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Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait 1999

Implications for dugong, turtle and fisheries management

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The Department of Primary Industries, Queensland has taken all reasonable steps to ensure the information contained in this publication is accurate at the time of the survey. Seagrass distribution and abundance can change seasonally and between years, and readers should ensure that they make appropriate enquires to determine whether new information is available on the particular subject matter.

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EXECUTIVE SUMMARY

1. The Mary River flood of February 1999 had the greatest adverse effect on the intertidal and shallow subtidal seagrasses in the Great Sandy Strait and Hervey Bay that were in the path of the flood plume.

2. Approximately 50% of intertidal seagrasses in the Great Sandy Strait disappeared after the February 1999 flooding of the Mary River. These losses were predominantly in the northern section of the Strait (including Urangan, Moon Point, down to Ungowa). The only other section of the Great Sandy Strait where seagrass disappeared or changed significantly is on the bank between the mouth of Kauri Creek and Tin Can Inlet. Seagrasses in the central section of the Strait (Maaroom, Poona, Boonooroo) were relatively unchanged.

3. Shallow sub-tidal (2–10 m depth below MSL) seagrass resources of Hervey Bay (adjacent to the City of Hervey Bay) declined dramatically in abundance and distribution since the Mary River flood of mid February 1999. Seagrass had completely disappeared by November 1999 within the shallow sub-tidal monitoring area, declining from 23.24 ±5.05 grams Dry Weight (DW) m^{-2} above-ground abundance in December 1998. A spot check of seagrasses in February 2000 (one year after the flood) found no evidence of recovery of seagrasses in shallow sub-tidal waters in the path of the plume.

4. Deepwater seagrass resources in Hervey Bay within the path of the flood plume declined significantly in abundance six months after the impact and remained significantly lower than outside the impact area after nine months. Floating and attached filamentous red and green algae was abundant at all deepwater sites in November 1999 (9 months after the flood). The impact area is likely to recover by spring 2000 if there are no further impacts (eg., another flood event or prolonged high nutrient loading).

5. Filamentous red algae were persistent and may be due to the unusually high nutrient loads in Hervey Bay waters and sediments after the flood. It is unknown what consequences the algae may have on the seagrass resources of the bay should they continue to persist.

6. Due to the decreases in seagrass resources in the region, dugong populations may be restricted to the central and southern sections of the Great Sandy Strait, the deepwaters of Hervey Bay or the intertidal/shallow subtidal localities in the south-east corner of Hervey Bay. Sufficient seagrass resources still remain to support the current populations, although some individuals may experience stress due to accessibility of food (ie. a result of boat activity, deep waters, *etc*).

7. Effects on fisheries of the region may not be severe, as the main recruitment areas in the Great Sandy Strait were not severely effected. Chronic water quality impacts in the adjacent watersheds are however, some cause for concern.

INTRODUCTION

The Environmental Protection Agency/Queensland Parks and Wildlife Service (EPA/QPWS) recommended undertaking seagrass-monitoring after flooding from the Mary River during mid February 1999 caused a large freshwater turbid plume to extend into the waters of Hervey Bay. Previous flooding and cyclone events in 1992 destroyed approximately 1000 km^2 of intertidal, shallow sub-tidal and deepwater seagrasses in Hervey Bay (Preen *et al.* 1995). These seagrass resources and took up to four years to recover. The loss of seagrass had a direct detrimental effect on the local dugong population, which fell from approximately 2000 to 200 individuals, through starvation and emigration (Preen and Marsh 1995).

This report presents the results of the three post-flood surveys conducted in April 1999, August 1999 and November 1999. The objectives were:

1. To monitor impacts on seagrasses within Hervey Bay following major flooding of the Mary River catchment;
2. To produce a detailed GIS on the results of seagrass monitoring;
3. To assess changes in seagrass biomass and species composition since recent detailed surveys were conducted prior to flooding;
4. Provide comments on seagrass survival and recovery relevant to fisheries, dugong and turtle population management.

General Seagrass Ecology

Seagrasses are important nursery habitat for commercial species of penaeid prawns and fish (Coles and Lee Long 1985; Coles *et al*. 1993; Watson *et al*. 1993). Seagrass meadows in Queensland are also essential food for dugong, *Dugong dugon* (Miller) and green sea turtles, *Chelonia mydas* (Linnaeus) (Lanyon *et al.* 1989). Intertidal seagrasses also provide important habitat for wading birds. Seagrasses in coastal regions are important for maintaining water quality and for buffering nutrient and sediment loads from land; helping to stabilise sediments and assimilate nutrients (Short 1987). Seagrasses are an important source of primary carbon production in food chains and are very important in coastal systems. They establish detrital-based food chains (which are the basis for fisheries productivity for target commercial and recreational fish species) and herbivore-based food chains (which are critical to dugongs and green sea turtles). Coastal seagrass meadows are therefore an important resource economically and ecologically.

Natural seasonal variation in seagrass biomass has been documented (McKenzie 1994) and more recent detailed surveys have indicated some large long-term changes in seagrass distribution at regional scales (Lee Long *et al*. 1998). The causes and scale of these long-term changes, and their ecological consequences for faunal populations of fisheries and conservation value, are poorly understood.

The potential for widespread seagrass loss has been well documented and the causes of loss can be natural, such as cyclones and floods (Poiner *et al.* 1989), due to human influences such as agricultural runoff (Preen *et al*. 1995), industrial runoff (Shepherd *et al*. 1989), oil spills (Jackson *et al.* 1989), harbour dredging (Onuf 1994), or any combination of these (Pringle 1989).

Hervey Bay & Great Sandy Strait dugongs & marine turtles

Large numbers of dugongs and turtles inhabit Hervey Bay and the Great Sandy Strait.

Dugongs are marine mammals of the order Sirenia. They look similar to a rotund dolphin or seal, although they are less streamlined. Despite their appearance, dugongs and their relative (manatees) are more closely related to elephants than to other marine mammals. Dugongs have a life span of about 70 years and an adult can grow to lengths greater than 3 m and weigh in excess of 400 kg (Marsh *et al.* 1999). Females (cows) have their first calf between 10 and 17 years. Calves are born singly between September and November, with an interval of 3 to 7 years between each calf being born. Calving occurs in specialised areas: often shallow waters removed from seagrass meadows. The gestation period is 13 months, and calves suckle for 18 months. During this time there is a strong bond between the cow and calf.

Dugongs are the only strictly marine herbivores, feeding almost exclusively on seagrasses. Dugongs prefer seagrasses that are lower seral or "pioneer" species (Preen 1995a, 1995b), especially species of the genus *Halophila* and *Halodule*. This selection is based on the chemical and structural composition of seagrass as the most frequently selected species are lower in fibre and higher in available nitrogen (*Halodule*) and digestibility (*Halophila*) (Lanyon 1991)

Dugongs have a wide geographical distribution in shallow tropical and subtropical waters of the Indo-Pacific Region. Their range includes waters of 43 different countries, extending from eastern Africa to Vanuatu and between 27° north and south of the equator (Marsh *et al.* 1999). Many dugong populations however, are relict or extinct. In Australia, their range is from Shark Bay in Western Australia, across the north to Moreton Bay, southeastern Queensland. There are an estimated 85,000 dugongs in Australian waters (Marsh *et al.* 1999).

Prior to 1992, Hervey Bay and the Great Sandy Strait supported an estimated 1753 ±388 dugongs, one of the largest dugong populations in eastern Queensland. Widespread loss of *Halophila* and *Halodule* in Hervey Bay after a cyclone and prolonged flooding in 1992 almost decimated the local dugong population to ~71 ±40 individuals (Preen *et al.* 1995; Preen & Marsh 1995). Some individuals successfully relocated to other localities but others died 6-8 months after the flood. A total of 99 dugong carcasses (emaciated from starvation) were recovered. In December 1993, the population had recovered to an estimated 600 ±126 individuals (Preen & Marsh 1995) and in November 1994 had continued to recover to ~807 ±151 individuals (Marsh *et al.* 1999). A recent survey of dugong numbers in the region was conducted in November 1999, however final results are still pending (H. Marsh, JCU, Pers. Comm.)

Worldwide the dugong is listed in the 1990 IUCN Red List of Threatened Animal as being *vulnerable* to extinction. The species is likely to move into the endangered category in the near future if the factors causing declines continue.

Dramatic declines in dugong populations in the southern Great Barrier Reef Marine Park and in Hervey Bay since 1987 prompted a November 1996 meeting of the Great Barrier Reef Ministerial Council to declare the need for emergency action to save dugong in the GBR. An outcome was to establish a two-tiered system of Dugong Protection Areas (DPAs) within the Great Barrier Reef region in which gill- and mesh-netting was either restricted/banned or modified. This was because the council deemed incidental catch in commercial nets to be a major threat to dugong populations. They also acknowledged that one of the other reasons for the decline in dugong numbers may be habitat loss.

A DPA of 1703 km^2 in which gill- and mesh-netting practices were modified rather than banned, was established in the southern part of Hervey Bay and the Great Sandy Strait in

January 1998. Marsh *et al.* (1999) implied however, that this DPA would be less effective and harder to enforce.

Marine turtles are reptiles of the order Testudines. Six species are found in eastern Queensland waters, five in Hervey Bay (green, loggerhead, hawksbill, flatback and leatherback) and four are common in the Great Sandy Strait (green, loggerhead, hawksbill and a few flatback) (S. Winderlich, QPWS Maryborough, Pers. Comm.). Of the six species, the green turtle (*Chelonia mydas*) is the only marine turtle that feed principally on seagrasses. Greens are large turtles that have a worldwide distribution in tropical and subtropical waters, inhabiting tidal and subtidal habitats including coral and rocky reefs, seagrass meadows and algal turfs on sand and mud flats. Greens are common in Queensland waters and there are two genetically distinct breeding populations - the northern and southern. As with most species of marine turtles, greens may take between 30 to 50 years to reach maturity.

Most species of marine turtles are listed as being *endangered.* The Wongarra Maine Park in the north-western section of Hervey Bay (Elliot Heads to South Head of Burnett River, including Mon Repos) was established in recognition of the importance of this region as turtle habitat.

Present day dugong and turtle populations face numerous impacts that contribute to a decline in numbers. Factors identified as currently posing a real or potential risk to populations include (in no particular order): boat traffic, pollution, coastal development, traditional hunting, commercial gill netting, habitat degradation, disturbance of nesting sites, commercial trawling, terrestrial practices and run-off, natural impacts including tropical cyclones, floods, storms and predators. For turtle and dugong populations to exist in a healthy state, these impacts must be effectively managed and where possible, prevented altogether.

Hervey Bay & Great Sandy Strait fisheries resources

The Hervey Bay and Great Sandy Strait region is one of the most productive fishing regions of Queensland. The fisheries resources of the region support an important trawl fishery for prawns and scallops and there is a large recreational fishery for whiting and other estuarine as well as various pelagics and some reef fish (Hyland 1993). The Hervey Bay and Great Sandy Strait region is second only to Moreton Bay as a destination for recreational fishers (Moore 1986).

The fisheries resources of Hervey Bay and the Great Sandy Strait include a wide variety of species which are caught by a range of fishing methods. More than 40 species of finfish and 10 species of crustaceans are commonly caught in a variety of habitats including estuaries, foreshores, reefs and bays (Hyland 1993). Fishing methods include trawling, potting, line fishing, gill netting, beach seining, set netting and drift netting.

A fishery for a complex of small prawns including greasyback prawns (*Metapenaeus ensis*), juvenile eastern king prawns (*Penaeus plebejus*), and less common species including hardback prawns (*Trachypenaeus* spp.) takes place in the estuarine and coastal waters of southern Hervey Bay, which supplies local markets with cooked prawns and bait for recreational use (Williams 1997). The fishery occurs in water depths less than 25 m. There are four components to the prawn fishery in Hervey Bay. These are the offshore otter trawl fishery, the inshore otter trawl fishery, the river beam trawl fishery and the stripe net fishery. Extensive management arrangements exist for the prawn fisheries in this region.

An important and variable scallop (*Asmusium* spp.) trawl fishery exists in the northern part of Hervey Bay. The scallop fishery supports an important export market with 90% of landings being exported (Hyland 1993). These trawl fisheries are managed as part of the

East Coast Trawl Fishery. Statewide annual catches of scallops have shown variability, but have no consistent trends.

A set net fishery for banana prawns occurs in the Mary River and contributes to an average annual catch of 50 t (Williams 1997). A major trawl fishery for banana prawns exist just north of Hervey Bay between Yeppoon and Baffle Creek. Other smaller fisheries for pelagic fish, reef fish, squid, bugs, spanner crabs and bait exit within the region.

The Great Sandy Strait provides an important habitat for a wide variety of estuarine finfish. Both recreational and commercial fishers target these. The commercial catch of estuarine fish is predominantly mullet, taken in rivers by general purpose net and along foreshore by beach seines. These fishing methods also take whiting, yellowfin bream, gar and dusky flathead. Commercial fishers may also use gill- or mesh-nets, baits nets or tunnel nets. Tunnel netting however, is limited and more common in Tin Can Inlet. Juvenile yellowfin bream occur in areas associated with seagrass and mangroves in estuaries. Dusky flathead are also dependent on estuarine and inshore coastal habitat throughout their lifecycle.

The marine plant habitats of the Great Sandy Strait are also considered to support a major trawl fishery for eastern king prawn (*Penaeus plebejus*) that produces 100t per year (Trainor 1990). Eastern king prawns recruit into shallow embayments and prefer seagrass habitats and the bare sandy substrates interspersed within them (Halliday 1995). There appears however, some confusion in the literature concerning the importance of seagrass habitats to eastern king prawn recruits. The earlier work by Young (1978) and Young & Carpenter (1977) in Moreton Bay gave some conflicting results in regard to the catch rates of juvenile and postlarval *P. plebejus* over seagrass and bare substrate. In one of their papers they conclude there were no significant differences between seagrass and bare substrate, however in another paper they conclude there was a difference. Other researchers do not consider seagrasses to be a major factor explaining the spatial distribution of postlarval and juvenile *P. plebejus* (unlike *P. esculentus*). *P. plebejus* are highly migratory, even from a young age, and occur in shallow waters that have low freshwater influence that offer shelter from strong currents and that the presence/absence of vegetation has less significance in determining their distribution (T Coutney, QDPI., Pers. Comm.).

The fishing grounds off Tin Can Bay have over time however, shown an appreciable decline in catch rates (Williams 1997). Corroborative fishery-independent survey data from Moreton Bay supports the belief that recruitment levels in this region have declined since the 1970s.

A smaller fishery in the Great Sandy Strait is inshore whiting (summer and winter varieties). Bay prawn trawlers also take winter whiting in commercial quantities as a byproduct. Although much of the statewide commercial catch is taken from Moreton Bay, a significant amount is taken from Hervey Bay. By comparison, most of the commercial summer whiting catch is taken by either seine or mesh net fishing operations, along sandy foreshores in the Great Sandy Strait. Juvenile and adolescent sand whiting prefer shallow waters over seagrass meadows and in mangroves.

A small declining snapper hook and line fishery occurs in the offshore reef region adjacent to Tin Can Bay. Statewide, the recreational catch is estimated to be several times larger than the commercial catch. Juvenile snapper are most abundant in seagrass meadows and also associated with reef and gravel areas.

The Great Sandy Strait is also one of the principal harvest locations for mud crab (*Scylla serrata*) in Queensland (Williams 1997). Juveniles and adults inhabit the same habitat within sheltered estuaries, the tidal reaches of mangrove lined rivers and streams, intertidal seagrass meadows and mangrove forests.

Several oyster leases also occur within the Great Sandy Strait. These leases produce only a small quantity of oysters and generally not considered as full time oyster culture operations.

General controls, which relate to both commercial and recreational fisheries, include size limits, closed areas, seasonal closures (spanner crabs and barramundi) and protection of certain species. Commercial fishers are also subject to weekend closures in certain areas.

There are 6 Fish Habitat Areas in the Hervey Bay and Great Sandy Strait region, totalling 38,960 ha (Beumer *et al.* 1997). Fish Habitat Areas have been declared to enhance existing and future fishing activities and to protect the habitat upon which fish and other aquatic fauna depend (Zeller 1998). Declared Fish Habitat Areas protect critical wetland habitats sustaining the fish and invertebrate stocks upon which recreational, commercial and indigenous fishing practices depend. It is of vital importance that the character and structure of the physical environment and the chemical environment remain unaltered by human impacts for continued fisheries productivity.

Hervey Bay & Great Sandy Strait seagrasses

Seagrass meadows in Hervey Bay and the Great Sandy Strait are one of the largest single areas of seagrass resources on the eastern Australian seaboard. Seagrasses are a major component of the Hervey Bay and Great Sandy Strait marine ecosystems and their contribution to the total primary carbon production is the basis for such regionally important dugong and turtle populations and productive fisheries.

Seagrasses in Hervey Bay were first mapped during a broad-scale survey between Water Park Point and Hervey Bay in October and November 1988 (Lee Long *et al.* 1992). Seagrass distribution was estimated to be a least 1026.34 km^2 (Lee Long *et al.* 1993) and mainly in large, dense meadows in the southern and western parts of the bay, extending from intertidal areas to 25 m depths in the centre of the bay.

Approximately 1000 km^2 of seagrasses in Hervey Bay was lost after two major floods and a cyclone within a 3 week period in 1992 (Preen *et al*. 1995). The deeper water seagrasses died, apparently as a result of light deprivation caused by a persistent plume of turbid water that resulted from the floods and the resuspension of sediments caused by the cyclonic seas. The heavy seas uprooted shallow water and intertidal seagrasses.

Recovery of sub-tidal seagrasses (at depths >5m) began within two years of the initial loss (Preen *et al*. 1995), but recovery of inter-tidal seagrasses was much slower and only appeared evident after 4-5 years (J. Comans, HBDSMP, Pers Comm). The seagrasses appeared to be fully recovered in December 1998 (McKenzie 2000).

In December 1998 a detailed dive and remote camera survey of Hervey Bay and the Great Sandy Strait estimated 2,307 ±279 km^2 of seagrass existed in Hervey Bay (McKenzie 2000). Seagrass meadows extended from the intertidal and shallow subtidal waters to a depth of 32 m. The dominant (43%) deep water (>10 m) meadows in the southern section of Hervey Bay were large continuous meadows of medium-high biomass *Halophila spinulosa* with *Halophila ovalis* (high cover of drift algae).

