A Vulnerability Assessment for the Great Barrier Reef

Australian Government
Great Barrier Reef Marine Park Authority

Seagrass

Information valid as of Feb 2012

Summary

Diversity

Fifteen species of seagrass occur within the Great Barrier Reef World Heritage Area (the World Heritage Area).

Susceptibility

The key elements for the survival of seagrass include:

- Suitable light
- Sediment
- Salinity and temperature ranges
- An appropriate level of nutrients
- Minimal natural and human disturbance.

Tolerance to different sediment, light and salinity regimes is known to vary between species, however thresholds for individual species are not well understood.

Seagrass species with long-blade structures, large root systems and rhizomes can potentially withstand a greater depth of sediment deposition than shallow-rooted, small-leafed species because they can grow through deeper deposits. Smaller, shallow-rooted species can regrow rapidly on newly deposited sediments if conditions are right.

Intertidal seagrass meadows are more vulnerable to increases in air and sea surface temperature, facing potential impacts such as burn-off and tissue damage. Deepwater seagrasses are less affected by changes in air and sea temperature due to the buffering effect of water depth.

Seagrass meadows that grow in locations at the margins of their requirements are most susceptible to disturbances.

Major pressures

Seagrasses are facing major pressures from:

- Poor water quality from catchment runoff (agricultural and urban/industrial)
- Habitat loss and modification from increasing coastal development
- Expansion in ports and shipping
- Increased intensity of storms, floods and cyclones
- Sea surface temperature and sea level rise.

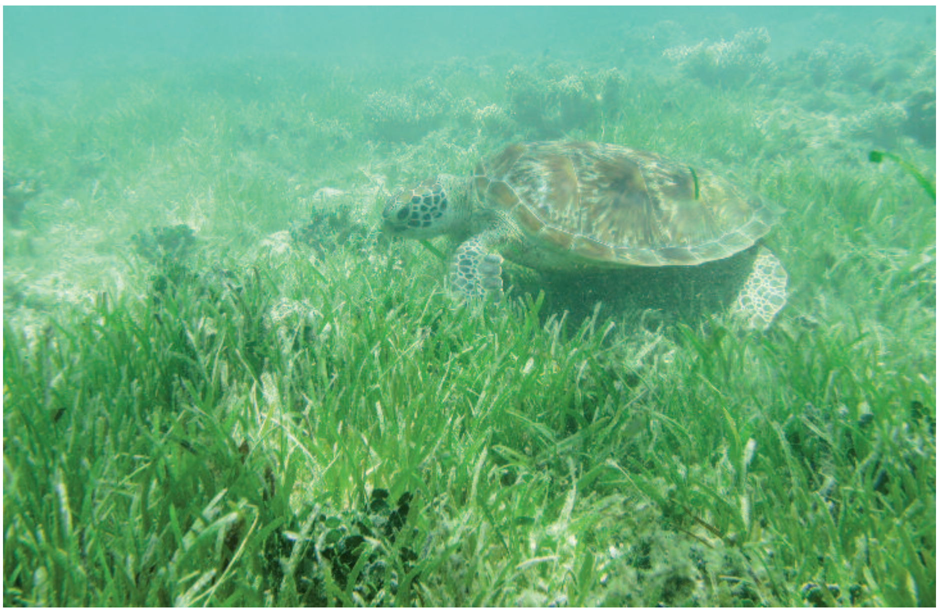
Cumulative pressures

Much of the coastal seagrass habitat in the Great Barrier Reef World Heritage Area lies in sheltered coastal bays and estuaries that are also the centres of urban, port and coastal development. Seagrasses are vulnerable to changes in water quality from non-point (diffuse) sources. Their location in coastal areas where human actions and developments are concentrated, means they are also under significant cumulative pressure from local activities such as modification of coastal processes, dredging, reclamation and point source discharge.

Seagrass habitat assessments concluded that seagrasses found in the Cairns/Trinity Inlet, Mourilyan, Townsville/Cleveland Bay, Abbot Point, and Gladstone harbour regions are the most at-risk from cumulative pressures[1,2], although individual pressures may have significant impacts on seagrasses in other locations.

The *Great Barrier Reef Outlook Report 2009* acknowledges that ultimately, if changes to the world's climate become too severe, no management actions will be able to climate-proof the Great Barrier Reef ecosystem, including seagrass.

Seagrass meadow on Green Island reef flat, offshore Cairns, North Queensland taken 2 October 2009. Photo courtesy of www.seagrasswatch.org



Green turtle feeding on seagrass. Photo courtesy of www.seagrasswatch.org

Management in the Great Barrier Reef and adjacent areas in Queensland

A direct legislative management tool for the protection of seagrasses is the requirement for notification and permission for plant removal under the *Fisheries Act 1994* (Queensland).

Other planning and assessment Acts and Regulations are used to protect seagrass meadows from potential development impacts, for example, through powers to refuse or manage particular activities, to declare protected areas, or to place conditions on discharges or runoff. Examples of these tools are the *Environment Protection and Biodiversity Conservation Act 1999*, the *Environment Protection (Sea Dumping) Act 1981*, the *Great Barrier Reef Marine Park Act 1975* (as well its complementary Queensland Marine Parks legislation) and the *Sustainable Planning Act 2009* (Queensland).

