass habitats across the Moreton Bay Marine Park (Figure 10.15) were impacted by a coastal flood event in February/March 2022. The flooding transported large quantities of turbid water to Moreton Bay (Udy et al. 2023). Seagrass extent declined by 33.2% between pre and post flood surveys in the portion of the Marine Park covered by surveys (Udy et al.2023), which were conducted between August 2022 and January 2023. While most of the seagrass loss was in subtidal habitats, a post-flood decline in the proportion of all meadow types was also recorded in shallow subtidal areas (less than 2 m deep). Seventeen dugong carcasses were recorded from the Moreton Bay region between March and December 2022, compared with five in 2020, 10 in 2021 and one in 2023 for the same period, suggesting a relatively low level of flood-associated mortality (Queensland StrandNet records provided by T. Shimada 2024). The number of reported carcasses is likely to be fewer than the actual mortalities and most animals were not necropsied, so it is not possible to be more definitive.

The low dugong calf counts recorded by Cleguer et al. (2023) are also consistent with seagrass loss in the bay (Marsh et al. 2022). Only six cow-calf pairs were detected during the 2022 survey of Moreton Bay. This represents 5.5% of the total number of dugongs detected during this survey, the lowest proportion recorded since 2005 and the third lowest of the 10 estimates since 1976.

The international Marine Mammal Protected Areas Task Force (MMPATF) declared 'Moreton Bay' to be an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022a; Figure 10.15).

- Moreton Bay supports the largest dugong population close to a major city in the world.
- This population is the most comprehensively studied dugong population globally.
- The most recent aerial survey estimate of the dugong population of Moreton Bay in December 2022 was 400 ± SE 116 (*Hagihara Method*).
- The 2022 estimate was 30% lower than the 2016 survey, reinforcing evidence for a shallow downward trend in density since 2005 of -1.2% per year. The probability of decline was 0.72 indicating only weak confidence in a decline, and that a zero-trend cannot be dismissed, and the status of this population is uncertain.
- Despite this apparent decline, extended surveys did not provide evidence of dugong movements to habitats north of Moreton Bay, and the recorded post-flood increase in dugong mortalities was not sufficient to explain the decline.
- 'Moreton Bay' has been declared an IMMA with the dugong as a qualifying species.

10.2.1.2 Hervey Bay and Great Sandy Strait (Great Sandy Marine Park) survey region

This region is located north of Moreton Bay and separated from the latter by approximately 200 km of mostly surf coast. The importance of the Hervey Bay dugong population has been recognized for many years. The region intermittently supported a cottage industry for dugong oil for almost 80 years between 1860 and 1969 (Daley et al. 2008; Daley 2014). The extent of seagrass in the region can be up to 2,651 km^2 (McKenzie 2017), making this the largest seagrass meadow on the east coast south of Cape York. During the last 30 years, the dugong population has fluctuated because of temporary emigration in response to seagrass loss caused by extreme weather events (see Preen and Marsh 1995).

Extensive flooding of the Mary River over two consecutive events in early 2022 resulted in persistent flood plumes in the Great Sandy Region. Three months after the flood, York et al. (2022) showed that the distribution and abundance of seagrass was significantly reduced compared to historical levels. In Hervey Bay, seagrass distribution (744 km^2) was less than a third of that found during historical (1998) surveys (2,307 km^2). Where seagrass existed, its density was extremely low (York et al. 2022). Nine months after the flood, in October 2022, Bryant et al. (2023) found that seagrass distribution had increased significantly (1343 km^2), mainly due to an expansion in the large deep-water meadow in the centre of the bay. Despite signs of recovery, total seagrass distribution was only 58% of that mapped in 1998, and where seagrass did occur, especially intertidally, it remained sparse with very low density compared to historical levels (Bryant et al. 2023).

In the Great Sandy Strait, the area of seagrass detected three months after the flood (approximately 12 km^2) was only 22% of the area found during historical (1998) surveys (55 km^2) and seagrass abundance was extremely low (less than 0.1 g Dry Weight (DW) m^2 and less than 1% cover) compared to historical levels. Follow up surveys in October 2022 found very little recovery (Bryant et al. 2023).

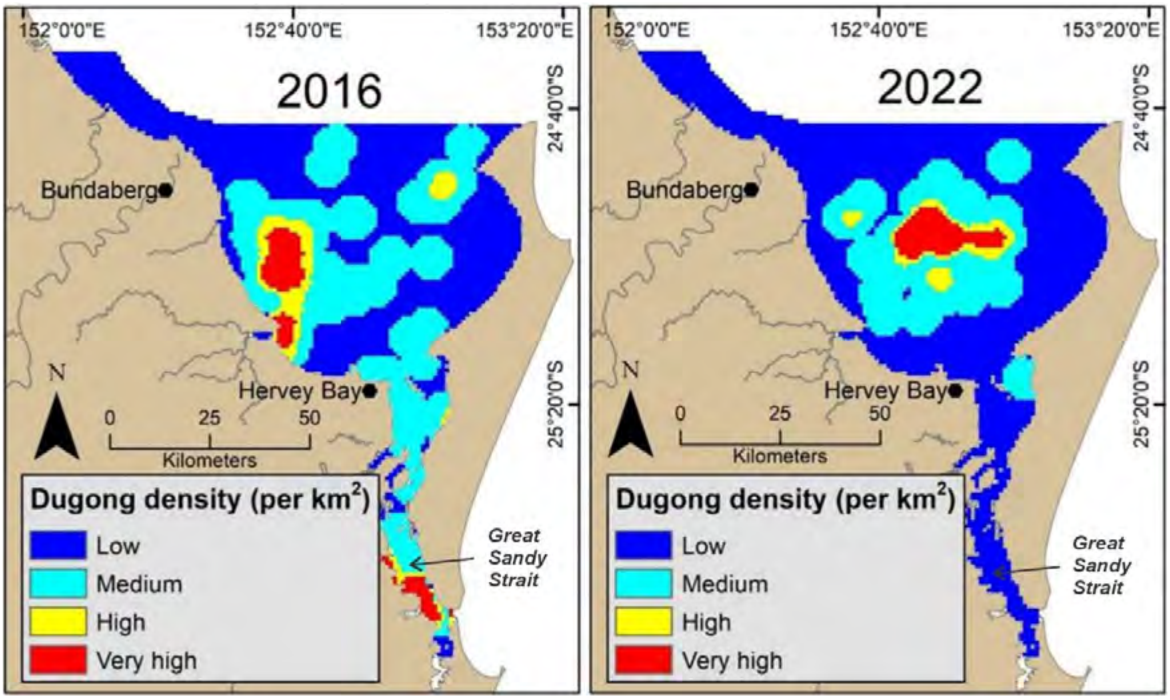
Cleguer et al. (2023) conducted a survey of Hervey Bay – Great Sandy Strait in November-December 2022 as part of their survey of the Queensland coast south from approximately 18° S. The dugong population size was estimated to be 1,533 ± SE 634 animals using the *Hagihara Method.* This estimate was similar to the estimates using the *Hagihara Method* on survey data collected in 2005 (1,388 ± SE 323) and 2011 (1,438 ± SE 438), but much lower than the 2016 estimate (2,055 ± SE 382) (see Appendix 10, Cleguer et al. 2023 for details).

There was also a marked change in the distribution of dugongs in Hervey Bay in 2022 compared with the previous survey (Figure 10.5). No dugongs were sighted in the Great Sandy Strait in 2022. There was a 3.7-fold decrease in the estimated number of dugongs present in the southern section of Hervey Bay and the estimated number of dugongs in the middle, deeper part of the bay increased from an estimated 610 ± SE 272 in 2016 to 1025 ± SE 592 in 2022 (Figure 10.5).

In 2022, Cleguer et al. (2023) estimated the Hervey Bay dugong population density as a function of transect length to be 0.094 individuals km^{-1} ± SE 0.03, a 69.7% decrease compared to 2016. Using a Bayesian approach, they concluded that the dugong population has been declining (probability = 0.995) at an estimated -5.7% per year since 2005. The 2022 survey data has a strong influence on this trend estimate; the results from the analysis of the data from 2005 through 2016 suggested a slight increase from 2005 to 2016 of + 0.28% and a probability of decline of 0.47 (i.e., less than 50%). These results suggest that the floods in early 2022, had a major effect on the dugong population, and that the apparent long-term trend may be confounded by both: (1) inadequate corrections for detection biases, because in 2022 the dugongs were concentrated in the deep water in the middle of the Bay where they are less visible to observers; and (2) temporary emigration from the Bay. In addition, long-term monitoring at sentinel sites throughout the Great Sandy Marine Park had shown a declining trend in seagrass abundance and extent since 2017 (McKenzie et al. 2023), compounding the adverse impact of the major flood events in early 2022.

Eighteen dugong carcasses were recorded from the Hervey Bay-Great Sandy Strait Bay region between April and December 2022, compared with 11 in 2020, 13 in 2021 and one in 2023 for the same period, suggesting a relatively low level of flood-associated mortality (Queensland StrandNet records provided by T. Shimada 2024). Although evidence

Figure 10.5. Spatially explicit models of dugong density per unit area in Hervey Bay using data from aerial surveys conducted in November 2016 and November-December 2022. Dugong density estimations were based on the *Hagihara Method*. Dugong densities were classified as Low (0 dugongs per km^2); Medium (0-0.5 dugongs per km^2); High (0.5-1 dugongs per km^2), and Very High (more than 1 dugongs per km^2). Reproduced from Cleguer et al. (2023) with permission.



of substantial mortality or temporary emigration from Hervey Bay was not convincingly detected elsewhere in the vast region surveyed by Cleguer and his team in 2022, the estimated number of dugongs in the Gladstone area, located approximately 200 km north of Hervey Bay and within the GBRWHA, was more than twice that of any of the other surveys this century (even though it was relatively low and had a large standard error: 280 ± SE 129). Low levels of population increase in areas supporting relatively few dugongs are very difficult to detect using large-scale aerial surveys. Nonetheless, Cleguer et al.'s (2023) survey results are consistent with evidence from past aerial surveys (e.g., Preen and Marsh 1995) and satellite tracking work (Sheppard et al. 2006) that some dugongs move between Hervey Bay and the GBR region.

Nine cow-calf pairs were detected in Hervey Bay during the 2022 survey. This represents 9% of the total number of dugongs detected during this survey year within the range of the corresponding data from the ten other surveys since 1979 (Cleguer et al. 2023).

Bryant et al. (2024) repeated their seagrass survey in November 2023. Total seagrass distribution in Hervey Bay (1,700 ± 404 km^2) had increased since the October/November 2022 survey but remained 26% lower than the 1998 distribution. The increase was mostly due to colonisation around the periphery of the large deepwater meadow in the middle of the bay by *Halophila decipiens*. Average seagrass biomass and percent cover had increased significantly especially at subtidal meadows, but the majority of intertidal seagrass remained low in density. In the Great Sandy Strait, the total area of intertidal seagrass mapped from August to November 2023 (53 km^2) had more than tripled since the first post flood survey in May 2022 and was very similar to the total area of intertidal seagrass mapped in December 1998 (53 km^2). There had been a change at many of the meadows along the mainland coast from *Zostera muelleri*- to *Halodule uninervis*-dominated communities, although it is possible that both species co-occur in these areas. The survey team is planning a repeat of the dugong survey in Hervey Bay in late 2024 to determine whether dugongs have returned, the timing of this future survey will enable comparison with past surveys (C. Cleguer personal communication via email to Marsh 2024).

The MMPATF declared 'Hervey Bay and Great Sandy Strait' an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022b; Figure 10.15).

- Hervey Bay is the most significant dugong habitat in eastern Australia, south of Cape York.
- The most recent aerial survey estimate of the dugong population of Hervey Bay (December 2022) was 1,533 ± SE 634, using the *Hagihara Method*.
- This estimate was almost 70% lower than the 2016 survey, indicating a downward trend of -5.7% per year since 2005. The two large flood events in early 2022, which resulted in extensive loss of seagrass, apparently had a major effect on the dugong population.
- The apparent long-term trend may be confounded by either or both: (1) inadequate corrections for detection biases, because in 2022 the dugongs were concentrated in the deep water in the middle of the Bay where they are hard to see; and (2) temporary emigration from the Bay. Thus, the dugong status on this survey region is currently uncertain.
- This trend needs to be further investigated with an additional dugong survey when the seagrass has recovered.
- 'Hervey Bay and Great Sandy Strait' has been declared an IMMA with the dugong as a qualifying species.

10.2.2 Great Barrier Reef (GBR)

The significance of the GBR region for dugongs was one of the reasons for its World Heritage listing (GBRMPA 1981). Thus, the status and trends of the distribution and abundance of dugongs are important information for the management of the GBR World Heritage Area (GBRWHA). Large-scale aerial surveys are scheduled for the waters of the urban (24° S to 15.23° S) and remote (15.23° S to 10.41° S) coasts in adjoining but separate years for logistical reasons. Whenever possible, the southern surveys of the urban coast have been combined with the surveys of Hervey and Moreton Bays and the northern survey of the remote coast with a survey of Torres Strait, which is biogeographically part of the GBR region but not part of the GBRWHA or the GBR Marine Park (GBRMP; Figure 10.15). However, in some years it has not been possible to complete these surveys as planned as a result of unsuitable weather and/or funding constraints.

10.2.2.1 Southern (urban) coastal waters of GBRWHA survey region

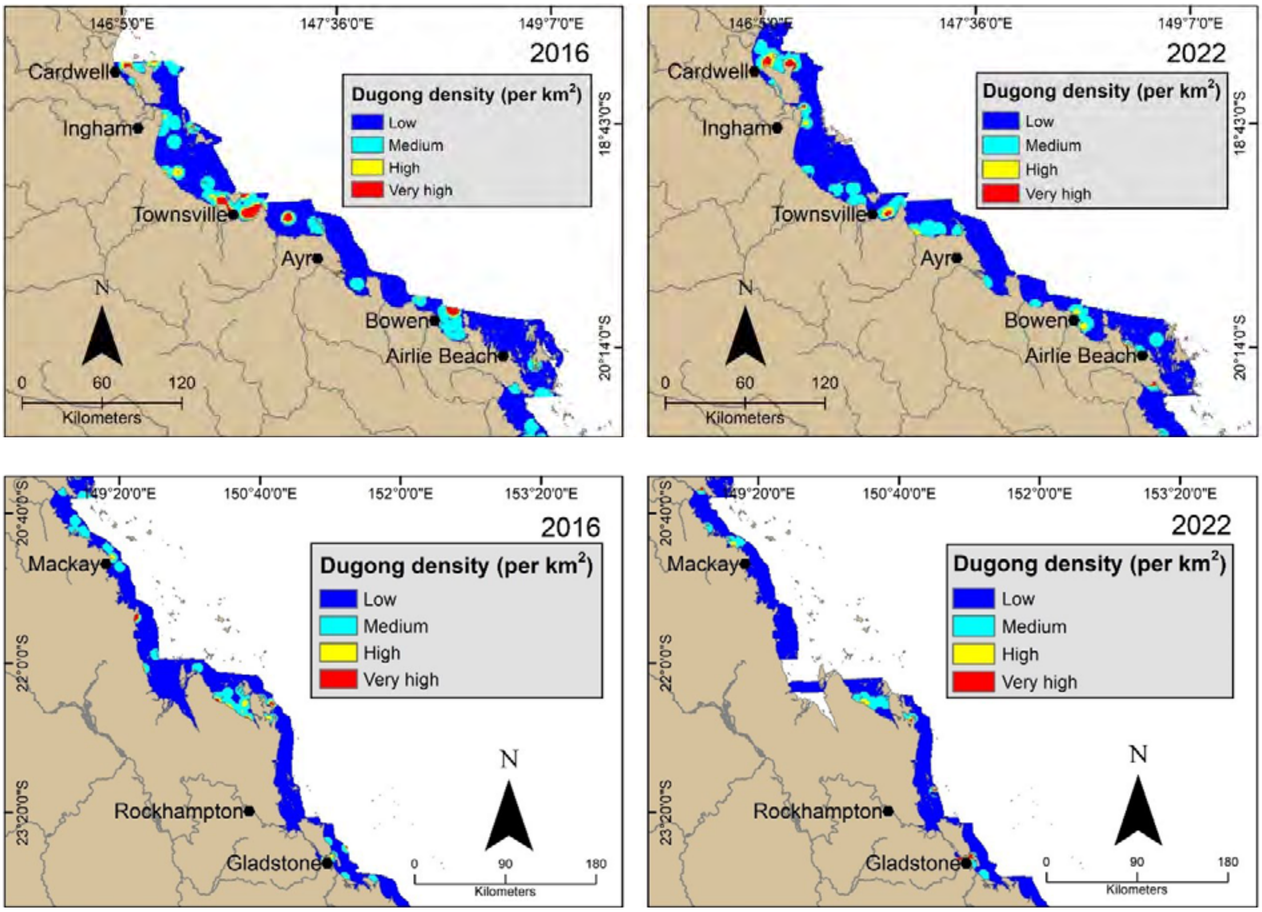
The original survey region extended over the inshore waters from Cape Bedford (15.23° S, 145.21° E) to the southern border of the GBRWHA (24° S; Figure 10.3). McKenzie et al. (2023) estimates that this part of the GBRWHA supports a total of 25,667 km^2 of seagrass, comprising shallow (1,591 km^2 in waters shallower or equal to 15 m deep) and deepwater (24,076 km^2 in waters deeper than 15 m) seagrass. It is not known whether the offshore deep-water seagrass meadows are used by dugongs, and these meadows have not been covered by the dugong aerial surveys for human safety reasons.

It has rarely been possible to survey the whole Southern GBR region in a single season and the coastal waters from Mission Beach (18° S) to Cape Bedford have often been omitted as relatively few dugongs have been sighted there, compared with further north. Cleguer et al. (2024) surveyed that region in 2023 and estimated that it supported around 1,414 ± SE 120 dugongs (*Hagihara Method).*

Using the *Hagihara Method,* Cleguer et al. (2023) estimated the dugong population between latitudes of approximately 18° and 24° S to be 2,124 ± SE 476. Excluding the region north of Hinchinbrook Island, which was not surveyed in 2016, this estimate decreased to 2,006 dugongs ± SE 466, a 29% decrease in the estimated number of dugongs in the survey region compared to the 2016 survey estimates (2,822 ± SE 600).

In 2022, dugongs were most abundant in the Townsville to Cardwell region (between Hinchinbrook Island and Halifax, Cleveland and Bowling Green Bays), and in Shoalwater Bay, the large bay between Rockhampton and Mackay (Figure 10.6). These coastal waters have consistently supported relatively high numbers of dugongs since the transect surveys began in the 1980s (see Marsh and Saalfeld 1990).

Figure 10.6. Spatially explicit models of dugong density per unit area along the urban coast of the GBRWHA using data from aerial surveys conducted in October-November 2016 and November 2022. The upper figures show the northern half of the survey region; the lower figures, the southern half. Dugong density estimations were based on the *Hagihara Method*. Dugong densities were classified as Low (0 dugongs per km^2); Medium (0-0.5 dugongs per km^2); High (0.5-1 dugongs per km^2), and Very High (more than 1 dugongs per km^2). Reproduced from Cleguer et al. (2023) with permission.



Cleguer et al. (2023) estimated the dugong population density as a function of transect length in the survey region to be 0.086 dugongs km^{-1} ± SE 0.017 in 2022, 40% less than the corresponding estimates. Cleguer et al. (2023) estimated a 93.8% probability of decline in dugong numbers in the survey area between 2005 and 2022, with an estimated rate of decline of -2.3% $year^{-1}$. The likelihood of the dugong densities recorded in 2022 being higher than those recorded in 2005 and 2016 respectively were low (less than 5%). Nonetheless, the 2022 dugong density was higher than in 2011 after the floods and cyclones of the austral summer 2010-2011 devastated the seagrass meadows in the region. These figures indicate that the estimates of overall decline may be confounded by temporary emigration but that there is strong and consistent evidence of overall decline in the region since 2005, the reasons for which have not been established.

The proportion of calves in 2022 was 6.7% (Cleguer et al. 2023). The proportion of calves in this region has fluctuated between zero (in 2011) and 12.6% (in 1999), since aerial surveys (initially shoreline rather than transect) commenced in 1974.

The MMPATF declared 'Hinchinbrook to Round Hill' an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022c; Figure 10.15).

- The estimated dugong population along the urban coastal waters of the GBRWHA between approximately 18° S and 24° S in 2022 was 2,124 ± SE 476.
- There is strong and consistent evidence of overall decline of -2.3% $year^{-1}$in the region between 2005 and 2022, the reasons for which have not been established.
- 'Hinchinbrook to Round Hill' is an IMMA with the dugong listed as a qualifying species.

10.2.2.2 Northern (remote) waters of the GBR survey region

Cleguer et al. (2024) surveyed the waters of the remote coast of the GBR from 15.38° S to 10.68° S in November 2023, an area that supports some 8,964 km^2 of seagrass (McKenzie et al. 2023). Using the *Hagihara Method*, they estimated that the dugong population of this survey region was 6,838 ± SE 968. Bayesian modelling using the N-Mixture estimator suggested that the dugong population in this region had increased at approximately 2% per year since 2006. Most of the population growth occurred between 2006 and 2019, with no statistical difference between 2019 and 2023.

Cleguer et al. (2024) reported that calves comprised 9.1% of dugong sightings, the highest percentage recorded since 2006. The highest percentage of calves (21.7%) was in the Cape Flattery-Cape Melville reef area, with varying percentages in other survey blocks ranging from 0% to 11.4%.

From 2006 to 2023, high and very high dugong densities were consistently found inshore and offshore between north of Cape Flattery and Bathurst Bay, and in sheltered bays like Lloyd Bay, Temple Bay, and Shelburne Bay. Consistently low dugong densities were found inshore north of Shelburne Bay (Cleguer et al. 2024). Figure 10.7 shows the dugong density in the region at the time of the four surveys conducted between 2006 and 2023.