The south eastern section of the bay was generally barren substrate with isolated patches of *Halophila spinulosa/ H. ovalis/ H. decipiens*. In the south western section of the bay however, the subtidal seagrass meadows were generally patchy, medium to high biomass, *H. spinulosa* with *H. ovalis/H. decipiens* on sand down to 15 m. The shallow subtidal Dayman Bank, extending from near Urangan out to near the fairway buoy, was covered with low biomass *H. spinulosa/ H. decipiens*.

Seagrass meadows were also present on the intertidal sand banks between Burrum Heads and Eli Creek (Point Vernon). These meadows were generally low biomass *Zostera capricorni*, or *Halodule uninervis*, with *H. ovalis*. A narrow intertidal band of sparse (1-10% cover) *Z. capricorni* with *H. ovalis* was also present on the sand banks adjacent to the Esplanade from Pialba to Torquay.

Seagrass beds are a major marine habitat of the Great Sandy Strait. A major population of dugong and green sea turtles are dependent on these meadows. Coastal meadows also are important nursery habitat to juvenile fish and prawns, and provide important habitat for wading birds. The area and density of seagrass meadows in the strait changes seasonally and periodically (Conacher *et al*. 1999).

Seagrass distribution was first mapped in the Great Sandy Strait in July/December 1973 (Dredge *et al.* 1977). Seagrass was found south of the co-tidal line, which occurs at Moonboom Islands (25°20' S) and within Tin Can Inlet. No seagrass was found north of the co-tidal line. Aerial photographs and ground truthing at 25 locations, were used to map an area of seagrass covering >4,800 hectares (~5,232 hectares digitised from Fig 2 in Dredge *et al.* (1977)). There were six species of seagrass within the study area, although the total extent of the subtidal *Halophila spinulosa* meadows could not be estimated.

Lennon & Luck (1990) estimated that the Great Sandy Strait had approximately 12,300 hectares of seagrass covering extensive intertidal and subtidal areas. This estimate is based on remote sensing analysis and may have overestimated the intertidal (confused with algae) and underestimated the subtidal (high turbidity) seagrass habitat.

In October-November 1992 an aerial photographic survey of the Strait was conducted and significant decreases were reported in Tin Can Inlet (Fisheries Research Consultants 1993). Increases in seagrass distribution however, was reported in the northern section of the Strait, between River Heads and Urangan, and Blackfellow's Point and Moon Point. Seagrass community changes were also reported, especially in the dense monspecific *Cymodoea serrulata* meadow off Kauri Creek, which changed to sparse *C. serrulata* subtidally and *Z. capricorni* intertidally.

In 1994, a broad scale survey of the Great Sandy Strait was conducted (mainly by air) which estimated approximately 6,630 ha of seagrass meadows (Fisheries Research Consultants 1994a). An increase in distribution was reported in the central and northern sections of the Strait. Meadows south of Urangan, and between Maaroom and Tinnanbar, increased in area and density. Decreases in distribution were reported to be continuing in the Tin Can Inlet section.

In June 1994, long-term monitoring transects were established throughout the Great Sandy Strait, to determine any changes in seagrass presence and depth profiles. Resurveys were conducted in March 1995, November 1996, February 1998, September 1998 and February 1999. Large decreases in seagrass distribution were recorded in 1996 and recovery to the most recent resurvey was still low (Conacher *et al.* 1999).

In December 1998 a detailed dive survey of the Great Sandy Strait was conducted which estimated 5,554 ±1,446 ha of seagrass habitat (McKenzie 2000). Seven species of seagrass were present in the Great Sandy Strait (*Zostera capricorni, Halodule uninervis, Halophila ovalis, Halophila decipiens, Halophila spinulosa*, *Cymodocea serrulata* and *Syringodium isoetifolium*). Most of the meadows throughout the Great Sandy Strait were intertidal on large mud- and sand-banks, and were predominantly in the northern and central sections.

In the north, dense *Zostera capricorni* with *Halophila ovalis* (mud/sandy) were present on mud/sand banks. Smaller low to medium biomass *Zostera capricorni* meadows and medium biomass *Halophila spinulosa* meadows were present between Mangrove Point and Big Woody Island on the large sand banks and in some gutters, respectively.

In the central section of the Strait, meadows dominated by *Zostera capricorni* with *Halophila ovalis* covered much of the intertidal banks surrounding the mangrove islands. Similar *Zostera capricorni* dominated meadows, but of lower biomass were present on the large intertidal banks surrounding the villages of Poona and Boonooroo.

In the southern section of the Strait, large meadows were present on the intertidal and shallow subtidal banks, but did not extend into Tin Can Inlet past Eudlo Point. Most meadows were dominated by *Zostera capricorni* with the exception of Kauri Creek bank which was dominated by *Cymodocea serrulata*.

Subtidal meadows contributed to only 5% (256 ±105 ha) of the total seagrass distribution of the Great Sandy Strait. Subtidal meadows were mostly in the northern and southern sections of the Strait in narrow bands along the edge of intertidal banks, or extending across the large subtidal banks. Subtidal meadows were dominated by *Halophila* species (*H. spinulosa, H decipiens, H. ovalis*) or *Z. capricorni*. Algae were often mixed within the subtidal meadows with cover ranging between 5 and 40%.

It is difficult to identify accurately the extent of change in seagrass resources in the Strait, due to the significant errors in different mapping techniques and the extent of ground truthing in surveys prior to 1998.

↬ *Mary River flood*

In mid February 1999, the Mary River flooded into Hervey Bay and the Great Sandy Strait. Peaking at 8.75 m (*measured at Maryborough*), the flood was the fifth highest in the last 50 years, and ninth highest since reliable recordings were first made in 1870. The flood was only 0.75 m less than the February 1992 floods which, when combined with the effects of tropical cyclone “Fran”, caused devastating losses of seagrass resources within Hervey Bay. The 1999 flood produced a large freshwater plume of suspended sediments which extended 35 km north-west into Hervey Bay (QPWS, unpublished data 1999). Substantially reduced light conditions were logged by light meters at 4 sites (Ben Longstaff, UQ, Pers. Comm.) coinciding with the fairway buoys and lead markers (Map 1). Light conditions in the main plume were significantly reduced for 19 days before returning to pre-flood levels (Ben Longstaff, UQ, Pers. Comm.).

The purpose of the present study was to monitor any delayed impacts at key sites in the parts of Hervey Bay and Great Sandy Strait that were impacted by the flood plume. Three monitoring surveys were conducted at key sites to assess change in seagrass communities and abundance using a Geographic Information System (GIS) and statistical analyses. Post-flood monitoring data was compared with the data collected in the December 1998 (McKenzie 2000) survey.

METHODOLOGY

Description of study locality

Hervey Bay is one of the largest bays along the Queensland coast containing an area of 3,940 km^2 (Hyland 1993) (Figure 1). The bay itself is U-shaped and is open to the Coral Sea on the northern side, although it is partly protected from oceanic swells by the southern extension of the Great Barrier Reef (Beach Protection Authority, 1989). The bay is also protected by the World Heritage listed Fraser Island to the east, the largest sand island in the world. One-quarter of the bay is less than 10 m deep, half the bay is 10-20 m deep and less than 1% of the bay is over 30 m deep (Preen *et al*. 1995). Bottom sediments are primarily fluvial, with a high mud content in the south-west of the bay (Beach Protection Authority, 1989). Grain size and carbonate component increases towards the north-east.

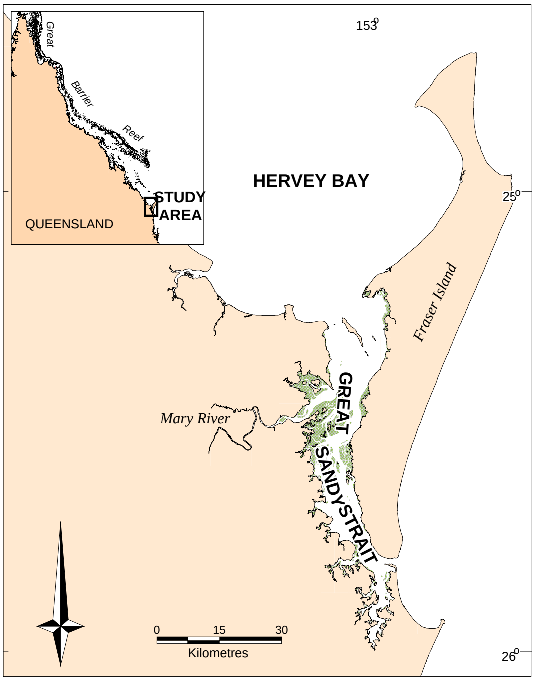


Figure 1. Location of Hervey Bay – Great Sandy Strait Region study area.

The Great Sandy Strait is a sand passage estuary between the mainland and Fraser Island and encompasses a area of approximately 93,160 hectares, making it the fifth largest enclosed embayment on Queensland's coastline. The region is defined in this report as south of a line between Moon Point and Dayman Point, to a line between Hook point and Inskip Point, and includes Tin Can Inlet (Map 2). The hinterland to the south and west of the strait is made up of two major drainage basins; these are the Tin Can watershed and the Boonooroo watershed (Dredge *et al*. 1977). The Tin Can watershed includes the watercourses of Teebar Creek, Snapper Creek and Kauri Creek (Map 2). The watershed is bounded by the Cooloola National Park to the east, which includes a significant sand mass of coastal dunes, and open layered woodland, sclerophyll woodland and heath to the west. The Boonooroo watershed extends north-south between Tinnanbar and Shoulder Point (south head of Mary River) and is characterised by broad ridges and low, gently undulating country covered with layered woodland (Dredge *et al*. 1977). This section of the Strait also has extensive mangrove wetlands. The major watercourse in this section includes Poona and Tuan Creeks, which drain from extensive pine plantations and agricultural lands. The eastern side of the Great Sandy Strait is bounded by Fraser Island, from which several small watersheds drain from the high sand dunes. There are several unsewered villages scattered along the shores throughout the Great Sandy Strait and the fishing port of Tin Can Bay township within Tin Can Inlet.

The Great Sandy Strait (including Tin Can Inlet) was listed as the 992nd Wetland of International Importance under the Ramsar agreement, in May 1999. The Strait includes the largest area of tidal swamps within the southeast Queensland bioregion, consisting of intertidal sand and mud flats, extended seagrass meadows, mangrove forests, salt flats/marshes, and often contiguous with freshwater *Melaleuca* wetlands and coastal wallum swamps. It is an exceptionally important feeding ground for migratory shorebirds and important for a wide range of other shorebirds, waterfowl and seabirds, marine fish, crustaceans, dugong, sea turtles and dolphin (Ramsar 1999).

The Mary River flows into the northern Great Sandy Strait before entering Hervey Bay from the south (Figure 1). It drains a catchment of 9600 km^2 and has a mean annual discharge of 2,300,000 megalitres (Ml). Land use practices in this catchment have resulted in problems due to flooding, severe stream-bank erosion and land degradation (Queensland Department of Primary Industries 1993).

The Mary River catchment has been extensively cleared for agriculture and the lower reaches of the Mary River are under significant pressure from grazing and agriculture (QDPI 1993). The main land use is dairying, beef grazing, with some area of sugarcane and agriculture in the lower catchment areas. Fertiliser use is relatively low (QDPI 1993). The State of the Rivers Report rates most of the streams in the Mary catchment as being in a moderate to poor overall condition, emphasising the erosion problems as well as the poor status of the riparian vegetation (Johnson 1997). Herbicide and insecticide concentrations present in the Mary River and in Hervey Bay sediments were measured between 1993 and 1996 (Anonymous 1996). Sediment and river water pollutant concentrations were below detection limits for most compounds. The herbicides 2,4-D and Triclopyr were detected at trace concentrations ($<0.2\ \mu g\ l^{-1}$).

The major urban development in the region is the City of Maryborough on the Mary River and the City of Hervey Bay, in the northern Great Sandy Strait and southern Hervey Bay. Although input of pollutants from the urbanisation would be expected, there is no data available.

Climate in the region is subtropical and coastal. Seasonal influences are derived from the tropical zone to the north, the temperate zone to the south and the thunderstorm breeding area to the south west (Dredge *et al*. 1977). Mean annual rainfall (from 127 years data) is 1166 mm for the region (Bureau of Meteorology 2000). Rainfall is greatest between December and March. Mean daily temperatures ranged from 15.2 to 26.9°C (87 years average), with January being the hottest month and July the coolest (Bureau of Meteorology 2000).

Survey strategy

Sites suitable for post-flood monitoring were selected from intertidal, shallow sub-tidal (2-10m below MSL) and deepwater (>10m below MSL) areas that had been mapped in the fine-scale survey 6–14th December 1998 (McKenzie 2000) (Maps 1 & 2). QPWS staff mapped the extent of the flood plume from fixed wing aircraft on the 12th February 1999 using GPS. The flood plume map was digitised and aided in the selection of suitable sites for monitoring. Sites within and outside the path of the plume were selected for monitoring.

Post-flood monitoring surveys were conducted in April 1999, August 1999 and November 1999. April and August are typically low seagrass growth periods, whereas November is usually a period of high seagrass growth. Sampling intensity was at a level required for assessing changes in seagrass species composition and biomass at a range of depths and in a range of seagrass community types.

An additional unplanned spot check of shallow sub-tidal monitoring sites was undertaken in February 2000 (one year after the flooding event). Sixteen shallow sub-tidal sites where seagrass was present in April 1999, were sampled in February 2000. While this data was insufficient for comparative analysis, it was used for interpretation and discussion.

Survey Methods

Three survey strategies were used to identify post-flood impacts on intertidal, shallow sub-tidal (2-10m below MSL) and deepwater (>10m below MSL) seagrasses:

1. Intertidal seagrass distribution pre- and post-flood was assessed using aerial photographs and helicopter reconnaissance (post-flood only). Substantial areas of intertidal seagrasses in the northern parts of the Great Sandy Strait (from Ungowa to Urangan - Moon Point) were in the path of the flood plume and these areas were the focus for measuring change after the flooding event (Map 2).

   A helicopter was used to conduct two aerial surveys of intertidal seagrasses on 15–16th April and 23-24th November 1999 (Map 2). During the flights, observers interpreted the distribution of seagrass onto survey charts and a Hi8 video camera was used to store a visual record for future reference and to aid interpretation when mapping on the GIS. Seagrass meadows were also haphazardly selected for ground truthing. At these meadows, sites were sampled approximately 150 m apart from the helicopter. At each site, a standard quadrat (0.25m^2) attached to a rope was haphazardly thrown within a 5 m radius while hovering (3 quadrats per site), to visually estimate seagrass abundance and seagrass species composition.

   Aerial photographs were sourced from the Beach Protection Authority Tweed Heads to Urangan and Maryborough photographic flight runs taken in 1994 and 1999. These photos were taken at low tide when intertidal areas were exposed and were easily interpreted for presence or absence of seagrasses.

2. Three shallow sub-tidal (2-10m bMSL) transects were surveyed by diver observations (free-diving) on the 15th April, 17th August, and 26th November 1999. Transects were selected from the December 1998 survey. The transects east of Point Vernon were shaded by the flood plume, while the transect to the west was partially shaded (distances >5 km offshore) (Map 1). Dive sites were distributed haphazardly along transects according to changes in depth and habitat type (approximately 500 m apart). Inshore survey transects extended from the upper intertidal reaches to approximately the 10 m (below MSL) depth contour (up to 7 km offshore) (Map 1).

3. Twelve deep-water sites (>10m) were surveyed using real-time towed video and a sled-net in a replicated asymmetrical BARI (Before, After, Reference, Impact) design. Five minutes of towed video footage was recorded for each site. Site locations were chosen from an array of sites sampled in December 1998 and represented locations inside and outside the flood plume area (Map 1). Sampling was conducted on the 14th April, 14th August and the 24-26th November 1999. Images were archived on VHS and DVCAM video tapes and visually compared with previous video records. Not all 12 sites in the original survey plan were visited on each sampling occasion due to availability of survey vessels.

   Researchers from the Marine Botany group, University of Queensland conducted post-flood sampling of light levels (PAR – Photosynthetically Available Radiation) and seagrass biomass (g DW m^{-2}) at four sites 18 km to 30 km north of the mouth of the Mary River (Map 1). Sampling was undertaken for nine weeks from 17th February until mid April 1999. Results from this study were used to assist with the interpretation of the results outlined in this report.

Data Collection

Seagrass habitat characteristics including above-ground seagrass biomass, species composition, % algae cover, sediment type, water depth and geographic location were recorded at each site.

Above-ground seagrass biomass was determined by a “visual estimates of biomass” technique modified from Mellors (1991). At each intertidal and shallow sub-tidal site, observers recorded an estimated rank of seagrass biomass and species composition in three replicates of a 0.25 m^2 quadrat per site. On completion of the survey, each observer ranked ten quadrats that were harvested and the above-ground dry biomass (g DW m^{-2}) measured. The regression curve representing the calibration of each observer's ranks was used to calculate above-ground biomass from all their estimated ranks during the survey. All observers had significant linear regressions ($r^2 > 0.85$) when calibrating above-ground biomass estimates against a set of harvested quadrats. Photographic examples of above-ground dry biomass (g DW m^{-2}) are included in Appendix 1.

Deepwater sites were checked for seagrass presence by replaying and examining the video tapes. Seagrass biomass estimates were based on 10 random time frames, at a one-second accuracy, allocated within the 5 minutes of footage for each site (within site variance was reduced by at least 50% with 10 replicates). Above-ground seagrass biomass was determined by a "visual estimates of biomass" technique modified from Mellors (1991). Seagrass species composition was also noted. The video was paused at each of the 10 random time frames selected. If the bottom was not visible the tape was advanced to the nearest point on the tape where the bottom was visible. From this frame an observer recorded an estimated rank of seagrass biomass and species composition. To standardise biomass estimates a 0.25 m^2 quadrat, scaled to the video camera lens used in the field, was superimposed on the screen. On completion of the videotape analysis, the video observer ranked five to ten additional quadrats that had been previously videoed for calibration. These quadrats were videoed in front of a stationary camera, and then harvested, dried and weighed. A regression curve was calculated for the relationship between the observer ranks and the actual harvested value. This curve was used to calculate above-ground biomass for all estimated ranks made from the survey sites. All observers had significant linear regressions ($r^2 = 0.98$) when calibrating aboveground biomass estimates against the harvested quadrats.