Implementation of legislative tools is supported by national, state and local policies and guidelines that can specify water quality criteria to protect aquatic ecosystems such as seagrass. Water quality management is applied to both point and diffuse sources. For example, under the *Environmental Protection Act 1994* (Queensland) point source facilities that discharge waters that may cause harm are assessed and licensed, and there are penalties for non-compliance. *Urban Stormwater Quality Planning Guidelines 2010* are an example of diffuse pollution management for developed lands, and the *Great Barrier Reef Protection Amendment Act 2009* for agricultural activities. Ship-sourced pollutant management is managed within the framework of an international, national, state and local implementation approach. This includes a commitment to a number of international conventions, legislation such as the *Commonwealth Protection of the Sea (Powers of Intervention) Act 1981*, the *Transport Operations (Marine Pollution) Act 1995* (Queensland) and the *Quarantine Act 1908*.

Existing management actions

The primary focus of actions to protect seagrass, aside from applying those tools identified above, is to improve water quality entering the Great Barrier Reef. The *Reef Water Quality Protection Plan 2009* sets targets for improvement and is supported by the resources of the Australian and Queensland governments, as well as significant investment by industry, to implement change and monitor progress. Other programs include education, awareness and action plans on what individuals can do to minimise their impacts on the environment such as the *Great Barrier Reef Climate Change Action Plan 2007-2012* and the Reef Guardian program.

Great Barrier Reef Outlook Report 2009 assessment

Good. Changes in seagrass communities were reported as appearing to be mainly due to natural cycles of decline and recovery, although influenced by runoff from catchments. However, since publishing of the *Great Barrier Reef Outlook Report 2009*, some warning signs have emerged that require consideration:

- The *Great Barrier Reef Second Report Card 2010* found seagrass to be in poor condition with declines reported over the last four years.
- McKenzie *et al* 2011 report significant losses of seagrass in the areas directly affected by the path of Tropical Cyclone Yasi.[3] They detail broader scale impacts of the 2010–2011 wet season on seagrass meadows exposed to flooding and cyclones in the Great Barrier Reef. These impacts are on seagrass ecosystems already stressed following a number of major freshwater inflow years and extended periods of cloud cover limiting growth periods.
- Seagrass meadows that had been consistently present for the past 15 years in Mourilyan Harbour[4] have been lost in recent years and substantial declines have occurred in the meadows adjacent to Cairns[5], Townsville[6], and Gladstone.[7] Annual long-term monitoring programs all showed large declines in 2010, with some locations showing declining trends in the recent years preceding this.
- McKenzie *et al* 2011 report that abundance of seagrasses south of Cooktown, while variable, has declined at monitored sites since 2009 (and earlier for some sites).[3,8,9,10,11,12,13]

Vulnerability assessment: High

Defining a single vulnerability level to seagrasses at the scale of the Great Barrier Reef can be difficult due to the:

- Nature of seagrass
- Geographical scale of the Great Barrier Reef
- Different species and habitats that support the growth of seagrass meadows
- Non-uniformity of pressures that meadows experience.

For example, seagrass meadows located within port expansion areas with approval for complete removal of meadows, have clearly a very high vulnerability, regardless of any offsets that may have been determined to potentially compensate for their loss.

Parts of the near shore coastal and intertidal environment along the urban or developed coast (south of Cooktown) are particularly exposed to poor water quality as well as other pressures, and, in some areas, repeated years of exposure have resulted in declines in abundance of seagrasses.

Where the number of reproductive structures is poor, there is insufficient seagrass remaining for successful vegetative regrowth, or nearby meadows to provide recruitment stock, the vulnerability assessment is high. There are also concerns that with increasing pressures, the ability of the system to recover from recent losses may be compromised. However, in the Cape York Peninsula region, both water quality and development pressures are, at present, low and meadows in this region have a low vulnerability assessment.

Climate change, whilst likely to affect all seagrass meadows, is predicted to be most damaging to intertidal and shallow seagrass meadows.

Seagrass meadow on Green Island reef flat offshore Cairns, North Queensland taken 17 March 2011. Photo courtesy of www.seagrasswatch.org

It will take many years to address the poor water quality entering the Great Barrier Reef, to improve practices that affect water quality throughout the catchments adjacent to the Reef, and then to see these improvements realised in the Reef lagoon itself. Hence, a substantial level of vulnerability remains, at least in the foreseeable future.

The population growth in Australia is resulting in expansion of the urban footprint along the Queensland coast. Urban expansion leads to an increase in infrastructure and services, and, unless well planned and implemented, can result in significant impacts on the coastal environment. This can lead to changes to the flow of water across the landscape, interrupted connectivity of waterways, disturbance of acid sulphate soils, sedimentation, reduced water quality and drainage impacts as well as increased visitation impacts such as anchor and physical damage to meadows from access.

The resources boom in Queensland has resulted in significant expansion of ports and shipping underway or proposed, including new ports, along the Great Barrier Reef coast.[14] Most involve direct and permanent loss of seagrasses. Although as a percentage of the World Heritage Area they are small, some extensive areas of coastal and estuarine seagrasses occur in port environments due to their sheltered location.

Suggested actions to address vulnerabilities

Catchment runoff

At the scale of the Great Barrier Reef, the most significant response to improve the resilience for seagrass meadows is to improve water quality. Therefore the most important action is to continue to implement the joint Australian and Queensland Government's Reef Water Quality Protection Plan to reduce pollutants released to receiving waters from diffuse sources. Actions to improve waterway stability, riparian and wetland condition and the maintenance of environmental flows are critical.