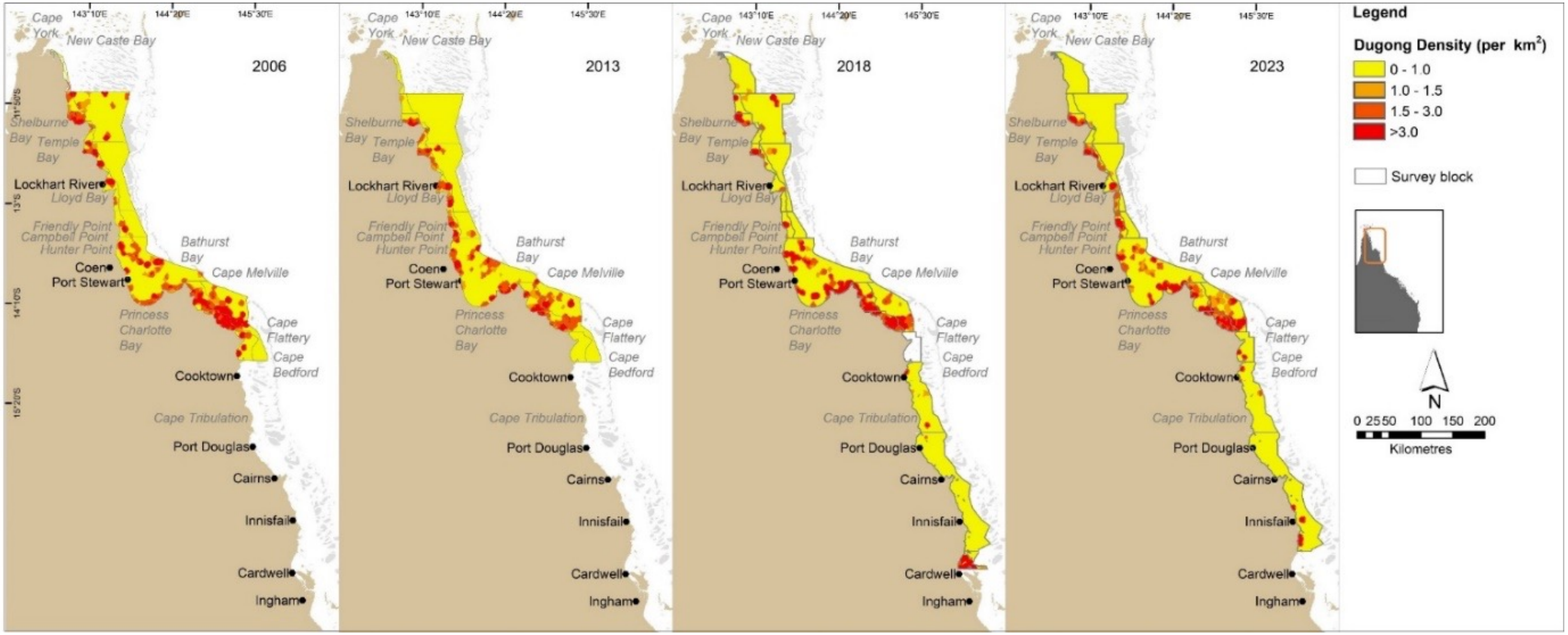
The MMPATF declared the 'Northern Great Barrier Reef' an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022d).

- The estimated size of the dugong population in the remote coastal waters of the GBRWHA between approximately 11° S and 15° S in 2023 was estimated to be 6838 ± SE 968.
- Bayesian modelling suggests that this dugong population had increased at around 2% p.a. since 2006.
- The 'Northern Great Barrier Reef' has been declared an IMMA with the dugong as a qualifying species.

10.2.2.3 Torres Strait survey region

Torres Strait or Zenadth Kes is the shallow sea between Australia and the Melanesian island of New Guinea (Figure 10.1 inset). It is 150 km wide at its narrowest extent. To the south is Cape York, the northernmost extremity of the Australian mainland. To the north is the Western Province of PNG. The jurisdictional boundary between the PNG and Australia waters of Torres Strait is very close to the PNG coastline (Figure 10.1) enabling a large-scale survey of Australian waters to provide a comprehensive picture of dugong distribution and abundance in the region. Torres Strait supports some 13,447 km^2 of seagrass (Carter et al. 2023), most of which occurs in Central and Western Torres Strait. Seven transect aerial surveys for dugongs have been conducted over 41,640 km^2 survey area

Figure 10.7. Spatially explicit models of dugong density in the central and northern sections of the GBR using data from aerial surveys conducted in 2006, 2013, 2018-19, and 2023. Dugong density estimations were based on the *Hagihara method*. Dugong densities were classified as Low (less than 1 dugongs km²), Medium (1–1.5 dugongs per km²), High (1.5–3 dugongs per km²), and Very High (more than 3 dugongs per km²). Reproduced from Cleguer et al. (2024) with permission.



in this region between 1987 and 2013 (see Cleguer and Marsh 2023 for links to the relevant reports). The survey region extended south to the northern boundaries of the surveys of the Queensland coast of the Gulf of Carpentaria (11.17° S) and the remote coast of the GBRWHA (10.95° S) as outlined earlier in this section.

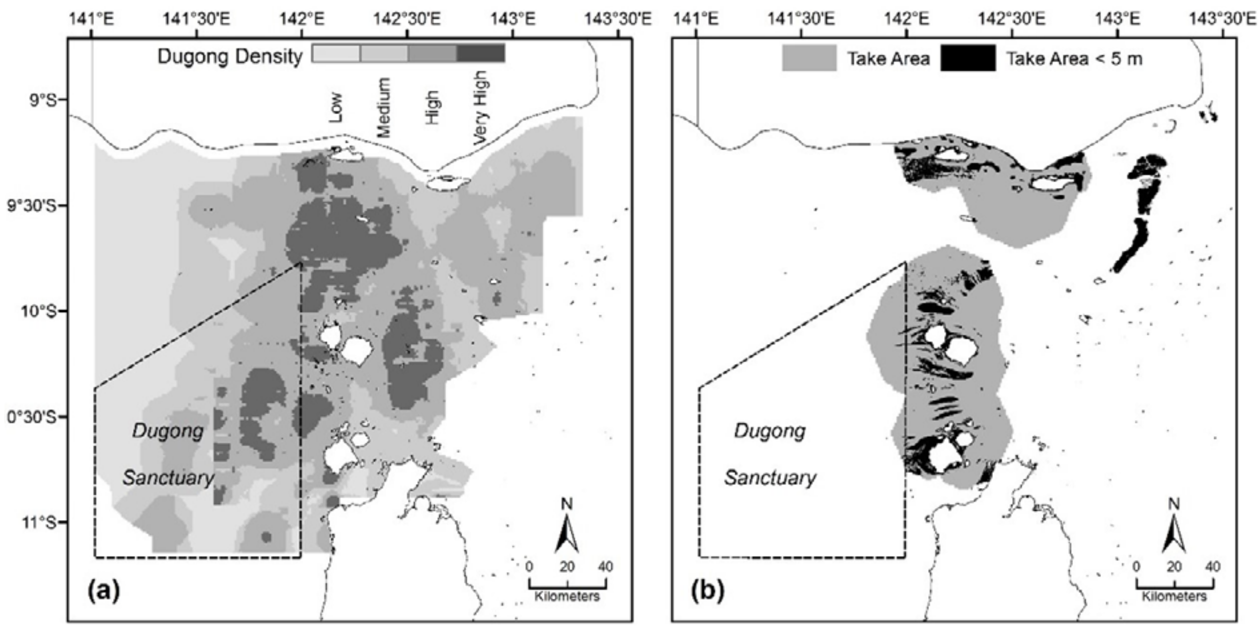
Dugongs have been harvested by the Indigenous peoples of Torres Strait between Australia and PNG, for at least 4,000 years (Crouch et al. 2007). The harvest has been substantial for at least the last 400–500 years (McNiven and Bedingfield 2008). Marsh et al. (2004) provided estimates of the catch of dugongs in various Torres Strait communities between the 1970s and the 1990s. The catch estimates reflected differences in monitoring technique, as well as spatial and temporal variation. The most accurate records are those of Kwan (2002) who lived on Mabuiag Island, one of the major hunting communities, and recorded a harvest of 170 dugongs over nine months in 1998. Comparable data are not available for any of 17 other Australian Torres Strait communities and at least 15 PNG coastal communities bordering Torres Strait. Nonetheless, the total harvest across Torres Strait must have been much higher than recorded for Mabuiag, even though not all communities engaged in dugong hunting.

Although Torres Strait Islanders have legal rights to hunt dugongs in their Sea Country[5] (see Section 10.3), hunting in Australia is controversial and the issue has featured in Federal and State government elections (Delisle et al. 2014). After negotiations with Islanders, a Dugong Sanctuary of over 13,000 km^2 was established in Western Torres Strait in 1987 banning dugong hunting (Figure 10.8).

Heinsohn et al. (2004) and Marsh et al. (2004) used the aerial survey estimates of population size to evaluate the sustainability of the contemporary dugong harvest using two different modelling techniques and concluded that the harvest must be unsustainable, a conclusion disputed by Torres Strait Islanders. Subsequently, Marsh et al. (2015) assembled several lines of evidence that suggested that the harvest was sustainable: (1) dugong relative density was significantly higher in 2013 than in any other survey year; (2) the dugong's Area of Occupancy in the region had trended slightly upward since 1987; (3) the proportion of calves in 2013 was the highest recorded; (4) genetic diversity was high; and (5) comparisons of dugong density maps obtained from the aerial surveys and spatial information on hunting demonstrated that dugongs were caught in only 5% of the 5,268 km^2 of very high dugong density habitat, as the result of the controls on the harvest and socio-economic factors.

Given all this evidence, Marsh et al. (2015) concluded that the data on dugong numbers from aerial surveys (e.g., 15,727 ± SE 2,942 in 2013, using the

Figure 10.8. Evidence that hunting does not occur throughout Torres Strait and that hunting is unlikely to occur in some high density dugong habitats: (a) spatially explicit model of dugong relative density per unit area and distribution in Torres Strait based on data from the 2011 and 2013 aerial surveys; and (b) hunting areas assuming that dugong harvest is: (1) not depth limited and (2) limited to waters shallower than 5 m. Reproduced from *Biological Conservation* with permission.



Pollock Method) could not be accurate. Hagihara et al. (2018) hypothesized that the probability of a dugong being available for detection is dependent on water depth and that dugongs spend more time underwater in deeper water seagrass habitats such as in Torres Strait than in shallower water seagrass habitats. They tested this hypothesis by quantifying the depth use of 28 wild dugongs fitted with GEN4 GPS/Argos Systems units (Telonics Inc., Mesa, Arizona, USA) and archival Time Depth Recorders (Mk9 or MiniPAT; Wildlife Computers Woodinville, WA, USA). The fitted instruments were used to measure the times the dugongs spent in experimentally determined detection zones under various environmental conditions. The estimated probability of detection was applied to the 2013 aerial survey data in Torres Strait and the population estimates increased 6–7 fold using depth-specific availability correction factors, compared with the *Pollock Method* estimates that assumed homogeneous detection probability across water depth and location. The revised population estimate for Torres Strait was 102,519 ± SE 20,146. The differences between the *Pollock* and *Hagihara* estimates were much less for New Caledonia and Moreton Bay, where the bathymetry is different (Hagihara et al. 2018) or in the Northern Territory Gulf of Carpentaria, where the *Hagihara* estimates were almost 25% less than the *Pollock Method* because the waters are shallow, and seagrass is mostly restricted to inter-tidal areas (Section 10.2.3.2).

Torres Strait has not been surveyed for dugongs since 2013 and there are no contemporary data on the dugong harvest, so the status of the dugong population is uncertain. Indigenous knowledge and scientific research indicate that there has been another substantial dieback of the deep-water seagrass in Torres Strait that was first noticed in 2019 (Carter et al. 2021). The cause of this dieback is unknown. An apparently similar seagrass dieback in the 1970s was linked to recruitment failure in the dugong population that was still detectable in the age distribution of harvested dugongs in the 1990s (Marsh and Kwan 2008). The most recent report card on the status of seagrass in Torres Strait (Carter et al. 2022) indicated that seagrass condition was variable across the region, but that: (1) the biomass of subtidal seagrasses was very low, and (2) the percent cover at some intertidal sites was also well-below average.

The MMPATF declared 'Central and Western Torres Strait' an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022e; Figure 10.15).

- Dugong abundance in Torres Strait is higher than anywhere else in the world. The dugong population estimate for Torres Strait was 102,519 ± SE 20,146 based on the 2013 survey using the *Hagihara Method*.
- An aerial survey for dugongs in Torres Strait has not been carried out for more than 10 years and there are no contemporary data on the Indigenous dugong harvest. Thus, the status of the population is uncertain.
- The most recent report card on the status of seagrass in Torres Strait indicated that seagrass condition was variable but poor in some areas.
- 'Central and Western Torres Strait' has been declared as an IMMA with the dugong as a qualifying species.

10.2.3 North Marine Region

10.2.3.1 Gulf of Carpentaria: waters off the Queensland coast survey region

The waters off the Queensland coast of the Gulf of Carpentaria (Figures 10.1, 10.3) have not been surveyed for dugongs for more than 16 years, so their status is uncertain. The last survey in October 2007 covered the coastal waters from 11.17° S on the west coast of Cape York to the Queensland Northern Territory border (17.45° S, 139° E), a region estimated to support 679 km^2 of seagrass (Carter et al. 2023).

Using the *Pollock Method*, Marsh et al. (2008) estimated a population of 7,095 ± SE 1,565 dugongs: a higher estimate than the previous comparable estimate for this region. This difference can be partially attributed to changing the method used to correct for availability bias from the original *Marsh and Sinclair Method*.

Standardized comparisons of the results for 2007 with the results of previous surveys suggest that overall dugong density was not significantly different between 1997 and 2007, averaged over all regions of the Gulf in the waters off Queensland for which such comparisons could be made. Dugong density varied substantially among regions between surveys, suggesting movement of dugongs between survey blocks. A plausible reason for the movement of dugongs within the region is the susceptibility of tropical seagrasses to damage from extreme events and diebacks from unknown causes (see accounts of Moreton Bay and Hervey Bay in Sections 10.2.1.1 and 10.2.1.2; GBR in Sections 10.2.2.1 and 10.2.2.2; Torres Strait 10.2.2.3; Shark Bay and Exmouth Gulf in Section 10.2.4.4).

The most important dugong area in the region is around the Wellesley Islands (Figure 10.1), where an estimated 80% of the population was sighted. The proportion of dugong sightings that were identified as calves was 10.6%, which is within the range of values recorded for other dugong surveys in other areas of northern Australia.

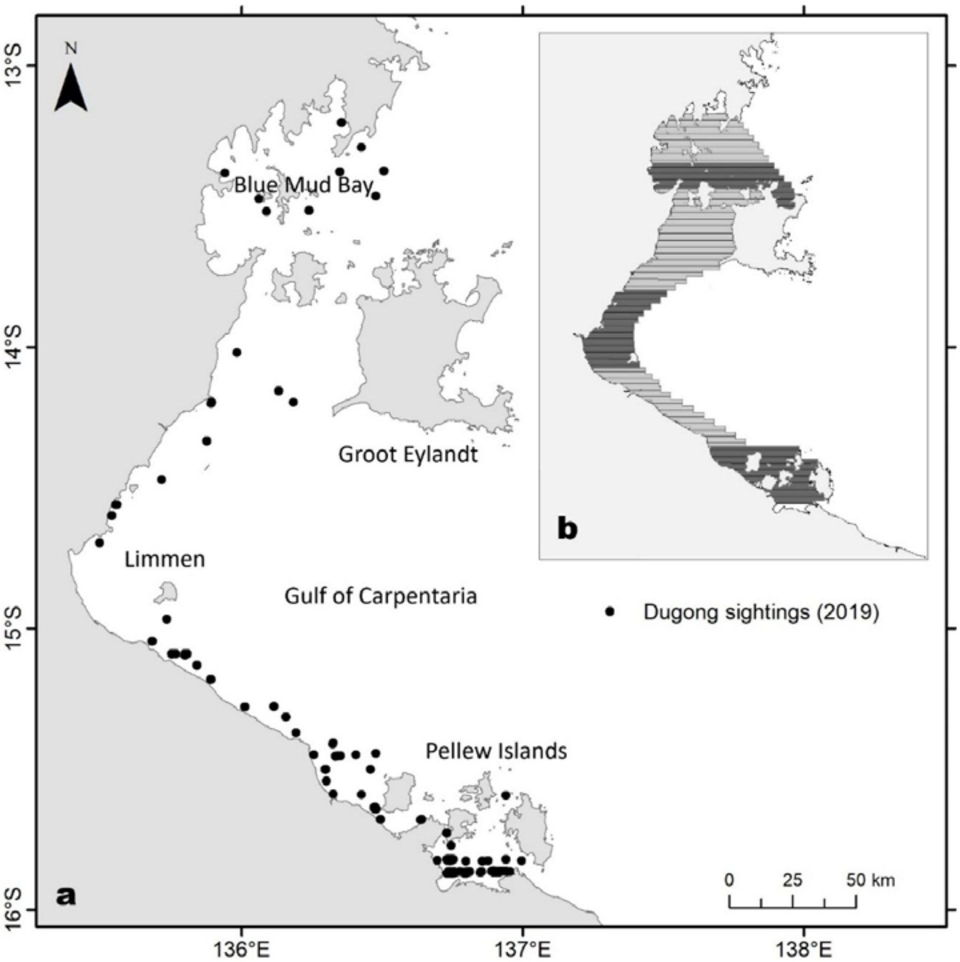
The MMPATF declared the 'Southern Gulf of Carpentaria', which includes waters off both Queensland and the Northern Territory, an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022f; Figure 10.15).

- The dugong population off the Queensland coast of the Gulf of Carpentaria was estimated to be 7,095 ± SE 1,565 in 2007.
- As no surveys have been conducted since 2007, the dugong population trend in this region is uncertain.
- 'Southern Gulf of Carpentaria', which includes waters of both Queensland and the Northern Territory, has been declared an IMMA, with the dugong as a qualifying species.

10.2.3.2 Gulf of Carpentaria: waters off the Northern Territory coast survey region

In collaboration with partners, the Northern Territory Government has conducted five strip–transect aerial surveys of the waters off its Gulf of Carpentaria coast since 1984 (Figure 10.1, 10.3, 10.9). Griffiths et al. (2020) documented the results of the most recent survey conducted in October 2019, which covered over 13,507 km^2 from the Sir Edward Pellew Islands in the south to Blue Mud Bay in the north (Figure 10.9).

Figure 10.9. Dugong sightings in Northern Territory waters of the Gulf of Carpentaria in 2019 from Griffiths et al. (2020). Inset (b) shows the transects flown. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Redrawn by Mélanie Hamel; reproduced with permissions from Mélanie Hamel and the Northern Territory government.



Griffiths et al. (2020) analysed the 2019 data using both the *Pollock* and *Hagihara Methods* and the results compared with previous surveys (1994, 2007, 2014). Based on the *Pollock Method*, the 2019 population estimate was 4,586 SE ± 1,318 dugongs; the *Hagihara Method* estimate was 3,390 SE ± 1,092. The difference between the two methods was attributed to the survey being mostly over relatively shallow water (shallower than 5 m deep), which increases the availability detection probability compared with the probabilities used in the *Pollock Method*, which relies on consistent water visibility but not water depth. Consistent with previous surveys, the waters surrounding the Sir Edward Pellew Island group and the adjacent Limmen area (Figure 10.9) contained the highest proportion of the population (80%) including calves. These results suggest the dugong population in the Northern Territory portion of the Gulf of Carpentaria is stable, although there appears to be a continual decline in the density of dugongs in the survey blocks north of Limmen (Griffiths et al. 2020). A cross-jurisdictional dugong survey of the Gulf of Carpentaria is scheduled for 2025 (C. Cleguer personal communication via email to Marsh 2024).

The MMPATF declared the 'Southern Gulf of Carpentaria', which includes waters of both Queensland and the Northern Territory, an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022f; Figure 10.15).

- The estimate for the dugong population in the waters along the Northern Territory coast of the Gulf of Carpentaria in 2019 was 3,390 SE ± 1092 (*Hagihara Method*).
- Comparison of these results with those from previous surveys suggests that this population is stable, although there may be a decline in the density of dugongs in the survey blocks north of Limmen.
- 'Southern Gulf of Carpentaria', which includes waters of both Queensland and the Northern Territory, has been declared an IMMA, with the dugong as a qualifying species.

10.2.3.3 Waters off the northern coast of the Northern Territory

In 2015, Groom et al. (2017) conducted the first comprehensive megafauna survey of the coastal waters of the entire Northern Territory, from its border with Queensland in the east to the border with Western Australia, using the Marsh and Sinclair (1989b) survey technique (Figures 10.1, 10.3). This was the first such survey of the Northern Region from just north of Blue Mud Bay (13° S, 136° E) to the Joseph Bonaparte Gulf (14° S, 129° E). This Northern Region is estimated to support 121 km^2 of seagrass (Roelofs et al. 2005; Lucieer et al. 2023).

Using the *Pollock Method,* the dugong population estimate for the Northern Region (approximately 44,548 km^2), was 2,648 ± SE 318. Dugong densities per unit area were relatively low in all survey blocks (less than or equal to 0.11 dugong km^{-2}), a result consistent with the reconnaissance survey conducted by Elliot in 1978 (Elliot 1981). As this has been the only systematic dugong survey conducted along this coast, the status of the dugongs in this region is uncertain.

- A 2015 baseline population estimate for dugong population off the northern coast of the Northern Territory was 2,648 ± SE 318 (*Pollock Method).*
- As this is the only dedicated dugong survey conducted along this coast, the status of dugongs in this region is uncertain.

