Issues for seagrass conservation management in Queensland

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Coastal, reef-associated and deepwater (>15 m) seagrass habitats form a large and ecologically important community on the Queensland continental shelf. Broad-scale resource inventories of coastal seagrasses were completed in the 1980s and were used in marine park and fisheries zoning to protect some seagrasses. At least eleven of the fifteen known species in the region reach their latitudinal limits of distribution in Queensland and at least two *Halophila* species may be endemic to Queensland or northeastern Australia. The importance of seagrasses to Dugongs *Dugong dugon,* Green Turtles *Chelonia mydas* and commercially valuable prawn fisheries, will continue to strongly influence directions in seagrass research and conservation management in Queensland. Widespread loss of seagrasses following natural cyclone and flood events in some locations has had serious consequences to regional populations of Dugong. However, the impacts to Queensland fisheries are little studied. Agricultural land use practices may exacerbate the effects of natural catastrophic events, but the long-term impacts of nutrients, pesticides and sediment loads on Queensland seagrasses are also unknown. Most areas studied are nutrient limited and human impacts on seagrasses in Queensland are low to moderate, and could include increases in habitat since modern settlement. Most impacts are in southern, populated localities where shelter and water conditions ideal for productive seagrass habitat are often targets for port development, and are at the downstream end of heavily modified catchments. For Queensland to avoid losses experienced by other states, incremental increases in impacts associated with population and development pressure must be managed. Seagrass areas receive priority consideration in oil spill management within the Great Barrier Reef and coastal ports. Present fisheries legislation for marine plant protection, marine parks and area closures to trawl fishing help protect inshore seagrass prawn nursery and Dugong feeding habitat, but seagrasses in deep water do not yet receive any special zoning protection. Efficacy of the various Local, State and Commonwealth Acts and planning programmes for seagrass conservation is limited by the expanse and remoteness of Queensland's northern coast, but is improving through broad-based education programmes. Institutional support is sought to enable community groups to augment limited research and monitoring programmes with local "habitat watch" programmes. Research is helping to describe the responses of seagrass to natural and human impacts and to determine acceptable levels of changes in seagrass meadows and water quality conditions that may cause those changes. The management of loss and regeneration of seagrass is benefiting from new information collected on life histories and mechanisms of natural recovery in Queensland species. Maintenance of Queensland's seagrasses systems will depend on improved community awareness, regional and long-term planning and active changes in coastal land use to contain overall downstream impacts and stresses.

INTRODUCTION

PRIOR to the 1980s, seagrasses and their values were poorly understood in Australia, and received little conservation attention. Information on the extent of seagrasses in Queensland was limited to a few locations near population centres. Young and Kirkman (1975) mapped seagrasses in Moreton Bay and Kirkman (1978) provided the first documented seagrass loss for Moreton Bay and for Queensland. Seagrasses in northern Queensland were only documented in collections for taxonomic classifications (den Hartog 1970; Greenway 1979) and studies of succession in intertidal seagrasses at Townsville (Birch and Birch 1984). A reconnaissance of the Torres Strait (Bridges *et al.* 1982) indicated that seagrasses were an important habitat in that region. Broad-scale seagrass surveys along the Queensland coastline (by the Queensland Department of Primary Industries) were not initiated until 1984 following recognition of the importance of seagrasses as nursery habitat for juvenile prawns of commercially valuable prawn fisheries (Coles and Lee Long 1985). The importance of seagrasses to survival of Dugong *Dugong dugon* (Heinsohn *et al.* 1977) and Green Turtles *Chelonia mydas* (Lanyon *et al.* 1989) led to further seagrass surveys. Conservation management priorities for these threatened fauna strongly influence the direction of seagrass research and conservation management in Queensland.