For more localised (point source) and urban impacts continued implementation of waste water management remains important including:

- Tertiary treatment technology and re-cycling
- Urban storm water management through best practice erosion and sediment control
- The application of water sensitive urban design techniques to new and existing urban land development.

Coastal development

The Australian and Queensland governments are working together to undertake a comprehensive strategic assessment of the Great Barrier Reef World Heritage Area and the adjacent coastal zone. The adequacy of the protection for seagrass habitat in the Great Barrier Reef Marine Park will be an important component of this assessment.

Avoiding disturbance should always be the first consideration, but where, after careful assessment consideration, it cannot be avoided, environmental offsets should be required and applied to reduce other threats to seagrasses.

Developers should consider the potential for shoreline retreat and subsequent movement of seagrass habitat inland, particularly under a climate change scenario, and factor this in to all planning schemes to ensure the long term viability of these habitats.

Understanding status and trends and requirements for ecosystem health

It is important to ensure management of seagrass meadows is based on good science underpinned by an effective research and monitoring program. Almost all the current seagrass monitoring is on intertidal meadows and much of it in close proximity to ports. Despite this focus the limits and tolerance of even intertidal seagrass species to various threats such as reduced light and increased nutrients are still not well understood. Very little is known about the population status, species diversity, ecological roles and/or pressures and thresholds for subtidal and deepwater meadows and how close these species live to the limits of their viability. A program to understand the distribution and abundance of subtidal and deepwater seagrasses should be implemented.

Climate change

The broader national and global initiatives required to address climate change are not considered here. Efforts by the Great Barrier Reef Marine Park Authority (GBRMPA) are primarily aimed at understanding the vulnerability of the Great Barrier Reef ecosystems, including seagrass meadows, and helping to build resilience to climate change in the ecosystem and the communities and industries that depend on it. Focus should continue on actions to reduce threats from climate change and improve the resilience of high-risk habitats and species.

Background

Brief description of seagrass

Some 30 seagrass species occur in Australian waters, half of which are found within the Great Barrier Reef.[14] Seagrasses are highly specialised flowering plants with roots, leaves and rhizomes that with the exception of one species (*Enhalus acoroides*) can live entirely immersed in seawater.[15,16,17] They are not a taxonomically unified group, and not true grasses, but an ecological group that arose through convergent evolution.[15,16,17]

Seagrasses vary morphologically and ecologically, ranging from short-lived structurally small *Halophila* species to robust, long-lived structurally large species such as *Enhalus acoroides.*[18,19] They reproduce either asexually through rhizome growth, or sexually via seeds from flowers fertilised by water-borne pollen.

Seagrasses are habitats for diverse communities. They are primary producers, stabilise bottom sediments and are a store for carbon.

Generally, the growth rates of seagrasses in the Great Barrier Reef is seasonally-dependent. The high-growth season is from June to November, with growth (both biomass and cover) peaking in spring and early summer. Later in summer, conditions generally become less favourable and growth slows, leading into the wet season when conditions can become unfavourable for growth (depending on the severity of a wet season) and growth can even cease. This can result in losses of whole meadows.

Geographical distribution

Seagrasses are distributed widely along the Great Barrier Reef coast, especially in the protected sediment-covered areas.[20,21,22] They colonise a broad range of habitats - rivers, inlets, coastal, reef and intertidal, sub-tidal and deepwater[23,24] and also substrates - ranging from the nutrient rich soft mud adjacent to mangrove fringes to carbonate sands around cays on the outer Great Barrier Reef and some species even colonise coral reef platforms[18].

Whether or not a particular meadow is present or absent is determined by many factors including:

- Suitable light levels
- Sediment
- Salinity and temperature ranges
- An appropriate level of nutrients
- Minimal natural and human disturbance regime.

Notwithstanding those factors, seagrass distribution has been mapped or surveyed at varying scales, times and precision, and with different aims and methodologies, throughout the Great Barrier Reef. Seagrasses probably cover up to 5668 km^2 of the intertidal and shallow subtidal habitat in the Great Barrier Reef (or about 20 per cent of the approximately 26, 000 km^2 of the area seaward to a depth of about 15 metres) of which about 3063 km^2 has been mapped. Figure 1 is a composite map covering findings of surveys conducted between 1984 and 2008 showing all the locations where seagrass was located.

