Evaluating risk to seagrasses in the Tropical Indo-Pacific Region

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Abstract. Seagrass meadows are a major ecosystem component of coral reef environments in northern Australia and the Indo-Pacific. Providing advice on the protection and management of seagrasses at ecosystem or regional scales is difficult because of the costs and challenges associated with collecting and analysing data at that scale. To address this we have combined geospatial data with qualitative measures of the vulnerability of seagrass habitats from multiple threats and evaluated the risk to seagrasses at a local and regional scale. In the Great Barrier Reef World Heritage Area, Queensland Australia (GBRWHA), the highest ranked threats to seagrass were agricultural and urban runoff followed by coastal infrastructure. There was a spatial pattern to risk with very low levels in the remote north compared with the urbanised south. The relative impact of multiple threats was also estimated for the Indo-Pacific using the seagrass regions of Short et al. (2007). There were consistencies in threats to seagrass with three of the highest ranked threats found in the GBRWHA in the top five threats for the Indo-Pacific region. Threats associated with climate change received mostly low scores. The approach summarized here provides an estimation of the relative importance of threats and enables coastal management interventions to be directed to issues and locations that will maximise returns for investment in data collection analysis and intervention.

Key words: seagrass, risk, Great Barrier Reef

Introduction

Since 1980 seagrass habitats have declined worldwide at a rate of around 110 km^2 per year (Waycott et al. 2009). Globally, it is estimated fifteen percent of seagrass species are now threatened (Randall-Hughes et al. 2009; Short et al. 2011). The causes of this decline vary globally (Orth et al. 2006) due to multiple factors including local species resilience, exposure to natural events, the nature of anthropogenic activities and the frequency and scale of exposure to impacts. Seagrasses are one of the world's most productive ecosystems (Waycott et al. 2009) providing a variety of ecosystem services with an estimated global value of over AU$3.8 billion per annum in 1997 (Constanza et al. 1997) so these declines are of global concern.

The east coast of Queensland, Australia has extensive inshore, coastal and deep water (15 metres to 60 metres) seagrass with an estimate area for all species of 55,300 square kilometres (Coles et al. 2009; McKenzie et al. 2010) (Fig. 1) This coast is globally important as it is almost entirely within the Great Barrier Reef World Heritage Area and its conservation managed area; the Great Barrier Reef Marine Park (GBR). While the GBR is publically recognised for its iconic coral species and coral reefs by far the greatest area of the park is coastal waters and inter-reef lagoon. The health of these habitats is closely linked with the health of the wider coral province (Unsworth and Cullen 2010).

Unlike the global trend coastal seagrass meadows in the GBR (Fig. 1) remained relatively stable in distribution until late in 2009 (McKenzie et al. 2010) but since then there is evidence of declines at some locations (McKenzie et al. 2012). Seagrasses in the GBR and the tropical Indo-Pacific are simultaneously subjected to many natural and anthropogenic threats and the interrelationships between these stressors and changes in seagrass distribution are poorly understood (Duarte 2002). The natural variability of many seagrass meadows, the lack of good recent baseline information, and the remote locations of many seagrass meadows in the region make it difficult for traditional field surveys and science-based assessments to determine if changes in seagrass distribution and abundance are a result of natural causes or are in response to anthropogenic factors.

Development planning and coastal management decisions are often made at country level scales and a cost effective approach to inform management agencies of likely impacts of coastal activities on coastal seagrass meadows at that scale is required.