10.2.4 North-West Marine Region

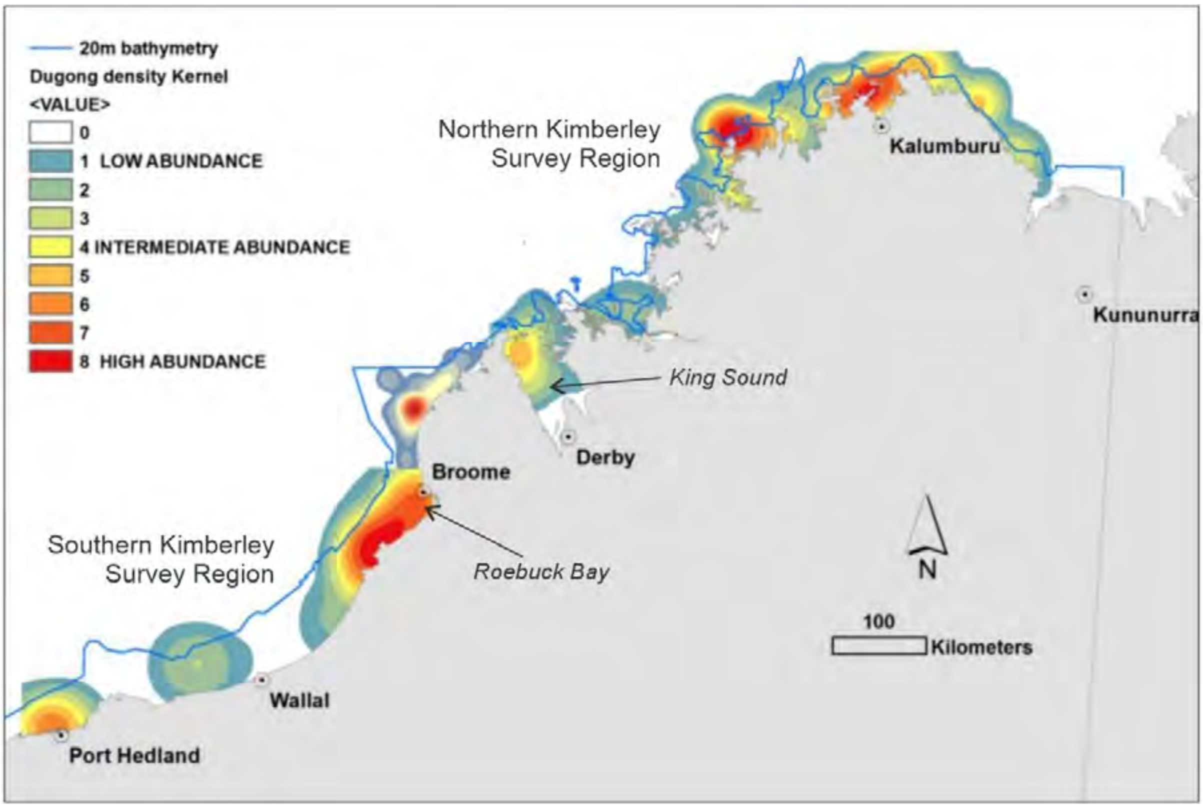
10.2.4.1 Kimberley Region: Western Australian Northern Territory border to Port Hedland

Bayliss and Hutton (2017) conducted the first aerial survey of the coastal waters in the Kimberley Region to the 20 m isobath (Figure 10.10) in September–October 2015 (North Kimberley), and May 2017 (South Kimberley), a survey area totalling 67,163 km^2. Dampier Peninsula was not resurveyed in 2015 or 2017 and the September 2009 Woodside Petroleum (SKM 2009) survey data were used to fill this knowledge gap in the assumption that the method used was compatible for the purposes of mapping regional distribution and relative abundances of dugongs.

No estimate of the seagrass area was available as of March 2024.

The North Kimberley survey covered the region between the Western Australian–Northern Territory border in Joseph Bonaparte Gulf to King Sound near Derby; the South Kimberley survey was between Broome and Port Hedland (Figure 10.10). Survey protocols generally followed those developed for the Queensland surveys outlined above. The North Kimberley survey was completed in partnership with

Figure 10.10. Dugong relative density along the Kimberley coast in 2015 and 2017. All sighting data were used to map extrapolated and smoothed Kernel densities across the 5 km aerial survey grid. Within the North and South Kimberley survey areas, red colours have the highest relative abundances and blue colours the lowest, with an intermediate colour abundance range (orange, yellow and green). The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Reproduced from Bayliss and Hutton (2017) with permission.



Indigenous rangers after a five-day intensive training course (Bayliss and Wilcox 2015; Bayliss et al. 2015).

Using the *Pollock Method*, Bayliss and Hutton (2017) estimated the dugong population in the entire Kimberley region to be 12,600 ± 601, an average density per unit area of 0.25 ± SE 0.02 km^{-2}. Dugong abundance in North Kimberley (10,513 ± SE 497) was approximately five times that of South Kimberley (2,087 ± SE 197), most likely reflecting the differences in coastal morphology in the two regions; the southern region has a more open coast. The percentage of calves was 5.8% for North Kimberley and 8.3% in South Kimberley.

The highest densities of dugongs were in areas with extensive seagrass habitat associated with sheltered areas of shallow waters (shallower than 20 m bathymetry, relatively clear water; Figure 10.10). Many of these areas were within Wunambal Gaambera Sea Country in the North Kimberley Marine Park (Figure 10.15). Roebuck Bay was identified as an abundance 'hotspot' for dugongs. Comparison between dugong density in the May 2017 component of the survey and an estimate derived from the July 2009 Woodside Petroleum survey (around eight years prior; SKM 2009) indicated that there has been no significant change in density, suggesting that cultural harvests had been sustainable over that period.

Bayliss and Hutton (2017) developed a Bayesian likelihood model to identify and map important dugong areas. Their work integrated seagrass likelihood data, aerial survey data and seasonal TEK to identify the probability of dugong occurrence. The key outcome of this approach was a map that can be used as a tool to inform culturally appropriate monitoring and decision-making for dugong management (Figure 10.10). This model allows for new information to be incorporated for adaptive monitoring as Traditional Owner led and partnered research opportunities increase throughout Kimberley. This approach should be explored with relevant Traditional Owners for application in other areas.

The MMPATF declared the 'Northwest Australian Coastal Waters and Inlets' an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022g; Figure 10.15).

- Baseline surveys were conducted off the Kimberley coast in 2015 (King Sound to Western Australian border) and 2017 (Broome south).
- The resultant dugong population estimate for the entire region was 12,600 ± SE 601 (*Pollock Method)*.
- As this is the only such survey conducted along this entire coast, the status of dugongs in this region is uncertain.
- 'Northwest Australian Coastal Waters and Inlets' has been declared an IMMA with the dugong as a qualifying species.
- The process of integrating seagrass data, aerial survey data and Traditional Ecological Knowledge to identify the probability of dugong occurrence in Kimberley coastal waters should be explored with Traditional Owners for possible application in other areas.

10.2.4.2 Ashmore Reef

Ashmore Reef is part of Australia's territorial seas and lies 350 km north-east of the Australian mainland within the Ashmore Reef Marine Park (Figures 10.1, 10.15 upper figure). Ashmore Reef is 150 km from the Indonesian Island of Roti (Chapter 7), from which it is separated by a deep oceanic trench (Director of National Parks 2018). The distances of Ashmore Reef from other dugong habitats are within the ranges of large-scale movements of satellite-tracked dugongs (Deutsch et al. 2022), but such movements would be expected to be rare. Brown and Skewes (2005) report that Ashmore Reef supported sparse seagrass, dominated by *Thalassia hemprichii*, a species eaten by dugongs in reef environments (André et al. 2005).

Dugongs were first recorded on Ashmore Reef in 1986 and have been sighted occasionally since then, mostly from Australian Customs vessels. These sightings included a group of seven animals (Hale and Butcher 2013). Whiting (1999) and Whiting and Guinea (2005) opportunistically observed a herd of eight dugongs including two calves on Ashmore Reef on a Coastwatch flight in 1996. Whiting (1999) estimated that the population could number over 100 individuals, by extrapolating from a spatially biased sample of only 6% of the reef area. Keesing et al. (2024) recorded an incidental sighting of one dugong in May 2022, the first recorded sighting since 2005.

Whiting (1999) also refers to an anecdotal report of three dugongs in water 90 m deep, 130 km east of Ashmore Reef on the Sahul Banks, a large area with numerous shallow shoals. This report suggests that the area of dugong habitat may be greater than Ashmore Reef *per se*.

Blair et al.'s (2014) genetic analysis of the mitochondrial control region of three dugongs from Ashmore Reef showed that one dugong belonged to the widespread dugong haplogroup from Australia and New Caledonia, while another two belonged to the northeastern haplogroup more characteristic of dugongs from Asia, including Indonesia (Chapter 1, Figure 1.2).

Dugongs at Ashmore Reef and the Sahul Banks are geographically isolated and possibly genetically unique. They are potentially subject to impacts from illegal fishing due to their isolation (Keesing et al. 2021). Their status merits further investigation with a view to a possible IUCN Red List of Threatened Species 'subpopulation' listing. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has applied for funds to conduct a combined drone and vessel survey (J. Keesing personal communication by email to Marsh 2024).

- Dugongs at Ashmore Reef and the Sahul Banks are geographically isolated and possibly genetically unique.
- They are potentially subject to impacts from illegal fishing due to their isolation.
- Their status merits further investigation with a view to a possible IUCN Red List of Threatened Species 'subpopulation' listing.

10.2.4.3 Pilbara coast: Mouth of De Grey River to North-West Cape survey region

The only transect survey of this entire coast (Figure 10.3) was in 2000 (Prince 2001). Thus, the status of the dugong in this region is uncertain. Prince (2001) undertook a strip transect aerial survey for dugongs between the mouth of the De Grey River (20° S, 119.25° E) and North-West Cape (21.75° S, 114.17° E) (Figure 10.1, 10.3) to the 20 m isobath in April 2000. He analysed the results using the *Marsh and Sinclair Method* and estimated 2,026 ± SE 376 dugongs in the survey region waters at an average density per unit area of 0.1 km^{-2}. This region is estimated to support at least 188 km^2 of seagrass, however, a greater area of seagrass is likely to be present because mapping efforts across the region have been very limited. As this is the only dedicated dugong survey conducted along the entire Pilbara coast as defined here, the status of dugongs in this region is uncertain.

Aerial surveys for dugongs over the southern, more industrialised part of this region (Onslow) were conducted by the Murdoch University Cetacean Research Unit for the Chevron-Wheatstone project, which involved building and operating a multi-train liquefied natural gas plant. The population estimates for the Onslow region in 2015 were 617 ± SE 236 in May and 548 ± SE 263 in October using the *Pollock Method* (Chevron 2016).

The IUCN Marine Protected Area Taskforce declared the Dampier Archipelago, a collection of small island and coastal waters along the Pilbara coast, an IMMA with the dugong as a qualifying species (IUCN-MMPATF 2022 h).

- A baseline survey was conducted off the Pilbara coast in 2001. The resultant dugong population estimate for the entire region was 2,026 ± SE 376 (*Marsh and Sinclair Method)*.
- As this is the only such survey conducted along this entire coast, the trend in the dugong population in this region is uncertain.
- The Dampier Archipelago, a collection of small islands and coastal waters along the Pilbara coast has been declared an IMMA (IUCN-MMPATF 2022h).

10.2.4.4 North-West Cape to Shark Bay including Exmouth-Ningaloo survey region

Coastal waters between North-West Cape (21.75° S, 114.17° E) and the southernmost reaches of Freycinet Estuary in Shark Bay (26.6° S, 113.7° E) (Figures 10.1, 10.3, 10.11) have been covered in a single dugong survey on several occasions (July 1989, June 1994, May-June 2007, June 2018 and June 2023). There is some evidence suggesting that some dugongs may have moved from Exmouth Gulf to Shark Bay after cyclone Vance destroyed seagrass meadows in the Ningaloo-Exmouth Gulf region in 1999 (Gales et al. 2004).

The coastal waters of this region include the Shark Bay World Heritage Area (WHA), which was inscribed on the World Heritage List in 1991. The Statement of OUV states: 'Shark Bay is one of the world's most significant and secure strongholds for the protection of Dugong'. Dugongs also occur in the Ningaloo Coast WHA (Figure 10.15) but are not listed in the Statement of OUV.

One of the other World Heritage values of Shark Bay is its extensive seagrass meadows. In 2010, before the extreme marine heatwave in the austral summer of 2010/11, Shark Bay supported around 4,366 km^2 of both dense (70%) and sparse (30%) seagrass (Strydom et al. 2020). The large temperate seagrasses, *Amphibolis antarctica* and *Posidonia australis, were* historically dominant. The marine heatwave caused the loss of some 1,310 km^2 of seagrass, predominantly *A. antarctica*.

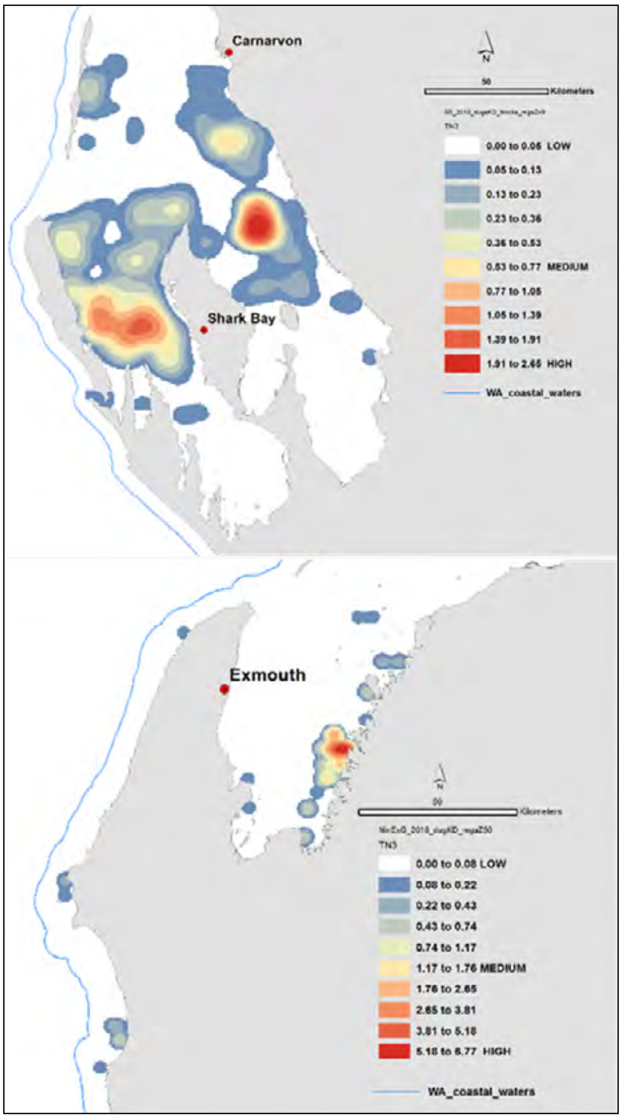
The main objective of the 2018 survey by Bayliss et al. (2018) was to assess how the Shark Bay and Exmouth/Gulf dugong populations had responded to the seagrass loss caused by the marine heatwave. Some areas in Shark Bay where *A. antarctica* had been lost had subsequently been colonised by fast-growing tropical seagrass species that are eaten by dugongs, namely *Halodule uninervis* and *H. ovalis*. (Kendrick et al. 2019).

The estimated numbers of dugongs in Shark Bay and Exmouth/Ningaloo in winter 2018 were 18,555 ± SE 3,396 and 4,831 ± SE 1,965, respectively, using the *Hagihara Method* (Bayliss et al. 2018).

Bayliss et al. (2019) used two different Analysis of Variance (ANOVA) models to test for changes in dugong density in each of Exmouth/Ningaloo and Shark Bay between 2007 and 2018. In each region, both models indicated that overall, dugong density had not significantly decreased. Bayliss et al. (2019) concluded that these results: (1) cannot be used to draw conclusions about potential large-scale movements between Shark Bay and the Ningaloo-Exmouth Gulf regions in either direction as a result of the seagrass dieback event in Shark Bay in 2010/11, and (2) suggest that, for Shark Bay at least, dugong populations have been relatively stable between 1989 and 2018, a conclusion supporting Hodgson et al.'s (2008) findings for 1989 to 2007.

In contrast, the trend in the percentage of dugong calves counted during the surveys between 1989 and 2018 inclusive suggested that recruitment likely failed after the seagrass dieback; only one calf was seen in a partial survey of Shark Bay in mid-2012 during which 356 dugongs were sighted (Hodgson et al. 2023). Dugong recruitment failure has also been reported after seagrass diebacks in Torres Strait in the 1970s (Marsh and Kwan 2008) and in the southern GBR in 2011 (Sobtzick et al. 2012).

Figure 10.11. Relative abundance of dugongs mapped by Kernel smoothing using all sighting data in Shark Bay (upper figure) and the Ningaloo-Exmouth Gulf (lower) survey areas in June 2018. Observed dugong densities per unit area (km^{-2}) were standardized for effort (four observer counts) but uncorrected for detection biases and are considered 'minimum' estimates. Red colours have the highest relative abundances and blue colours the lowest, with a colour-abundance range in between (orange, yellow and green). The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Reproduced from Bayliss et al. (2018) with permission.



Another survey of this region was performed in winter 2023; preliminary data indicated that the number of dugong sightings is within the range of previous surveys, but detailed analysis of population estimates and trends had not been completed as of March 2024.

Bayliss et al. (2019) modelled the relationship between dugong density from aerial surveys and the estimated areas of dense (over 40% cover) and sparse (less than 40% cover) seagrass in Shark Bay obtained from medium resolution satellite images for 2002, 2010, 2014 and 2016. The extent or percentage cover of sparse seagrass habitat were generally the most predictive of all the seagrass mapping variables for dugong distribution and abundance, particularly for 2018 (adjusted R^2 = 0.97). This result accords with current understanding of dugong feeding ecology, which indicates that dugongs prefer to feed by excavating the soft and delicate tropical species, rather than cropping the leaves of high biomass species such as *A. antarctica* (Bayliss and Hutton 2019).

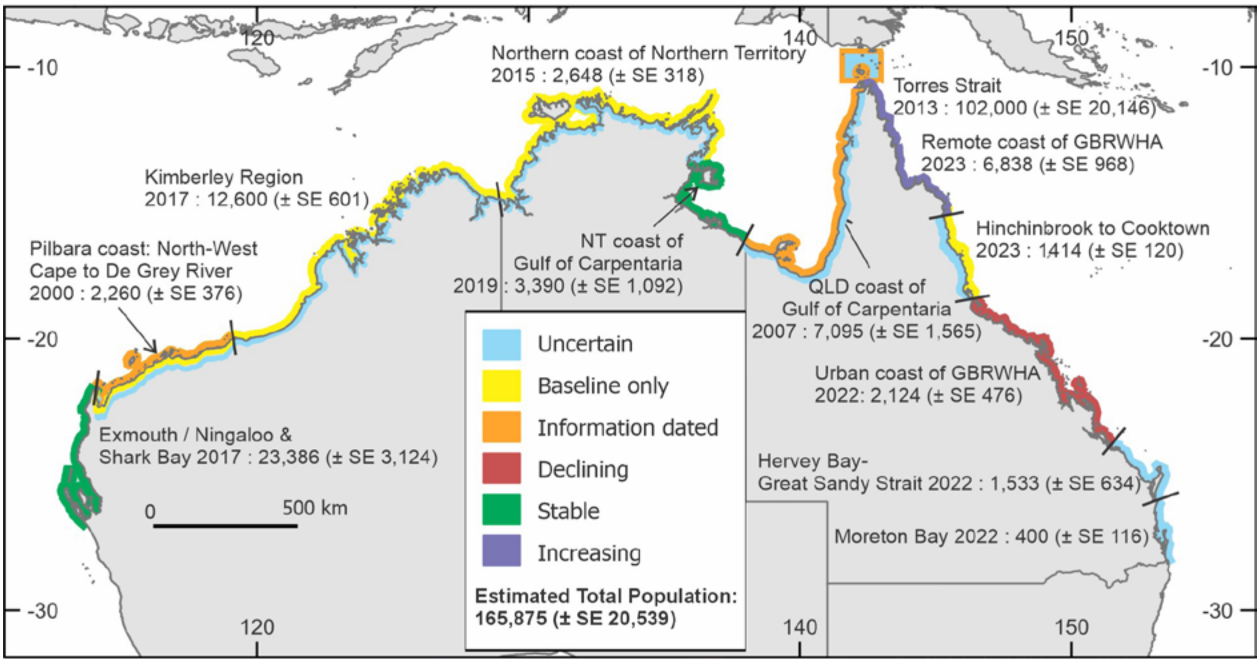
The MMPATF declared the 'Ningaloo Reef to Montebello Islands' and 'Shark Bay' IMMAs with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022 i, j; Figure 10.15).

- The estimated number of dugongs in Shark Bay and Exmouth/Ningaloo in winter 2018 was 23,386 ± SE 3,124 (*Hagihara Method*). Shark Bay dugong populations appeared relatively stable between 1989 and 2018.
- Both 'Ningaloo Reef to Montebello Islands' and 'Shark Bay' have been declared IMMAs, with the dugong as a qualifying species.

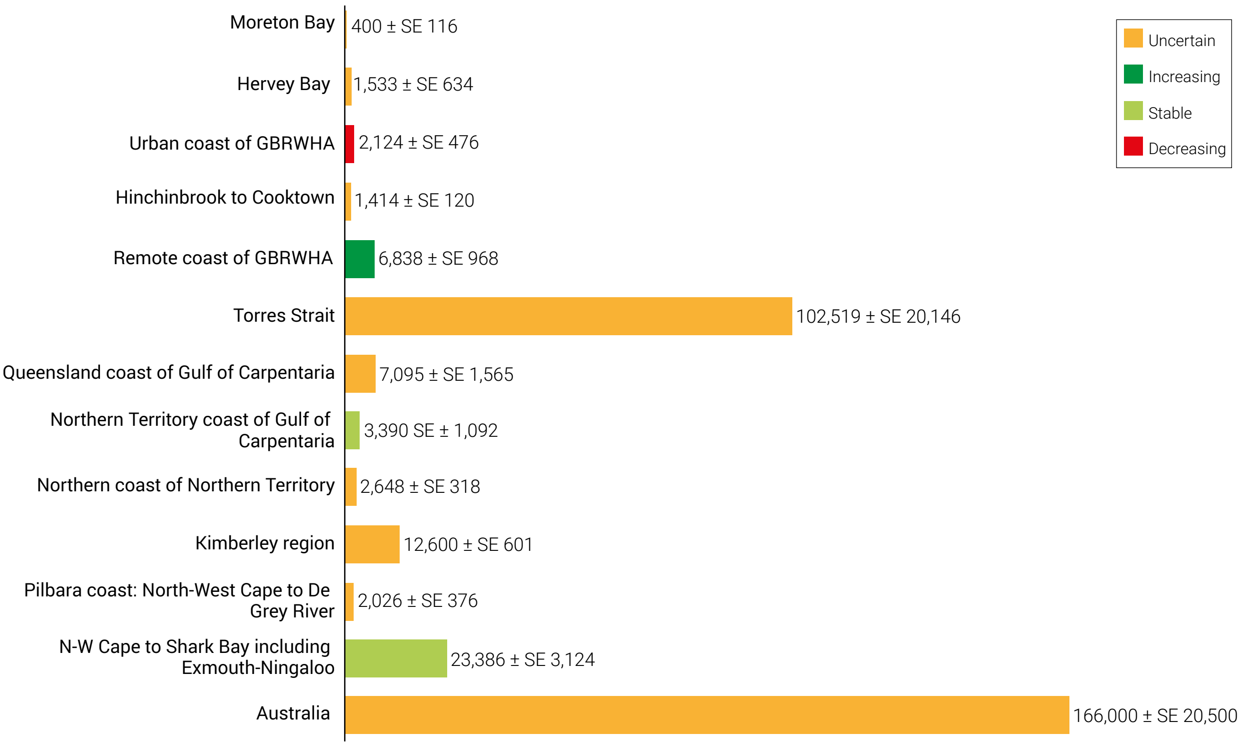
10.2.5 Overview of dugong abundance and trends across the Australian region

Collectively, the results of the large-scale surveys indicate that dugongs are far more abundant in the Australian region than anywhere else in their range and that their conservation status varies regionally within Australian coastal waters (Clark et al. 2021). Confidence in this assessment varies because of regional and temporal differences in survey recency and frequency, and the different approaches used to assess trends (Figure 10.12, Table 10.1).