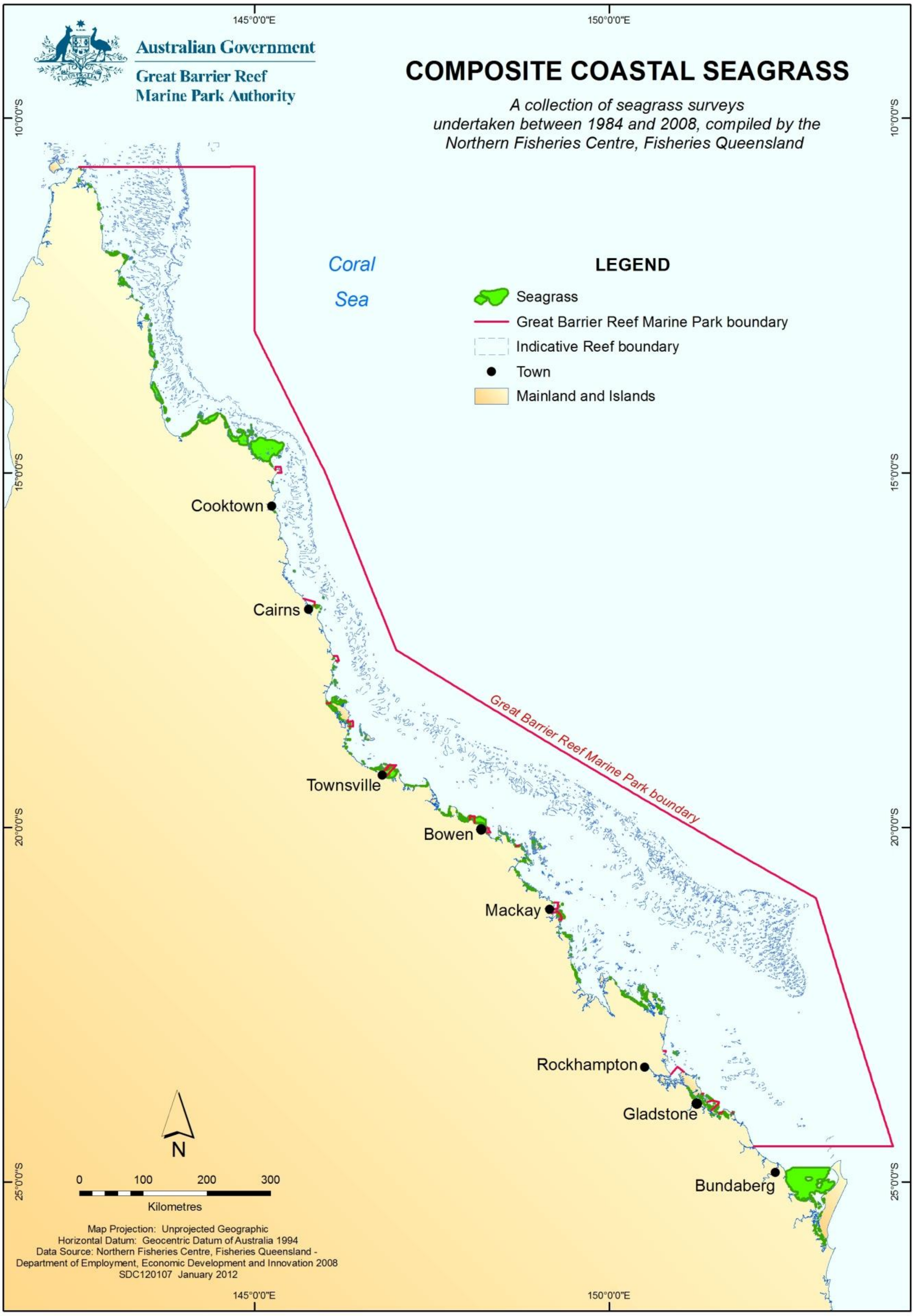


Figure 1: Composite coastal seagrass distribution

Reports of where individual seagrass meadows have been surveyed and mapped are numerous. It is difficult to present them meaningfully here as meadows might have been extensive at a location in one year and absent in another or may not have been surveyed for some time. Survey reports are referenced below by region to assist people to find more detail:

- Cape York Peninsula region.[25,26,27] Extensive meadows have occurred in the Starke region, and in Bathurst, Princess Charlotte, Shelbourne and Margaret Bays. Seagrass communities are dominated by *Halophila uninervis/H. ovalis* and *H. ovalis/H. spinulosa* in the coastal intertidal and subtidal areas respectively.
- Wet Tropics region. [25,28] Extensive meadows have occurred around Low Isles, Green Island and Hinchinbrook Channel. No regional species dominance has been evident. As many as eight species of seagrass have been reported as common throughout the region.
- Burdekin Dry Tropics.[16,29,30,31,32,33,34,35] Extensive meadows have occurred in Upstart, Cleveland and Bowling Green Bays. The main seagrasses in shallow waters near Townsville are *Halophila ovalis, Halophila spinulosa, Halodule uninervis,Zostera muelleri* subsp*. capricorni* and *Cymodocea serrulata.*
- Mackay – Whitsunday.[36,37,38,39,40] Between Bowen and Yeppoon the intertidal areas are dominated by *Halodule uninervis* and *Zostera muelleri* subsp*. capricorni* grow in intertidal areas.
- Fitzroy.[41,42,43,44,45] There are large seagrass areas in Shoalwater Bay and Port Curtis. Between the mainland and the Capricorn-Bunker Island Group, and in the shelter of the Swain Reefs deepwater *Halophila* meadows have been found. South of Yeppoon, *Zostera* and *Halodule* communities dominate intertidal areas, with *Halophila* communities dominating subtidal areas.
- Mary-Burnett.[46] Only the northern part of the regional catchment is within the Great Barrier Reef World Heritage Area. Large deepwater seagrass areas have occurred around Rodds Bay dominated by *Halophila decipiens* and *H. Spinulosa*. Extensive seagrass meadows also have occurred to the south of the Great Barrier Reef. Intertidal and shallow sub-tidal banks are dominated by *Halodule uninervis* and *H. ovalis, with Zostera muelleri* subsp*. capricorni* meadows in estuarine habitats.