A second set of video images of quadrats that had been harvested, dried and weighed were used by the observers as a quick reference to minimise any drift in estimation over time during a series of video estimations. Sites that were used for biomass estimation were selected at random from the entire data set to limit the potential for bias through time.

Taxonomic specimens were collected from the towed dredge samples and by divers where ground truthing was undertaken. Seagrass species were identified according to taxonomic keys of Kuo and McCombe (1989) and Lanyon (1986). Seagrass voucher specimens for taxonomic use were lodged with the QDPI Northern Fisheries Centre Herbarium Collection. Seagrass identifications were made from video tape alone only where species were clearly identifiable.

Algae species were identified according to Cribb (1996) and percent cover of algae was estimated for each site.

Field descriptions of sediment type from video observations were recorded for each site: shell grit, rock gravel, coarse sand, sand, fine sand and mud.

Water depths of survey sites were recorded with an echo-sounder and converted to depths in metres (m) below mean sea level (bMSL), correct to tidal plane datum's (Queensland Department of Transport 1996) for the port of Urangan.

Geographic location of sampling sites (±5 m) was accurately determined by a differential Global Positioning System (dGPS).

Geographic Information Systems (GIS)

The GIS basemap of the study region including coastline, sandbanks, mangroves and islands was created by DPI (McKenzie 2000), using rectified aerial photographs, the Digital Cadastral Database (DCDB courtesy DNR) and AusLig© database (digitised at 1:250,000 scale).

A GIS of the intertidal, shallow sub-tidal and deepwater post-flood monitoring sites was created in MapInfo using the survey information. A CD Rom copy of the GIS with metadata was archived at EPA/QPWS Maryborough and the original archived with the custodians (DPI) at Northern Fisheries Centre.

Errors in GIS maps include those associated with digitising and rectifying basemaps and with Global Positioning System (GPS) fixes for survey sites. The point at which divers estimated bottom vegetation may be up to 5 m from the point at which a GPS fix was obtained. Differentially corrected GPS fixes were also only precise to within 5 m. These errors are considered to be within the errors associated with distance between survey sites.

In the Great Sandy Strait, each seagrass meadow was assigned a qualitative mapping value, determined by the data sources and likely accuracy of mapping. A rank system for mapping quality was used, based on the range of mapping information available for each area and associated estimates of reliability (R) in mapping meadow boundaries (Table 1). A mapping quality rank of 1 is the highest. Estimates of reliability in mapping meadow boundaries ranged from 7.5 m to 100 m.

Table 1. Ranks of mapping quality for seagrass meadows mapped in the Great Sandy Strait.

Map Quality	Data sets	Comments
1	Helicopter reconnaissance & aerial photos & ground truth (incl. dive survey)	Detailed checking of meadow boundary during dive surveys. Images and photos of high resolution. *Error = 7.5 to 15 m.*
2	Helicopter reconnaissance & aerial photos & ground truth (incl. dive survey)	Some meadow boundaries checked, and several transects during ground truth survey. Images and photos of high resolution *Error = 10 to 75 m.*
3	Helicopter reconnaissance & aerial photos & ground truth (incl. dive survey)	Occasional meadow boundary checked during dive surveys. Reasonable definition in images & photos. *Error = 15 to 100 m.*
4	Helicopter reconnaissance & dive survey	No image or photo available at required resolution. Some meadow boundaries checked during ground truth survey. High reliance on video from low level helicopter flight. *Error = 20 m.*
5	Dive survey only	Subtidal meadows not visible in remote-sensing images. Data densities generally low and reliant solely on dive survey. *Error = 30 m.*
6	Helicopter reconnaissance & aerial photos	Photos of suitable resolution. Meadow boundaries checked during ground truth survey. No dive survey. *Error = 25 to 100 m.*

Analysis

Data collected from the post-flood monitoring surveys was compared with the baseline survey undertaken in December 1998. Data recorded in the 1992/1993 and 1988 seagrass surveys (Preen *et al.* 1995) used percent cover of seagrass per quadrat and per site methodology and therefore cannot be used for direct comparisons to the post-flood monitoring results where estimates of above-ground biomass techniques were used.

Intertidal seagrass distribution was determined from the GIS (incl. Error) polygons using MapInfo© and compared against the previous December 1998 GIS baseline.

Aerial photographs of the intertidal areas of Moon Point, Urangan and Tin Can Inlet were scanned and rectified as a layer in the GIS and visually compared for the extent of seagrass before and after the flood.

Biomass estimated from the ground truthed seagrass meadows examined in the helicopter flights over the intertidal seagrasses in the Great Sandy Strait were pooled for individuals meadows. The Hi8 video of the helicopter flight was archived at the Northern Fisheries Centre, Cairns.

Transects were used to determine whether seagrass presence and abundance was changing with depth distribution in the shallow sub-tidal habitats (2-10m bMSL). Transects were also positioned so as to give an indication of changes in seagrass habitats within and outside the main flood plume. To represent the shallow sub-tidal region in southern Hervey Bay, sites were pooled across transects and an average above-ground seagrass biomass g DW m^{-2} was calculated for each monitoring event (Table 2).

Changes in above-ground seagrass biomass at deep-water sites (>10m) was analysed in a BARI design (*cf*. BACI) using standard parametric tests (Sokal and Rolf 1987). Deepwater survey data from December 1998 was used as the 'Before' impact level. ANOVAs were performed using Statistix for Windows . Only sites within similar seagrass communities were compared statistically. Six of the thirteen sites surveyed were used in the analysis. Four 'impact' sites (D53, D56, D58, and D59) were included from inside the defined flood plume area and two 'reference' sites (D41, D51) were from outside the plume (Map 9). These sites were all similar in habitat type and seagrass abundances when surveyed in December 1998. The other seven sites were excluded from the analysis due to their different habitat types and seagrass species composition, and were used to assist with overall interpretation of results.

RESULTS

Intertidal Seagrasses of the Great Sandy Strait

The area of intertidal seagrass in the Great Sandy Strait (mapped predominantly from a helicopter) decreased from 5554 ±1446 hectares in December 1998 to 4034 ±1115 hectares in April 199, and to 2779 ±862 hectares in November 1999 (Figure 2). This represents an overall loss of approximately 50% of the total seagrass in the Great Sandy Strait after the flood in February 1999.

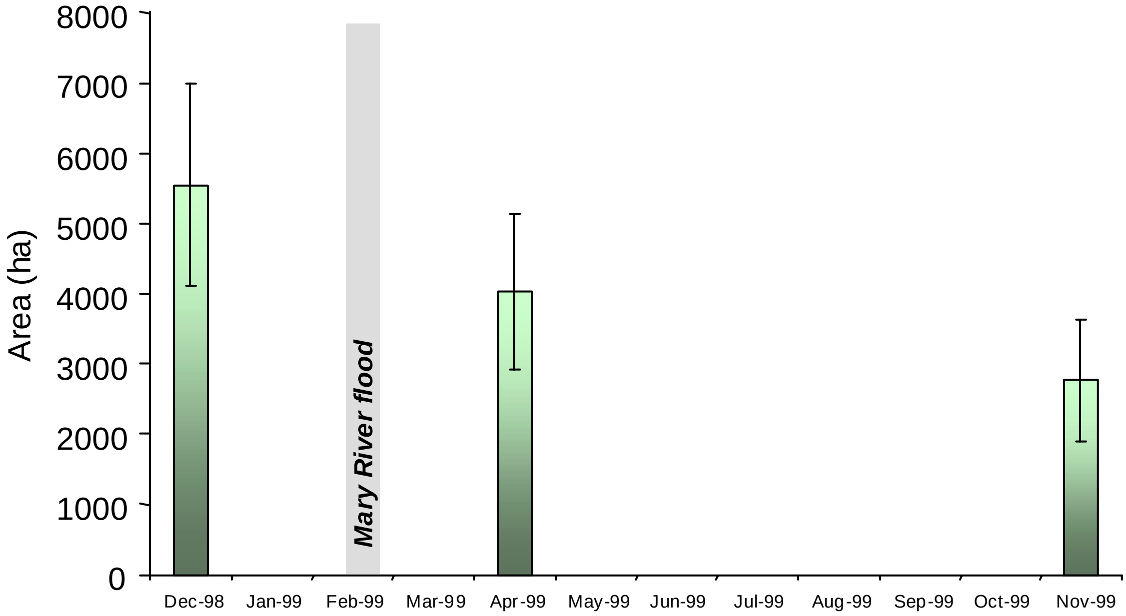


Figure 2. Mean area ±R (*estimate of reliability*) for seagrass mapped in the Great Sandy Strait pre- and post-flood.

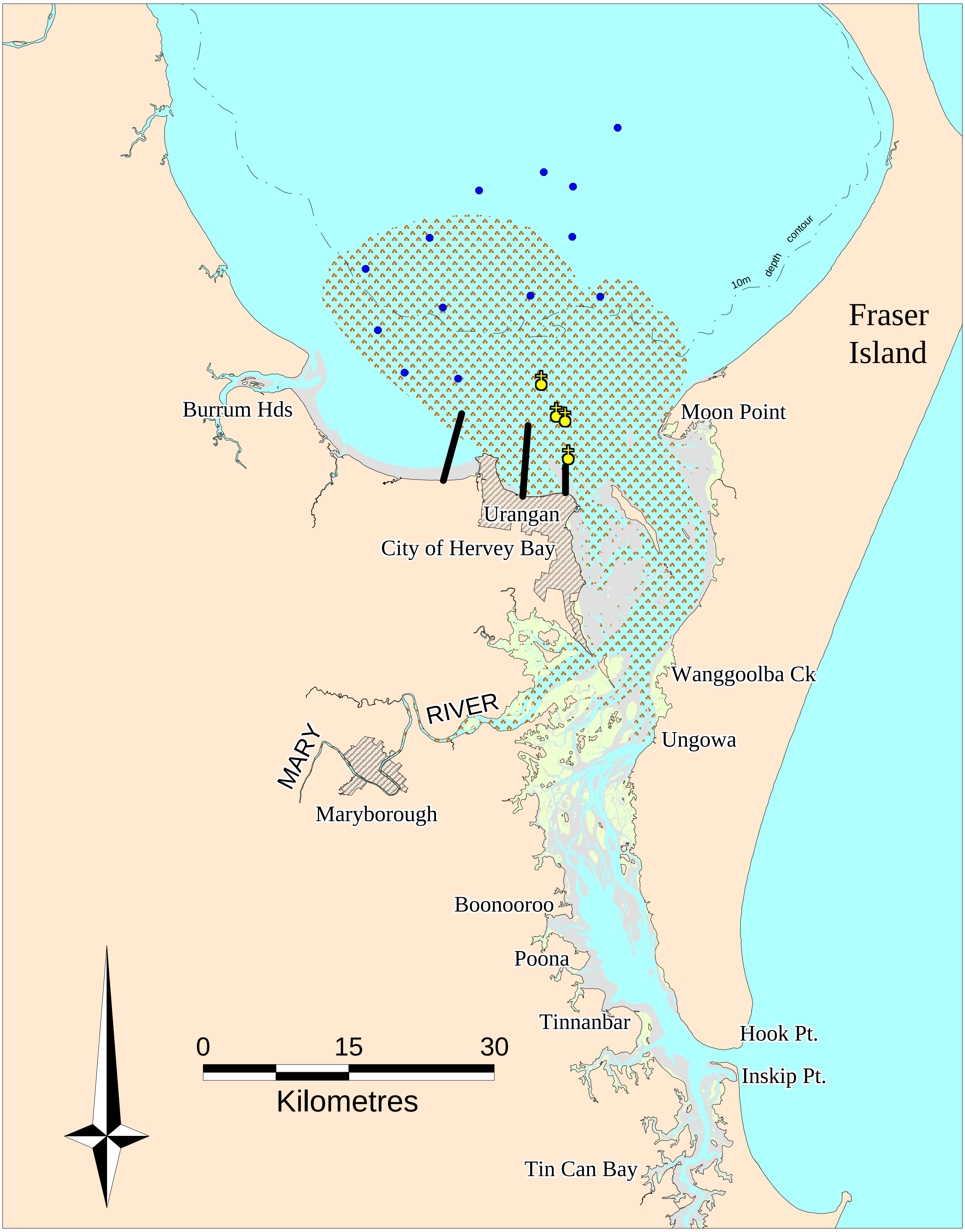
These losses occurred mostly within the plume area in the northern section of the Great Sandy Strait (Urangan - Moon Point in the north to Ungowa in the south) (Map 2).

In the April 1999 helicopter intertidal survey, no seagrass was found at Urangan or between Mangrove Point and Big Woody Island (Map 3). The large scale disappearance of these dense *Zostera capricorni* dominated meadows from Urangan is apparent when comparing aerial photographs taken prior to the flood (May 1994) and approximately 6 months after the flood (August 1999) (Plate 1). Similarly, the dense *Zostera capricorni* meadows south of Moon Point and adjacent to the mouth of Wanggoolba Creek also decreased significantly in abundance and distribution (Maps 4 & 5).

In the November helicopter intertidal survey, no seagrass was found at Urangan, Moon Point or the mouth of Wanggoolba Creek (Maps 3, 4 & 5; Plate 2).

Ground truthing of sites at Urangan and Wanggoolba Creek in August 1999 (as part of the Seagrass-Watch program) failed to find any above-ground plant material, although below ground plant material (rhizomes and roots) were abundant in each area. These localities had once contained abundant seagrass meadows with biomasses at Urangan recorded up to 29.2 g DW m^{-2} in March 1998 and up to 31.8 g DW m^{-2} at Wanggoolba Creek in November 1998. (Plates 3 & 4).

MAP 1. Extent of the Mary River flood plume (February 12, 1999) and location of post-flood monitoring sites in Hervey Bay and the Great Sandy Strait, 1999.



LEGEND

- Shallow subtidal transect (<10m)
- Deepwater survey site (>10m)
- Extent of flood plume (12th February 1999)
- UQ light meters
- Mangroves
- Mudbank

Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management.

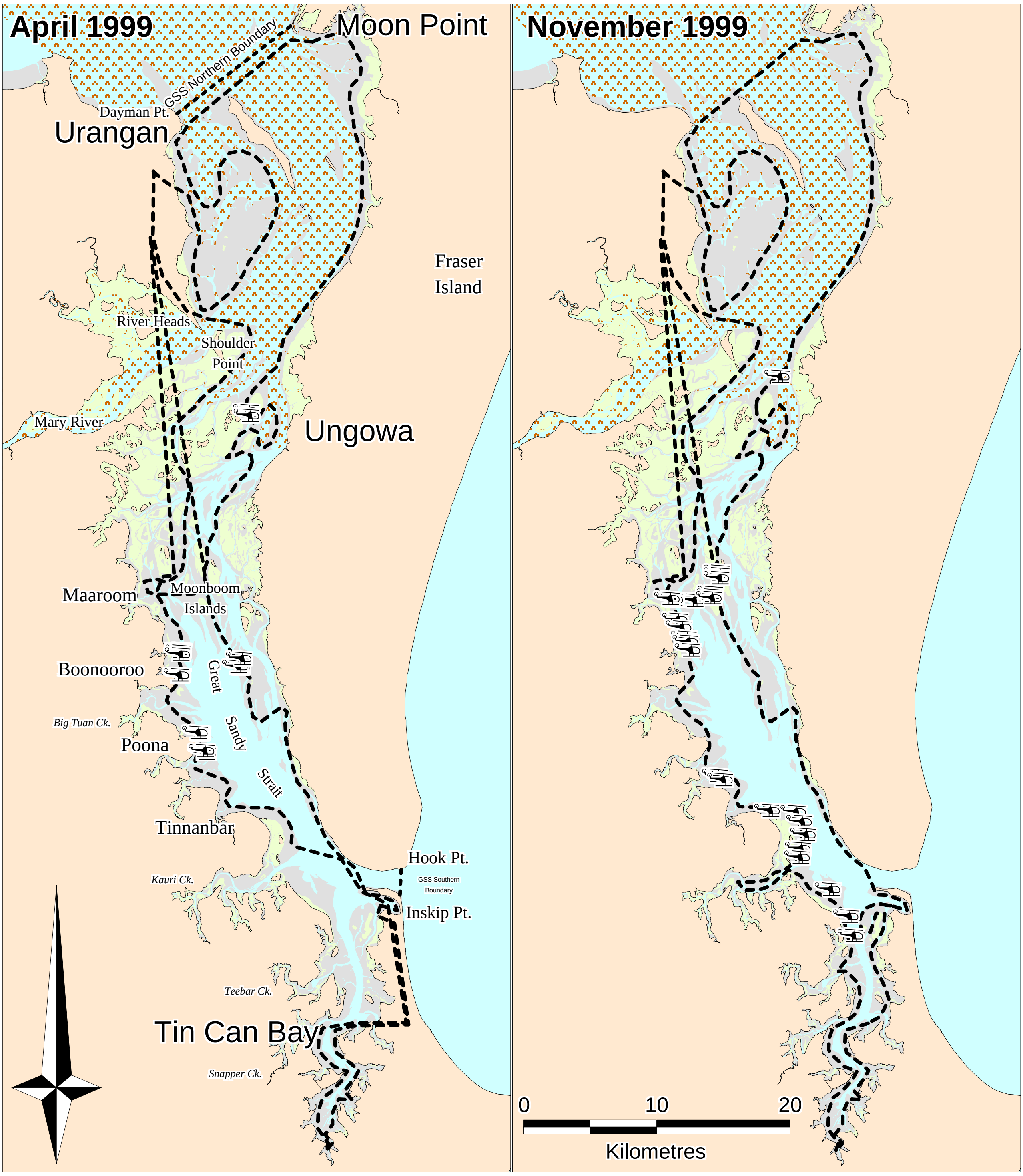
DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Sampling dates 14-17th April 1999, 14-17th August 1999 and 24-26th November 1999.

Funded by the Queensland Environmental Protection Agency, CRC Reef and the Department of Primary Industries.

Produced by the Marine Plant Ecology Group, DPI, Northern Fisheries Centre, Cairns, 2000.

MAP 2. Extent of the Mary River flood plume (February 12, 1999) and location of post-flood helicopter flight path and ground truth sites in the Great Sandy Strait, 1999.