Figure 10.12. Summary of the results of the most recent large-scale dugong aerial survey across northern Australia and the status of the dugong population in each region, based on survey frequency, the timing of the last survey and the likelihood of recent temporary emigration. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Figure created by Adella Edwards; reproduced with permission.



Size and status of the dugong in Australia



Comment: Summary of the most recent dugong population estimates for various surveys, the inferred status of the population in each region and the confidence in that assessment based on survey frequency, timing and the likelihood of recent temporary emigration.

Table 10.1. Summary of the most recent dugong population estimates for various surveys, the inferred status of the population in each region and the confidence in that assessment based on survey frequency, timing and the likelihood of recent temporary emigration.

Survey region	Date latest survey	Population Estimate	Correction Availability Bias	Status/Confidence	Reference
Moreton Bay	2022	400 ± SE 116	*Hagihara*	Uncertain, weak trend	Cleguer et al. (2023)
Hervey Bay-Great Sandy Strait	2022	1,533 ± SE 634	*Hagihara*	Uncertain, possible temporary emigration	
Urban coast of GBRWHA	2022	2,124 ± SE 476	*Hagihara*	Declining	
Hinchinbrook to Cooktown	2018-2019	1,414 ± SE 120	*Hagihara*	Uncertain; baseline only	Cleguer et al. (2024)
Remote coast of GBRWHA	2023	6,838 ± SE 968	*Hagihara*	Increasing	Cleguer et al. (2024)
Torres Strait	2013	102,519 ± SE 20,146	*Hagihara*	Uncertain; information out-of-date	Hagihara et al. (2018)
Queensland coast of Gulf of Carpentaria	2007	7,095 ± SE 1,565	*Pollock*	Uncertain; information out-of-date	Marsh et al. (2008)
Northern Territory coast of Gulf of Carpentaria	2019	3,390 SE ± 1,092	*Hagihara*	Stable	Griffiths et al. (2020)
Northern coast of Northern Territory	2015	2,648 ± SE 318	*Pollock*	Uncertain; baseline only	Groom et al. (2017)
Kimberley region	2017	12,600 ± SE 601	*Pollock*	Uncertain; baseline only	Bayliss and Hutton (2017)
Pilbara coast: North-West Cape to De Grey River	2000	2,026 ± SE 376	*Marsh and Sinclair*	Uncertain; information out-of-date and baseline only	Prince (2001)
N-W Cape to Shark Bay including Exmouth-Ningaloo	2018	23,386 ± SE 3,124	*Hagihara*	Stable	Bayliss et al. (2018)
Total (rounded)		**166,000 ± SE 20,500**			

10.3 Cultural values

10.3.1 Indigenous values

Dugongs have been important to the Indigenous peoples of Australia and the Western Province of PNG for thousands of years. Much of the evidence of early contact would now be submerged by the sea level rise since the last glacial maximum. The oldest known rock art depicting a dugong is today located at approximately 15 km inland south of the Arafura Sea in the Northern Territory. When it was painted 6,000–9,400 years ago, the rock art site would have been much further from the sea, but within walking distance (Taçon et al. 2020).

As explained in Section 10.2.2.3, there is archaeological evidence from Torres Strait that dugong hunting was occurring there at least 4,000 years ago (Crouch et al. 2007). At that time, the dugong was the largest animal hunted by Aboriginal and Torres Strait Islander peoples and the quality and quantity of its flesh provided a windfall of high-quality meat and fat unequalled by other species (Chase 1981). Kiwai hunters in Western Province of PNG were revered as the greatest hunters of dugongs in PNG (McNiven and Feldman 2003) and being a successful dugong hunter conferred high status and great prestige (Hudson 1986; Parer-Cook and Parer 1990; McNiven and Feldman 2003).

Different techniques were used traditionally to catch dugongs in different areas. For example, netting was used to catch dugongs in the Wellesley Islands in the Gulf of Carpentaria (Marsh et al. 1981); Torres Strait Islanders hunted using harpoons (*wap*) thrown from the front of large double-outrigger canoes, and from *gnaths*, platforms built over fresh dugong feeding trails in reef top seagrass beds at low tide in anticipation of a dugong returning to feed on subsequent nights (Nietschmann and Nietschmann 1981; Parer-Cook and Parer 1990), while other groups speared dugongs from bark canoes (Bradley 1997) or in Western Province PNG, from outrigger sailing canoes using harpoons (Landtman 1927; Parer-Cook and Parer 1990).

There are numerous totemic sites connected to ritual increase (fertility) for dugongs, human burial sites, and ceremonial hunting ritual sites marked by piles of dugong bones across northern Australia (see, for example, Chase et al. [1981] for the east coast of Cape York; Bradley [1997] for the Sir Edward Pellew Islands and Limmen areas in the Northern Territory, and McNiven and others for Torres Strait [see McNiven 2023 for a review]). It is likely that many sites are unknown to archaeologists due to the vast spatio-temporal scale of habitation in Australia.

Bradley (1997) described sites throughout the Sir Edward Pellew Islands and the coastal margins of the south-west Gulf of Carpentaria (Figure 10.9) where the fecundity of the spirit ancestors is embodied in features of the landscape. An important site is the resting place of the Dugong Spirit Ancestor at Wunubarryi or Mount Young in Limmen, where some of the quartzite outcrops look remarkably like semi-submerged dugongs with their backs and snouts out of the water.

In Torres Strait, bone mounds revealed the ritual treatment of dugong bones, especially skulls, to increase hunting success (Figure 10.13; McNiven and Feldman 2003). These mounds also provided evidence of dugongs being harvested sustainably in large numbers for centuries before European settlement in the 1890s (McNiven and Bedingfield 2008; Urwin et al. 2016).

Dugong hunting was a dangerous and difficult activity. Magic and ritual were used with the aim of increasing hunter success. Both Torres Strait Islanders and the Kiwai people of southern PNG used dugong hunting charms (Figure 10.14) to provide spiritual aid in the capture of dugongs.

Figure 10.13. A dugong bone mound on Tudu Island, Torres Strait, Australia, in 1840. Note the large number of skulls and rib bones. Dumont D'Urville 1846: pp. 189; out of copyright.

These charms were mounted in the bow of boats or underneath offshore platforms to attract dugongs.

Parer-Cook and Parer (1990) recounted how: (1) Kiwai hunters were ritually rubbed with 'sacred dugong stones' before a dugong hunt to give strength and bring good fortune, (2) the *Baura* dance was performed after feasting on dugongs, and (3) Kiwai elders believed that '*the bounty of the sea was inexhaustible, and the dugong could never disappear*'.

The cultural and spiritual value of the dugong remains of deep significance to many coastal Indigenous peoples in Australia and is represented in their art, music, and dance. Delisle et al. (2017) used cognitive mapping and multidimensional scaling to identify separable groups of benefits (cultural services, provisioning services, and individual benefits) associated with traditional hunting for communities on two islands in Torres Strait. They demonstrated that the cultural services associated with the traditional hunting of dugongs and green turtles were considered significantly more important than the provisioning services.

Watkin Lui et al. (2016) investigated the contemporary cultural significance of Torres Strait Islanders sharing this 'marine bushmeat' with their

Figure 10.14. A dhangal (dugong) charm for harnessing good luck on a dugong hunt collected on Tudu Island by Alfred Cort Haddon in 1888. Measurements: 22x9x11.5 cm. British Museum Asset number 1539430001. The protruding vulva (not shown but verified by Marsh) suggests that the charm depicted a pregnant female. British Museum photograph released under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license.

mainland urban diaspora from the perspective of the diaspora living in three Australian mainland cities. The motivations for sharing dugong and turtle meat were almost exclusively cultural, even though each mainland recipient consumed relatively little dugong and turtle meat (less than 1 kg $person^{-1}$ $year^{-1}$). As one participant in the study explained:

'*So I think dugong is really important, I know to me it really is, you know, like, people say, they are soul food, our soul food. . . I think it's our genetic makeup . . . around that connection back to where we're from, and . . . it nourishes your body, you feel reconnected, you feel like you're just in that zone . . . and it makes you think of your family then because your mum's standing over the stove cooking.*' (Female participant, Brisbane).

Traditional Owner(s) is the term used in Australia to describe Aboriginal or Torres Strait Islander individuals or groups, which have legally recognized traditional or historical connections, attachments, and/or relationships with a specified area of land or sea. Section 211 of the *Native Title Act 1993 (Commonwealth)* recognizes that Australian Aboriginal and Torres Strait Islander peoples have common law rights and interests to their lands and waters according to their traditional law and customs, including hunting, gathering, or fishing rights and interests. Thus, dugong hunting is legal under Australian Law for Traditional Owners, who have Native Title rights over a particular area of sea, known as their Sea Country. In addition, the right of Torres Strait Islanders to hunt dugongs 'traditionally' with harpoons (*wap*) is recognized and protected under the Torres Strait Treaty, ratified by the governments of Australia and Papua New Guinea in 1985, and the *Torres Strait Fisheries Act Commonwealth 1984*. The agreements that have subsequently been negotiated with the objective of ensuring that traditional hunting is sustainable are considered in Section 10.5.3.

There are numerous coastal clan groups of Aboriginal and Torres Strait Islander peoples in northern Australia. For example, there are 70 clan groups in the GBR region and at least 15 in northern Western Australia alone, each with their own Sea Country. These groups often regard 'their' dugongs as a transboundary stock that moves across the boundaries between clan groups.

10.3.2 Non-Indigenous values

10.3.2.1 Historical values: cottage industry for dugong oil

European colonists regarded the dugong and its oil as extremely valuable. Thorne (1876) in his book, 'Queen of the Colonies or Queensland as I knew it' p.248 said:

'Of all the resources of Queensland waters, none is more extensive or valuable as its flocks of dugongs, which abound in all its northern waters as far south of Moreton Bay, although they are here in much less profusion than further north.'

Daley et al. (2008) and Daley (2014) outline the history of the dugong oil industry in Queensland, a cottage industry for dugong oil, hides, bones, and meat that persisted intermittently at a minimum of 10 locations on the east coast of Queensland from Moreton Bay to Torres Strait from 1847 until dugongs were protected in Queensland by an *Order in Council* (subordinate legislation published in the Queensland Government Gazette) on 1 September 1969.

10.3.2.2 Contemporary non-Indigenous values

A variety of artefacts attest to the contemporary value of dugong to non-Indigenous Australians. Examples include a tourist drive with a dugong motif along the western shores of southern Moreton Bay, a giant dugong near Rockhampton, a dugong sculpture on the foreshore at Airlie Beach near the Whitsunday Islands, a dugong model on the Townsville Strand and at Monkey Mia in Shark Bay, and a children's playground with a dugong slippery dip and dugong painted on the pavement around the playground on the Cardwell foreshore, between Townsville and Cairns. There are also displays in the Western Australian and Queensland Museums.

A captive dugong named 'Pig' is a feature of the Sydney Aquarium. This animal was reared in captivity after being found as an abandoned neonatal calf in 1998 (Marsh 2022).

Seagrass beds are increasingly valued as a source of Blue Carbon as discussed in Chapter 1.

10.4 Threatening processes

10.4.1 Habitat loss

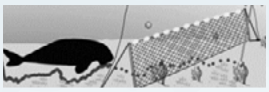
Despite much of the dugong's range in Australia being in areas with a low human population density (Chapter 11, Figure 11.2), habitat loss is the greatest long-term threat to dugongs in this region. Dugongs are seagrass community specialists (Marsh et al. 2011, 2018). The most significant threats to dugongs in their Australian range since at least the 1990s have been the effects of extreme weather events (cyclones, floods, and marine heatwaves) on seagrass communities. Section 10.2 details these impacts for several of the survey regions (e.g., Moreton Bay, Hervey Bay-Great Sandy Strait, Urban GBR region, Torres Strait, North-West Cape to Shark Bay) and explains how loss of seagrass eaten by dugongs results in dugong life history changes, an increase in mortality, especially neonatal mortality, and a decrease in fecundity (Marsh et al. 2022; Marsh and Cleguer 2024). In such circumstances, some dugongs undertake temporary emigration, presumably to locations where seagrass has not been lost (see Chapter 1).

These threats are likely to be exacerbated by climate change (Marsh et al. 2022) as well as the ongoing loss of seagrass caused by anthropogenic pressures in the coastal zone (Waycott et al. 2009). Any reduction in subtidal seagrasses will be particularly important to dugongs in Torres Strait, where animals use deeper water than on the east coast (Hagihara et al. 2018). As detailed in Section 10.2.2.3, extensive diebacks of deep-water seagrasses of unknown cause have occurred in Torres Strait.

Loss of deep-water seagrass will presumably result in animals spending more time in intertidal waters where they are more accessible to anthropogenic stressors (Marsh et al. 2022). Contrastingly, in regions with disturbed shallow seagrass beds, dugongs may depend more heavily on deeper-water seagrasses. However, the implications of this shift in habitat use on the energetic requirements of dugongs and their ability to adapt to such changes remain unclear.

Threats from continued agricultural activities and coastal development are also likely to reduce the resilience of seagrass meadows to climate change,

Threatening Processes



By-catch in gillnets, including shark nets set for bather protection, has been a major source of dugong mortality. Gillnets are scheduled to be phased out in most of the dugong's Australian range by mid-2027. If they are replaced by sustainable gears, the interactions resulting from fishing interactions should be reduced to close to zero.

Dugong hunting by Traditional Owners in their Sea Country is legal. Poaching in the Sea Country of others is an unquantified source of dugong mortality.

Loss and degradation of coastal seagrass is a major threat to important dugong habitats due to: extreme weather, coastal development, including reclamation, agricultural and urban pollution and is expected to be exacerbated by climate change.

Collision, especially with large vessels in urbanized areas, is a largely unquantified cause of dugong mortality.

The most significant threat is the effects of cyclones, floods, and marine heatwaves on seagrass communities. These threats are likely to be exacerbated by climate change.

especially on the urban coast of the GBR. The effects of sea level rise in the remote regions of northern Australia are expected to be ameliorated to some extent by limited coastal armouring. Nonetheless, the pattern of sea level rise is expected to be geographically uneven, and the local loss of estuarine and coastal seagrass is expected to further reduce the carrying capacity of the Northern Australian coastal waters for dugongs (Marsh and Cleguer 2024).

The most relevant unknown is how climate-induced changes in seagrass community composition will affect dugong food quality, biomass, and preferred feeding locations. The basis for the dugong's food choice is poorly understood, and determinants of food quality are unknown (Aragones et al. 2006, 2012; Chapter1). We do not know whether the dugong's preferred feeding locations reflect environmental parameters, food quality or quantity, socially transmitted knowledge of resources, or some combination of these factors or how changes in food quality and/or biomass change will affect their time budgets.

10.4.2 Incidental capture in nets

Drowning in gillnets is a major threat to dugongs throughout much of their range (Chapters 1-9). In Australia, shark nets set for bather protection were introduced at popular beaches along much of the Queensland coast from 1962 (Marsh et al. 2005). The catch rate of dugongs in shark nets in six groups of beaches between Cairns 16.5° S and the Gold Coast 28° S, declined at an average of 8.7% per year during this period, presumably because the populations of resident dugongs were severely reduced, as there is no evidence that they learned to avoid the nets. Shark nets have been replaced by drumlines in the GBRMP and there are few such nets remaining in the rest of the dugong's range in Queensland (Department of Agriculture and Fisheries [DAF] 2023). Shark nets have not been used for bather protection in the Northern Territory or Western Australia.

Incidental captures in commercial gillnets remains an unquantified threat to dugongs in Australia despite area closures to commercial gillnetting in eastern Queensland in the 1990s, a commitment to phase out commercial gillnetting in the GBRWHA by mid-2027 (see Section 10.5), a Dugong Protection Area in the south-western Gulf of Carpentaria, and area closures to fishing in several marine parks (Figure 10.15). In the Northern Territory, bilateral support for a phase out of gillnetting for barramundi was announced in June 2024 (Australian Marine Conservation Society 2024).

Commercial fishers are required by law to report their interactions with dugongs along with other protected species. Nonetheless, without fishery-independent surveys, it is impossible to validate the risk of fishing to dugongs and their habitats from these reports. Thus, unknown numbers of dugongs are caught in the Queensland East Coast Inshore Finfish Fishery, the Queensland Gulf of Carpentaria Inshore Finfish Fishery, the Northern Territory Barramundi Fishery, and the Northern Territory Offshore Net and Line Fishery. In the dugong's range in Western Australia, nets including gillnets are deployed in the small-scale commercial finfish fisheries in nearshore and estuarine waters in the Gascoyne Coastal (including parts of Shark Bay and Exmouth Gulf) and North Coast Bioregions (Newman et al. 2023). The Western Australian Northern Shark Fishery has been inactive since 2008/09. In 2021, the Western Australia Department of Fisheries self-assessed the impact of commercial fishing on dugongs and their seagrass habitats as a negligible risk (Newman et al. 2023), but without fishery-independent surveys, it is impossible to validate this assessment. Closures to commercial gillnetting in northern Australia are discussed further in Section 10.5.3.2.

10.4.3 Poaching and hunting

As explained in Section 10.3, dugong hunting by Traditional Owners in their Sea Country is legal in Australia. There is anecdotal evidence that poaching by Indigenous people in the Sea Country of others is an unquantified source of dugong mortality of concern to some Traditional Owners (Marsh and Raudino unpublished data 2024). The incidence of poaching by non-Indigenous people in Australian waters is unknown.

10.4.4 Interactions with vessels

There is evidence that dugongs may sometimes fail to flee or evade the approach of fast advancing vessels until an impact is unavoidable (Groom et al. 2004; Hodgson 2004), though there is much less evidence for vessel strike having a serious impact on dugong populations than for Florida manatees as pointed out by Ponnampalam et al. (2022). Along the urban coast of Queensland, the Queensland Stranding and Mortality database (StrandNet) recorded four interactions between dugong and vessels between 2013 and 2015; resulting in three dugong deaths (Meager 2016). Two interactions between dugongs and vessels were recorded in StrandNet for 2020-23 (T. Shimada personal communication by email to Marsh 2024). Vessel strike has also been confirmed as a source of mortality for dugongs in Exmouth Gulf in Western Australia (H. Raudino personal communication by email to Marsh 2024). Hodgson (2004) believed that vessel speed is the primary factor affecting collision risk due to '*the time available to flee being equal to the time the boat takes to travel the distance from the flee threshold to the dugong*'. The risks to dugongs seem greatest in shallow water, especially large intertidal areas with high vessel traffic where: (1) dugongs are forced to spend more time close to the surface; (2) dugongs have little opportunity to escape to deeper water; (3) vessels and dugongs can be constrained to channels during low tide periods and find it difficult to access deeper water, increasing the probability of vessel interaction (Hodgson and Marsh 2007). Groom et al. (2004) also recorded dugongs responding to an approaching vessel by moving towards deeper water, which again may result in dugongs interacting with vessels in channels. Vessel traffic can also interrupt dugong feeding (Hodgson and Marsh 2007).

There are no data on whether, or how, the recent increase in the number and size of commodity ports that export Australia's mineral resources has impacted the dugong, even though such impacts must be considered in government approvals processes because the dugong is a MNES, under the main national environmental law, the *EPBC Act.* The dugong's range in northern Australia contains 12 major and numerous subsidiary ports (Figure 10.1) including some of the nation's largest commodity ports, as well as the major cities of Brisbane, Townsville, Cairns, and Darwin (Australian Government 2015), which are all commodity as well as container ports. The Queensland Government set to reduce the impacts of port development in the GBR region through the *Sustainable Ports Development Act*, *Qld 2015,* which established a legislative framework to balance the protection of the GBR with the development of the state's major bulk commodity ports in that region.

10.5 Conservation initiatives

10.5.1 International conventions

Australia is a Party to the Convention on Biological Diversity (CBD) and the Convention on the Conservation of Migratory Species of Wild Animals (CMS). Australia is also a Signatory State to the Memorandum of Understanding on the Conservation and Management of Dugongs (*Dugong dugon*) and their Habitats throughout their Range (Dugong MOU), and a Party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the United Nations Framework Convention on Climate Change (UNFCCC).

10.5.2 National and state laws

The dugong is listed as a marine and migratory species under the *EPBC Act*, which makes it a Matter of National Environmental Significance (MNES) under Australian national law. The *EPBC* Act prohibits the direct use of and domestic (and international) trade in dugongs, their parts, or products, whilst allowing exceptions for traditional subsistence and customary use. The Act also requires any action that has the potential to have a significant impact on the dugong to be assessed to determine if approval would be required and if so, what conditions may need to be implemented to ensure minimal impact on the dugong. The protection for dugongs was increased by the *Environment Legislation Amendment Act Commonwealth 2015,* which tripled penalties for killing or injuring them.

The dugong is not listed as threatened at a national scale. Zichy-Woinarski et al. (2012) evaluated it as 'Near Threatened' in their *Action Plan for Australian Mammals 2012,* a document that has no force in law. The dugong is listed as Endangered in New South Wales (*Biodiversity Conservation Act, NSW 2016*), Vulnerable in Queensland (*Nature Conservation Act Qld 1992*), Near Threatened in the Northern Territory, and as Other Specially Protected Fauna in Western Australia (*Biodiversity Conservation Act, WA 2016*). There is no national Wildlife Conservation Plan for the dugong, although as a MNES the dugong is eligible for one.