Model outputs show the predicted likelihood of presence of seagrass for the coastal Great Barrier Reef (Figures 2 and 3).[2,47,48]

Deepwater seagrass models are also available and meadows are estimated to cover ~40,000 square kilometres.[22] Deepwater surveys located vast areas of seagrass habitat at depths between 15 and 58 metres, composed primarily of *Halophila* species.[49,50] Beds were found on the mid-shelf off Townsville, and the inner-shelf Capricorn region and Turtle-Howick Is group.

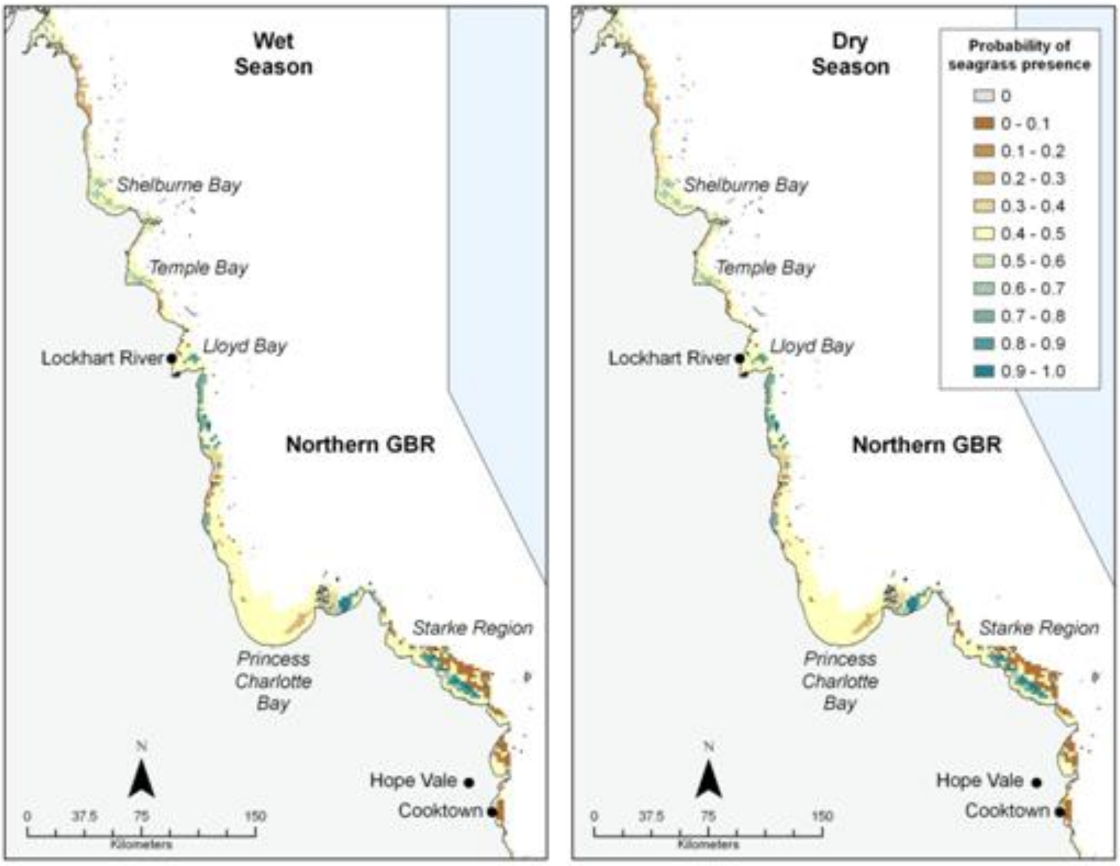


Figure 2: Probability of seagrass presence Cape York region during wet and dry seasons[47]