LEGEND

Ground truth site

Helicopter survey path

Extent of flood plume (12th February 1999)

Mangroves

Mudbank

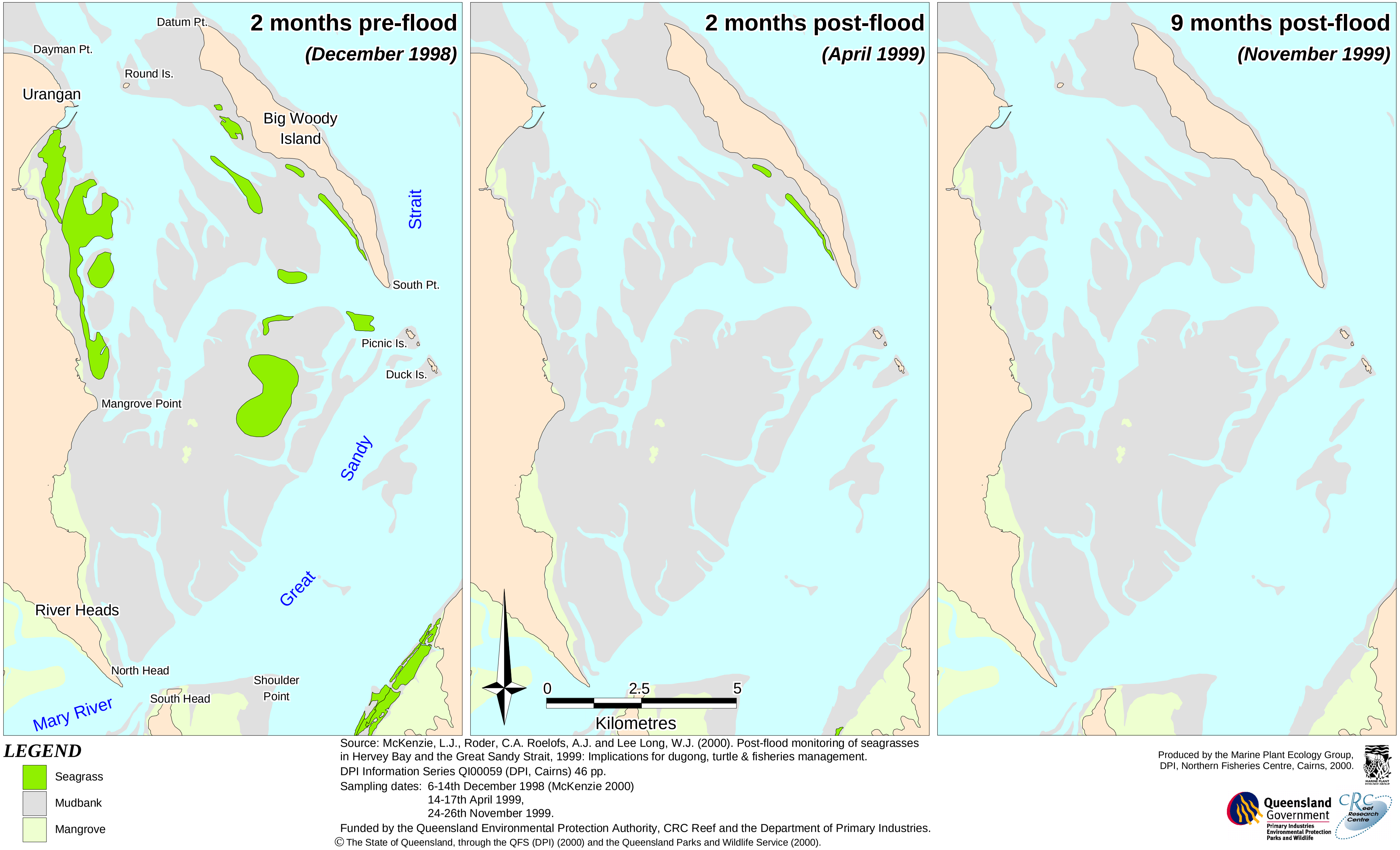
Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Sampling dates 14-17th April 1999 and 24-26th November 1999.

Funded by the Queensland Environmental Protection Authority, CRC Reef and the Department of Primary Industries.

Produced by the Marine Plant Ecology Group, DPI, Northern Fisheries Centre, Cairns, 2000.

MAP 3. Distribution of seagrass meadows pre- and post-flood between Urangan, River Heads and Big Woody Island.



Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

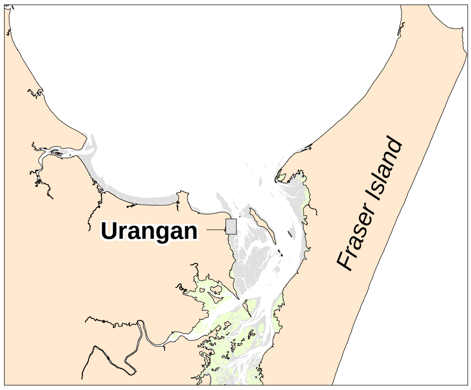
Sampling dates: 6-14th December 1998 (McKenzie 2000)
14-17th April 1999,
24-26th November 1999.

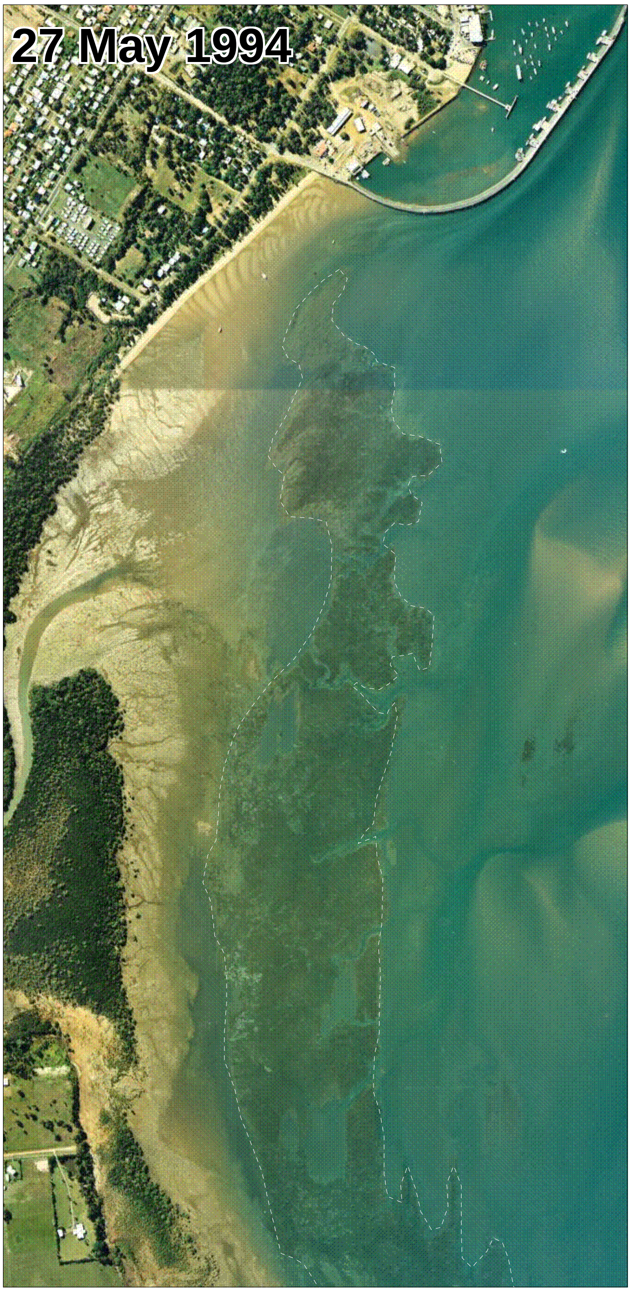
Funded by the Queensland Environmental Protection Authority, CRC Reef and the Department of Primary Industries.

Produced by the Marine Plant Ecology Group, DPI, Northern Fisheries Centre, Cairns, 2000.

PLATE 1.

Aerial photos of intertidal seagrass habitat at Urangan, 1994 and 1999.





Approximate outline of seagrass habitat

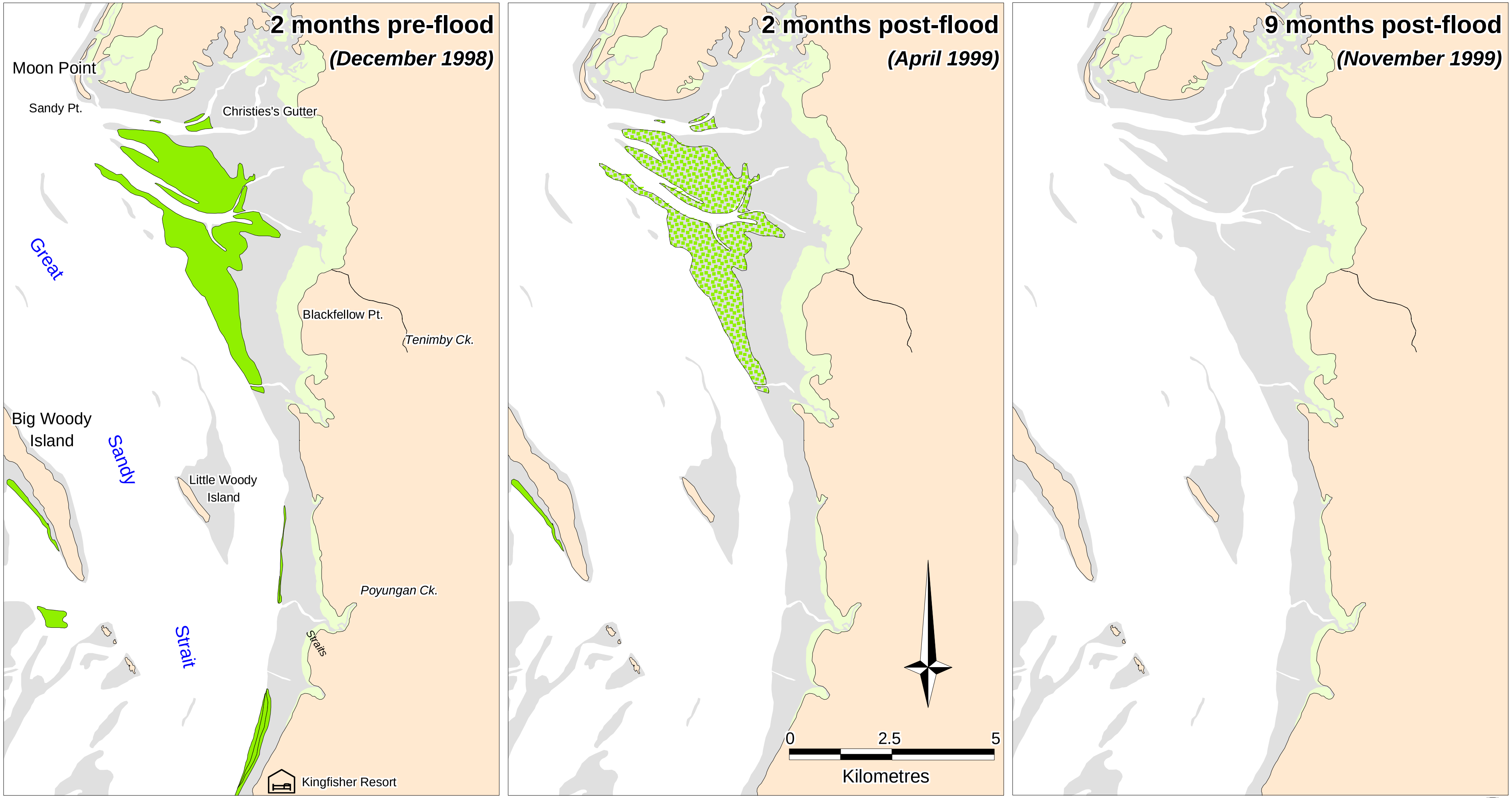
Aerial photographs (1:12,000) from Tweed Heads to Urangan, courtesy of the Beach Protection Authority.

Produced by the Marine Plant Ecology Group
QDPI, Northern Fisheries Centre, Cairns, 2000

Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Funded by the Queensland Environmental Protection Authority, CRC Reef and the Department of Primary Industries.

MAP 4. Distribution of seagrass meadows pre- and post-flood between Moon Point and Kingfisher Resort.



Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Sampling dates: 6-14th December 1998 (McKenzie 2000)
14-17th April 1999,
24-26th November 1999.

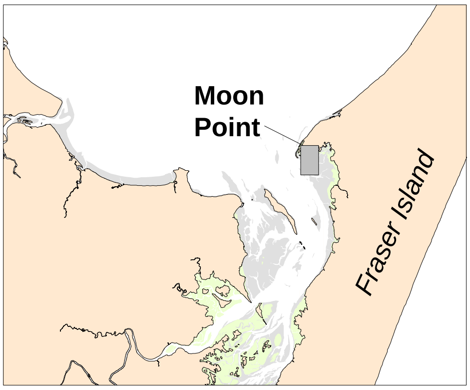
Funded by the Queensland Environmental Protection Authority, CRC Reef and the Department of Primary Industries.

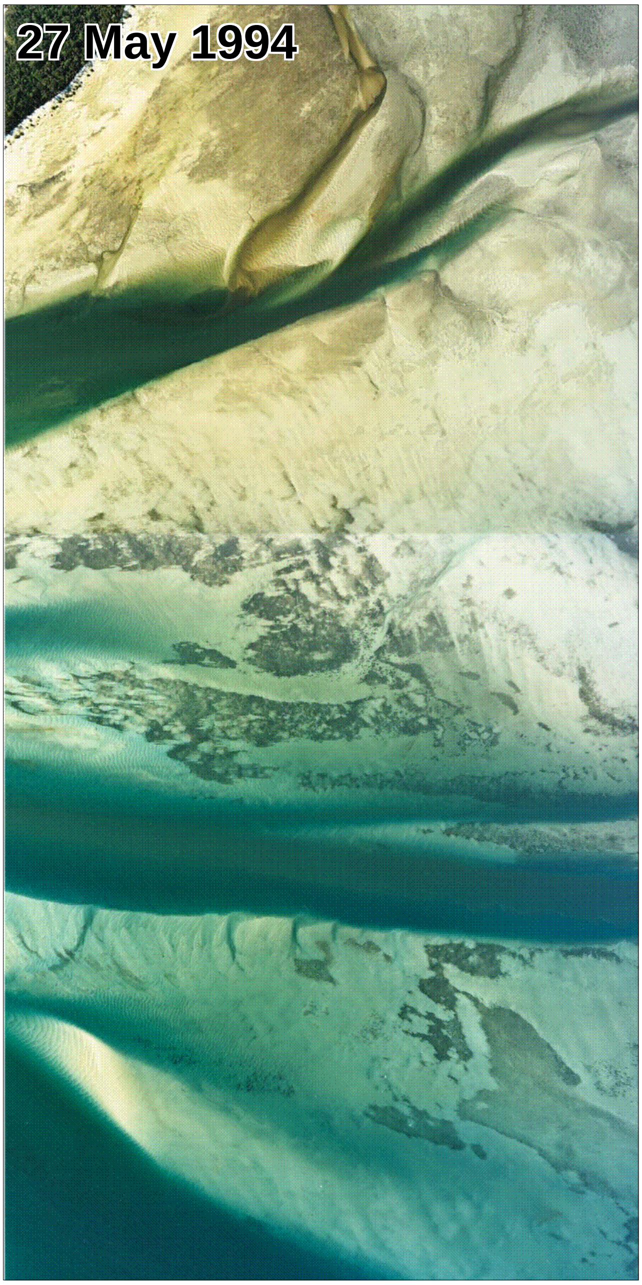
Produced by the Marine Plant Ecology Group, QDPI, Northern Fisheries Centre, Cairns, 2000.

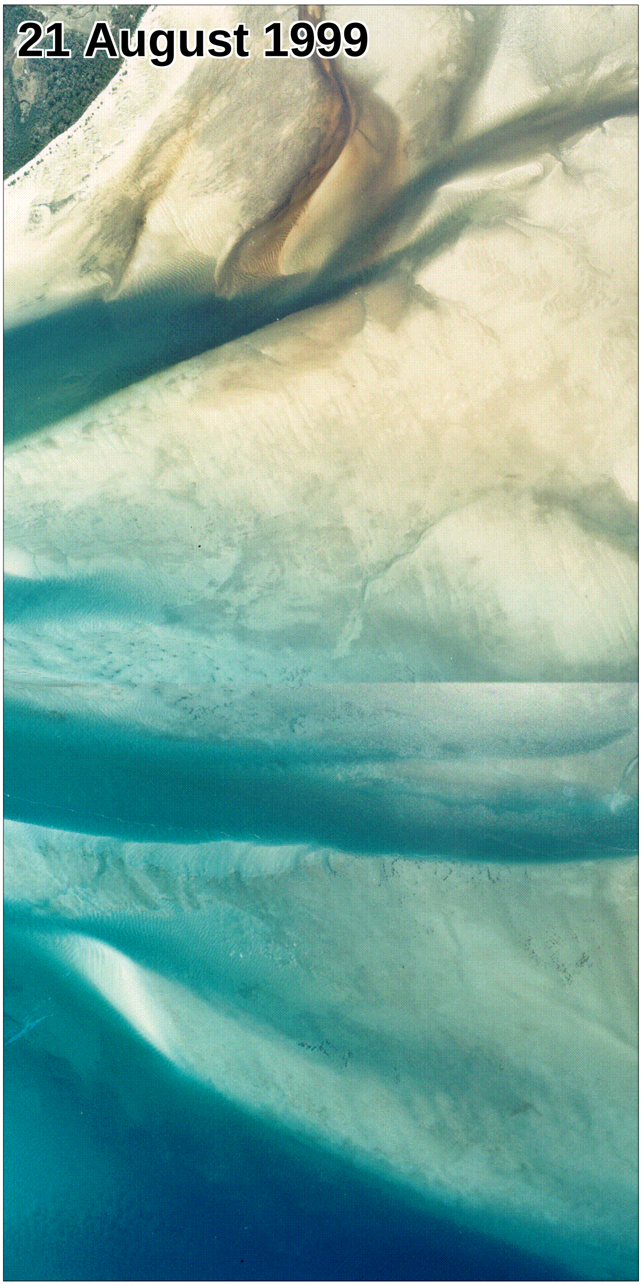
PLATE 2.

Aerial photos of intertidal seagrass habitat at Moon Point, 1994 and 1999.

(Dark patches in the 1994 aerial photograph are seagrass habitats.)