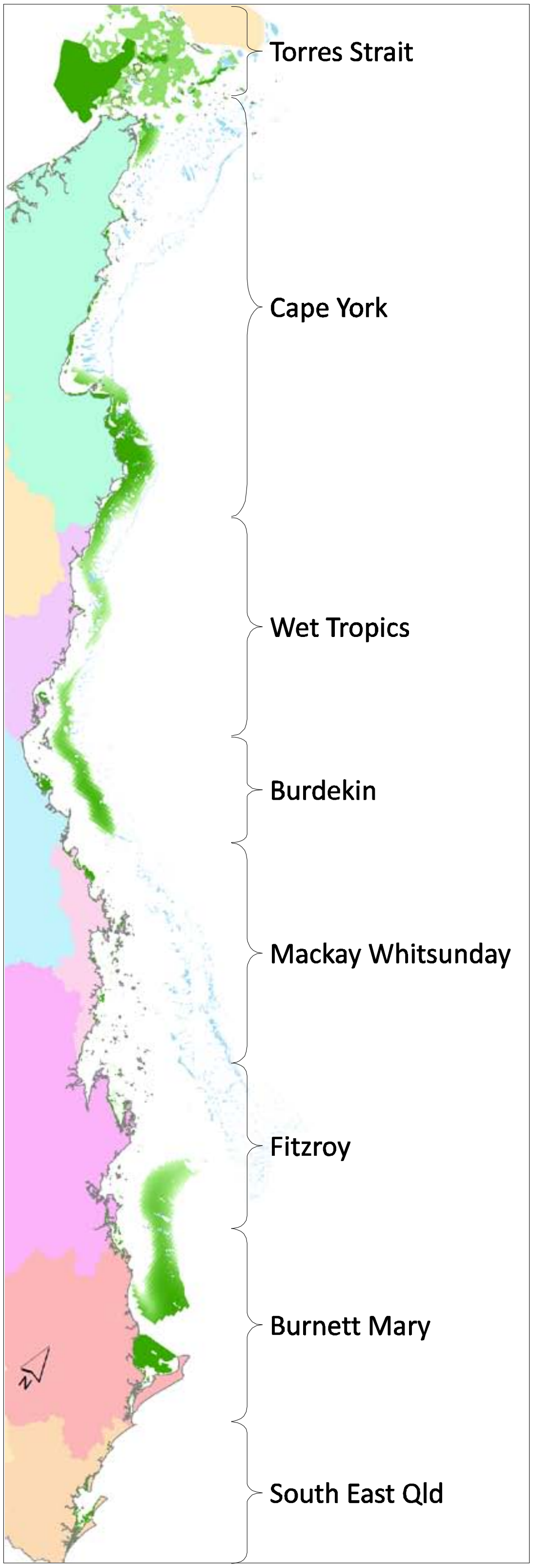

Figure 1: Seagrass distribution along the east coast of Queensland within each of the Natural Resource Management (NRM) areas. Distribution from McKenzie et al. 2010, is composite of all maps pooled; deepwater meadows (>15m) are modelled probabilities (>50%, pixel size of 2km^2) from ground truth points.

We describe our approach to advising coastal management and on risks to seagrass meadows and how this approach at GBR wide scales (2,600 kilometres of coastline) can extend to the much larger and more complex social and biological environment of the Indo-Pacific Region.

Material and Methods

The Queensland Government's Marine Ecology Group based in Cairns has focused on the ecology of seagrass meadows and their role as key primary producers since the early 1980s. The group has adopted four themes to meet the need to influence coastal management decisions and policy to best protect or conserve the seagrass resource. These include: 1) Providing a baseline measure of the extent and composition of seagrass meadows including distribution modelling; 2) Monitoring trends in abundance and meadow "health"; 3) Understanding the ecological processes and parameters that influence seagrass health and survival and; 4) Vulnerability and risk modelling to understand the distribution and level of threats to seagrasses particularly those in shallow waters close to shore.

This approach to seagrass management which includes collaborative research with James Cook University and University of Technology Sydney as well as many overseas agencies provides a collective set of information on which management decisions; land use planning, protected areas for dugong, fish habitat protection, marine park management and estuarine and port development can be made. It also extends to understanding which anthropogenic activities are of most threat to seagrass meadows and how those threats may accumulate using spatial risk mapping and expert elicitation (Grech and Coles 2010 and Grech et al.2011).