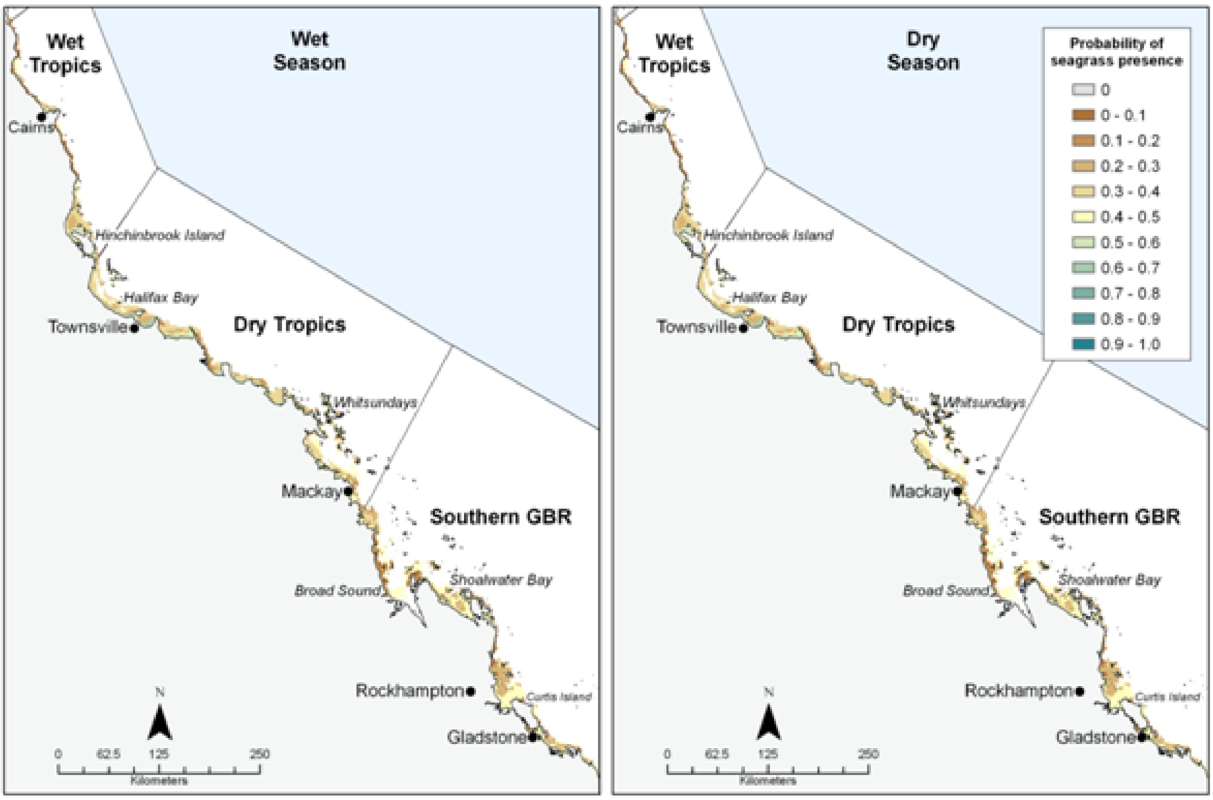


Figure 3: Probability of seagrass presence Wet Tropics, Dry Tropics and Southern regions during wet and dry seasons[47]

Population status in the Great Barrier Reef

Seagrass ecosystems are in decline globally[51], and their rate of loss is accelerating[52]. At the Great Barrier Reef-wide scale, overall extent of seagrass meadows was considered to be relatively stable at the time of writing the *Great Barrier Reef Outlook Report 2009*. Few changes in extent had occurred over the preceding 20 years with only localised fluctuations observed inshore mainly due to natural cycles of decline and recovery although influenced by runoff from catchments.[14,53] Seagrass lost in several regions due to storms, flooding and cyclones[54] had recovered substantially[9], while other meadows had expanded. Considering populations/groups of species, seagrass status was assessed as good. Observations suggested that there have been shifts in species composition in some seagrass meadows, but did not indicate any significant reef-wide changes.[22]

Since publishing the 2009 Outlook Report however some warning signs have emerged:

- *The Great Barrier Reef Second Report Card 2010* finds seagrass to be in poor condition with declines reported over the last four years (P McGinnity, pers comm, 2012).
- McKenzie et al report significant losses of seagrass in the areas directly affected by the path of Tropical Cyclone Yasi under the findings of the Intertidal Seagrass Marine Monitoring Program for 2011. In addition, there have been broad-scale impacts of the 2010 - 2011 wet season on seagrass meadows across the regions exposed to flooding and cyclones in the Great Barrier Reef (south of Cooktown). These impacts are on seagrass ecosystems that are already stressed following a number of years of major freshwater inflow and extended periods of cloud cover limiting growth periods.
- Seagrass meadows present for the past 15 years in Mourilyan Harbour[4] have been lost in recent years and substantial declines have occurred in the meadows adjacent to Cairns[5], Townsville[6], and Gladstone Harbour[7]. Annual long term monitoring programs all show large declines in 2010 with some locations also exhibiting declining trends over the last couple of years.[3]
- Cover of seagrass at a Great Barrier Reef-wide scale shows no evidence of long term sustained loss or gain. There is no consistent monitoring north of Cooktown but aerial surveys in the Princess Charlotte Bay region supports other evidence that seagrass in the northern Great Barrier Reef is stable, at least in terms of area. However, McKenzie et al further report that abundance south of Cooktown, while variable, has declined at monitored sites since 2009 (and earlier for some sites)[3,8,9,10,11,12,13] although the decadal trend is relatively stable.

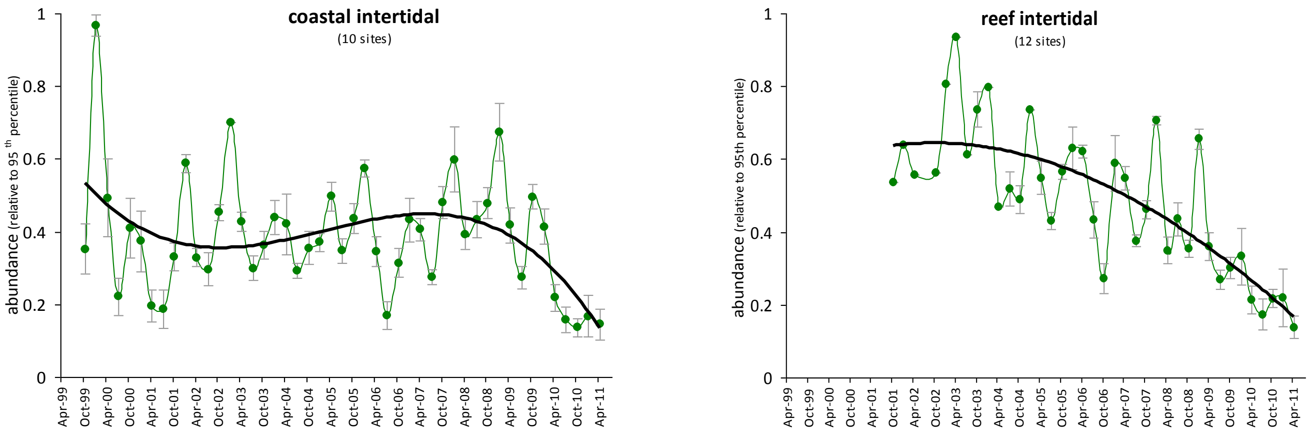


Figure 4: Generalised trends in seagrass abundance for coastal and reef intertidal habitat type relative to the 95th percentile (equally scaled)[3]