Placing values on Queensland seagrasses

Seagrasses world-wide represent important components of coastal primary production (Hillman *et al.* 1989) and support complex marine food webs (e.g., Howard *et al.* 1989). In Queensland, estuarine and shallow coastal seagrass meadows are nursery habitat for commercially important prawn populations (Coles *et al.* 1993; Watson *et al.* 1993) and appear to be more important than deepwater seagrasses as nursery habitat for commercially and recreationally important species of prawns and fish (Derbyshire *et al.* 1995). Meadows dominated by *Halophila* and *Halodule* species are preferred Dugong feeding areas (e.g., Preen 1995). Dugong feeding habitats include seagrasses in shallow and deep (>15 m) water, and centres of high Dugong numbers were indicators of vast areas of seagrass in shallow to deep water in the Lookout Point to Barrow Point region (Lee Long *et al.* 1989) and in

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Hervey Bay (Lee Long *et al.* 1992). Seagrasses in shallow coastal waters play important roles in maintaining sediment stability and water clarity. The influence of seagrasses in deep water (>15 m) on sediment dynamics is less understood. Recent discoveries of new *Halophila* species (Greenway 1979; Larkum 1996) and other morphologies (Coles *et al.* 1996; Lee Long *et al.* 1997) and possible endemism of some species to the region (Lee Long *et al.* 1993) may place higher conservation value on some habitats.

Status of seagrasses in Queensland

Broad-scale resource inventory surveys between 1984 and 1989 (Coles *et al.* 1985, 1987a,b, 1992; Hyland *et al.* 1989; Lee Long *et al.* 1992) have mapped seagrass habitats in estuaries, shallow coastal bays and inlets, on some fringing reefs, barrier reef platforms, inter-reef and Great Barrier Reef lagoon. The estimated area of seagrass habitats for the major regions surveyed is approximately 18 500 km^2, but at least another 4 000 km^2 are expected to be recorded for areas still under study and not all Queensland waters have been completely surveyed (Table 1). The additional seagrass habitat areas not yet calculated include recently discovered habitats in the northern Great Barrier Reef lagoon, inter-reef, inshore-reef and barrier-reef platforms (Lee Long *et al.* 1996). Approximately 13 425 km^2 of seagrass habitat on reef platforms and non-reef soft bottoms (Long and Poiner 1997) was found in the Torres Strait bio-geographic region which includes waters that come under special inter-governmental jurisdiction arrangements between Papua New Guinea and Australia.

There are fifteen known seagrass species recorded from surveys of Queensland coastal, island and reef waters (Bridges *et al.* 1982; Hyland *et al.* 1989; Lee Long *et al.* 1993; Long and Poiner 1997; QDPI, unpubl. data). Most of these species are common to the Indo-West Pacific region, but at least eleven reach the southern limits of their distribution in Queensland (Kuo and McComb 1989; Lee Long *et al.* 1993). Only *Halophila ovalis, H. decipiens* and *Zostera capricorni* are known to extend south of Queensland (Kuo and McComb 1989), and at least two species (*Halophila tricostata* and *Halophila* sp.) may be endemic to Queensland. One recently discovered species (*Halophila capricorni*, Larkum 1995) and additional undescribed plants in the Genus *Halophila* improve the seagrass species list for Queensland (Kuo, pers. comm.) as surveys continue to explore new habitat types. However, considerable phenotypic plasticity in the broadly defined group of *Halophila* species including *H. ovalis* and *H. decipiens* in Queensland, creates confusion as to the taxonomic certainty of these species and close relatives (Waycott, pers. comm.).

The few studies of long-term changes in seagrasses in Queensland have shown that large-scale depletion may occur following cyclone or flood events (e.g., Preen *et al.* 1995; QDPI, unpubl. data), and recovery has usually occurred within periods up to ten years (e.g., Birch and Birch 1984). Studies extending up to four years at specific locations (e.g., McKenzie *et al.* 1998) have shown that Queensland's tropical seagrass species are also naturally highly variable in abundance and distribution. Seagrass habitat at two seaward locations in Moreton Bay, near the city of Brisbane, was remarkably stable over a 25 year period (Poiner 1985), although near-shore meadows have been much more vulnerable to losses from impacts associated with coastal developments and catchment run-off (Hyland *et al.* 1989).

ECOLOGICAL ISSUES INFLUENCING MANAGEMENT

Natural impacts

Short-term catastrophic impacts such as tropical cyclones and floods caused widespread depletion of seagrasses in Hervey Bay in 1992

Table 1. Estimated area of seagrass habitat, and number of species for major regions surveyed in Queensland.