Results and Discussion

Our coastal seagrass survey data has been combined with historical published data and modelled data to construct a composite representation of the seagrass meadows within the GBR and the areas immediately to the north (Torres Strait) and to the south (Hervey Bay) (Fig. 1). We estimate that around 18,400 square kilometres of seagrass meadows are in shallow coastal waters and from statistical modelling about 37,500 square kilometres of sea floor in water deeper than 15 metres in the GBR and surrounding waters has some seagrass cover (Coles et al. 2009; McKenzie et al. 2010).

Long term trends in meadow health are monitored in each of the eight regions/watersheds and monitoring includes estuarine, coastal and reef sites. Seagrass meadows were mostly stable to 2009 but the impact of two major tropical cyclones (Larry and

Yasi) and severe floods in 2011 have led to losses in area and abundance particularly in the southern part of the state. Assessment of risk to seagrass from cumulative threats in the GBR (Grech et al. 2011) identified agricultural runoff as the major threat to seagrass health followed in order by urban/industrial runoff, urban/port infrastructure development, dredging, and shipping accidents (Table 1).

For the Indo-Pacific region (Short et al. 2007) seagrass maps were compiled through expert workshops (Green and Short 2003) and change monitored through global monitoring programs (www.seagrasswatch.org). A vulnerability assessment similar to that conducted by Grech et al. (2011) has identified urban industrial runoff as the major risk in the region followed in order by urban/port infrastructure development, dredging, trawling, and aquaculture.

The GBR seagrass meadows were first surveyed and mapped in the mid 1980s and because of the importance of the regions environment, mapping, monitoring and research has been continuous in some form to the present time. This has provided a valuable management tool with information layered through time. The key driver of this program has been the need for detailed coastal management and planning advice to protect and manage the seagrass resource. Major initiatives such as the Seagrass-Watch and associated Reef Rescue Marine Monitoring Program (www.seagrasswatch.org; McKenzie et al. 2012) and data collected as part of industrial port monitoring (Coles et al. 2007), now provide long-term data sets for trend information. This knowledge base also extends to our neighboring Indo-Pacific region through local collaborations (Seagrass-Watch and SeagrassNet programs) (Coles and Fortes 2001, Coles et al. 2002a, Coles et al. 2002b, Freeman et al. 2008) although the regional knowledge is far less precise than that available for the GBR.

Table 1 Status of seagrass within each NRM region habitat on the East Coast of Queensland in 2009 and 2011. Trend is visually assessed 5 year trajectory *(>20% difference between sampling events)*.

Watershed/NRM	Major threats to seagrass	Habitat	Status 2009 (from McKenzie et al. 2010)	Status 2011
Torres Strait	Agricultural runoff (from PNG) Trawling Shipping accidents (e.g. oil spills)	Estuary	*unknown*	*data deficient*
		Coastal	Stable/increasing	Stable/increasing
		Reef	Stable increasing	Stable/increasing
Cape York	Shipping accidents (e.g. oil spills)	Estuary	Variable/uncertain	*data deficient*
		Coastal	Variable/uncertain	Variable/uncertain
		Reef	Stable/increasing	Variable/uncertain
Wet Tropics	Agricultural runoff Urban/industrial runoff Urban/port infrastructure development Dredging Shipping accidents (e.g. oil spills)	Estuary	Stable/increasing	Decreasing
		Coastal	Stable/increasing	Decreasing
		Reef	Stable/increasing	Stable/decreasing
Burdekin Dry Tropics	Agricultural runoff Urban/industrial runoff Urban/port infrastructure development Dredging Shipping accidents (e.g. oil spills)	Estuary	Decreasing	Decreasing
		Coastal	Decreasing	Decreasing
		Reef	Decreasing	Decreasing
Mackay/ Whitsunday	Agricultural runoff Urban/industrial runoff Urban/port infrastructure development Dredging Shipping accidents (e.g. oil spills)	Estuary	Decreasing	Decreasing
		Coastal	Stable/increasing	Decreasing
		Reef	Stable/increasing	Decreasing
Fitzroy	Agricultural runoff Urban/industrial runoff Urban/port infrastructure development Dredging Shipping accidents (e.g. oil spills)	Estuary	Variable/uncertain	Variable
		Coastal	Stable/increasing	Decreasing
		Reef	Variable/uncertain	Decreasing
Burnett/ Mary	Agricultural runoff Urban/industrial runoff Urban/port infrastructure development Shipping accidents (e.g. oil spills) Trawling	Estuary	Stable/increasing	Decreasing
		Coastal	Variable/uncertain	Variable
South East Queensland	Urban/industrial runoff Urban/port infrastructure development Agricultural runoff Dredging Shipping accidents (e.g. oil spills) Trawling	Estuary	Stable/increasing	Variable
		Coastal	Stable/increasing	Variable