A loss of meadows from surrounding or nearby regions, as was the case in the Mourilyan region, severely reduces recovery potential, as they serve as a regeneration source for regrowth. Seed banks or germination of seeds from nearby meadows will be more important in these cases. Repeated declines and recovery of meadows over the recent preceding years is likely to have reduced available stores[55], therefore the reproductive status of this region is considered to be poor.[8,9,10,11,12,13]

Recovery of seagrass meadows from impacts that have reduced them to their current state can take more than a decade.[31] Successful recovery is reliant on good conditions in future seasons, including sufficient light, and low levels of pollutants, as well as integrity of the substrate available for recruiting to.

Regional status reports are released each year on those meadows routinely monitored. Almost all the seagrass monitoring is on intertidal meadows. Despite this focus the limits and tolerance of even intertidal seagrass species to various threats such as reduced light and increased nutrients are still not well understood. Very little is known about population status, ecological roles and/or pressures and thresholds for subtidal and deep meadows and how close these species live to limits of their viability.

Intertidal seagrass status for 2010-2011 is summarised below and in Table 1.

Cape York
Species composition is stable and follows seasonal trends at the one site on a fringing reef that has been monitored regularly since 2003[12] in a protected section of the bay adjacent to Archer Point, 15km south of Cooktown.

Wet Tropics
Seagrass meadows appear to be relatively healthy, albeit dynamic with respect to biomass, area and species composition, with local and regional climate being the primary driver of change. However, seagrass cover in more southern sites of the region has been lower in recent years, and has been severely reduced following Cyclone Yasi[3]. Many of the meadows monitored in the region have low numbers of reproductive structures limiting capacity to reproduce after stress.[8,9,10,11,12,13]

Seagrass habitat in Cairns Harbour and Trinity Inlet was reported in poor condition and in a highly vulnerable state in 2010.[5] Cairns Harbour meadows had been exhibiting a general downward trend for four to six years (depending on the meadow) and in 2010 had been reduced to their smallest area and density recorded since the monitoring program began in 2001. A small shift in species presence in several of the meadows with a higher component of *H. ovalis* than previous years was noted. Baseline surveys pre-2001 had reported there were nearly 1,000 hectares of seagrass close to Cairns with a mixture of four species (*Zostera muelleri* subsp*. capricorni*, *Halodule uninervis* and *Halophila ovalis* were the most common).

Previously extensive meadows of seagrass in the Mourilyan Harbour region monitored since 1993[56,57] have shown declining trends over recent years and were reported to be in an extremely vulnerable state in 2009[58]. Three of the five meadows that were monitored over the period were completely absent in 2009 and the two remaining meadows showed significant decline. Surveys also indicated a complete species shift to the pioneering *H.ovalis* from the previously dominant *Z. muelleri* subsp*. capricorni* in one of the meadows. In 2010 almost all the Mourilyan Harbour meadows had disappeared with only an isolated patch of pioneering *Halophila* remaining.[4] Additionally, aerial surveillance conducted outside of the Mourilyan Harbour monitoring area in 2009 could not find evidence of nearby meadows.

Burdekin Dry Tropics
Seagrass status is reported as poor.[59] Abundance in the region had been good overall, but declined in recent years at coastal and reef locations.[13] Previously extensive meadows of seagrass in the Townsville Harbour region (monitored annually since 2007) underwent a third consecutive year of major decline to seagrass biomass (density) and area in 2010, remaining well below the peak levels seen in 2007 and 2008. Seagrasses in Townsville harbour are in a highly vulnerable state.[6] There are low numbers of reproductive structures indicating reduced resilience and capacity for recovery.[13]

Mackay-Whitsunday
Seagrass cover is variable throughout the region; however, all but one monitored site was in poor condition late in the 2010 monsoon season. Seagrass reproductive capacity is poor in the region, raising concerns about the ability of local seagrass meadows to recover from disturbances.[13] Subtidal meadows are not monitored. Deepwater seagrass appeared relatively stable, but with inter and intra-annual variability at the local level.[13]

Fitzroy
At coastal and estuarine locations, seagrass cover in the region has increased or is stable. There is a trend of decrease in seagrass cover at reef sites although they have had less than 10 per cent cover since monitoring started in 2007. There are low numbers of reproductive structures. The Shoalwater Bay site contains the most healthy coastal seagrass meadows along the urban coast of the Great Barrier Reef.[13]

Ongoing monitoring of seagrass meadows in Port Curtis indicates that there are large areas of seagrass present, although following the floods of February 2011 the area had decreased to its lowest level since monitoring commenced in 2002.[7]

Burnett-Mary
Ongoing monitoring of coastal and subtidal seagrass meadows in Rodds Bay indicate that there are still large areas of seagrass present, although following the floods of February 2011 the area had decreased to its lowest recorded level since monitoring commenced in 2002.[7,60]

Estuarine meadows monitored at Rodds Bay were in poor condition. There has been a decrease in seagrass cover since monitoring began in 2007 and no evidence of meadows could be found by late monsoon 2010. Seed banks and reproductive effort are in a poor state.[13]