Aerial photographs (1:12,000) from Tweed Heads to Urangan, courtesy of the Beach Protection Authority.

Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management.

DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Funded by the Queensland Environmental Protection Authority, CRC Reef and the Department of Primary Industries.

Produced by the Marine Plant Ecology Group, QDPI, Northern Fisheries Centre, Cairns, 2000.

Plate 3. *Zostera capricorni* at **Urangan**: ***A***. 28 March 1998, above ground biomass 29.2 g DW m^{-2} (quadrat 0.25 m^{-2}); ***B***. 23 February 2000, nil seagrass (quadrat 0.25 m^{-2}).

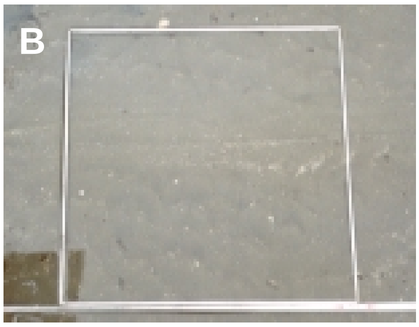
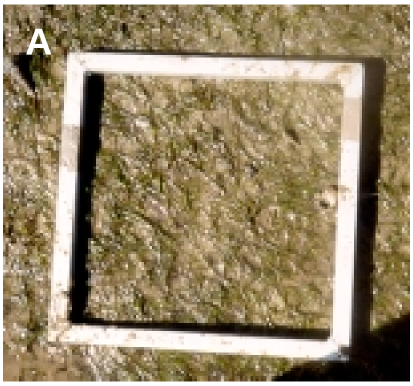
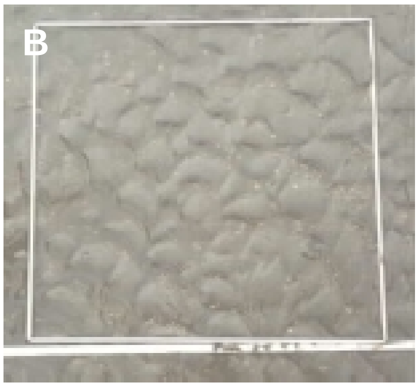


Plate 4. *Zostera capricorni* at **Wanggoolba Creek**: ***A***. 4 November 1998, above ground biomass 31.8 g DW m^{-2} (quadrat 0.09 m^{-2}); ***B***. 18 February 2000, nil seagrass (quadrat 0.25 m^{-2}).



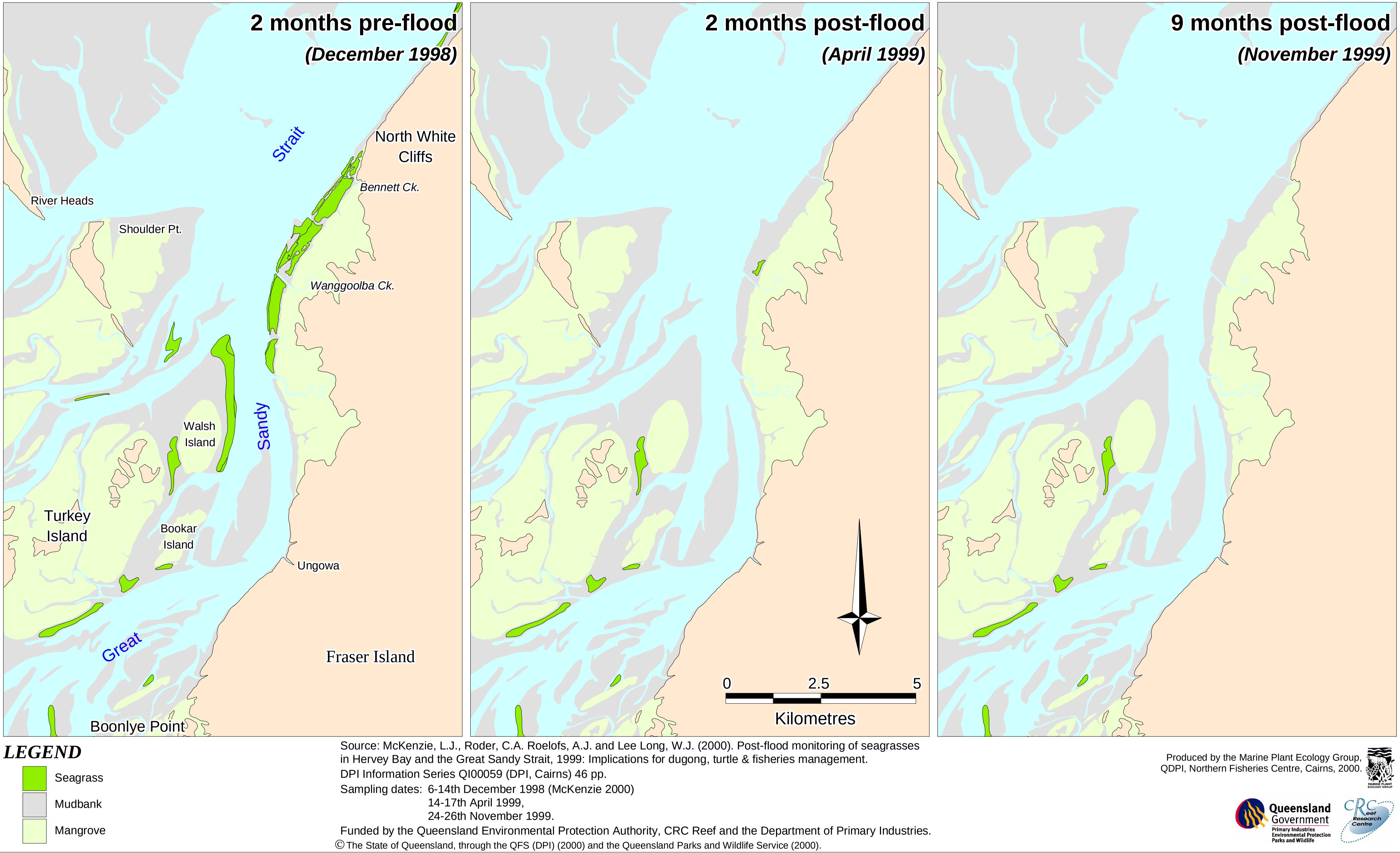


The seagrass sites were also revisited in February 2000 as part of ongoing monitoring within the Seagrass-Watch program, and the only evidence of seagrass recovery was an isolated plant.

The only other significant losses of seagrass detected within the Great Sandy Strait was from the large intertidal bank between Kauri Creek and Tin Can Inlet (Tin Can Bay) (Map 6). Extensive dense seagrass meadows were present on this bank in December 1998 and were easily recognisable from aerial photographs prior to 1999 (Plate 5). These meadows were predominantly *Zostera capricorni* intertidally, and *Cymodocea serrulata/Halophila ovalis* subtidally. Sites in this meadow recorded the highest abundance of all seagrass meadows in the Great Sandy Strait in December 1998. In April 1999, a significant amount of the meadows on the bank had gone, and only sparse low biomass patches of intertidal *Zostera capricorni* and *Halophila ovalis* remained. However, due to the high turbidity resulting from strong winds at the time, the full extent of the loss could not be clearly ascertained. Similarly in November 1999, poor tidal conditions at the time made a thorough investigation of the loss unachievable. Aerial photographs on the 28th April 1999 however, clearly demonstrate a significant change/loss of seagrasses on the bank (Plate 5).

Although no significant losses in seagrass distribution were recorded in the central Great Sandy Strait (Map 7), the abundance of the seagrass meadows significantly declined over the monitoring period.

MAP 5. Distribution of seagrass meadows pre- and post-flood between North White Cliffs and Boonlye Point.



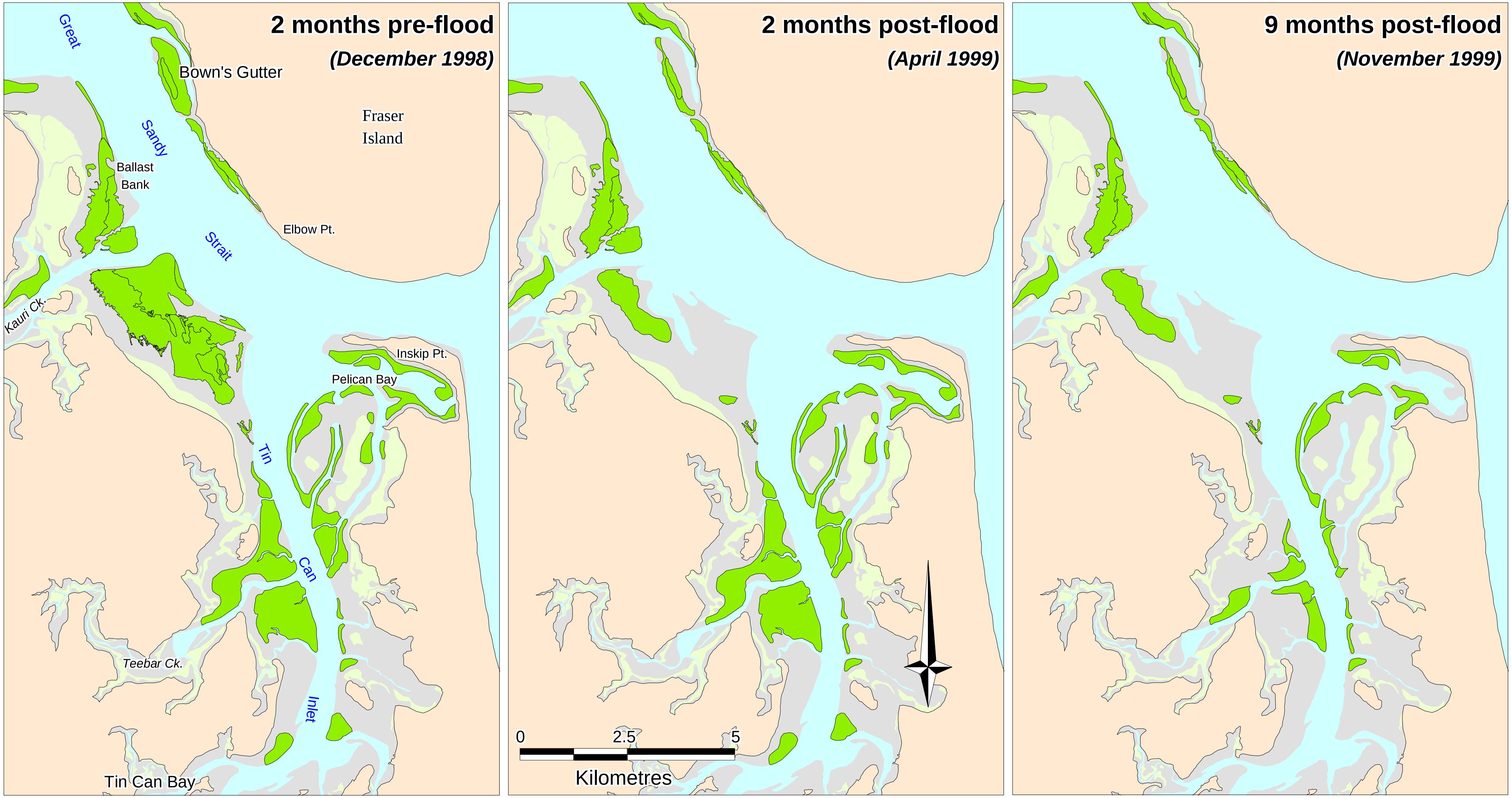
Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Sampling dates: 6-14th December 1998 (McKenzie 2000)
14-17th April 1999,
24-26th November 1999.

Funded by the Queensland Environmental Protection Authority, CRC Reef and the Department of Primary Industries.

Produced by the Marine Plant Ecology Group, QDPI, Northern Fisheries Centre, Cairns, 2000.

MAP 6. Distribution of seagrass meadows pre- and post-flood between Brown's Gutter and Tin Can Bay.



LEGEND

- Seagrass
- Mudbank
- Mangrove

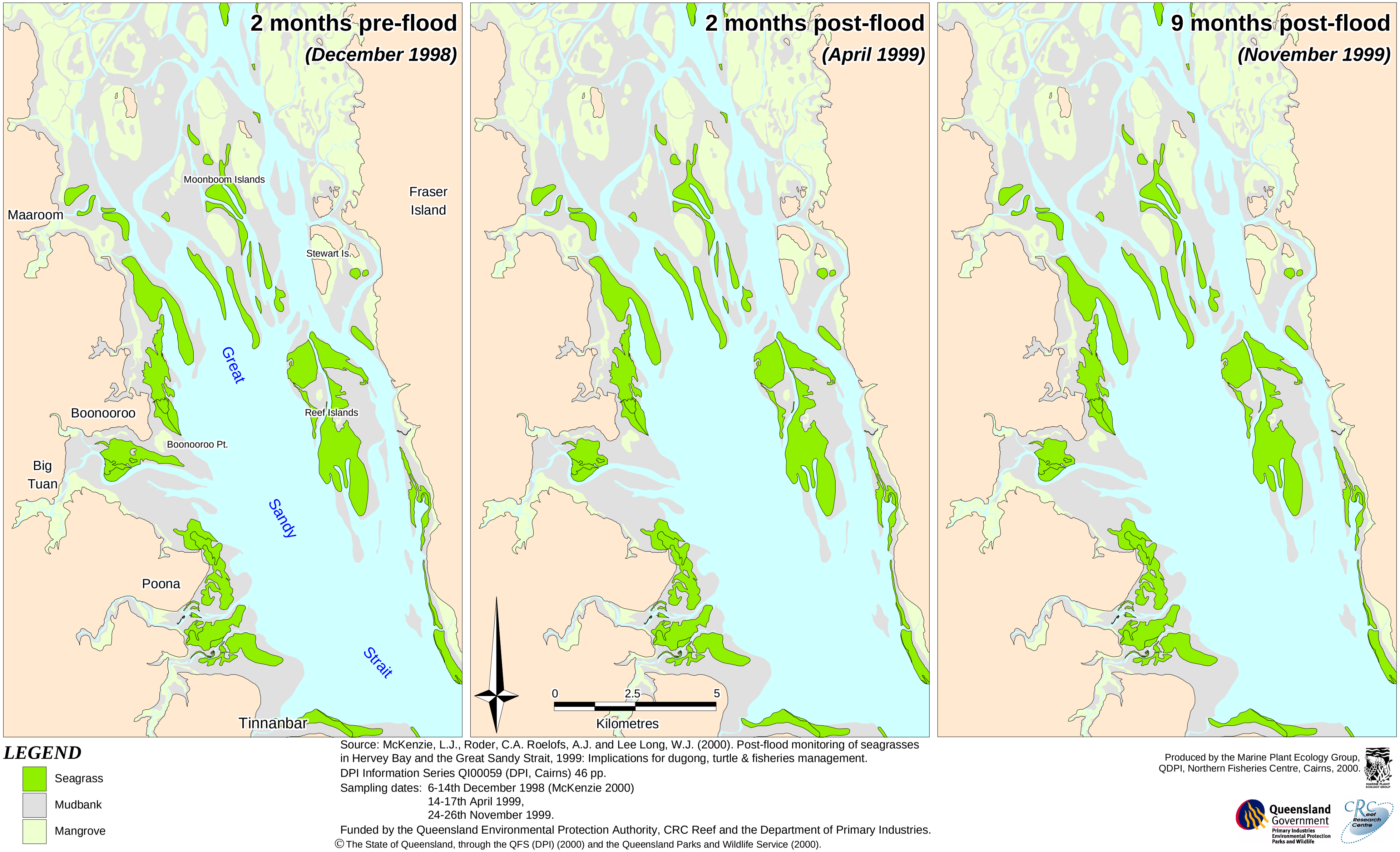
Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Sampling dates: 6-14th December 1998 (McKenzie 2000)
14-17th April 1999,
24-26th November 1999.

Funded by the Queensland Environmental Protection Authority, CRC Reef and the Department of Primary Industries.

Produced by the Marine Plant Ecology Group, DPI, Northern Fisheries Centre, Cairns, 2000.

MAP 7. Distribution of seagrass meadows pre- and post-flood between Boonlye Point and Tinnanbar.



Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Sampling dates: 6-14th December 1998 (McKenzie 2000)
14-17th April 1999,
24-26th November 1999.

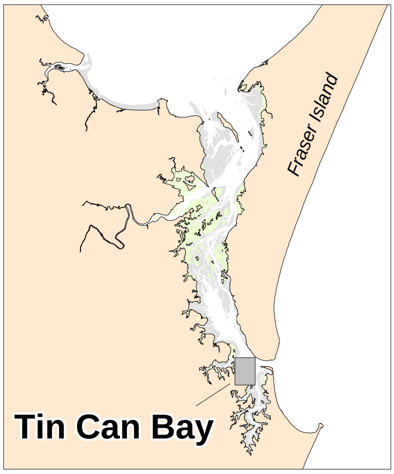
Funded by the Queensland Environmental Protection Authority, CRC Reef and the Department of Primary Industries.

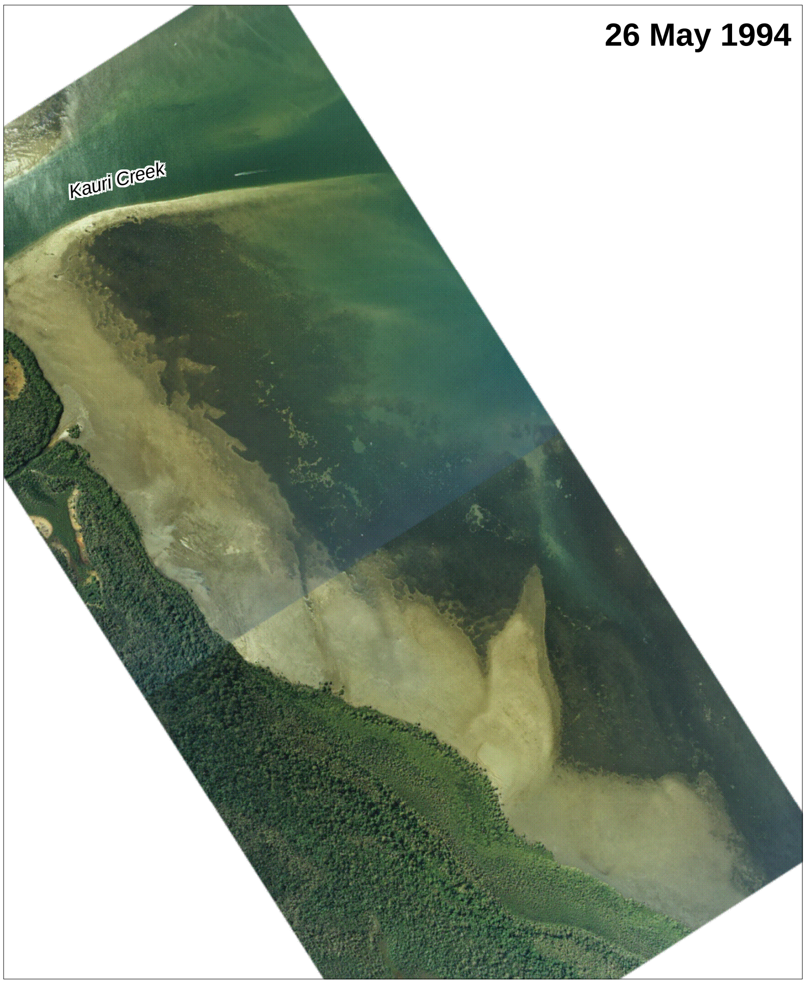
Produced by the Marine Plant Ecology Group, QDPI, Northern Fisheries Centre, Cairns, 2000.