While the maps are an invaluable baseline for coastal management and marine planning decisions (they underpin Dugong (*Dugong dugon*) management plans and marine conservation park zoning) they represent only a first step in advice to management. The multiple approaches we have taken, (modelling the probability of seagrass presence (Grech and Coles 2010), identifying and prioritising risks and where those risks accumulate (Grech et al. 2011), following long term trends in components of seagrass meadow health (McKenzie et al. 2012), and better understanding seagrass ecosystems) add levels of confidence and precision to our advice. This approach has also allowed us to generalize from local estuaries and ports scales to regional level scales.

In this short paper it is only possible to give an overview of our understanding but consensus from our research is explicit for some concepts:

1) The leading threats to coastal seagrass in the GBR and Indo-Pacific region are terrestrial based and can only be addressed by intervention in land management approaches, watershed management and coastal planning;

2) There is clear regional subscale variation. In the GBR recent declines in seagrass abundance (McKenzie et al. 2012) have occurred only along the urban coast (southern half of the GBR) most likely from a combination of land use effects and La Niña triggered weather events in that region. Understanding how risk to seagrass is distributed (Grech et al. 2011) and how that may interact with natural events is vital in predicting a response from seagrass systems.

3) Agricultural runoff, seen as most important threat to seagrass in the GBR, is not ranked in the top five threats in the wider Indo-Pacific (Coles et al. 2011). The industrial/intensive coastal agriculture adjacent to the GBR and associated threats to seagrass meadows is not replicated in our neighboring countries where activities such as aquaculture are ranked higher. Concepts and approaches to managing seagrass issues developed for one country may not be appropriate in another; and

4) There is little consensus in risk surveys (Coles et al. 2011) on the likely impact to seagrass of climate change – there is likely to be variable impacts dependent on location. An increased probability of severe tropical cyclones ranked in the top six threats for the Indo-Pacific region, the only climate change parameter of real concern.

As human populations living along coastlines increase and we confront a massive need for urban and agricultural expansion and infrastructure development our view is that a coordinated regional approach to seagrass conservation including land and sea management approaches will be needed. It is also evident from our work that the concept of scale is poorly understood by decision makers and poorly integrated in management processes. Often enormous effort is expended in environmental research and monitoring at the scale of marina or port development and its associated footprint. This level of concern is not replicated when considering the expansion of city suburbs and the development of new intensive agriculture areas –more diffuse threats to seagrass but with the potential to impact at very large scales and over long time frames.

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References

Coles RG, Fortes MD (2001) Seagrass Protection Policy. In: Short FT and Coles RG (eds) (2001) Global Seagrass Research Methods. Elsevier Science BV, Amsterdam pp445-464

Coles RG, McKenzie LJ, Campbell SJ (2002a) The seagrasses of eastern Australia. In: Green EP, Short FT, Spalding MD (eds) The World Atlas of Seagrasses: present status and future conservation University of California Press, Ch 11, pp 131-147

Coles RG, McKenzie LJ, Campbell SJ, Fortes M, Short FT (2002b) The seagrasses of the Western Pacific Islands. In: Green EP, Short FT, Spalding MD (eds) The World Atlas of Seagrasses: present status and future conservation University of California Press, Ch 15, pp 161-170