Region	Estimated area of seagrass habitat mapped (km^2)	Number of seagrass species	Source references
Coolangatta to Noosa	286	7	Hyland *et al.* 1989
Great Sandy Straits to Hervey Bay	1 223	9	Lennon and Luck 1990; Lee Long *et al.* 1993
Burnett Heads to Cape York (incl. Great Barrier Reef region)	2 950 (plus at least 4 000 km^2 partially surveyed)	14 (plus possibly 3 undescribed species)	Lee Long *et al.* 1993; Lee Long *et al.* 1996
Torres Strait	13 425	11$^+$	Long and Poiner 1997; QDPI, unpubl. data
Eastern Gulf of Carpentaria	520	12	QDPI, unpubl. data
Queensland Total	18 405 (plus incompletely surveyed deepwater areas)	14$^+$	

(Preen *et al.* 1995), and localized reductions have been documented elsewhere following cyclones (e.g., Upstart Bay 1989, QDPI, unpubl. information) and floods (e.g., Moreton Bay, Kirkman 1978). All of these impacts were followed by recovery periods that ranged up to ten years. Long-term changes in climate could influence seagrasses and these might occur over time scales of El Nino Southern Oscillation (ENSO) cycles or be associated with other processes such as global climate change. There is some evidence of region-wide changes in seagrass abundance over several years (e.g., in the Hinchinbrook region, Lee Long *et al.* 1998a, and Shoalwater Bay, Limpus, pers. comm.), and Green Turtle breeding may be affected by ENSO-related climate changes via the seagrass nutritional pathway (Limpus and Nicholls 1988). More information is needed on the natural patterns and scales of variability in Queensland seagrasses so that anthropogenic impacts on seagrasses can be fully assessed and influences on associated fauna can be understood.

Diseases — mostly fungal pathogens such as *Labrynthula* — appear to be present in seagrass areas in non-lethal abundance and only cause widespread loss when stress on seagrasses from other factors is high (den Hartog 1987). There was a suspected incidence of *Labrynthula* in loss of seagrasses in the Great Sandy Strait in the early 1990s (Wynuczynski 1997), but no other evidence exists of widespread pathogen impacts in Queensland.

In some areas (e.g., Moreton Bay) grazing by herds of Dugong appeared to maintain meadows, as *Halophila* or *Halodule* dominated the fastest recolonizers of grazed areas and the preferred dietary species of Dugong (Preen 1993). Losses of Dugong and reductions in grazing intensities could possibly result in changes in composition of some meadows away from species tolerant to grazing pressure, toward species less tolerant to grazing pressure and less palatable or nutritious to Dugong.

Anthropogenic impacts

Agricultural and urban land run-off impacts have caused deterioration and loss of seagrasses at temperate localities in Australia (e.g., Shepherd *et al.* 1989), where recovery has been extremely slow. Large-scale seagrass losses in Queensland have so far been mostly associated with natural catastrophic events and recovery has usually begun within two years (Preen *et al.* 1995) and been complete within a decade (e.g., Birch and Birch 1984; Hyland *et al.* 1989). All Queensland seagrasses are tropical species and fast-growing when conditions are suitable. In contrast to most temperate species (see Clarke and Kirkman 1989), Queensland seagrasses are naturally highly variable in abundance on seasonal and annual time scales. Experimental research on the responses of seagrass to nutrients indicates seagrass growth at Queensland coastal and reef localities is mostly nutrient limited (Mellors, pers. comm.) and it is likely that anthropogenic nutrient impacts have led to increases in seagrasses at some localities (Udy *et al.* 1999). This scenario is difficult to test without any methods for hind-casting tropical seagrass distribution and abundance.

Nevertheless, sediment and nutrient loads associated with agricultural land-clearing may have exacerbated the impacts on seagrasses when two cyclones and prolonged flooding led to the loss of approximately 1 000 km^2 of seagrasses in Hervey Bay (Preen *et al.* 1995). The loss represented approximately 25% of the known coastal seagrasses in Queensland (Preen and Marsh 1995).

The event at Hervey Bay raises the need for a cautious approach in managing downstream impacts on seagrasses in Queensland. At this stage, it is difficult to know whether catchment impacts in Queensland have led to increases in seagrass growth, exacerbated the effects of natural events through increased soil erosion and nutrient run-off, caused sub-lethal stresses, or even affected the recovery of seagrasses after depletion. Any combination of these may be occurring in different localities, and impacts from land run-off are probably greatest in semi-enclosed bays and harbours where excess nutrients and sediments reaching seagrass areas are retained longer and accumulate quicker. Integrated Catchment Management (ICM) programmes which seek to minimize these impacts are seen as sensible for coastal marine zone management in general and would benefit seagrass conservation in the long term.