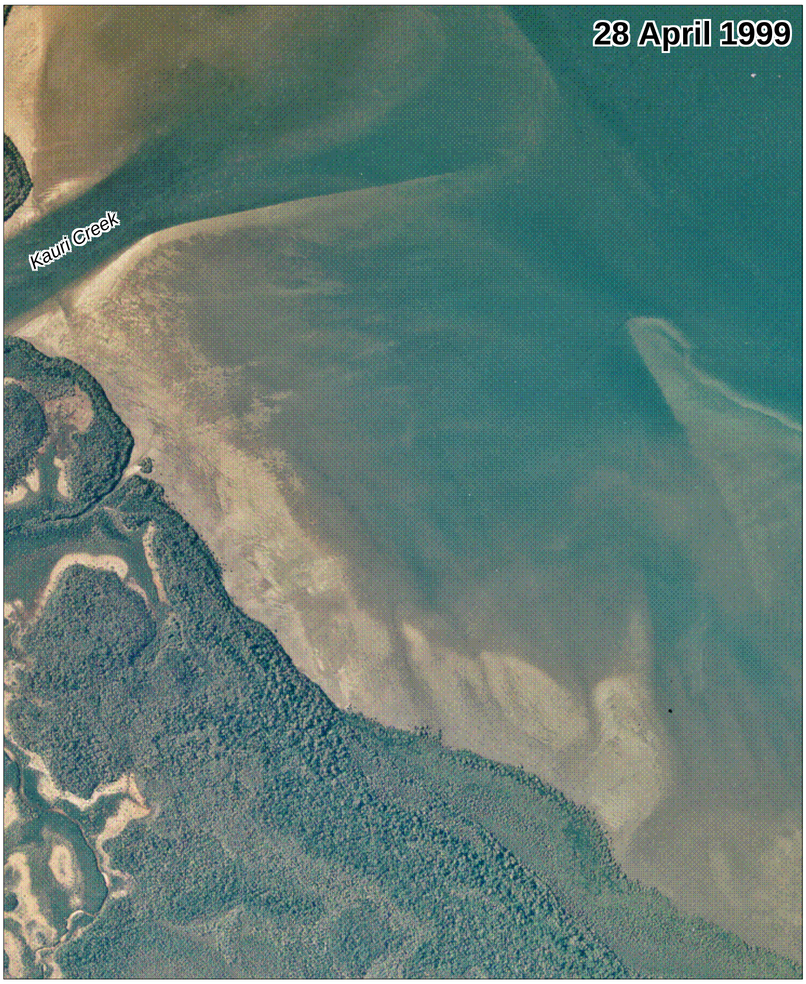
PLATE 5.

Aerial photos of intertidal seagrass habitat between Kauri Creek and Tin Can Inlet, 1994 and 1999.

(Dark patches in the 1994 aerial photograph are seagrass meadows.)







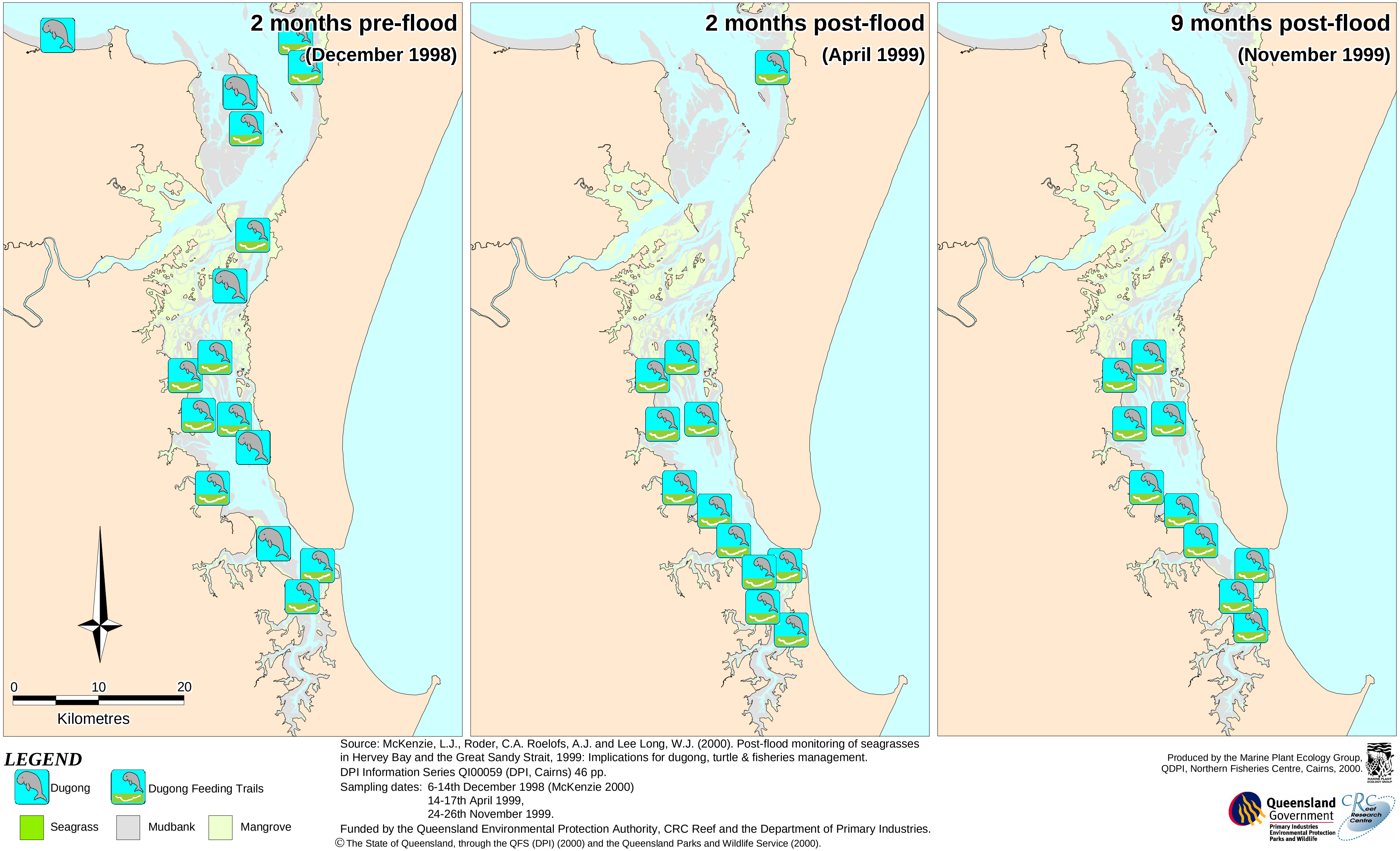
Source: McKenzie L.J., Roder C.A, Roelofs A.J. and Lee Long W.J. (2000) Post-flood monitoring of seagrasses in Hervey Bay and Great Sandy Strait, 1999: Implications for dugong, turtle and fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Aerial photographs (1:12,000) from Tweed Heads to Urangan, courtesy of the Beach Protection Authority.

Funded by the Queensland Environmental Protection Agency, CRC Reef and the Department of Primary Industries.

Produced by the Marine Plant Ecology Group, DPI, Northern Fisheries Centre, Cairns, 2000.

MAP 8. Distribution of dugong sightings & dugong feeding trails pre- and post-flood in the Great Sandy Strait.



Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

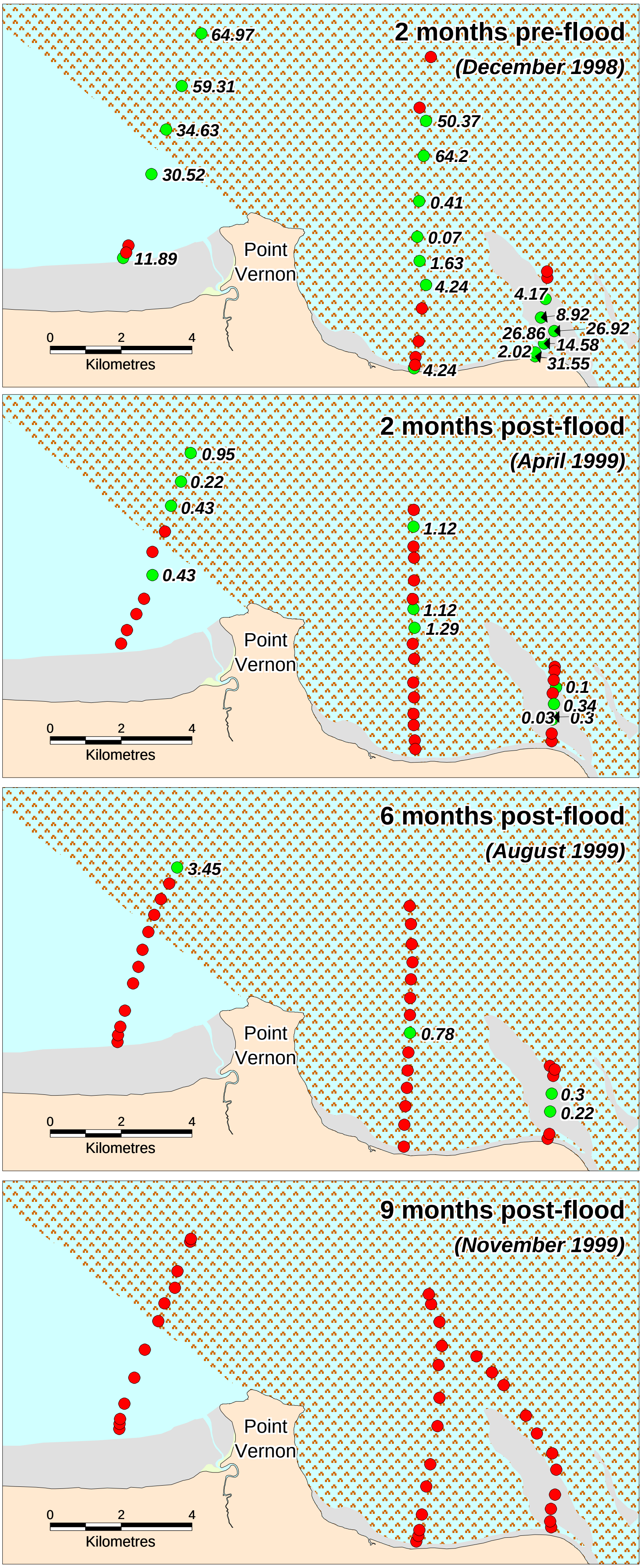
Sampling dates: 6-14th December 1998 (McKenzie 2000)
14-17th April 1999,
24-26th November 1999.

Funded by the Queensland Environmental Protection Authority, CRC Reef and the Department of Primary Industries.

Produced by the Marine Plant Ecology Group, QDPI, Northern Fisheries Centre, Cairns, 2000.

MAP 9.

Location of shallow sub-tidal (2-10m below MSL) pre- and post-flood monitoring sites in Hervey Bay.



LEGEND

- **Seagrass present** ***(above-ground seagrass biomass g DW m-2 in italics)***
- **Seagrass absent**
- **Extent of flood plume (12th February 1999)**
- **Mudbank**

Source: McKenzie L.J., Roder C.A, Roelofs A.J. and Lee Long W.J. (2000) Post-flood monitoring of seagrasses in Hervey Bay and Great Sandy Strait, 1999: Implications for dugong, turtle and fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Sampling dates: 7&14 December 1998, 14-17th April 1999, 14-17th August 1999 and 24-26th November 1999.

Funded by the Queensland Environmental Protection Agency, CRC Reef and the Department of Primary Industries.

Produced by the Marine Plant Ecology Group, QDPI, Northern Fisheries Centre, Cairns, 2000.

Queensland Government Primary Industries Environmental Protection Parks and Wildlife

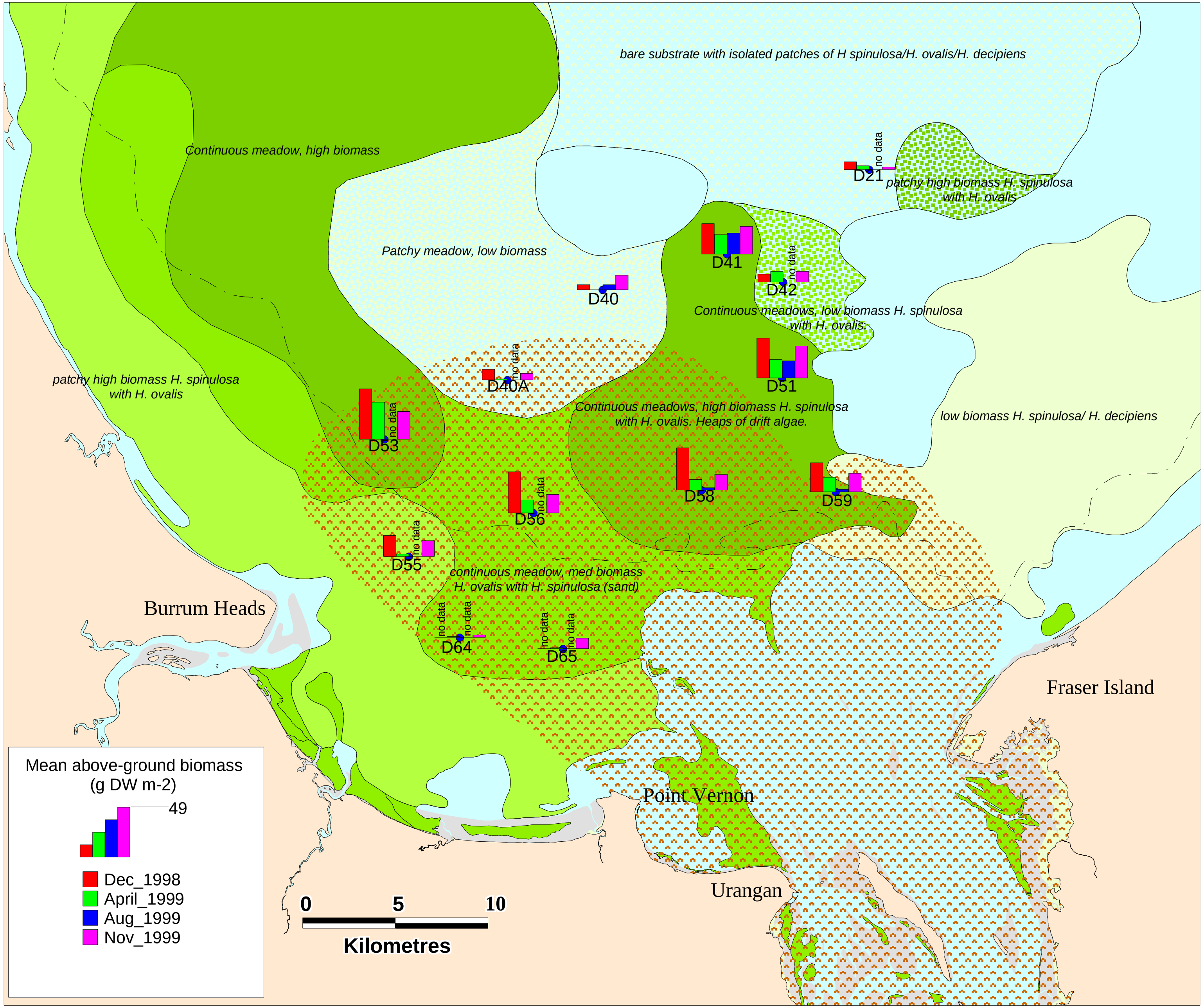
CRC Reef Research Centre

MAP 10.

Above-ground seagrass biomass at each post-flood deepwater monitoring site in Hervey Bay - December 1998 & April, August & November 1999.

Deepwater seagrass community types described from QDPI survey, December 1998. Coastal seagrass community types not shown. Flood plume digitised from QPWS aerial survey data (Feb 12, 1999).

Extent of flood plume (12th February 1999)



Source: McKenzie L.J., Roder C.A, Roelofs A.J. and Lee Long W.J. (2000) Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle and fisheries managment. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Sampling dates:
6-14th December 1998 (McKenzie 2000)
14-17th April 1999, 14-17th August 1999 and 24-26th November 1999.

Funded by the Queensland Environmental Protection Agency, CRC Reef and the Department of Primary Industries.