Coles RG, McKenzie LJ, Rasheed M , Mellors JE, Taylor H, Dew K McKenna S, Sankey TL, Carter AB, Grech A (2007) Status and Trends of Seagrass Habitats in the Great Barrier Reef World Heritage Area. Report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Limited, Cairns 122 pp

Coles R, McKenzie L, De'ath G, Roelofs AJ, Lee Long W (2009) Spatial distribution of deepwater seagrass in the inter-reef lagoon of the Great Barrier Reef World Heritage Area. Mar Ecol Prog Ser 392:57-68

Coles RG, Grech A, McKenzie L, Rasheed M (2011) Evaluating risk to seagrass in the tropical Indo-Pacific region. 21st Biennial Conference of the Coastal and Estuarine Research Federation, Daytona Beach Florida 2011

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill R, Paruelo J, Raskin R, Sutton P, van den Belt M (1997) The value of the world's ecosystem services and natural capital. Nature 387:253-260

Duarte C (2002) The future of seagrass meadows. Environ Conserv. 29(2):192-206

Freeman AS, Short FT, Isnain I, Razak FA, Coles RG (2008) Seagrass on the edge: Land-use practices threaten coastal seagrass communities in Sabah, Malaysia. Biol Conserv 141:2993-3005

Grech A, Coles RG (2010) An ecosystem-scale predictive model of coastal seagrass distribution. Aquat Conserv 20:437-444.

Grech A, Coles RG, Marsh H (2011) A broad-scale assessment of the risk to coastal seagrasses from cumulative threats. Mar Pol 35(5):560_567

Green EP, Short FT (2003) World Atlas of Seagrasses. UNEP World Conservation Monitoring Centre. University of California Press, Berkeley. USA

McKenzie L, Yoshida R, Grech A, Coles R (2010) Queensland Seagrasses: Status 2010 - Torres Strait and East coast. Fisheries Queensland DEEDI, Cairns. 6pp

McKenzie LJ, Collier C, Waycott M (2012) Reef Rescue Marine Monitoring Program: Nearshore Seagrass, Annual Report for the sampling period 1st July 2010 – 31st May 2011. Fisheries Queensland, Cairns. 177pp

Orth R, Carruthers T. Dennison W, Duarte C, Fourqurean J, Heck K, Hughes A, Kendrick G, Kenworthy W, Olyarnik S, Short F, Waycott M, Williams S (2006) A global crisis for seagrass ecosystems. BioScience. 56(12):987-996

Hughes R, A., Williams S, Duarte C., Heck K, Waycott M (2009) Associations of concern: declining seagrasses and threatened dependent species. Front Ecol Environ. 7(5):242-246.

Short F, Carruthers T, Dennison W. and Waycott, M (2007) Global seagrass distribution and diversity: a bioregional model. J Exp Mar Biol Ecol 350:3-20

Short F, Polidor B, Livingstone S, Carpenter K, Bandeira S, Bujang J, Calumpong H, Carruthers T, Coles R, Dennison W, Erftemeijer P, Fortes M, Freeman A, Jagtap T, Kamal A, Kendrick G. Kenworthy J, Nafie Y, Nasution I, Orth R, Prathe A, Sanciangco J, van Tussenbroek B, Vergara S, Waycott M, Zieman J (2011) Extinction risk assessment of the world's seagrass species. Biol Conserv 144(7):1961-1971

Unsworth KF, Cullen LC, (2010) Recognizing the necessity for Indo-Pacific seagrass conservation. Conserv Letters 3(2):63-73

Waycott M, Duarte C, Carruthers, T, Orth R, Dennison W, Olyarnik S, Calladine A, Fourqurean J, Heck K, Hughes A, Kendrick G, Kenworthy W, Short F, Williams S (2009) Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proc Natl Acad Sci USA 106(30):12377-12381