The Australian Government was in the process of identifying non-statutory Biologically Important Areas for dugongs at a national scale to facilitate impact assessment under the EPBC Act at the time of writing (March 2025).

10.5.3 Statutory restrictions that contribute to dugong conservation

10.5.3.1 Restrictions under fisheries legislation

Under the Torres Strait Treaty between Australia and Papua New Guinea, the Torres Strait Dugong and Turtle fisheries are traditional subsistence fisheries that are restricted to the Traditional Inhabitants of the region. A 13,000 km^2 Dugong Sanctuary, in which hunting is banned, was established in western Torres Strait in 1987, under the *Torres Strait Fisheries Act Commonwealth, 1984*, after negotiations with Torres Strait Islander leaders (Figure 10.15). In addition, the Statutory Management Regulations associated with that Act place controls on the dugong fishery: (1) dugongs can only be taken by Traditional Inhabitants; (2) dugongs must be caught with a traditional harpoon with a detachable head (*wap)*, (3) dugongs must only be caught from a vessel less than 6 m long; and (4) the sale of dugong meat is prohibited.

Community-based Dugong and Turtle Management Plans, developed by individual Torres Strait Islander communities are implemented on a voluntary basis throughout the Australian waters of Torres Strait with the assistance of the Torres Strait Regional Authority (TSRA). Each community-based plan includes traditional governance, which supports management arrangements that have been agreed to by the relevant community. The implementation of plans is supported by the Torres Strait Ranger Program, which is funded by the Australian Government. Some Western Australian First Nations groups, such as the Bardi Jawi, have also adopted hunting guidelines and are actively involved in the Buccaneer Archipelago Marine Park (H. Raudino personal communication by email to Marsh 2024).

In 1998, the Australian and Queensland Governments agreed to several measures aimed at arresting the decline of dugongs along the urban coast of Queensland. The most significant initiative was to establish a series of Dugong Protection Areas (DPAs) in known high value dugong habitat. The 16 DPAs include seven Zone A DPAs (total area 2,407 km^2), where foreshore and offshore set or drift nets were prohibited, and nine DPABs (total area 2,243 km^2), where there were less stringent restrictions on commercial gillnetting (Marsh 2000). Gillnets are currently being phased out of the GBRWHA as explained in section 10.5.3.2.

Northern Territory Fisheries implemented a gillnet closure area under the Barramundi Management Plan following a significant dugong mortality event (approximately 30 dugongs) in Yanyuwa country, near the McArthur River (Bradley 2010). The Dugong Protection Zones are within the 'Barramundi Fishery Management Plan', under clauses 8(2)(c) and (e). The implementation of these zones was originally from an agreement between the Barramundi Fishery, the Wurrahaliba Aboriginal Consultative Committee in Borroloola and Northern Land Council. These closures were first implemented into the Barramundi Fishery Management Plan in 2002 and updated in 2012. The Yanyuwa Indigenous people are working to optimise the protection of this area for dugongs by using multiple data layers and cultural knowledge of dugong habitat use. This combined information will be used to delineate a more suitable area of protection for dugongs than under the current arrangements.

Commercial fishing regulations implemented in the 1970s and 1980s preclude the use of large mesh gillnets and long-lines throughout the Gascoyne region in Western Australia, to prevent the incidental entanglement of dugongs and turtles (Newman et al. 2023).

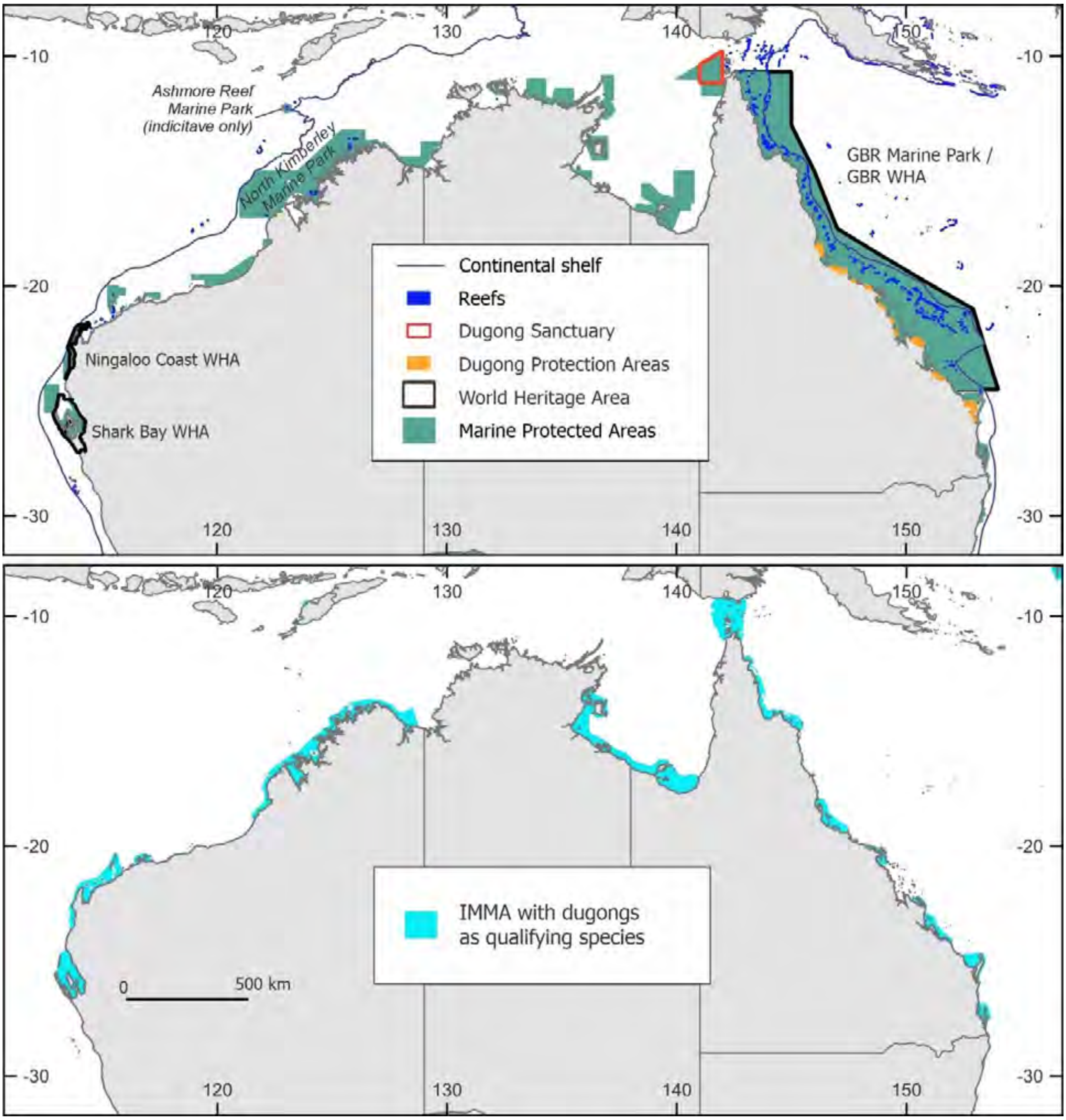
10.5.3.2 Marine parks

Marine park protection for dugongs in Australian waters reflects the jurisdictional complexity of the region. There are no marine parks in Torres Strait, where the dugong is a transboundary stock shared with PNG and possibly West Papua. In other areas, individual dugongs live in or traverse coastal waters under the jurisdiction of the Australian (Commonwealth) Government and/or state/territory governments.

In jurisdictions other than the GBR, state/territory waters are largely covered by state marine parks and Commonwealth waters by Commonwealth marine parks, although some areas have joint management plans. Each marine park has its own detailed management plan, which provides varying levels of protection, through an assortment of management zones, typically ranging across the IUCN protected area categories and including zones closed to commercial fishing. Figure 10.15 shows the coastal marine parks in the dugong's winter range in Australia. The management plan for each marine park provides spatial details of the zoning regime.

The GBR is managed as a partnership between the Australian and Queensland Governments and both governments have direct legislative responsibilities in the region. The GBRMP and the Queensland GBR Coastal Marine Park have mirror zoning because the boundary of the Queensland waters is defined differently by the two jurisdictions. The GBRMP was re-zoned from 2004 to maximise biodiversity protection through a comprehensive and representative multiple-use regime (Fernandes et al.

Figure 10.15. ***Upper figure:*** The statutory protection areas for dugongs in the Australian region. ***Lower figure:*** IMMAs in Australia with dugong as a qualifying species. Comparison of these maps indicates that most of the IMMAs receive statutory protection, even though they are not recognized under Australian law. The boundaries and names shown, and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



Marine Protected Areas extracted from The Collaborative Australian Protected Areas Database (CAPAD) 2022 (Marine) Licence: CC - Attribution (CC BY 4.0). This data has been licensed under the Creative Commons Attribution 4.0 International Licence. Dugong Protection Areas licensed under a Creative Commons - Attribution 3.0 Australia license.© State of Queensland (Department of Agriculture and Fisheries) 2023. Updated data available at http://qldspatial.information.qld.gov.au/catalogue//. Torres Strait Dugong Sanctuary TSRA (2003) ©Torres Strait Regional Authority (TSRA). Marine WHA extracted from Australia, World Heritage Areas, Department of Climate Change, Energy, The Environment and Water. CC BY 4.0 DEED, Attribution 4.0 International. IUCN Important Marine Mammal Area (IMMA) Geographical Information System (GIS) Dataset Version Release Dated: September 2023 Citation: IUCN MMPATF (2023) Global Dataset of Important Marine Mammal Areas (IUCN-IMMA). September 2023. Made available under agreement on terms of use by the IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force and made available at www.marinemammalhabitat.org/imma-eatlas.

2005), which increased area closures to commercial netting and trawling. Grech et al. (2008) evaluated the residual impacts of mesh netting to the dugong in the GBRWHA after the rezoning arrangements became law. They concluded that the combined effects of the DPAs and the rezoning (which often overlap) had resulted in bans on commercial gillnetting in around 67% of dugong habitats in the GBRWHA and that the accompanying industry restructuring also contributed to the decline in the spatial extent of netting.

This protection is being strengthened from 2024 as part of the Australian Government's response to the UNESCO World Heritage Committee's ongoing consideration of whether the GBRWHA should be listed as Endangered (Australian Government 2024b). The Queensland Government banned commercial gillnets from the northern third of the GBR and all DPAs, with the exception of the rivers and creeks in DPABs; accelerated implementation of the Queensland Sustainable Fisheries Strategy 2017-27, agreed to phase out gillnet fishing in the GBRWHA by mid-2027, and to introduce Independent Data Validation in Queensland's commercial fisheries, so that the incidental capture of protected species such as dugongs would be more likely to be reported. The number of commercial gillnet fishing licences had been reduced to 28 at the time of writing (June 2024) https://www.daf.qld.gov.au/business-priorities/fisheries/manage/industry/future-fishing/about.

Consideration of proposed additional closures to gillnets in the Gulf of Carpentaria were on-going at the time of writing. The intent to establish new gillnet-free zones was announced in 2023 by the Australian and Queensland Governments as part of the implementation of the Gulf of Carpentaria inshore fishery reforms under the Queensland Sustainable Fisheries Strategy. In June 2024, the Northern Territory government and opposition announced a bipartisan commitment to phase out commercial gillnet fishing for barramundi across Northern Territory waters from August 2024 (Australian Marine Conservation Society 2024).

10.5.3.3 Agreements with First Nations peoples regarding dugongs

10.5.3.3.1 GBRWHA

Within the GBRWHA, Traditional Owners are supported to assert their cultural authority over Sea Country and voluntarily regulate the dugong and turtle harvest through the Traditional Owners developing formal agreements with the GBRMP. These agreements are called Traditional Resource Use Management Agreements (TUMRAs) (Havemann et al. 2005). In 2024, there were 18 TUMRAs plus an Indigenous Land Use Agreement (ILUA) covering 18 Traditional Owner groups in place. These agreements are developed and implemented through the Indigenous Land and Sea Country Partnerships Program, an AUD 2.3 million (USD 1.52 million) investment in Traditional Owner management of the Reef that currently covers over 43% of the coastline of the GBR Marine Park and World Heritage Area (GBRMPA 2023b).

TUMRAs are community-based plans for management of traditional resources, which are accredited in legislation, and describe how Traditional Owner groups work in partnership with the Australian and Queensland Governments to manage traditional use activities in their Sea Country. Each TUMRA is managed by a committee. Management applies to all traditional use of marine resources in their Sea Country, including any traditional take of dugongs, and is based on both cultural lore and contemporary science. Formal agreements have not yet been accredited for several major hunting communities adjacent to the Northern GBRWHA, such as Lockhart River, Hope Vale and the Northern Peninsula Area. Several of the TUMRAs provide Traditional Owners with the powers to limit illegal take of dugongs, usually by poachers, who are not Traditional Owners of the area where the TUMRA applies. GBRMPA has a dedicated Indigenous Compliance Team which delivers targeted training and development of Compliance Management Plans to support Indigenous Rangers, Traditional Owners and Indigenous Communities and provides career pathways for Aboriginal and Torres Strait Islander people in land and sea management. Some Indigenous rangers have been appointed as Marine Park inspectors and this program is being extended on a national level (Australian Government 2024a).

10.5.3.3.2 Other regions

In northwestern Western Australia, Kimberley Indigenous Turtle and Dugong Initiative 2022–2032 (Lincoln et al. 2021) is a regional, long term, partnership approach to the conservation and management of those species. The Initiative was designed and led by local Indigenous saltwater managers as a tool for the Kimberley Indigenous Saltwater Advisory Group (ISWAG) to guide their activities and obtain funding for implementation.

Other Priorities for Action

Developing a National Wildlife Conservation Plan for the Dugong to enable a more systematic, prioritized and outcome-focussed approach to conservation. The Biologically Important areas being identified by the Australian Government could be a focus of this Plan.

Working with Traditional Owners to integrate survey data and Traditional Ecological Knowledge to identify dugong areas important to local Indigenous peoples.

Undertaking vulnerability assessments of key locations, including their susceptibility to climate change.

Evaluate the potential for the Ashmore Reef-Sahul Banks region to qualify for IUCN subpopulation listing.

Ensuring that the technological step-change to replace large-scale observer surveys using light aircraft with aerial imagery surveys maintains the integrity of the time series.

Ensuring that future monitoring adopts a jigsaw paradigm, using diverse methodologies to forms a cohesive and comprehensive framework for population assessments, harnessing the strength of several lines of evidence.

Increasing understanding of genetic population structure across the dugong's Australian range, including whole-genome data to increase understanding of genetic health and diversity, changes in population size and levels of inbreeding.

Using new technologies such as animal-borne, multi-sensor tags, e-DNA, acoustic technologies and small drones to improve knowledge of dugong's behavioural ecology.

10.5.3.3.3 Management of interactions with vessel traffic

The Australian National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Australian Government 2017) notes the risk of vessel strike to dugongs but is largely silent on practical measures, regarding what should be done about it, except at a very superficial level. Measures to mitigate the risk are implemented as part of government approvals for capital dredging campaigns at major ports, for example, the Channel Upgrade Project in Townsville (Port of Townsville 2023). In the Moreton Bay Marine Park near the major city of Brisbane, there are two types of turtle and dugong go-slow areas: (1) in five areas in the Bay, all vessels, including jet skis, must be operated off-the-plane or in displacement mode, and motorised water sports are prohibited; while (2) applies in southern Moreton Bay, where vessels larger than 8 m are restricted to a maximum speed of 10 knots (Department of Environment, Science and Innovation [DESI] 2024). In the GBRMP, the Hinchinbrook Plan of Management complements zoning and other management strategies by establishing transit lanes and go-slow areas to minimise the impacts of vessel traffic on dugongs (GBRMPA 2023a).

10.5.4 Other conservation initiatives

10.5.4.1 Education

GBRMPA, Queensland, the Northern Territory and Western Australia have educational information available on the dugongs, their habitat, and conservation in association with their materials on MPAs (Australian Government 2024a).

The captive dugong 'Pig' is one of the flagship attractions at Sydney Aquarium and receives a large number of visitors each year.

10.5.4.2 Water Quality

The Reef 2050 Water Quality Improvement Plan, launched in July 2018, was developed by the Australian and Queensland Governments to encourage industry, government, and the community to work to together to improve the quality of water flowing to the GBR, including to the seagrass habits vital to dugongs. Nonetheless, progress in achieving the targets has been of ongoing concern to the World Heritage Committee (Australian Government 2024b).

10.5.4.3 Marine debris

'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' is listed as a key threatening process under the *EPBC Act*. Harmful marine debris includes land-sourced garbage, fishing gear from recreational and commercial fishing abandoned or lost to the sea, and vessel-sourced, solid, non-biodegradable floating materials disposed of or lost at sea. A statutory Threat Abatement Plan incorporates the actions needed to address this threatening process and binds the Commonwealth and its agencies to respond to the impact of marine debris on vertebrate marine life, including dugongs (Australian Government 2018).

10.6 Research and monitoring

A significant proportion of pure and applied research on dugongs and their habitats has been performed in Australia. Topics investigated include research on their abundance and population trends, anatomy, anthropology, archaeology, behavioural ecology, contaminants, cultural values, distribution, foods and feeding, genetics, habitat, health, life history, movements, and physiology. Both this chapter and Chapter 1 summarizes research relevant to dugong distribution, abundance, status, trends and genetics. In addition, as summarized in Section 10.2, there has been significant research into monitoring techniques, particularly the correction of detection biases in aerial surveys.

Some of this research is ongoing. Nonetheless, additional multidisciplinary approaches will be required to progress our understanding of the distribution, abundance, status, and trends of Australia's dugong populations. Marsh and Cleguer (2024) developed ideas for such research for dugongs in the GBR region. Their suggestions are further elaborated below in no particular order.

10.6.1 Modelling

The results of the large-scale aerial surveys have been used to identify IMMAS with dugongs as the qualifying species throughout its Australian range (Figure 10.15). These assessments were based on dugong density data and expert scientific opinion but do not take cultural values into account. Bayliss and his co-workers (Bayliss and Wilcox 2015; Bayliss et al. 2015; Bayliss and Hutton 2017) integrated survey data and TEK to identify dugong areas important to local Indigenous peoples in the North Kimberley region. Given that the dugong is such a culturally important species for Indigenous peoples throughout their range in Australia (Section 10.3), it will be important to extend this transparent and culturally respectful approach to other areas and to work with the relevant Traditional Owners to undertake vulnerability assessments of key locations, including their susceptibility to climate change.

Extensive spatial datasets are available for both seagrasses and dugongs in large portions of its Australian range. Bayliss et al. (2019) modelled the relationships between the distribution and relative abundance of dugongs in Shark Bay and seagrass density. Parallel research is underway in the GBR region conducted by the dugong and seagrass groups at James Cook University (JCU). This exploration of the relationship between seagrass presence, community type, species, and their physical determinants has the potential to increase understanding of habitat choice in dugongs and the prediction and interpretation of temporal changes in dugong population size and distribution.

10.6.2 Field studies of dugong-seagrass interactions

Field experiments using enclosures and/or simulated feeding have provided important information on the effects of dugongs and other megaherbivores on seagrasses (e.g., Preen 1995; Aragones and Marsh 2000; Scott et al. 2020, 2021). Replicating these experiments in important dugong areas has the potential to provide important new information on the interactions between dugongs and seagrasses. Many of the experiments to date have been in meadows where excavating is the dominant form of dugong feeding, and priority should be given to areas where cropping is also used.

Rasheed et al. (2017) mapped dugong feeding trails in intertidal areas in the Gladstone region using photogrammetry. Extending this work across intertidal habitats in a range of locations would provide insights on the spatial pattern of dugong excavating behaviour within intertidal meadows. Similar research is planned for Yawuru Sea Country in the Kimberley (H. Raudino personal communication via email to Marsh 2024).

Across the Pilbara region in Western Australia, Said et al. (2020, 2025) have developed a novel approach for rapidly assessing dugong-habitat associations, integrating innovative aerial survey and imagery technology as in Cleguer et al. (2021), and comprehensive in-water habitat assessment to determine the environmental drivers of dugong occurrence in the region. Three locations identified as dugong hotspots (Exmouth Gulf, Mangrove Passage, and Regnard Islands) were surveyed using relatively small drones. A standard area was surveyed in each location (approximately 30 km^2) using either a standard line transect survey or a gridded, randomised approach and this was repeated up to three times in 2018/2019. From these surveys, a rapid assessment was performed to identify sites within each location where dugongs were present, named 'presence' sites, and absent, named 'possible absence' sites. Each of these sites (200 m^2) was then surveyed using drop-down cameras and environmental loggers to characterize the benthic habitat, habitat quality and the environmental features that could influence the distribution of dugongs. These datasets were analysed using generalised linear models (GLMs) to predict the drivers of dugong occurrence and distribution at the local scale. The study highlighted fine-scale patterns of habitat association in dugongs across the Pilbara region, with cover of seagrass, particularly the abundance of small colonising species, as well as the nutritional content of one of these species identified as best predictor of either the presence or abundance of dugongs over other environmental factors.

10.6.3 Application of new technologies

The dugong is a relatively cryptic animal that in northern Australia mostly occurs in turbid waters and is therefore difficult to study. In a collaboration between JCU and Murdoch University, custom-designed, animal-borne, multi-sensor tags are being used to improve understanding of the dugong's fine-scale, three-dimensional diving behaviour, diel patterns in activity budgets, buoyancy, habitat use, movement corridors, animal interactions, and the biophysical drivers influencing these aspects of the dugong's behavioural ecology. The resultant information also has the potential to improve the corrections for availability bias. Multi-sensor tags remain attached to the animals only for hours to days and must be retrieved to access data.

GPS-satellite tags have been used in different regions of Australia to study the movements and habitat use of dugongs across variable spatial and temporal scales (see Deutsch et al. 2022 for a complete and recent summary). Because of the necessary weak-link integrated in the GPS-satellite tag attachment apparatus (to ensure dugongs can break free of the tag should they get entangled), most GPS-satellite tags have remained attached for periods of only 3-6 months. Thus, long-term studies of individual dugongs based on satellite tracking have been very difficult. Nonetheless, such studies, particularly of mothers and their dependant calves, have the potential to provide new insights into dugong movements and socially transmitted knowledge. Lanyon et al.'s longitudinal study of gene-tagged dugongs in Moreton Bay (Lanyon et al. 2019) has the potential to provide key insights, which will become more revealing over time.