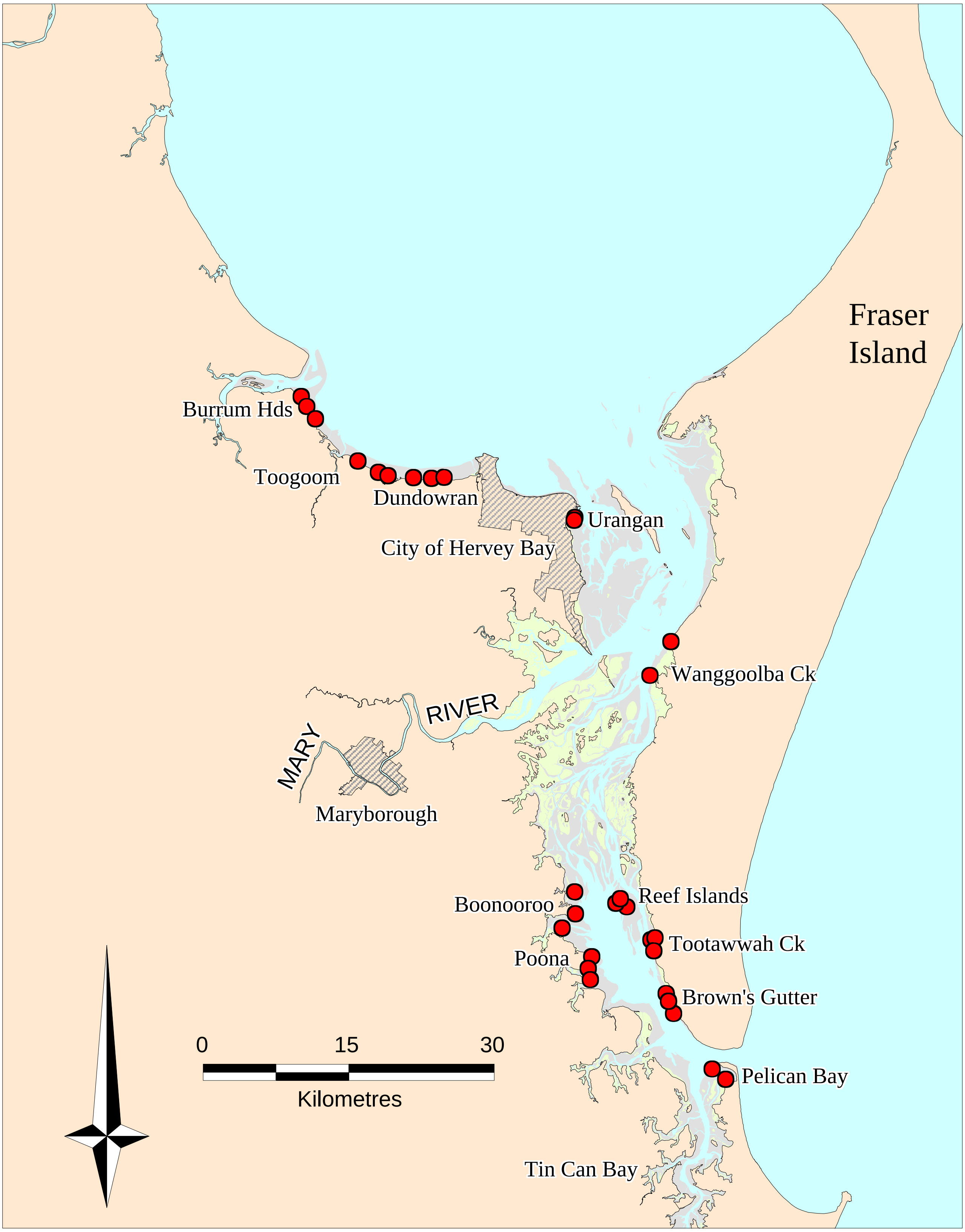
Produced by the Marine Plant Ecology Group, DPI, Northern Fisheries Centre, Cairns, 2000.

Plate 6. Specimens of *Halophila spinulosa* pre- (A) and post- flood (B) (8-10 m bMSL).

Plate 6A. *Halophila spinulosa* sample collected 7/12/1998

Plate 6B. *Halophila spinulosa* sample collected 15/03/1999.

MAP 11. Location of Seagrass-Watch long-term monitoirng sites in Hervey Bay and the Great Sandy Strait.



LEGEND

Seagrass-Watch monitoring site

Mangroves

Sandbanks

Source: McKenzie, L.J., Roder, C.A. Roelofs, A.J. and Lee Long, W.J. (2000). Post-flood monitoring of seagrasses in Hervey Bay and the Great Sandy Strait, 1999: Implications for dugong, turtle & fisheries management. DPI Information Series QI00059 (DPI, Cairns) 46 pp.

Funded by the Queensland Environmental Protection Agency, CRC Reef and the Department of Primary Industries. Seagrass-Watch is funded by the Natural Heritage Trust

Produced by the Marine Plant Ecology Group, DPI, Northern Fisheries Centre, Cairns, 2000.

Decreases in seagrass abundance were recorded in most ground truthed meadows during the helicopter flights. The abundance of the *Zostera capricorni* dominated meadows (with *Halophila ovalis* on sand substrate) on the banks surrounding Moonboom Island in the central Strait (Map 7) decreased from 10.92 ±1.63 g DW m^{-2} (all meadows pooled) in December 1998 to 3.01 ± 0.68 g DW m^{-2} in November 1999. Similarly, a medium biomass *Zostera capricorni* dominated meadow (with *Halophila ovalis* on sand/mud substrate) on the banks north of Boonooroo (Map 7) decreased from 6.40 ±0.99 g DW m^{-2} in December 1998 to 3.96 g DW m^{-2} in November 1999.

Although the distribution of the *Zostera capricorni* dominated meadow (with *Halophila ovalis* on sand substrate) on Ballast Bank at the mouth of Kauri Creek in the southern section of the Strait remained approximately the same (Map 6), the seagrass abundance decreased from 10.46 ±8.10 g DW m^{-2} in December 1998 to 1.84 ±0.79 g DW m^{-2} in November 1999.

Extensive dugong feeding trails were found in the intertidal meadows in the central and southern Great Sandy Strait during both surveys (Map. 8).

Coastal Shallow Sub-tidal Seagrasses (2-10m bMSL) of Hervey Bay

Thirty six sites in April 1999, 32 sites in August 1999, and 36 sites in November 1999 were surveyed along the shallow subtidal monitoring transects (Map 9). These sites were compared with 30 sites from the pre-flood December 1998 survey (Table 1). While seagrass was present at 19 sites in December 1998, seagrass presence was recorded at only 11 sites in April 1999, 4 sites in August 1999 and no sites in November 1999 (Table 1). Throughout all of the surveys the sediments remained predominantly sand/shell.

Abundance of shallow sub-tidal seagrass habitat declined promptly after the flood event, however the loss in area was gradual between April 1999 and November 1999. The spot check of the sub-tidal habitat in February 2000 (one year after the flood) found only one small patch of seagrass (<2m in diameter) at very low abundance.

In December 1998 (2 months pre-flood), the average above-ground seagrass biomass at sites where seagrass was present was 23.24 ±5.05 g DW m^{-2} in December 1998 (Table 1) (from McKenzie 2000). Four seagrass species were present along the monitoring transects. *Zostera capricorni* was present at 11 sites, *Halophila spinulosa* at 8 sites, *Halophila ovalis* at 2 sites, and *Halodule uninervis* (wide) was present at 1 site.

In April 1999 (2 months post-flood), above-ground seagrass biomass at sites averaged 0.58 ±0.13 g DW m^{-2} (Table 1). Three species of seagrass were found during the April 1999 survey. *Halophila spinulosa* was the only seagrass species found along the western and central transect, while *Halodule uninervis* (wide and narrow leaf morphologies) and *Zostera capricorni* were present on the eastern transect. New shoots of seagrass were observed along each transect. Algal turf mat, *Caulerpa* spp, *Udotea* spp and filamentous green algae were found distributed along transects.

The condition of seagrasses had also noticeably declined in April compared to December 1998. *Halophila spinulosa* in areas in the path of the flood plume had turned brown and deteriorated, and epiphytes were found covering the leaves. Plant stems appeared to be decomposing and some leaf drop from plants was observed (Plate 6).

In August 1999 (6 months post-flood), at the sites where seagrass was present, average above-ground seagrass biomass was 1.18 ± 0.76 g DW m^{-2}. Two species of seagrass were found on the survey. A small patch of *Halophila spinulosa* was present at the northern end of the Eli Creek transect (6.9 km offshore). A small patch of *Halodule uninervis* (wide leaf morphology) was found in the middle (3.6 km offshore) of the central transect, while a large patch of *Halodule uninervis* (narrow leaf morphology) was found in the middle of the Shelly Beach transect (1.0 km offshore). Exposed seagrass rhizome was found along each the central and eastern transects. Algal turf mat and filamentous green algae were also present along transects.

In November 1999 (9 months post-flood), no seagrass or exposed rhizome was found. All sites where seagrass was previously found in April and August 1999 were bare. Algal turf mat, *Caulerpa* spp, and *Udotea* spp and were observed in the shallow sub-tidal study area. Large amounts of *Polysiphonia spp* were found drifting along the substrate.

Table 2. Mean above-ground seagrass biomass of shallow sub-tidal (2-10m bMSL) monitoring sites.

Date of Survey	Type of monitoring	# sites sampled in shallow sub-tidal monitoring area	# sites with seagrass present	Mean biomass±SE (g DW m^{-2}) of sites with seagrass present
December 1998	Pre-flood	28	19	23.24 ± 5.05
April 1999	Post-flood	36	11	0.58 ± 0.13
August 1999	Post-flood	32	4	1.18 ± 0.76
November 1999	Post-flood	36	0	0

In February 2000 (one year after the flood), spot checks at the subtidal monitoring transects found only one site out of the 16 sampled had seagrass present. *Halodule uninervis* (narrow form) was found in very low abundance 0.01g DW m^{-2}. The drift algae recorded during the November 1999 survey was absent in February 2000.

Deepwater Seagrasses (>10m below MSL) of Hervey Bay

Video observations of deepwater seagrasses within the flood plume area over a 9 month period provided a visual record of seagrass plant physical responses to the effects of shading. As seagrass was measured at both flood-impacted and non-impacted sites, changes observed in seagrasses at non flood-impacted sites are possibly associated with normal seasonal fluctuations.

In December 1998 (pre-flood) the detailed dive and remote camera survey of Hervey Bay (McKenzie 2000) found seagrass meadows extended from the intertidal and shallow subtidal waters to a depth of 32 m. Seagrass meadows were distinguished on species composition, seagrass abundance, depth and bottom type. The dominant deep water meadows (43%) in the southern section of Hervey Bay were large continuous meadows of medium to high biomass *Halophila spinulosa* with *Halophila ovalis* (high cover of drift algae). Seagrass cover in these meadows was usually >50% and biomasses generally between 20 and 35 g DW m^{-2} on average.

The south eastern section of the bay was generally barren substrate with isolated patches of *Halophila spinulosa/H. ovalis/H. decipiens* (3.44 ±1.14 g DW m^{-2}). In the south western section of the bay, the subtidal seagrass meadows were generally patchy medium to high biomass (20.51 ±2.19 g DW m^{-2}, 50-100% cover) *H. spinulosa* with *H. ovalis/H. decipiens* on sand, down to 15 m. The shallow subtidal Dayman Bank, extending from near Urangan out to near the fairway buoy, was covered with low biomass H. *spinulosa/ H. decipiens* (19.69 ±3.48 g DW m^{-2}, 10-50% cover).

In April 1999 (2 months post-flood) *Halophila spinulosa* leaves at flood-impacted sites appeared brown and deteriorated with high cover of epiphytes (Plate 6). Plant stems appeared to be decomposing and some leaf drop from plants was observed. *Halophila ovalis* and *Halophila decipiens* had all but disappeared from impacted sites and abundance was low at sites outside the impact area (Figure 3). *Halophila spinulosa* above-ground biomass had decreased at non-impacted sites, but remained higher than impacted sites.

In August 1999 (6 months post flood), *Halophila spinulosa* plants remaining at impacted sites were shorter, largely denuded of leaves and mainly upright stems. *Halophila spinulosa* in non-impacted sites showed less physical response, with fewer instances of leaf drop, although biomass remained low (Figure 3).

In November 1999 (9 months post-flood), "lush" green tall new growth of *Halophila spinulosa* was evident at all sites and *Halophila ovalis* and *Halophila decipiens* shoots were more prevalent. Epiphytic filamentous green algae however, was present in high abundance.

Mean above-ground seagrass biomass at deepwater sites within the flood plume (Impacted sites) and for sites outside the flood plume (Reference sites) were pooled respectively for analysis. Impact and Reference sites did not differ significantly in abundance in December 1998 (39.5 ±2.5 and 34.0 ±3.1 g DW m^{-2} respectively) and both had declined in April 1999 to similar levels (18.0 ±2.2 and 18.2 ±2.1 g DW m^{-2} respectively) (Map 10, Figure 3). By August 1999 sites that had been located within the flood plume, had further declined in seagrass biomass (3.3 ±0.7 g DW m^{-2}) while sites located outside the path of the plume remained relatively constant (Figure 3). Seagrass biomass at both Impacted and Reference sites had recovered in November 1999 (9 months post-flood), although seagrass biomass at the Impacted sites remained significantly lower than December 1998 (Figure 3).

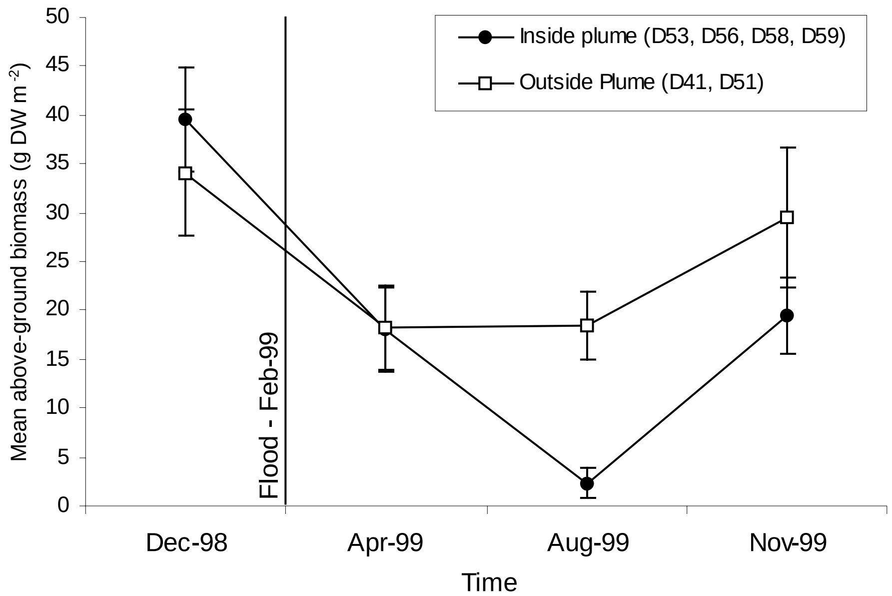


Figure 3. Plot of interaction of means for a BARI design of above-ground seagrass biomass (g DW m^{-2}, all species pooled) from survey sites inside (Impact) and outside (Reference) the Mary River flood plume following flooding in Hervey Bay and the Great Sandy Strait in February 1999. *Error bars represent 95% confidence limits.*

DISCUSSION

Seagrass

Tropical and sub-tropical seagrasses are inherently resilient, but not infinitely so. In most areas where losses have occurred due to acute impacts, the seagrass resources have recovered within 3 to 5 years.

Intertidal seagrass habitat in the northern parts of the Great Sandy Strait and the shallow sub-tidal habitat (2-10m below MSL) in the path of the flood plume have been the slowest seagrasses to recover. Deepwater seagrasses affected by the flood plume appear to be recovering well.

While substantial areas of intertidal habitat has been lost from Urangan, Moon Point, Wanggoolba Creek and Tin Can Inlet, large areas of habitat remains intact in the middle of the Great Sandy Strait (Maaroom, Poona, Boonooroo). These remaining areas of intertidal seagrasses are frequented by dugongs (Map 8).

Similarly, the shallow sub-tidal seagrass habitat lost from areas affected by the flood plume is by comparison only a small proportion of the total seagrass resources for the bay. Previous post-flood studies in Hervey Bay have found that recovery of sub-tidal seagrass habitat in Hervey Bay began within two years (Preen *et al.* 1995), and appeared fully recovered within 8 years (McKenzie 2000). Preen *et al.* (1995) found little or no seagrass recovery evident in sub-tidal and intertidal 10 months after the flooding event, although good recovery had occurred by the following year. Observed seagrass recovery was primarily through seed germination as most of the seagrass plants had been completely lost from the region. Seagrass recovery recorded in the present study is more likely due to combined vegetative growth and seed germination. This may have increased the rate of plant regrowth so as to show nearly full recovery in deepwater within 9 months of the impact. With two catastrophic events within the last ten years, the capacity of these habitats to fully recover again is unknown.

It is unlikely that the lack of light for 19 days reaching the seagrasses is the sole cause for the seagrass decline in shallow subtidal areas of Hervey Bay. Other studies have shown that *Halophila ovalis* has survived for over 30 days without light, with plant death occurring after 38 days in the dark (Longstaff and Dennison 1999). Preen *et al.* (1995) suggest that the intertidal and shallow subtidal seagrass habitat probably would have survived the turbid waters of the flood plumes of the flood – cyclone – flood event in 1992 had it not been for the substrate disturbance associated with cyclonic seas.

Sediment deposition and disturbance associated with the flood may be the cause for the immediate seagrass loss at localities such as Urangan or Wanggoolba Creek. Also, at these localities, there has been no recovery of seagrasses, although abundant amount of roots and rhizomes still persist. There appears to be no seed germination, suggesting no viable seed bank has remained. Sediment deposition and disturbance associated with the flood, may have deeply buried the seeds, or they may have been damaged by the sediment movement. We recommend that estimates of potential for recovery (ie. seagrass seed availability within the local sediments) in intertidal and shallow sub-tidal areas affected by the flood plume should be investigated. These sites however, may also be suitable for restoration, by replanting vegetative shoots of *Zostera capricorni* from other locations within the Great Sandy Strait and we recommend that the issue be further investigated.

Much of the seagrass in the shallow sub-tidal regions of southern Hervey Bay and in the intertidal regions on the northern Great Sandy Strait disappeared immediately or in the first few months after the flood impact. Deepwater seagrass resources within the path of the flood plume declined significantly in above-ground biomass after the impact and remained significantly lower than outside the impact area after nine months. It has been speculated that immediate losses in marine angiosperms may also be a result of hebicides attached to sediment particles washed down in the flood waters.

While algae's such as *Udotea* spp. and *Caulerpa* spp. were present on the monitoring transects pre- and post flood, *Polysiphonia* was found in large amounts in the November 1999 survey. This large increase in *Polysiphonia* may be a result of nitrogen (N) contamination from the flood waters. These increases in algae could have also had an effect on the growth and distribution of seagrasses in the bay, by smothering and thereby reducing available light.