Seagrasses are common in sheltered inlets, ports and bays which are the target for intensive coastal development, and where urban and industrial runoff, dredging and habitat modifications are increasing. Studies of port developments in Queensland so far indicate direct impacts can occur under the footprint of dredging or reclamation activities, but collateral impacts could not be easily separated from naturally high variations in these tropical seagrasses (e.g., Lee Long *et al.* 1998b). Impacts which increase water column sediments and nutrients, or phytoplankton or epiphyte density can lead to greater attenuation of light and reduced seagrass survival at depth (Dennison *et al.* 1993). Introduction of exotic marine species to Queensland ports, via ships hulls or ballast water, present potential threats to local seagrass communities. Port authorities in Queensland and the Co-operative Research Centre for the Great Barrier Reef World Heritage

Area are investigating the potential threats and measures to minimize introductions of sea-urchins, other invertebrate seagrass grazers and potentially noxious marine plants. Seagrasses in the far northern portion of the State do not face the same impacts from urban and agricultural runoff, or coastal and reef-site development that occur in southern populated regions.

Before the 1998 implementation of Dugong Protection Areas, the level of zoning to protect seagrasses (and Dugong) was far greater in the northern Great Barrier Reef than in the southern region. Marsh and Corkeron (1996) noted that in 1993 a Dugong located in the northern Great Barrier Reef region was eleven times more likely to be within a zone with some protection from destructive or extractive activities than a Dugong in the southern Great Barrier Reef. Seagrasses offshore, in the Great Barrier Reef lagoon and inter-reef waters, still receive less formal protection through zoning than seagrasses in shallow coastal waters.

Impacts of prawn trawl operations on seagrasses are poorly understood, but may include chronic, low level disruption within meadows (causing patchiness and erosion) or incremental impacts on the edges of meadows. Most seagrasses in shallow coastal bays and inlets are in water too shallow for trawlers to operate. North of Cape Tribulation (approx. 12°S) coastal strip closures should help protect shallow-water, inshore seagrass meadows from trawling activity, but these closures are difficult to police. Dense meadows in deep water are usually avoided by prawn trawl fishers whenever the seagrasses begin to clog their nets, but little is known of the long-term impacts of various levels of trawling on seagrass meadows in deep water. Until better information is available, precautionary measures (e.g., formal zoning) may be necessary to protect seagrass in deepwater from activities such as trawling. The largest areas of deepwater seagrass habitat occur in Hervey Bay and in the Cairns and Far Northern Sections.

Increases in shipping traffic along eastern Queensland will lead to the increased likelihood of oil spills. Oil spills may cause severe and immediate damage to intertidal seagrass meadows but subtidal seagrasses would be at lesser risk (Jackson *et al.* 1989; Kenworthy *et al.* 1993). Impacts on the invertebrate and fish communities which seagrasses support can be severe, but these communities may respond positively to subsequent regeneration of seagrasses (Jackson *et al.* 1989).

Widespread depletion of seagrasses in shallow and deep water in Hervey Bay had devastating effects on local Dugong populations (Preen *et al.* 1995; Preen and Marsh 1995). There is also evidence of widespread reduction in seagrasses, with possible impacts on Dugong populations, in the northern Torres Straits in 1992 (Long and Skewes 1996). Management plans and management responses to impacts on Queensland seagrasses are designed primarily around the maintenance of seagrasses for commercial prawn fisheries and for Dugong and turtle populations. The Great Barrier Reef Marine Park Authority, the Ports Corporation of Queensland and other port authorities, support seagrass management measures which also consider the broader ecological importance of seagrasses in maintaining coastal water quality, sediment stability, and as the basis for other marine fisheries and food-webs. A major difficulty for management agencies is the scarcity of formal studies and documented information on seagrass losses and associated impacts on fisheries and fauna. Increases in seagrass abundance (resulting from nutrient additions, Udy *et al.* 1999) may be indications of adverse impact on coastal and reef systems and could deserve as much attention as seagrass loss.