Environmental DNA (eDNA) is a promising tool for both species' detection and biodiversity monitoring (Sigsgaard et al. 2020). Dugongs leave a 'footprint' in surface waters including genetic materials from their skin, mucus, and/or faeces. eDNA is being used to detect dugong presence in Japan (Hiraishi et al. 2020) and Sibu Island, Johor, Peninsula Malaysia (Heng et al. 2025).eDNA could also be used to detect dugong occurrence in estuarine areas, which are difficult to survey, and local areas that have not been surveyed from the air, such as bays in northern NSW and the saline reached of rivers and creeks opening into the coastal waters of northern Australia. Such studies have the potential to inform decisions about continuing to allow gillnetting in such areas.

Off-the-shelf small unoccupied aerial vehicles (UAVs or drones), which are relatively cheap and easy to use, are increasingly used by citizen scientists and communities to conduct local scale assessments of dugong presence and distribution (Cleguer et al. 2021). Using small drones to conduct 'backyard surveys' is limited in spatial coverage (and thus is not an adequate tool for dugong population assessments over hundreds of km^2) but they empower their trained users in conducting independent surveys at a relatively low cost and they are enhancing collaborations among Traditional Owners, TUMRA representatives, land and sea ranger programs, and scientists conducting local scale seagrass and dugong surveys. This approach, which is being rolled out in multiple places around Australia (C. Cleguer personal communication to Marsh by email 2024) has the potential to inform the understanding of the relationship between the dugong's fine-scale habitat use and their biophysical environment as demonstrated by Cleguer et al. (2021) and Pryor et al (2024).

10.6.4 Health assessment

Lanyon et al. (2002, 2019) and their University of Queensland researchers have conducted a longitudinal study of dugongs in Moreton Bay for more than 20 years. This study has provided many important insights into dugong biology as outlined in Chapter 1.

As part of this study, health assessments of wild dugongs in Moreton Bay have been conducted annually since 2008 (Lanyon et al. 2010; Walsh et al. 2018). These comprehensive assessments involve the capture of wild animals and take advantage of the proximity of dugongs in Moreton Bay to the infrastructure and expertise available in a major city. Such an approach could not be used in remote locations.

Images from small drones are being used to estimate the body condition of marine mammals. These methods have been used to study manatees (e.g., Ramos et al. 2022) and are being developed for dugongs (Goudalier et al. 2025). Scientists are collaborating with local Sea Rangers and citizen scientists including members of the Indigenous communities across Australia in the use of drone technology.

10.6.5 Acoustic behaviour

Acoustic receivers have been used to record dugong vocalizations and investigate the functions of the calls, especially in Thailand, where 'vocal hotspots' have been identified (Tanaka et al. 2017, 2023). The functions of different types of vocalizations remains unclear. If such hotspots also occur in Australia, this approach could provide new insights to inform dugong management. In association with animal-borne acoustic transmitters, acoustic receivers also have the potential to provide new information on the dugongs' use of three-dimensional space and their interactions with biophysical and anthropogenic environments, especially near ports (Zeh et al. 2015). Similar work is planned using the acoustic array in Roebuck Bay near Broome, Western Australia (H. Raudino personal communication by email to Marsh 2024).

10.6.6 Genetics

Most of the Australian research on dugong genetics to date has been carried out in Queensland as outlined in Section 10.1.2. More samples are being obtained by JCU scientists from its range west of Torres Strait to increase understanding of genetic population structure across the dugong's range in Australia. More whole-genome data will increase our understanding of genetic health and diversity, changes in population size and levels of inbreeding.

10.6.7 Monitoring

For the last 40 years, most of the advances in dugong monitoring using large-scale aerial surveys have been in attempting to improve: (1) the corrections for detection biases; and (2) statistical techniques for detecting trends (Marsh et al. 2019). A technological step-change is underway to transition to the use of aerial imagery surveys and Artificial Intelligence (AI) with a resultant increase in survey accuracy and human safety and a potential decrease in cost (Maire et al. 2015). Research has been progressing for several years to support this transition, which is occurring in two stages by: (1) fitting cameras to light aircraft, an approach that is under development in Queensland, the Northern Territory and Western Australia (C. Cleguer, A. Hodgson and H. Raudino personal communications by email to Marsh 2024); and (2) replacing light aircraft with large drones (Hodgson et al. 2013, 2017, 2023). In the future, integrating the outcomes of aerial surveys with these complementary methods for assessing dugong population health will be important. This approach adopts a jigsaw paradigm, where the combination of diverse monitoring methodologies forms a cohesive and comprehensive framework for population assessment, thereby harnessing the strength of several lines of evidence.

10.6.8 National Wildlife Conservation Plan for the Dugong

In Australia, the dugong is a MNES. Australia has by far the largest dugong population in the world. As a developed country, Australia has the potential to conduct research and develop monitoring techniques that inform dugong conservation globally. A national Wildlife Conservation Plan for the dugong would enable a more systematic and prioritized approach to conservation than has occurred to date. Such a Plan would need to be developed in colloboration with Traditional Owners across the dugong's range in Australia, because of the dugong's deep cultural significance to them.

10.7 Regional co-operation

The Australian Government currently engages with its northern neighbours on the management of dugongs as a transboundary species through two forums: (1) the Torres Strait Treaty and (2) the Arafura and Timor Seas Ecosystem Action (ATSEA)

Programme. For over 30 years, the management of dugongs within and in the vicinity of the Torres Strait has been a standing agenda item for the Torres Strait Treaty Environmental Management Committee (EMC) represented by government officials and traditional custodians from Australia and PNG. ATSEA is a long-standing partnership between Australia, Indonesia, Papua New Guinea, and Timor-Leste for transboundary cooperation on marine values and threats in the shared waters of the Arafura and Timor Seas (Figure 10.1). The conservation of regional populations of endangered, threatened, and protected species and their critical habitats is a major strategic objective of ATSEA (N. Montgomery Australian Department of Climate Change, Energy, the Environment and Water [DCCEEW] personal communication via email to Marsh 2023).

10.8 Regional summary

- Australia is the most important location for dugongs and their seagrass habitats in the world and is the region with the most dugong research conducted. The vast areas of shallow continental shelf in northern Australia provide extensive areas of seagrass supporting habitat and the human population density of most of this region is very low.
- Australian dugong populations appear to be in good genetic health in terms of genetic diversity, population size and low levels of inbreeding.
- The total estimated dugong population is approximately 166,000 ± SE 21,500. The total area of seagrass estimated with moderate to high certainty in the dugong's Australian range is approximately 57,500 km^2 including 24,076 km^2 in waters over 15 m deep offshore from the urban coast of the GBRWHA. This offshore area has not been surveyed for dugongs.
- The dugong is a MNES under national law and receives protection under the laws of all relevant jurisdictions in their Australian range.
- Table 1.2 lists confirmed areas of high dugong concentration in the Australian region. Ten IMMAS with dugongs as a qualifying species are recognized in Australian coastal waters: five in Queensland, one straddling Queensland and Northern Territory waters, and four in Western Australia. In most of these IMMAs, dugongs receive some statutory protection under marine park and/or fisheries legislation, even though IMMAs are not recognized under Australian laws.
- The dugong population is explicitly recognized as an attribute of OUV in both the GBR and the Shark Bay World Heritage Areas (WHAs).
- The results of the large-scale aerial surveys that have been conducted over dugong habitats in Australia since the 1980s suggest that dugong

Areas of high dugong concentration in Australia

REGION	KEY LOCATIONS
Temperate Queensland	Moreton Bay; Hervey Bay -Great Sandy Strait
GBR southern border to Cape Bedford	Shoalwater Bay; Townsville -Cardwell region: Bowling Green Bay, Cleveland Bay, Halifax Bay, Hinchinbrook
GBR Cape Bedford North	Lookout Point to Bathurst Head; bays between Friendly Point and Shelbourne Bay; large reefs, especially in Princess Charlotte Bay
Torres Strait	Central and Western Torres Strait
Gulf of Carpentaria; Queensland coast	Wellesley Islands
Gulf of Carpentaria: Northern Territory Coast	Sir Edward Pellew Islands; Limmen Bight
Kimberley region of Western Australia	North Kimberley; Roebuck Bay
Gascoyne coast of Western Australia	Shark Bay; Exmouth Gulf; Pilbara Region

The following areas in **Australia** have been declared Important **Marine Mammal Areas (IMMAS)** with the dugong as a qualifying species:

1. Moreton Bay
2. Hervey Bay and Great Sandy Strait
3. Hinchinbrook to Round Hill
4. Northern Great Barrier Reef
5. Central and Western Torres Strait
6. Southern Gulf of Carpentaria
7. Northwest Australian Coastal Waters and Inlets
8. Dampier Archipelago
9. Ningaloo Reef to Monebello Islands
10. Shark Bay

conservation status varies regionally within Australian coastal waters from increasing along the remote coast of the GBRWHA, stable in the Gulf of Carpentaria coast of the Northern Territory and Shark Bay, to declining along the urban coast of the GBRWHA, and uncertain in most other parts of their Australian range.

- Confidence in this assessment varies because of regional and temporal differences in survey recency and frequency, and approaches to assessing trends. Much of the dugong's range in Western Australia and the Northern Territory has only been surveyed once and key areas have not been surveyed for more than ten years including: Torres Strait, which supports the largest dugong population, the Gulf of Carpentaria Coast of Queensland, and the Pilbara coast of Western Australia.
- With further information, the geographically isolated and remote dugong 'subpopulation' of the Ashmore Reef-Sahul Bank region in Australian waters situated between the northwest coast of Western Australia and the island of Rote in Indonesia may be a candidate for IUCN Red List of Threatened Species regional listing.
- The dugong is a culturally significant species for coastal Indigenous peoples across their range in northern Australia, where they have been hunted for thousands of years.
- Dugong hunting by Traditional Owners (Aboriginal or Torres Strait Islander individuals or groups with legally recognized traditional or historical connection, attachment, and/or relationship to an area of land or sea) is legal under Australian Law.
- Extreme weather events (cyclones, floods, and marine heatwaves) have been the most significant threats to dugongs in their Australian range since at least the 1990s. Loss of the seagrasses eaten by dugongs results in dugong life history changes including an increase in mortality, especially neonatal and early juvenile mortality, and a decrease in fecundity. In such circumstances, some dugongs undertake temporary emigration, presumably to seek locations where seagrass has not been lost.
- As a developed country, Australia has the potential to conduct research and develop monitoring techniques that inform dugong conservation globally and a high proportion of modern dugong research has been conducted in Australia.
- A national Wildlife Conservation Plan would enable a more systematic and prioritized approach than has occurred to date.

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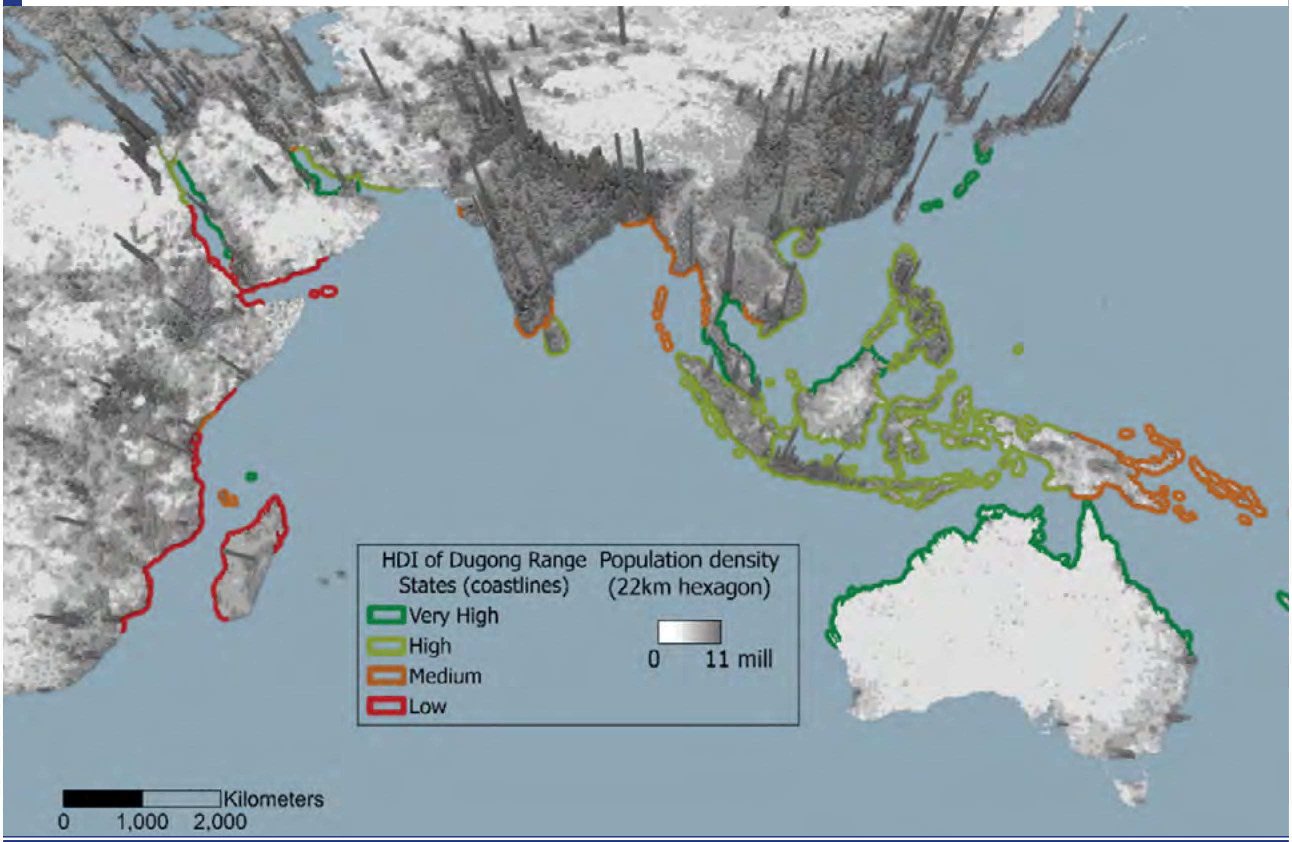
Chapter 11



KEY LEARNINGS

Authored by: Helene Marsh, Lauren Lopes, Len McKenzie and Abdelmenam Mohamed

Helene Marsh[1], Lauren Lopes[2], Len McKenzie[3], Abdelmenam Mohamed[2]

[1]College of Science and Engineering, James Cook University, Townsville, Queensland, Australia.
[2]Convention on the Conservation of Migratory Species of Wild Animals, Al Reem Island, Abu Dhabi, United Arab Emirates.
[3]Centre for Tropical Water & Aquatic Ecosystem Research TropWATER, James Cook University, Cairns, Queensland, Australia.

Correspondence to Helene Marsh helene.marsh@jcu.edu.au.

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Cover figure: Map illustrating the diversity of socioeconomic conditions in the dugong's global range. Lucas Langlois figure.

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Contents

Global Actions

01 Revise the global range of the dugong

02 Develop additional IUCN subpopulation listings

03 Conduct additional seagrass mapping

04 Update the Dugong and Seagrass Research Toolkit and keep it up to date

05 Conduct spatial risk assessment for important populations

06 Collaboratively develop generic interventions to protect coastal megafauna, especially in areas of low dugong density

07 Encourage regional cooperation

08 Keep this report up to date with the assistance of the Dugong MOU Dugong Technical Advisory Group

Summary

Need to revise global range information

- The International Union for Conservation of Nature (IUCN) Red List of Threatened Species lists the dugong as Vulnerable to Extinction at a global scale.
- The assessment includes a global range map, which this report indicates needs revision by the IUCN Sirenia Specialist Group.

Potential for additional 'subpopulation' listings

- The IUCN has listed the following dugong 'subpopulations'[1] at a regional scale: Eastern Africa Coastal (Critically Endangered); Nansei, Japan (Critically Endangered); New Caledonia (Endangered).
- This report has identified a further 11 'subpopulations', including three transboundary 'subpopulations', as potentially appropriate for assessment for IUCN Red List of Threatened Species listing as Threatened.
- These assessments should be undertaken by the IUCN Sirenia Specialist Group.

Global prospects

- Dugong Range States are socioeconomically diverse and include some of the world's richest and most highly developed countries as well as some of the poorest and most war-torn.
- The dugong's prospects are uneven across its global range as confirmed by the evidence in Chapters 2-10 of this report and the current and prospective IUCN 'subpopulation' listings.
- Nonetheless, the conservation prospects for the dugong at a global scale should be better than for any other sirenian species because an extensive area of dugong habitat occurs in the waters of very highly developed countries with the capacity to implement effective conservation practices.
- The prospects for dugongs surviving in the coastal waters of Island Range States with low seagrass extent, relatively small areas of coastal waters shallower than 20 m and some level of isolation (e.g., separated from adjacent continental land masses or islands) are likely to be precarious.

1 'Subpopulation' is the technical term used by IUCN when making a regional assessment. Population is the more accepted terminology and is used in the report, outside the context of an IUCN regional assessment.

Need for additional seagrass mapping

- The area of seagrass in sub-tropical and tropical Indo-Pacific waters shallower than 20 m deep can be used as a crude index of dugong carrying capacity.
- While not all shallow coastal waters are potential seagrass habitat, the area of seagrass known with moderate to high confidence as a proportion of the area of coastal waters less than 20 m deep shows the need to undertake additional seagrass mapping in all regions of the dugong's range, especially the Red Sea, the Asian regions and the Pacific Islands.
- The need to map dugong habitat is recommended for inclusion on the roadmap for the 2030 Seagrass Breakthrough, announced during the United Nations Framework Convention on Climate Change Conference of the Parties No. 28 in December 2023.

Desirability of prioritized revision of Dugong and Seagrass Toolkit

- The Dugong and Seagrass Research Toolkit contains many sections that need to be prioritized for updating.
- The section on estimating dugong abundance, which is of key relevance to evaluating dugong status and trends, is out-of-date.
- The Toolkit is silent on recent advances in methodology, such as in the use of unoccupied aerial vehicles (UAVs or drones) for population assessment and monitoring and condition assessment, e-DNA, survey design and the analysis of trends.

Desirability of spatial risk assessment of threats at important locations

- The direct and indirect threats to dugongs are relatively consistent across their range, although their root causes differ with socioeconomic context.
- The relative importance of these threats varies at both regional and local scales.
- An important initiative would be to consider the relative risks, including the climate risks, to the globally and regionally important dugong habitats identified in this report.

Desirability of generic interventions to protect coastal megafauna

- Dugong density is now so low in many locations that there is little community

awareness of dugongs or support for dugong-specific interventions.
- In Range States with low dugong density, generic interventions to protect coastal megafauna and their habitats could be a more efficient and effective approach to addressing threats that affect all megafauna, such as gillnetting. This approach also accords with some of the decisions of the Conference of the Parties to the Convention on Migratory Species of Wild Animals (CMS), which foreshadows a generic approach to develop methods to address threats that affect multiple CMS-listed species of marine megafauna.

Desirability of increased regional cooperation

- Regional cooperation on dugong conservation management and research is at various stages of development across dugong Range States.
- It would be highly desirable for each of the regions in the dugong's global range to consider developing or updating a Regional Action Plan to guide the development and delivery of practical and resource-efficient conservation strategies for dugongs and their habitats (and if appropriate, associated megafauna).

Opportunity for keeping this report and the Dugong and Seagrass Research toolkit up to date

- The technology now exists to create and modify on-line content in an organized manner, while ensuring that the information remains of high quality. Such an approach could be used to keep this report and the Dugong and Seagrass Research Toolkit up to date with the assistance of the Dugong MOU Dugong Technical Advisory Group (DTAG).

11.1 Purpose of this chapter

This chapter summarizes new findings obtained through the process of developing this report that are relevant to conservation policy and practice at the spatial scale of the dugong's global range. Regional-specific information is presented in Chapters 2-10 as follows: East Africa (Chapter 2), Red Sea (Chapter 3), Arabian/Persian Gulf (Chapter 4), South Asia (Chapter 5), Continental Southeast Asia (Chapter 6), Maritime Southeast Asia (Chapter 7), East Asia (Chapter 8), Pacific Islands (Chapter 9) and Australia (Chapter 10).

11.2 Evidence of need to revise the dugong's global range

This report indicates that the published information on the dugong's global range requires revision. The following countries and territories are listed as dugong Range States on the Dugong MOU website (UNEP/CMS 2024a): Australia, Bahrain, Bangladesh, Brunei Darussalam, Cambodia, China, Comoros, Djibouti, Egypt, Eritrea, France, India, Indonesia, Islamic Republic of Iran, Iraq, Israel, Japan, Jordan, Kenya, Kingdom of Saudi Arabia, Kuwait, Madagascar, Malaysia, Maldives, Mauritius, Mayotte (Department of France), Mozambique, Myanmar, New Caledonia (Territory of France), Oman, Pakistan, Palau, Papua New Guinea, Philippines, Qatar, Seychelles, Singapore, Solomon Islands, Somalia, Sri Lanka, Sudan, Thailand, Timor Leste, United Arab Emirates, United Republic of Tanzania, Vanuatu, Viet Nam, and Yemen.

The evidence in Chapters 2-10 indicated that the Dugong Range States can be categorized as follows:

1. **Range States that support resident populations of dugongs:** Australia (Chapter 10), Bahrain (Chapter 4), Brunei Darussalam (Chapter 7), Cambodia (Chapter 6), Comoros (Mohéli; Chapter 2), Djibouti (Chapter 3), Egypt (Chapter 3), Eritrea (Chapter 3), India (Chapter 5), Indonesia (Chapter 7), Japan (Chapter 8), Kenya (Chapter 2), Kingdom of Saudi Arabia (Chapter 4), Madagascar (Chapter 2), Malaysia (Chapters 6 and 7), Mayotte (Department of France; Chapter 2), Mozambique (Chapter 2), Myanmar (Chapter 6), New Caledonia (Territory of France; Chapter 9), Palau (Chapter 9), Papua New Guinea (Chapter 9), Philippines (Chapter 7), Qatar (Chapter 4), Seychelles (Chapter 2), Singapore (Chapter 6), Solomon Islands (Chapter 9), Sri Lanka (Chapter 5), Sudan (Chapter 3), Thailand (Chapter 6), Timor-Leste (Chapter 7), United Arab Emirates (Chapter 4), United Republic of Tanzania (Chapter 2), Vanuatu (Chapter 9), Viet Nam (Chapter 6), and Yemen (Chapter 3).
2. **Range States that possibly support resident populations of dugongs, but further investigation is required to confirm the situation**: Bangladesh (Chapter 5), China (Chapter 8) Islamic Republic of Iran (Chapter 4), Israel (Chapter 3), Kuwait (Chapter 4), Oman (Chapter 4), and Somalia (Chapter 3).