The cause of the seagrass loss in the Tin Can Inlet may not be easily identified. The *Cymodocea serrulata* meadow that has decreased significantly since December 1998, was highlighted from earlier surveys (Dredge *et al.* 1977, Conacher *et al.* 1999) as an unusual feature of the region, possibly even a relic from periods when warmer waters occurred in the region. It is unlikely that runoff from the Mary River catchment is the predominant cause as the main flood plume only extended to Ungowa, and the flood waters within the Strait lasted only a few days (Kai Yeung, QPWS, Pers. Comm). Runoff from the adjacent Kauri Creek and Tin Can Inlet watersheds is more likely. These watersheds include large defence force training areas, urban development and pine plantations in their upper reaches.

Fisheries

Hervey Bay and Great Sandy Strait seagrass support a diverse and stable estuarine fishery and recruits to an oceanic prawn stock. Loss of seagrass may have some effect on both primary production and fisheries productivity in the area.

Dredge *et al.* (1977) considered that the majority of eastern king prawn recruits to the Tin Can Bay trawling grounds, come from the central and southern sections of the Great Sandy Strait. In response to declining eastern king prawn catches in the fishery, QDPI Fisheries (Deception Bay) are currently conducting research aimed at establishing a fishery independent index of recruitment (A. Courtney, QDPI, Pers. Comm.) (Retif 1998). Six 1 nautical mile transects around the Boonooroo region are beam trawled from October to January each year. Results from the study are still pending.

In October 1999, one of the authors collected samples of seagrass associated macrofauna with a beam trawl (1.5 m wide, 0.5 m high with a 2.0 mm mesh) towed at approximately 0.5 m s^{-1} (cf. Coles *et al.* 1993) across the intertidal seagrass banks adjacent to Boonooroo Point. The samples were collected for a community display (Seafood Festival) and the samples contained an abundance of juvenile eastern king prawns (<10 mm carapace length), juvenile fish, crabs, squid, and miscellaneous crustaceans (shrimps, isopods, amphipods, stomatopods). These samples, although only qualitative, indicate that there was still significant recruitment to the seagrass habitats in the central Great Sandy Strait.

As most of the seagrass losses due to the flooding occurred predominantly in the northern section of the Strait, we would consider that the effect on the adjacent fishery would not be severe. As there is little information on the relationship between seagrass abundance and prawn recruit abundance, it is difficult to speculate on the size of the effect to the fishery. A project in currently being developed, to use commercial (CFISH) logbook data and long-term seagrass monitoring data to establish the link between a major flood event in 1992 affecting Hervey Bay seagrasses and the extent of long-term changes to tiger prawn harvest levels in Hervey Bay (B Zeller, QDPI, Pers. Comm.). Although studies of a similar nature have been conducted in the Gulf of Carpentaria, this study would be the first to provide industry with information on key flood-induced habitat changes linked to spatial and temporal changes in prawn resources in Hervey Bay and allow for more efficient trawling effort.

The significance of the seagrass loss may take several years before it's impact on the fisheries, if any, is known. We recommend that habitat type and structure be considered as an additional factor measured when conducting recruitment studies.

Dugong and turtle

Recent aerial surveys found very few dugongs in shallow subtidal areas in the southern pocket of Hervey Bay (Ivan Lawler, JCU. Pers Comm.). It is unsure what ramifications the loss of this habitat will have on the feeding and migration behaviour of local dugong populations. Although seagrasses are still abundant in the deeper waters of the bay, the shallow sub-tidal meadows are restricted to the Burrum Heads region of the Bay. For the adult dugong in the bay, this may not be significant, however for a young calf, feeding on seagrass in deeper waters may be difficult and this may restrict a herds movements within the bay. Restriction of food may increase the possibility of intensive grazing, further limiting the food supply, and also make the populations more vulnerable to other impacts (eg. boating).

Movements of dugong populations from their main feeding territory into other areas may also increase stress on individuals. Increased stress may inturn reduce fecundity. Food shortage is known to lengthen pre-reproductive period and/or calving interval (Marsh *et al.* 1999). Dugongs may be short of food for several reasons including loss of seagrass, decline in the nutrient quality of available seagrass or a reduction in the time available for feeding due to boat traffic (Marsh *et al.* 1999).

Halophila spinulosa observed after the flood, appeared in a poor quality compared to samples collected in December 1998. It is unknown if the nutritional "quality" of the plants was reduced and what effect this may have on dugong feeding on these plants.

Epiphytic filamentous green algae was observed in November 1999 to be in greater abundances than December 1998 and December 1988. Although algae generally makes up a small percentage (2% volume) of dugong diets (Marsh *et al.* 1982), dugong have been shown to avoid feeding on *Halophila spinulosa* and *Syringodium isoetifolium* carrying large quantities of epiphytic algae (Preen 1995a). Following the loss of shallow sub-tidal and intertidal seagrasses in Hervey Bay and northern Great Sandy Strait, the deepwater seagrass resources may become more relied on for food by dugong and sea turtle. It is not known if the presence of large quantities of epiphytic algae may repel these grazers from feeding upon these seagrasses. It is possible dugong and sea turtles may be forced to seek food resources from areas other than the Hervey Bay region (e.g. southern area of Great Sandy Strait) placing increased grazing pressure on already limited seagrass resources.

After the 1992 floods devastated the seagrass resources within Hervey Bay, anecdotal evidence suggests that dugongs were forced to move down into the central and southern sections of the Great Sandy Strait. Local fishers in the region reported increased dugong numbers and several incidents of aggression between herds of dugong (Kai Yeung, QPWS Maryborough, Pers. Comm.). The local fishers were of the opinion that the resident dugongs were defending their feeding territory from the Bay dugongs.

While deepwater seagrass resources are currently available for dugong to feed on, there is a lack of shallow sub-tidal and intertidal seagrasses in the southern part of Hervey Bay. JCU researchers found that most dugong were found in deepwater in the aerial survey conducted in November 1999 (I. Lawler, JCU Pers Comm, 2000). Evidence of dugong feeding trails in the seagrass meadows of the Great Sandy Strait from this study, also show that the distribution of dugongs has contracted into the central and southern sections. Whether these populations are resident to the Strait or have moved from the bay is unknown.

Dugong Protection Areas essentially protect dugongs only from netting and other pressures that are related to fishing practices. To manage DPA's effectively, water quality-related problems which effect dugong health, the sources of which lie outside the DPA borders, need to be addressed. Pollutants (incl. Dioxins) have already been detected in high concentrations in dugongs in Great Sandy Strait (D Haynes, GBRMPA, Pers. Comm.).

Significant reductions in nutrient, sediments and pollutant inputs could be achieved by the adoption of industry codes of best practice by all farmers and by the implementation of the Intergrated Catchment Management program (ICM). ICM programs incorporate better land management methods, retention and rehabilitation of riparian zones and wetlands, vegetation management on grazing lands, better fertiliser application technology, and urban stormwater management.

There is no information regarding the affect of the February 1999 Mary River flood on the local turtle population. Green turtle population fluctuations are known to vary from year to year, and recent evidence suggests this may be linked to their food resources. Limpus and Nicholls (1990 & 2000) suggested that changes in climate (indicated by the SOI) probably affects turtle food sources, and that this is a nutritional basis to annual fluctuations in fat deposition, vitellogenesis, spermatogenesis and growth within total population of green turtle. Limpus and Nicholls (2000) reported significant correlations between the Southern Oscillation Index (SOI) two years before a breeding season and the number of females recorded on the nesting beach. They found that in the extremes, massed nesting occurs two years following major El Niño events and crashes in nesting numbers occur two years after major anti-El Niño events (Limpus and Nicholls 2000). Although the mechanism of the ENSO (El Niño Southern Oscillation) linkages to green turtle fluctuations have not been established, potential linkages could range from damage to seagrass pastures during cyclones, or changes in growth of pastures in response to flood run-offs to changes in nutrient quality of water brought to the pastures by onshore currents or upwellings.

At present however, there is no suitable database to verify whether these fluctuations in green turtle populations are driven by the changes in quantity and quality of the food resource, and multidisciplinary studies that examine seagrass meadows and associated green turtle populations would be invaluable. The loss of expansive areas of intertidal and shallow subtidal habitat, and the degeneration of deepwater seagrasses, in the Great Sandy Strait and Hervey Bay as a result of the February 1999 Mary River flood, is likely to have affected the feeding behaviour and ultimately the breeding cycle of local turtle populations. This may not be evident however, until the 2001 nesting season. Without adequate knowledge of the distribution or abundance of green turtles in the region before or after the flood, it is unclear to what extent this climatic event may have affected the regional population.

To identify and help manage destructive human activities in order to protect crucial fisheries, dugong and turtle habitats, a long term monitoring program for seagrasses has been established in the region - *Seagrass-Watch.* Community volunteers monitor seagrass abundance and composition at selected sites throughout Hervey Bay and the Great Sandy Strait (Map 11). This is the most intensive seagrass monitoring program in the region and is currently funded to November 2001. Information from this program will be invaluable in monitoring the rate and extent of recovery of seagrass resources in the region.

Catchment/urban runoff and water quality

Seagrasses are affected by land use (agriculture, industrial and urban) through discharges from major catchments. Agricultural land-use practices (eg, land clearing, grazing pastures, unvegetated stream banks) were suspected as agents which exacerbated soil erosion, sediment and nutrient loads and turbidity over seagrasses during the flood and cyclones that led to the loss of seagrass beds in nearby Hervey Bay in 1992.

With mainly agricultural or forestry industries operating within the adjacent catchment, contaminated runoff into intertidal and shallow subtidal habitat is likely to have occurred as a result of sediments being transported in the flood. Much of the seagrass loss occurred within 3 to 6 months after the flood impact. Use of persistent herbicides such as diuron (DCMU) [3-(3',4'-dichlorophenyl)-1,1-dimethylurea] is common in south-eastern Queensland catchments. Diuron is used for treating dicotyledons and is known to be toxic to seagrasses (Haynes *et al.* 2000a). Diuron (DCMU) has an aquatic half-life of approximately 4 months and applications of these herbicides can be pre- and post-wet season, so it was possibly contained in run-off waters onto nearshore seagrass habitats. No diuron (DCMU) was detected remaining in subtidal sediments samples collected by the authors from Dayman Bank (southern Hervey Bay) in February 2000 (12 months after the flood event) or in Hervey Bay sediment in 1997 (Haynes *et al.* 2000b).

There has been some monitoring of the ambient water quality in the Great Sandy Strait. Monthly measures of water quality (salinity, turbidity, DO, N, P and chlorophyll-a) are taken from six sites within the Great Sandy Strait as part of the long-term Queensland Ambient Water Quality Program. The program began in 1993 and results indicate no discernible patterns or trends in the parameters measured (A. Moss, EPA, Pers. Comm.).

Indirect methods of measuring the water quality have also been established since June 1994. Long-term seagrass monitoring transects were established throughout the Great Sandy Strait, to monitor changes in seagrass depth range due to changes in light availability (ie. water quality effected) (Fisheries Research Consultants. 1994b). The seagrass depth range method is based on the assumption that the upper distributional limit of seagrasses is affected by the tolerance of seagrasses to tidal exposure/desiccation and the lower distributional limit is determined by light availability to the seagrasses. Water quality factors that effect light availability to seagrasses include suspended solids and nutrients (causing increased chlorophyll-*a* and epiphytes). Monitoring the depth distribution of seagrasses not only provides an indication of their health and survival, but can also be used as a valuable tool to determine the effects of environmentally significant changes in water quality (Abal and Dennison 1996). In 1996, large decreases in seagrass depth distribution were recorded at transects located at Boonooroo, Kauri Creek and Bullock Point in the central and southern sections of the Great Sandy Strait (all other transects in the Strait remained relatively unchanged) (Conacher *et al.* 1999). By February 1999 (2 weeks after the flood) some of these transects had recovered, although significant changes in species composition and recovery had occurred in the Tin Can Inlet region, suggesting chronic environmental impacts (Conacher *et al.* 1999).

There is some local concern that runoff from urban and agricultural land-use is continuing to impact seagrasses the Great Sandy Strait. In April 2000, there was public concern in regard to the declining seagrass meadows in the Great Sandy Strait and the resulting poor prawn catches. These were attributed to commercial, residential and plantation development runoff (*Gympie Times,* April 11 (Anon 2000)). Although there are several small unsewered villages scattered along the length of the Great Sandy Strait, the largest development is the adjacent 88,000 ha *Pinus* plantation. Most of the plantation runoff however, is into the Mary River catchment rather than the Strait.

A Queensland Department of Primary Industries Forestry study was commenced in 1994 to examine the impacts of exotic *Pinus* plantation (*Pinus elliottii*, *Pinus caribaea* and a hybrid) management on water quality and water yield in the coastal lowlands of south-east Queensland (Bubb 2000a). The study was based within the Toolara *Pinus* plantation estate in the upper reaches of Sandy Creek, within the Mary River catchment, and conducted between two weirs. After calibrating the catchment for 4 years, 80 ha of mature plantation was clearfalled and 250 ha of approximately 25-year-old plantation was thinned. Immediately following the harvest, the clearfall area was prepared and a second rotation crop was established which also included an initial application of inorganic nitrogen-phosphorous fertiliser and regular weed tending with a residual herbicide (simazine). The harvest and early establishment period is widely recognised as the major disturbance phase within a forest plantation rotation. Water samples were collected by regular (1 to 2 monthly) grab and intensive automated sampling during flood events. Catchment groundwater was also monitored through a network of piezometers. During the 12-month post harvest period, there was no detectable treatment effect on stream water and groundwater quality indicators of total nitrogen, nitrate, ammonium, total phosphorus, orthophosphate or suspended solids. This result also suggested an absence of major erosion events during the monitoring period. Simazine was generally not detected in grab samples (i.e. periods of baseflow or zero flow) or groundwater samples, however it was regularly detected at low concentrations (i.e. generally < 2 $\mu g\ L^{-1}$) throughout flood events (Bubb 2000b). These studies however, have not expanded to investigate the effects of plantation runoff into the central and southern Great Sandy Strait. Big Tuan residents (central Great Sandy Strait) often report orange/brown waters from Big Tuan Creek during low tide and point to the upstream plantations. In areas around Big Tuan and Boonooroo, there is some cane farming (~20 ha) and the pine plantation (~5,000-10,000 ha) that flows into the Big Tuan Creek catchment has a 20-30 m buffer of natural vegetation. Whether this poor water quality is a result of the fertilisers and herbicides used in cane or *Pinus* plantations is unknown. Alternately, the discolouration of the waters could also be a natural phenomena caused by leachate from the iron rich laterite (coffee rock) in the region and water soluble polyphenols derived from the abundance of *Melaleuca sp* found along streams throughout the adjoining catchment.

In conclusion, there is a need for information on the sub-lethal and chronic impacts of land run-off (eg., sediments, nutrients, agro-chemicals) on the seagrasses and dependant fauna. Research is urgently required to describe the response of seagrasses to natural and human factors and to establish (*1*) acceptable levels of change in response to such factors and (*2*) the water-quality conditions that lead to these changes.

↳ *Recommendations:*

- Additional funding to ensure the continuation of the Seagrass-Watch program to monitor intertidal seagrass habitats in the Hervey Bay and Great Sandy Strait by community volunteers be supported.
- Long-term depth monitoring transects established by Fisheries Research Consultants (1994b) in the Great Sandy Strait be resurveyed and compared with the February 1999 (Conacher *et al*. 1999) results.
- Multidisciplinary studies that examine seagrass meadows and associated green turtle and dugong populations be supported.
- A collaborative water quality program be undertaken to examine the effects, if any, that pine plantations and other developments in the catchments have on the water quality of the central and southern Great Sandy Strait.
- A valuable piece of information for management would include estimates of potential for seagrass recovery (ie. seagrass seed availability within the local sediments) in intertidal and shallow sub-tidal areas affected by the flood plume. This information is presently not available.
- Restoration of seagrass meadows be considered for some limited localities within the Great Sandy Strait.
- Additional research to address issues influencing habitat quality, such as the effects of land runoff constituents (nutrients, metals, herbicides) on the performance and health of seagrasses, be supported.
- A complete resurvey of Hervey Bay and the Great Sandy Strait be undertaken in December 2001, at similar intensity to the pre-flood survey (December 1998, McKenzie 2000) to assess seagrass recovery.

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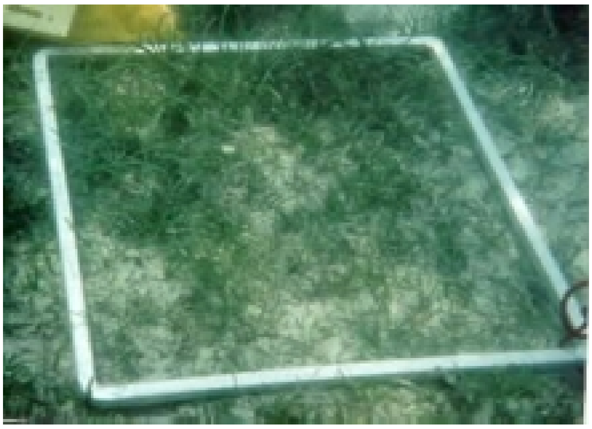
APPENDIX 1. Examples of seagrass above-ground biomass, from reference photos of a 0.25 m^2 quadrat.

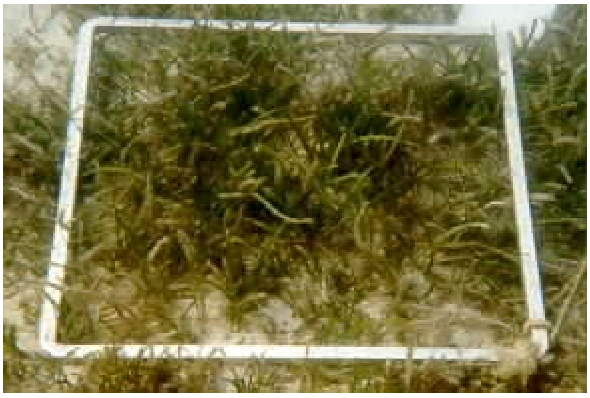
Halophila ovalis **3.12 g DW m^{-2}**

Halodule uninervis **(wide) 6.44 g DW m^{-2}**

Halodule uninervis **(wide) 12.92 g DW m^{-2}**



Halodule uninervis **(wide) 36.24 g DW m^{-2}**



Syringodium isoetifolium/
Halodule uninervis **(wide) 51.04 g DW m^{-2}**

Halophila spinulosa **58.16 g DW m^{-2}**

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