MANAGEMENT OPTIONS

Legislation

The Great Barrier Reef Marine Park Authority, the Queensland Fish Management Authority (QFMA), the Queensland Department of Environment Protection Agency (EPA), and Queensland Department of Primary Industries (QDPI) are the primary agencies responsible for seagrass management in coastal zone, marine park and fisheries areas.

Seagrass conservation in Queensland is formally enforced via a suite of State and Commonwealth legislation (e.g., Marine Parks Act, Coastal Protection, Clean Waters, Harbours, Environment Protection, Fisheries and Department of Transport Spill and Discharge Acts). Seagrasses receive statutory protection under the Queensland *Fisheries Act (1994)*, which prohibits the damage or destruction of marine plants without a permit and allows for declaration of Fish Habitat Areas where stricter development controls can be imposed to protect marine plants. A recently established *Integrated Planning Act* (by the State Government) intends to bridge these various tools of legislation together with other Acts to ensure development proposals take all pertinent issues into account.

In 1990, the Queensland Fish Management Authority (QFMA), in consultation with the prawn trawl industry, acknowledged the value of seagrasses to prawn stocks, and added to the seasonal prawn closures with a coastal strip closure system to protect juvenile prawns and their seagrass habitat. Most shallow, coastal seagrass habitat north of Cape Tribulation is currently in areas zoned as free from trawling activity, either within the QFMA policy of coastal strip closures or within Great Barrier Reef Marine Park Authority zoning. An extension of this reasonably effective strip closure system to protect coastal seagrasses south of Cape Tribulation is also being considered for evaluation. Protection measures for conservation of some deepwater seagrass habitats are likely to include marine park zoning and trawl area closures. The remoteness of Queensland's coast and reef waters makes implementation and policing of the above legislation measures very expensive and difficult. Introduction of GPS-based vessel monitoring systems (VMS) in 1999 will enable tracking of the position of fishing vessels, and will assist in policing trawl fishing closures where seagrass areas require protection (Anon. 1998).

Planning

Seagrass habitats are considered an important downstream habitat in most coastal planning programmes, including Local Government Development Control Plans, Catchment Management Programmes, Regional Development/Use Plans, Marine Park planning and zoning. Regional plans will need to be implemented with broad-based support if they are to be successful at improving catchment land use, minimizing downstream impacts and direct adverse impacts in the coastal zone. The consultative process in planning ensures multiple stakeholders' views are used, but can also be slow and compromising on conservation needs.

Education

Education programmes at several levels are encouraging changes in community behaviour to protect seagrasses. Community and industry training and participation is facilitated by government agencies through environment monitoring (e.g., community Seagrass-Watch programmes), and changes in land use (Integrated Catchment Management and Landcare programmes). Education is affecting overall community, as well as institutional attitudes, to seagrass conservation. Changes have been greatest in recent years with noteable increases in the release of information through various media, to educational institutions and to industry and community stakeholders.

Integrated Catchment Management programmes have wide acceptance across Queensland and would be beneficial to seagrass conservation, since seagrasses are at the "downstream end" of catchment run-off. From a Dugong management perspective, improved catchment management would be especially useful in the southern Great Barrier Reef region, where seagrasses are mostly restricted to the more vulnerable coastal strip. Alternative Dugong feeding areas offshore are far fewer in the south than in the northern Great Barrier Reef.

Point-source discharges are also being addressed and effluent controls are being introduced at reef and coastal locations to help minimize overall impacts on seagrasses and corals. Introduction of secondary and tertiary sewage treatment at large population centres might also benefit coastal seagrass systems. Incremental expansions in population and development pressures on the Queensland coast may mask the overall impacts on seagrass systems. Long-term conservation management of seagrasses will need long-term regional plans supported by positive changes in use of the coastal zone and by effective policing.

SEAGRASS RESEARCH PRIORITIES

The body of research information which is used for seagrass conservation management in Queensland has come mostly from work conducted in only the last decade or so. The major areas of research on seagrasses include mapping and monitoring, physiological processes and plant-environment interactions, plant-animal interactions. Research directions are now influenced by a mixture of community and industry needs and opinion and scientific opinion from the major research and management institutions. Research has developed most vigorously during the 1990s to include a balance of issue-driven and strategic programmes. The Co-operative Research Centre for Sustainable Development of the Great Barrier Reef also supports new initiatives in seagrass studies to improve the information base for sustainable use of the Great Barrier Reef.