3. **Putative 'Range States' that are unlikely to currently support resident populations of dugongs and may have never supported dugongs**: Iraq (Chapter 4), Jordan (Chapter 3), and Maldives and Pakistan (Chapter 5). Further investigation is required to confirm these designations.
4. **Former Range States or regions within Range States**: The dugong is likely to be **extinct** in Comoros (outside Mohéli; Chapter 2), Mauritius (including Rodriguez; Chapter 2); and the Seychelles (outside Aldabra; Chapter 2).

There is no evidence that dugongs were ever **resident** in the Laccadive Islands (India), the Maldives, or Taiwan (a province of China), despite previous claims to the contrary. Husar (1975) reported that dugongs were extinct in the Maldives and Laccadive islands citing Snow (1970). Snow's (1970) paper does not mention the dugong at either location. Brownell et al. (2019) concluded that dugongs no longer occur in the waters of Taiwan, with the last recorded strandings there in 1986. The recent live sighting of a dugong off Taiwan and the occasional historical strandings there (Chapter 8) suggest that these records may be extralimital rather than evidence of a resident population.

However, on March 28 2025, a dugong was caught in a fishing net in waters 800m off Fenniaolin fishing port in Yilan (~24,8oN), in northeast Taiwan and released alive (Jeng Ming-shiou (鄭明修), executive director of Academia Sinica's Biodiversity Research Center personal communication to Central News Agency (CNA), the national news agency of the Republic of China). Media photographs seen by Marsh suggest the animal was an immature male.

In addition, the ranges of the dugong within the Gulf[2], India, Somalia and Yemen as presented in Marsh and Sobtzick (2019) need to be reconsidered by IUCN. The IUCN dugong global range map should also be restricted to coastal waters shallower than 20 m in the Red Sea (as in Chapter 3) and the Sulu Sea (as in Chapter 7).

The likely extinctions of the dugong in Comoros (outside Mohéli; Chapter 2), Mauritius (including Rodriguez; Chapter 2); and the Seychelles (outside Aldabra; Chapter 2) are indicative of the precarious survival prospects of dugongs in the waters of isolated islands (see Section 11.5).

All this information suggests that the IUCN global assessment of dugong status (Marsh and Sobtzick (2019) needs to be revised by the IUCN Sirenia Specialist Group (see Figure 11.1).

- The IUCN lists the dugong as Vulnerable to Extinction at a global scale.
- This assessment needs to be revised by the IUCN Sirenia Specialist Group. In particular, the global range map, needs revision in accordance with this report.

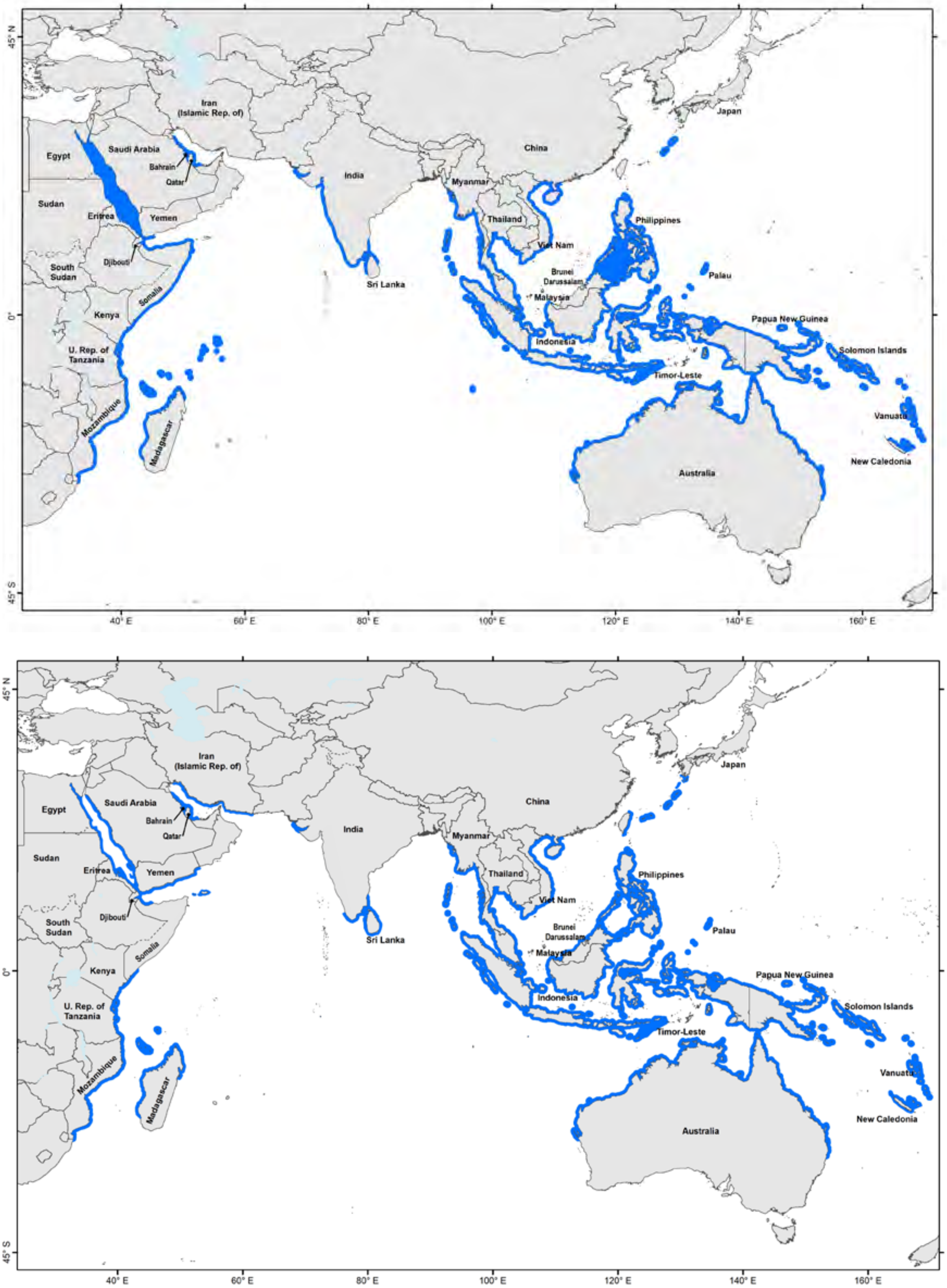
Although the dugong is currently listed as Vulnerable globally, IUCN has recently listed two 'subpopulations' as Critically Endangered (Eastern Africa Coast; Trotzuk et al. 2022); Nansei Japan; Brownell et al. 2019) and one 'subpopulation' as Endangered (New Caledonia; Hamel et al. 2022). This report has identified 11 additional 'subpopulations', including three transboundary 'subpopulations', as appropriate for assessment for IUCN listing as Threatened. Of these, six could be assessed without additional information: (1) Aldabra (Seychelles; Chapter 2), (2) China (Chapter 8), (3) Comoros (Mohéli; Chapter 2), (4-5) India (each of the Gulf of Kutch and Andaman and Nicobar Islands; Chapter 5), (6) Palau (Chapter 9). The remaining 'subpopulations' would require additional information on the number of mature dugongs: (7) Arabian Gulf (Chapter 4), (8) Ashmore Reef (Australia; Chapter 10), (9) Côn Đảo Archipelago (Viet Nam; Chapter 6), (10) Palk Bay and the Gulf of Mannar (India and Sri Lanka; Chapter 5), and (11) the Red Sea (Chapter 3).

The advantage of subregional listing is that it draws attention to local 'subpopulations', the status of which can be masked by global listing. In addition, dugong 'subpopulations', which have been listed as Critically Endangered or Endangered in the IUCN Red List of Threatened Species should be eligible for listing on Appendix I of CMS, placing more stringent obligations on the relevant Range States (CMS 1979).

Assessment of the 'subpopulations' listed above for IUCN listing should be undertaken by the IUCN Sirenia Specialist Group. IUCN listing of dugong 'subpopulations' in most other parts of their range is unlikely because: (1) the connections between dugongs in adjacent Range States are not known; (2) the number of mature dugongs cannot be estimated with confidence; and/or (3) the trend in numbers has not been quantified.

2 In the present report 'the Gulf' refers to the Arabian/Persian Gulf.

Figure 11.1. The dugong's global range map based on Marsh and Sobtzick (2019) (top map) and proposed on the basis of evidence assembled in this report (bottom map). The dugong's former range in China is included in the bottom map because that population does not yet meet the IUCN criteria for extinction (Chapter 8) Iran has been included in the lower figure because of the recent evidence suggesting that dugongs may be resident there. The boundaries and names shown, and the designations used on these maps do not imply official endorsement or acceptance by the United Nations. Adella Edwards figure; reproduced with permission.



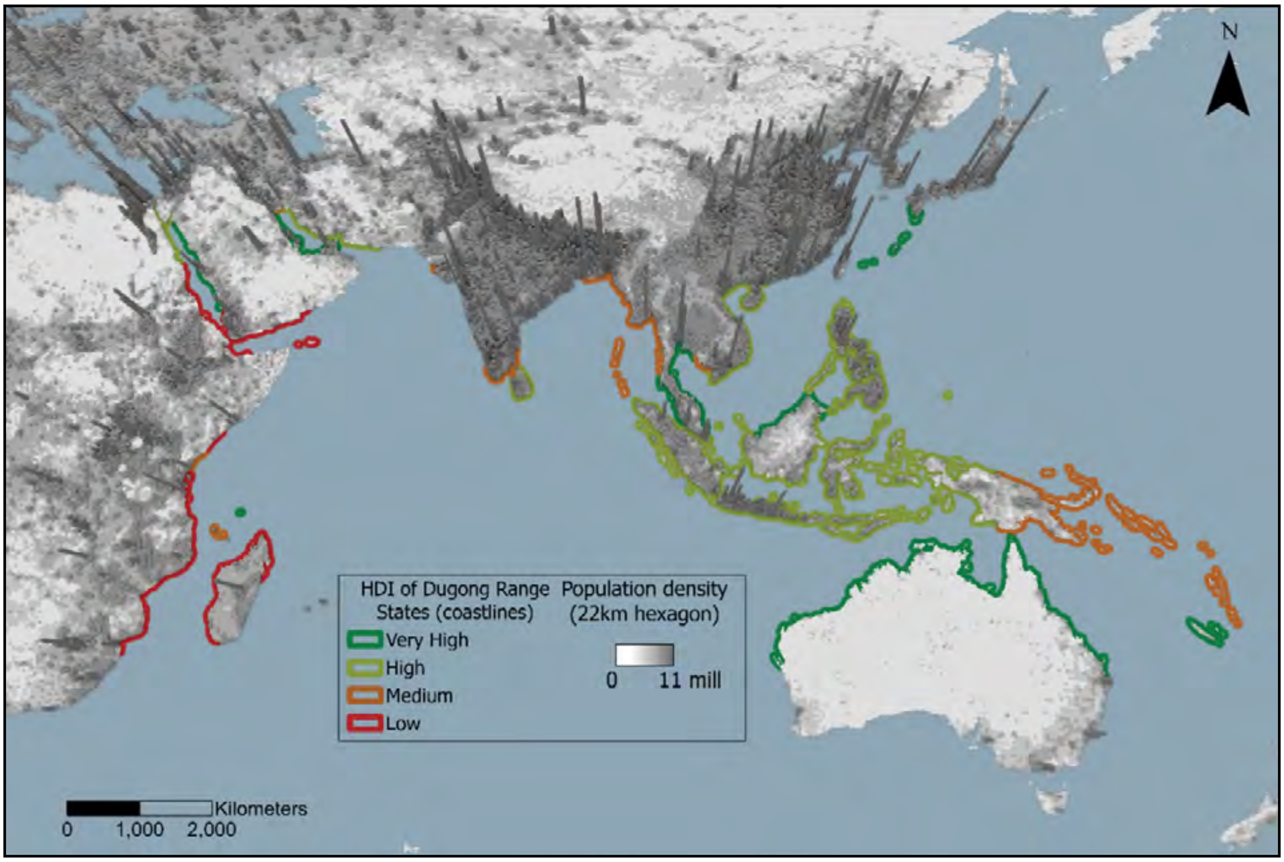
- In addition to listing, the dugong as Vulnerable to Extinction at a global scale, the IUCN has listed the following dugong 'subpopulations' at a regional scale: East Africa Coastal (Critically Endangered), Nansei, Japan (Critically Endangered), and New Caledonia (Endangered).
- This report has identified a further 11 'subpopulations', including three transboundary 'subpopulations', as appropriate for assessment for IUCN regional listing as Threatened.
- These assessments should be undertaken by the IUCN Sirenia Specialist Group as the requested data become available.
- 'Subpopulation' listing draws attention to local populations, the status of which can be masked by the global listing.

11.3 Social and economic considerations

The dugong's range spans the coastal waters of approximately 40 subtropical and tropical Indo-West Pacific countries (Section 11.2). These countries are socioeconomically diverse and include some of the world's richest and most highly developed countries (e.g., Arabian Gulf States, Australia, Singapore) and some of the least developed and conflict-affected countries (e.g., Somalia, Sudan, Yemen). The coastal human population density of dugong Range States extends from 0-10 to more than 400 people per km^2 (Figure 11.2). The dugong's survival prospects are uneven throughout this region as outlined in Chapters 2-10.

The cumulative proportion of seagrass habitat shallower than 20 m deep in the Range States with various levels of Human Development Index is 71% Very High, 14.5% High, 4.7% Medium and 10% Low (L. McKenzie unpublished data 2024). These percentages indicate that an extensive area of dugong habitat is in the waters of very highly developed countries. This situation is very different from that of any other sirenian, apart from the Florida manatee, *Trichechus manatus latirostris,* a sub species of the West Indian manatee. Much of the ranges of all other manatee species/sub-species are largely in low-income countries (Marsh et al. 2011). Northern Australia, which supports a high proportion of the world's dugongs, has the dual advantages of being a

Figure 11.2. Map illustrating the diversity of socioeconomic conditions in the dugong's global range. The Human Development Index (HDI) is from UNDP (2024); the three-dimensional human population density per 22 km hexagon is from Kontur (2023). Lucas Langlois figure; reproduced with permission.



region of very low human population density in one of the world's most highly developed countries (Figure 11.2). The dugong's prospects are uneven across their global range as confirmed by the evidence in Chapters 2-10 of this report and the current and prospective IUCN subpopulation listings.

- Dugong Range States are socioeconomically diverse and include some of the world's richest and most highly developed countries as well some of the least developed and conflict-affected countries.
- An extensive area of dugong habitat occurs in the waters of very highly developed countries that should have the capacity to implement effective conservation.
- The conservation prospects for the dugong at a global scale are better than for any other sirenian species, even though the dugong's conservation prospects and geographically diverse.
- The prospects for dugongs surviving in the coastal waters of Island Range States with low seagrass extent, relatively small areas of coastal waters shallower than 20 m and some level of isolation (e.g., separated from adjacent continental land masses or islands) are likely to be precarious.

11.4 Seagrass mapping should be a high priority for informing dugong conservation

As explained in Chapter 1, the area of seagrass in waters shallower than 20 m can be used as a crude index of dugong carrying capacity. To estimate this area for each dugong Range State, data were assembled from published and available sources as described in Chapter 1. Only seagrass areas of moderate to high confidence (*sensu* McKenzie et al. 2020; McKenzie et al. 2022) were used.

Approximately 41,000 km^2 of seagrass in waters shallower than 20 m have been mapped with moderate to high confidence across the dugong Range States. The Range State with the largest area of mapped seagrass is Australia, followed by Indonesia, Mozambique, Madagascar, Iran (possible Range State) and the United Arab Emirates (see Figure 11.3 for areas). Each of these Range States has a mapped seagrass area greater than 1,000 km^2, and together their seagrass resources encompass approximately 80% of the total mapped seagrass across the shallow waters of the dugong's range.

The area of mapped seagrass relative to area of water shallower than 20 m (Figure 11.4) is much greater in Range States with shallow (less than 100 m depth) enclosed seas (e.g. Arabian/Persian Gulf) or where the continental shelf supports large shallow gulfs (e.g., Gulf of Mannar–Palk Bay region, India and Sri Lanka) and lagoons (e.g. Great Barrier Reef, Australia) (McKenzie et al. 2020).

Island Range States which have low seagrass extent, relatively small areas of coastal waters shallower than 20 m and some level of isolation (e.g., separated from adjacent continental land masses or islands) are likely to present precarious prospects for dugong conservation, especially if their seagrass meadows are under pressure from anthropogenic impacts as is occurring throughout much of the world (Dunic et al. 2020). Such Range States include Comoros, Mayotte, Palau, Vanuatu, and Seychelles. Range States with small areas of mapped seagrass that are less isolated (e.g., Djibouti, Singapore, Timor Leste) should also be important conservation priorities.

The total area of confirmed seagrass across the Range States is believed to be a significant underestimate of the actual area of potential dugong habitat (UNEP 2020). Additional seagrass mapping should be a high priority, especially in Range States and regions where: (1) the current seagrass area is less than 5% of coastal waters shallower than 20 m deep, or (2) the area of shallow waters is more than 50, 000 km^2 (Figures 11.3, 11.4). New and emerging technologies and improved mapping approaches are showing some promise to address the challenge of mapping seagrass as outlined in Chapter 1. The imperative for establishing a cohesive framework for seagrass conservation on a global scale was announced during the United Nations Framework Convention on Climate Change Conference of the Parties 28 (UNFCCC COP28) in December 2023 (Text Box 11.1). Support for the establishment and implementation of this initiative is in the proposed Programme of Work 2024-2027 for the Secretariat of the Dugong MOU, subject to the endorsement of the next Meeting of Signatory States to the Dugong MOU (MOS4). The need to map dugong habitat could be included in the roadmap for this initiative.

Figure 11.3. Area of confirmed seagrass meadows with moderate to high confidence[3], within each dugong Range State (country). *Estimated for dugong's range within country. Len McKenzie figure, reproduced with permission.

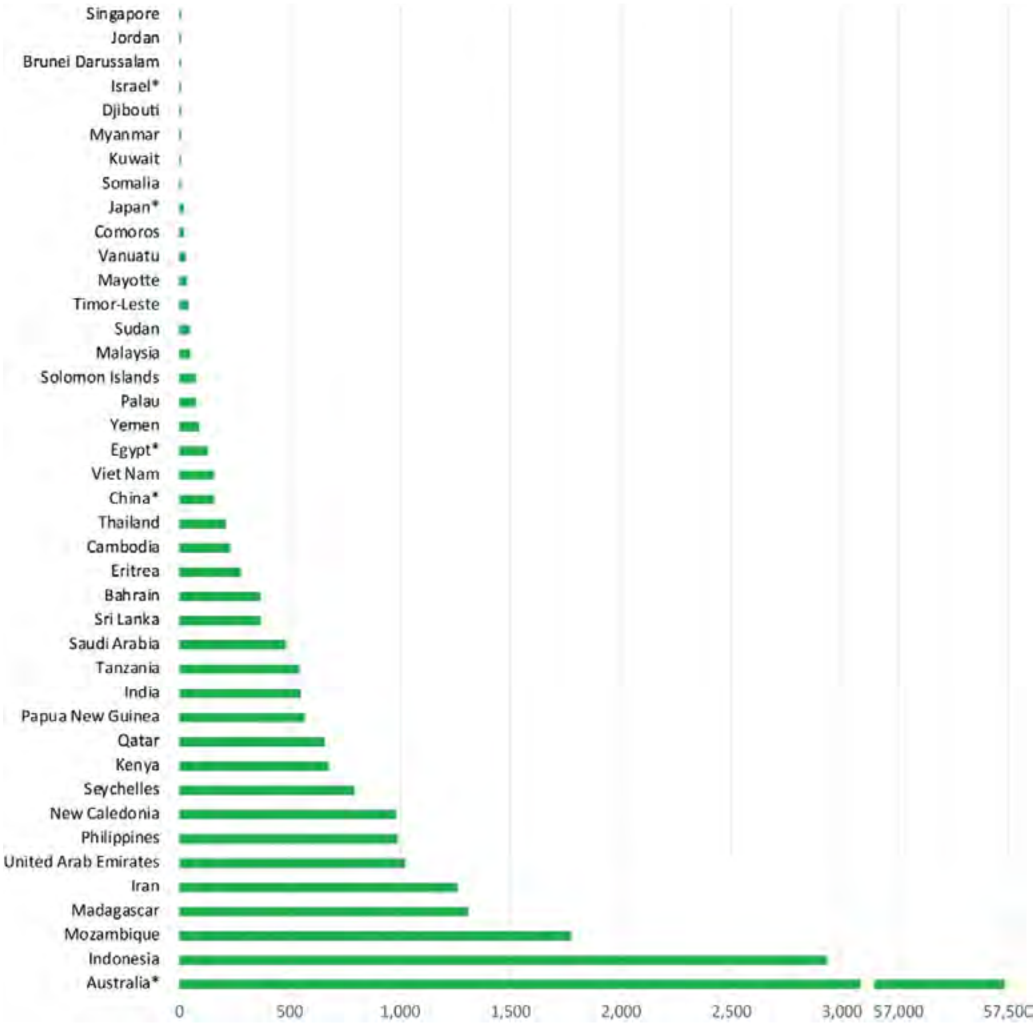
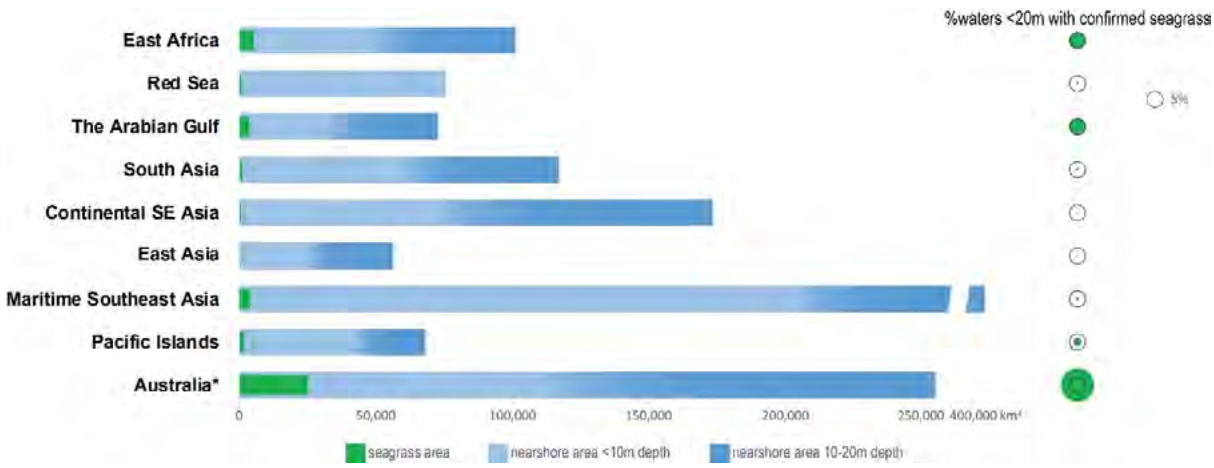


Figure 11.4. Area of seagrass known with moderate to high confidence in the regions in Chapters 2-11 in this report for the area of coastal waters less than 20 m deep. While not all shallow coastal waters are potential seagrass habitat, the figure shows the need to undertake additional seagrass mapping in all regions, especially outside Australia. Even in Australia, seagrass mapping is far from complete. Len McKenzie figure, reproduced with permission.