Status and trends

Information from the original seagrass surveys (1980s) is becoming dated for use in zone planning. Data from those broad-scale surveys are only sufficient for assessing broad-scale and regional changes and finer scale surveys are needed for monitoring and assessing local impacts.

Temporal variability in Queensland seagrasses is documented in only a few studies. Mellors *et al.* (1993) recorded a two-fold increase from winter to summer biomass in a *Halodule uninervis*/*Cymodocea serrulata* meadow at Green Island, but McKenzie (1994) measured up to six-fold changes in above-ground biomass of a coastal *Zostera capricorni* meadow from winter to summer nearby, at Cairns. Information on year-to-year variability in Queensland's tropical seagrasses improves slowly, since opportunities for long-term monitoring are few. Anecdotal information indicates large changes in seagrass distribution and abundance may occur on regional scales in tropical Queensland, but monitoring data are still required to clarify such a possibility. Many of Queensland's tropical seagrass species (e.g., *Halophila, Halodule* and *Zostera* spp.) appear to recover from losses more quickly than temperate species (e.g., *Posidonia, Amphibolis* spp.), via both reproductive and vegetative growth (Clarke and Kirkman 1989; Poiner and Peterken 1995). Long-term variation in seagrasses has potentially large consequences for prawn fisheries, Dugongs and sea turtle populations, and successful management of these populations requires quantitative information on seasonal and long-term variation in seagrass distribution and abundance. Attempts are being made to formalize seagrass monitoring programmes and establish community Seagrass-Watch programmes, with robust and cost-effective methods that will provide early warnings of seagrass loss.

Biology, physiology and ecology

Seagrass conservation measures in Queensland have improved with recent advances in knowledge of the processes which influence seagrass growth and survival — at the shoot, plant, patch and meadow scales. This includes improved understanding of the physical environment parameters and conditions which influence seagrasses. The responses of seagrasses to changes in light and nutrients has been described in simple models where seagrass growth and distribution are used as broad indicators of water quality and environmental health (Dennison *et al.* 1993; Abal and Dennison 1996).

Seagrass-fauna links

As management of seagrass habitats becomes more sophisticated there is need for more detailed understanding of the links between seagrasses and the health of fisheries and herbivore populations. Zone plans for protection of seagrasses will benefit from studies which show which seagrass areas are most productive and important to fisheries, to the growth and survival of Dugongs and Green Turtles, and to biodiversity. Seagrass productivity is likely to be at least as important as seagrass abundance in affecting the growth and survival of seagrass-dependant fauna. There are very few measures of the impact of seagrass loss on fisheries in Queensland and most such records have been anecdotal.

CONCLUSIONS

Seagrass conservation in Queensland benefits from a wide recognition of the importance of seagrasses to commercial and recreational fisheries production and to populations of "charismatic mega-fauna". Seagrass management initiatives have included special protection measures for areas of importance to commercial fisheries production (e.g., fisheries coastal strip closures). Impacts on seagrasses from activities such as trawling are poorly understood and formal zoning to protect seagrasses from potential damage of this type is limited. Present impacts on Queensland seagrasses from agricultural and urban land run-off are low, but increasing population and development pressures will require careful coastal zone and catchment management to help minimize downstream impacts on seagrasses. Legislation and planning programmes need the support of imaginative education campaigns which also provide the community with solutions for protecting seagrasses.

Information is still required on habitats grazed by Dugong and turtles, to identify the locations important to these fauna. Programmes which address downstream impacts of land run-off will help seagrass conservation. Protection of coastal seagrasses may be particularly important in southern regions where potential threats are currently greatest. These regions also appear to have no offshore seagrass areas for Dugong populations to seek alternative food resources.

A basic resource inventory for Queensland seagrasses is now almost complete and contributes to zoning plans for seagrass protection. Difficulties for management of seagrasses stem from the expanse and remoteness of the coast and shelf, as well as a scarcity of detailed information on the natural ranges of variability and the causes of change in seagrasses. Priorities for study include establishment of long-term seagrass monitoring programmes at sites over a range of latitudes, locations and habitat types, and areas of conservation priority. Studies which identify the causes of change in seagrasses and seagrass responses to anthropogenic impacts will help in developing tools for monitoring impacts and the health of seagrass systems.

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