3 These levels of confidence are sensu McKenzie et al. (2020). Confidence intervals are not available.

- The area of seagrass in subtropical and tropical Indo-Pacific waters shallower than 20 m deep can be used as a crude index of dugong carrying capacity.
- Island Range States with low seagrass extent, relatively small areas of coastal water shallower than 20 m and some level of isolation (e.g., separated from adjacent continental land masses or islands) are likely to have precarious prospects for dugong survival without significant conservation initiatives. Such Range States include Comoros, Mayotte, Palau, Vanuatu, and Seychelles. Similar Range States which are less isolated (e.g., Djibouti, Singapore, Timor Leste) may also be important conservation priorities.
- Seagrass extent as a percentage area of water shallower than 20 m is much greater in Range States with shallow (less than 100 m) enclosed seas (e.g., Arabian/Persian Gulf) or where the continental shelf supports large shallow gulfs (e.g., Gulf of Mannar–Palk Bay, India and Sri Lanka) and lagoons (e.g., Great Barrier Reef, Australia).
- While not all shallow coastal waters are potential seagrass habitat, the area of seagrass known with moderate to high confidence as a proportion of the area of coastal waters shallower than 20 m deep shows the need to undertake additional seagrass mapping in all regions of the dugong's range, especially the Red Sea, the Asian regions and the Pacific Islands.
- The 2030 Seagrass Breakthrough, a cohesive framework for seagrass conservation on a global scale, was announced during the 28th meeting of the United Nations Framework Convention on Climate Change Conference of the Parties in December 2023.
- Support for the establishment and implementation of this initiative is in the proposed Programme of Work 2024-2027 for the Secretariat of the Dugong MOU, subject to the endorsement of MOS4.
- The need to map dugong habitat could be considered for inclusion on the roadmap of the 2030 Seagrass Breakthrough.

Text Box 11.1: The 2030 Seagrass Breakthrough

In the face of mounting challenges posed by climate change and biodiversity loss, the 2030 Seagrass Breakthrough aims to harness the potential of seagrass ecosystems as nature-based solutions for climate change mitigation, biodiversity maintenance, and socioeconomic development. This initiative seeks to establish a cohesive framework for seagrass conservation on a global scale.

Announced during United Nations Framework Convention on Climate Change Conference of the Parties 28, the 2030 Seagrass Breakthrough represents a collaborative effort between the Convention on Migratory Species (CMS) Office in Abu Dhabi and the United Nations High-Level Climate Change Champions as an integral part of the broader Ocean Breakthroughs initiative, which is addressing critical challenges facing oceans and marine life.

This initiative garnered recognition with the adoption of CMS Resolution 14.8 on Conservation and Sustainable Management of Seagrass Ecosystems (UNEP/CMS 2024b) and Decisions 14.65-68 on seagrass ecosystems (UNEP/CMS 2023) at the 14th Meeting of the Conference of the Parties to CMS (COP14, Samarkand, February 2024), emphasizing the significance of the 2030 Seagrass Breakthrough and the collective commitment to safeguarding this vital marine ecosystem.

The 2030 Seagrass Breakthrough aims to secure the future of seagrass meadows globally by putting in place a collective framework of action by State and non-State actors by 2030 for mobilising sustainable financing for conservation and restoration efforts.

The Guiding Principles of the 2030 Seagrass Breakthrough encompass Ecosystem Stewardship, Science-Based Decision-Making, Inclusivity and Collaboration, Holistic Sustainability, Adaptability, Global Action with Local Solutions, Empowerment and Capacity-Building, Transparency and Accountability, and the fostering of Innovation and Resilience Beyond 2030. These Guiding Principles serve as the foundation for all actions and strategies under the initiative, ensuring effectiveness, inclusivity, and forward-thinking.

A comprehensive roadmap and action plan will outline strategies, such as strengthening policy frameworks at international and national levels, mobilizing financial resources through innovative mechanisms, engaging local communities in conservation efforts, and utilizing scientific research and remote sensing for monitoring and management.

11.5 The Dugong and Seagrass Research Toolkit should be a high priority for revision, particularly the section on estimating dugong abundance

The proposed Programme of Work 2024-2027 for the Secretariat of the Dugong MOU (UNEP/CMS 2024c) includes coordinating a review of the Dugong and Seagrass Research Toolkit (Dugong and Seagrass Hub n.d.) to ensure that it remains relevant and up to date. The development process for this report has identified many sections of the Toolkit that need updating; these sections need to be prioritized for review. The Dugong Technical Advisory Group (DTAG) may wish to consider bringing these points to the attention of MOS4 for its consideration.

The Toolkit section on estimating dugong abundance is key to evaluating dugong status and trends, however, it currently does not reflect recent advances in methodology. The section on the use of abundance aerial surveys is particularly outdated because it fails to consider:

1. Recent developments in the use of UAVs of different sizes, ranging from Scan Eagles (13.1 kg; Hodgson et al. 2013, 2017, 2023) to off-the-shelf small drones (2kg; Cleguer et al. 2021).
2. The information that can be obtained from cameras attached to conventional high-wing aircraft (Cleguer et al. unpublished), helicopters (e.g., Das et. al. 2021) and ultralight aircraft.
3. The use of artificial intelligence to process UAV or camera images (e.g., Hodgson et al. (2017, 2023); Jahanbakht et al. 2024).
4. New methodologies for designing and conducting aerial surveys for dugongs:
   - distributed in areas lacking extensive areas of seagrass, such as where animals are distributed along a linear habitat (see Martin et al. 2015 for Florida manatees);
   - at local scales including within extensive areas of seagrass (Cleguer et al. 2021; Said et al. 2020, 2025; Pryor et al. 2024);
   - in large aggregations (e.g., Khamis et al. 2023).
5. New statistical methodologies for detecting trends (e.g., Rankin and Marsh 2020).

- The proposed Programme of Work 2024-2027 for the Secretariat of the Dugong MOU includes coordinating a review of the Dugong and Seagrass Research Toolkit.
- The Toolkit contains many sections that need updating and these need to be prioritized.
- The section on estimating dugong abundance is of key relevance to evaluating dugong status.
- The Toolkit is silent on recent advances in methodologies for aerial abundance surveys using UAVs or drones, survey design and the analysis of trends.
- The Toolkit is silent on recent advances in methodologists including aerial abundance surveys using unoccupied aerial vehicles (UAVs or drones) for population assessment and monitoring and body condition assessment, e-DNA, survey design and the analysis of trends.

11.6 Desirability of spatial risk assessment for threats to dugongs across their global range

The threats to dugongs are relatively consistent across their range (Chapters 2-10), although their root causes differ greatly with the socioeconomic context (Figure 11.2). In less-developed countries the root causes include: (1) limited capacity and political will; (2) corruption; (3) human migration to coastal areas; (4) armed conflict; (5) food insecurity resulting from extreme weather events; (6) high human population growth rates; and (7) declining fish stocks (Chapters 2, 3, 5, 6, 7, 9). These circumstances put severe pressure on marine ecosystems to support food provisioning. Climate change is likely to exacerbate this situation as it is a threat multiplier (Marsh et al. 2022).

As explained in Chapter 1, threats to dugongs can be categorised into two types: those that cause direct dugong mortality, and indirect threats that result in dugong habitat loss or degradation, which in turn, negatively affect dugong fecundity. As dugongs are long-lived, slow breeding mammals, threats to mortality are generally more serious than threats to fecundity (Marsh et al. 2011).

As identified by Marsh and Sobtzick et al. (2019) in their global assessment, the primary threats to dugongs are:

- Incidental capture in fishing gear, largely in small-scale fisheries; illegal, unreported, and unregulated (IUU) fishing, particularly if incidental captures are 'targeted' for later consumption; entanglement in marine debris including discarded fishing gear and plastic litter.
- Hunting and direct fishing, which is illegal in most of the dugong's range, apart from traditional use in the Andaman and Nicobar Islands (Chapter 5), Pacific Islands including PNG, Solomon Islands, Vanuatu and New Caledonia (Chapter 9), and Australia (Chapter 10).
- Vessel strikes.
- Extreme natural events (e.g., storm surges and tsunamis).

Threats to dugong fecundity due to habitat loss, fragmentation, and modification include:

- Habitat damage caused by human settlements and infrastructure development in the coastal zone, oil and gas exploration and production, shipping, destructive fishing (netting and trawling).
- Degradation of seagrass habitat, including from untreated sewage disposal, coastal dredging and reclamation, inshore commercial trawling, declining water quality due to land clearing and resultant erosion.
- Extreme weather and climate change impacts on seagrass communities (e.g., extreme tropical storms, marine heatwaves).
- Chemical pollution (e.g., oil spills and heavy metal loads).

The relative importance of these threats varies at both regional and local scales as explained in Chapters 2-10. Tensions between biodiversity conservation and the imperative for food security, fisher livelihoods, resource extraction, infrastructure and other forms of development are acute throughout most of the dugong's developing Range States, especially in areas where dugongs are already rare and unlikely to be a conservation priority.

Subject to the endorsement of MOS4, the proposed Programme of Work 2024-2027 for the Secretariat of the Dugong MOU (UNEP/CMS 2024c) includes working with the CMS Scientific Council to:

- identify regions where a review of relative levels of dugong bycatch in commercial and artisanal fisheries would be a priority and/or beneficial;
- collaborate with relevant organizations to develop regional reviews into ways of reducing bycatch;
- identify and prioritize fisheries and areas in which adverse bycatch impacts are highest;
- cooperate with relevant organizations to develop appropriate bycatch mitigation measures for high priority fisheries;
- develop appropriate bycatch mitigation measures with associated timebound action plans;
- identify priority forms of pollution affecting dugongs and review the significance of these threats, including their cumulative impacts, and the localities where marine pollution and dugongs significantly intersect;
- facilitate the exchange of information and best practices on reducing the risk of dugong vessel strikes among Signatory States, relevant organizations, and other stakeholders;
- assess the vessel collision risk for dugongs and identify areas where conservation measures may be most needed;
- assess the long-term effects and biological significance of boat-based and in-water interaction disturbances for dugongs;
- recommend areas where activities should be strictly limited to boat-based activities;
- investigate the desirability of developing guidance regarding the use of unmanned aerial and underwater vehicles and other relevant technologies around marine wildlife during recreational activities.

As pointed out in the Dugong and Seagrass Research Toolkit (Dugong and Seagrass Hub n.d.), threat risk assessment is a tool that can be used to compare the levels of relative risk to dugongs and their habitats caused by various direct or indirect threats or hazards with the aim of helping stakeholders prioritize conservation responses within and between localities.

Specialist tools have been developed for risk-based climate vulnerability assessments as proposed by the IPCC Fifth Assessment Report (AR5), in which vulnerability is defined as an internal property of a system determined by its sensitivity and adaptive capacity (IPCC 2014). Although there has been an assessment of the risk to sirenians including dugongs and their habitats from climate change (Marsh et al. 2022), and an assessment of the risk to the dugong relative to other marine mammals (Albouy et al. 2020), there do not seem to be comparative assessments of risk across regions or key habitats within regions.

This report has identified key localities for dugongs in each of the regions considered in the regional chapters. An important next step might be to consider the risks, including climate risks, to the globally and regionally important dugong habitats identified in this report. There are data deficiencies in some regions that might support significant dugong populations, such as the African coast of the Red Sea, much of Southeast Asia outside Thailand and Malaysia, Indonesia, Papua New Guinea and the Solomon Islands, but that should not delay a spatial risk assessment, which could be updated as new information becomes available.

- The threats to dugongs are relatively consistent across their range, although their root causes differ with socioeconomic context.
- Threats to dugongs include:
  - direct threats causing dugong mortality: incidental capture in fishing gear and marine debris; illegal hunting and direct fishing; vessel strikes; extreme natural events; plastic litter; and.
  - indirect threats that result in dugong habitat loss or degradation: human settlements and infrastructure development; oil and gas exploration and production; shipping; destructive fishing (netting and trawling); untreated sewage disposal; coastal dredging and reclamation; inshore commercial trawling; declining water quality due to land clearing and resultant erosion; extreme weather and climate change impacts on seagrass communities; chemical pollution.
- The relative importance of these threats varies at both regional and local spatial scales.
- In addition to working with the CMS Scientific Council to develop methods to ameliorate threats to CMS-listed marine megafauna, an important initiative would be to consider the relative risks, including the climate risks, to dugongs and their habitats in the globally and regionally important areas identified in this report.

11.7 Desirability of a megafauna approach to threat abatement, especially in areas of low dugong density

In regions, such as much of East Africa outside Mozambique (Chapter 2), the African coast of the Red Sea (Chapter 3), Iran (Chapter 4), Sri Lanka south of Gulf of Mannar–Palk Bay region (Chapter 5), much of Continental Southeast Asia outside the Andaman Coast of Thailand (Chapter 6), Maritime Southeast Asia (Chapter 7), East Asia (Chapter 8), and the Pacific Islands outside New Caledonia (Chapter 9), dugong density is now so low that there is little community awareness of dugongs or support for dugong-specific interventions. In such cases, generic interventions to protect marine megafauna and their habitats should be a more efficient and effective approach to addressing threats that affect all megafauna, such as gillnetting.

Interviews with fishers should seek information on all megafauna. The Dugong MOU Standardized Catch and Bycatch Questionnaire developed by Pilcher et al. (2017) included questions on cetaceans and turtles. Braulik et al. (2010, 2022) obtained information on dugongs on field trips primarily aimed at obtaining information on cetaceans to Iran and Somalia respectively.

At the time of writing (June 2024), the IUCN Marine Mammal Protected Areas Task Force (MMPATF) had identified 33 Important Marine Mammal Areas (IMMAs) with dugongs as a qualifying species. Fifteen of those IMMAs include species of humpback dolphins (*Sousa*) as a qualifying species, 14 include the Indo-Pacific bottlenose dolphin, *Tursiops aduncus,* and seven *Orcaella species*. All these species are subject to similar destructive interactions with fisheries.

These examples illustrate the potential for regional collaboration on megafauna research and management. This approach also accords with some of the decisions of the 14th Conference of the Parties to the CMS (CMS COP14), which foreshadow a generic approach to develop methods to address threats that affect multiple CMS-listed species of marine megafauna (CMS 2024).

- In many locations, dugong density is now so low that there is little community awareness of dugongs or support for dugong-specific interventions in these areas.
- In such cases, generic interventions to protect coastal megafauna and their habitats should be a more efficient and effective approach to addressing threats that affect all megafauna, such as gillnetting.
- This approach also accords with some of the decisions of the 14th CMS COP, which foreshadows a generic approach to develop methods to address threats that affect multiple CMS listed species of marine megafauna.

11.8 Potential for additional regional cooperation

Chapters 2-10 demonstrate that regional cooperation is at various stages of development across dugong Range States. Regional cooperation seems most advanced in East Africa (Chapter 2) and the Pacific Islands (Chapter 9). There have been some cross-country initiatives in the Gulf (Chapter 4), and South Asia (Chapter 5), and between Australia and her northern neighbours (Chapter 10).

Commitment to the conservation of marine mammals in the Pacific, including the dugong, has been ongoing since the South Pacific Regional Environment Programme (SPREP) was established in 1993. SPREP has launched several campaigns to increase awareness of dugongs and their seagrass habitats across the Pacific. SPREP has developed a series of regional action plans for marine species including the dugong; their 'Dugong Action Plan' was last updated in 2022 (Hendriks and Baird 2022). The Dugong and Seagrass Conservation Project (2015-2019) supported by the Global Environment Facility (GEF), has also been instrumental in advancing plans and discussions on dugong and seagrass conservation in the Pacific Islands region (Dugong and Seagrass Conservation Project 2024).

There is burgeoning cross-country cooperation in the Arabian/Persian Gulf. The UAE, Qatar, Bahrain and Saudi Arabia are discussing how to implement coordinated dugong aerial surveys, following the CMS/Dugong MOU Regional Meeting on Science and Management for Dugongs in the Arabian Gulf in 2023 (CMS Dugong MOU Secretariat 2023). The Cooperation Council for the Arab States of the Gulf (مجلس التعاون لدول الخليج العربية), also known as the Gulf Cooperation Council (GCC مجلس التعاون الخليجي), has endorsed a regional convention calling for the conservation of threatened species, including dugongs (A. Khamis personal communication via email to Marsh and Schramm 2024). The proposed Programme of Work 2024-2027 for the Secretariat of the Dugong MOU (UNEP/CMS 2024c) includes establishing an Arabian Gulf Regional Working Group (under the aegis of ROPME) and a South Asia Working Group.

It would be desirable for each region in the dugong's range to establish a Regional Working Group as a vehicle for developing Regional Action Plans to guide the development and delivery of practical and resource-efficient strategies to collaborate in, and implement, regional conservation and management initiatives for the conservation of dugongs and their habitats (and if appropriate, associated megafauna) and enhance communication among participating countries and organizations.

- Regional cooperation on dugong conservation management and research is at various stages of development across dugong Range States.
- The proposed Programme of Work 2024-2027 for the Secretariat of the Dugong MOU includes establishing an Arabian Gulf Regional Working Group and a South Asia Regional Working Group.
- It would be desirable for each region in the dugong's range to consider establishing a Regional Working Group as a vehicle for developing Regional Action Plans to guide the development and delivery of practical and resource-efficient strategies for conserving dugongs and their habitats (and if appropriate associated megafauna).

11.9 Keeping this report and the Dugong and Seagrass Research Toolkit up-to-date

The ongoing conservation initiatives and research into dugongs and their seagrass habitats mean that a report such as this one quickly becomes out-of-date, especially in this era of biodiversity crisis and climate change. Fortunately, the technology now exists to create and modify content in an organized manner, while ensuring that the information remains of high quality.

The Dugong MOU Technical Advisory Group (DTAG) could be given responsibility for keeping this on-line report up to date while ensuring quality, and alerted when substantive new information becomes available in peer-reviewed publications and reports. One member of the TAG could perhaps be appointed as overall editor and other members of the TAG given responsibility for different chapters. Invitations to provide additional information could be on the Dugong MOU Website and in each issue of *Sirenews*, the biannual newsletter of the Sirenia Specialist Group (Clearwater Marine Aquarium 2024). The use of AI should be investigated.

A similar approach could be considered for maintaining the Dugong and Seagrass Research Toolkit which contains excellent information, some of which is now out-of-date as explained in section 11.6.

- The technology now exists to create and modify on-line content in an organized manner while ensuring that the information remains of high quality.
- Such an approach could be used to keep this report and the Dugong and Seagrass Research Toolkit up to date.
- Options for keeping both this report and the toolkit current include a dedicated role for the Dugong MOU Dugong Technical Advisory Group.

11.10 Concluding remarks

The dugong has one of the largest (if not the largest) ranges in the subtropics and tropics of any coastal, marine mammal listed as Threatened by IUCN (IUCN 2024). The geography of, and the social and economic conditions in, the dugong's Range States are diverse as explained in Sections 11.3 and 11.4 and illustrated in Figures 11.2 and 11.3. This situation means that a key finding of this report is that the dugong's conservation prospects are very uneven across its huge range. Although extensive dugong habitat occurs in the waters of very highly developed countries, the dugong's prospects of survival are precarious in island Range States with low seagrass extent, relatively small areas of water shallower than 20 m and some level of isolation (e.g., separated from adjacent continental land masses or islands).

This situation would be clarified and highlighted by the additional IUCN Red List of Threatened Species subregional assessments suggested in this report. These assessments would facilitate customization of responses to threats.

Maintenance of the currency of a global report such as this and the Dugong and Seagrass Research Toolkit would also facilitate appropriate responses to the threats to dugongs and their seagrass habitats. Mapping seagrass communities in the waters of dugong Range States would be a desirable inclusion in the roadmap for the 2030 Seagrass Breakthrough. The establishment of and support for additional Regional Working Groups would enhance the prospects of developing and delivering practical and resource-efficient strategies for conserving the conservation of dugongs and their habitats (and if appropriate, associated megafauna) among the Range States.

11.11 References

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The Convention on the Conservation of Migratory Species of Wild Animals (CMS)

is an environmental treaty of the United Nations that provides a global platform for the conservation and sustainable use of migratory animals and their habitats. This unique treaty brings governments and wildlife experts together to address the conservation needs of terrestrial, aquatic, and avian migratory species and their habitats around the world.

CMS Secretariat
UN Campus, Platz der Vereinten Nationen 1
53113 Bonn, Germany
Tel: (+49) 228 815 24 01 / 02 | E-mail: cms-secretariat@un.org | www.cms.int

CMS Office - Abu Dhabi
c/o Environment Agency - Abu Dhabi
P.O. Box 45553, Abu Dhabi, United Arab Emirates
Tel: (+ 971) 2 6934 437 / 541 | E-mail: cmsoffice.ae@un.org | www.cms.int/dugong