Table 1: Intertidal Great Barrier Reef seagrass status summary (2010-11)[3]

Region	Seagrass abundance	Reproductive status	Light & nutrient status (C:N ratio)	Overall status
Cape York	Very Poor	Good	Moderate	Moderate
Wet Tropics	Poor	Very Poor	Poor	Poor
Burdekin	Very Poor	Very Poor	Very Poor	Very Poor
Mackay Whitsunday	Very Poor	Very Poor	Very Poor	Very Poor
Fitzroy	Poor	Moderate	Moderate	Poor
Burnett Mary	Very Poor	Very Poor	Poor	Very Poor
Reef-wide	Very Poor	Very Poor	Poor	Very Poor

The number of reproductive structures was poor or very poor in three of the six regions, indicating limited resilience.[8,9,10,11,12,13] Intertidal seagrass meadows in the Great Barrier Reef region often have low or variable numbers of reproductive structures. Many of these meadows may have reduced resilience to recover from future adverse environmental conditions such as flooding or mass sediment movements created by cyclonic conditions.[8,9,10,11,12,13]

The ability of seagrasses to recover requires either recruitment via seeds or through vegetative growth.[61] There is a lack of understanding of seed bank processes such as seed resistance, survival and germination success to inform managers on the future of seagrass meadows that may be reliant on these features for their regeneration.

Species diversity is highest near the tip of Cape York, and decreases with latitude. In addition, different species dominate in different regions and across the shelf.[15]

Deepwater seagrass
There is little information about deepwater meadows and none are routinely monitored. Studies at Hay Point near Mackay indicate that these deepwater meadows are highly variable both seasonally and inter-annually and were likely to be growing at the limits of their light requirements.[20] Although we expect these habitats to be under lower pressure from changing water quality, it may be that they are actually more sensitive to changing water quality.

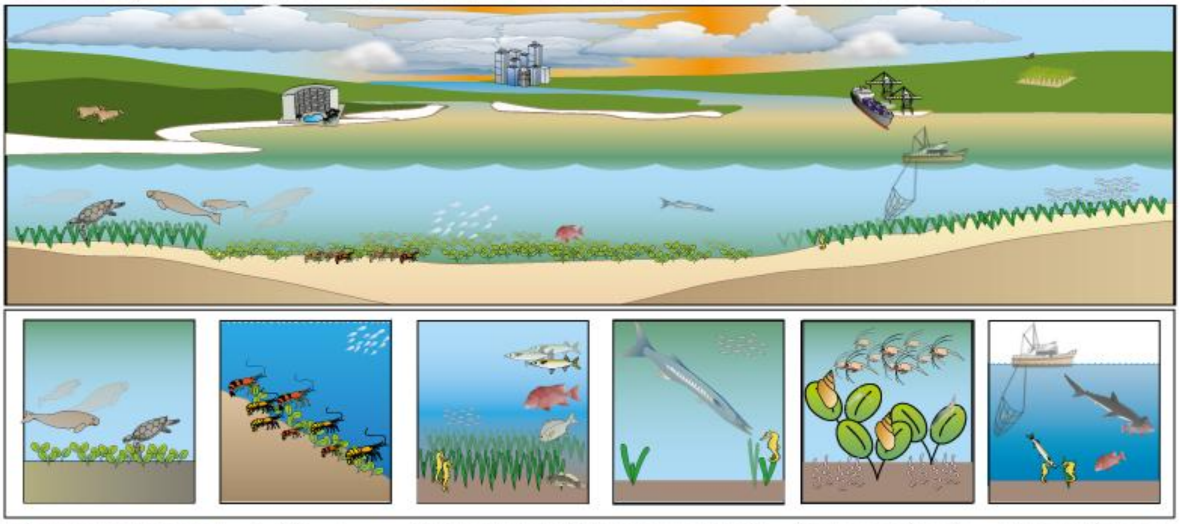
Ecosystem role/function

Seagrass meadows are an important part of the Great Barrier Reef ecosystem. Their importance is mainly due to the shelter they provide (through their three-dimensional structure in the water column), their very high rate of primary production and their role in the food chain of many marine animals, including the charismatic mega fauna such as dugong and green turtles. Refer to the Vulnerability Assessment for the Great Barrier Reef Dugong and the Vulnerability Assessment for the Great Barrier Reef Marine Turtles for more information on these species.

Ecosystem goods and services

Ecosystem goods and services category	Services provided by the species, taxa or habitat
Provisioning services (e.g. food, fibre, genetic resources, biochemicals, fresh water)	Crucial food for mega herbivores comprising more than 97 per cent of adult green sea turtle and dugong diet [62,63]. Food for many other species through direct grazing or detrital pathways for micro and meso herbivores (including amphipods, isopods, gastropods and copepods)[32,64], some of which are part of marine food chains which lead to commercially and recreationally fished species[65].. Connectivity across the shelf[66]. Larger predators also use seagrass meadows as foraging grounds[67]. Food, gathering, hunting and fishing sites for coastal people including Traditional Owners.
Cultural services (e.g. spiritual values, knowledge system, education and inspiration, recreation and aesthetic values, sense of place)	As the major food for species such as dugong and green turtles seagrass has great importance to Traditional Owner interests in sea country management. An important cultural resource for recreation and spiritual fulfilment for Traditional Owners. Community spirit and activity through successful community monitoring program Seagrass Watch[68].
Supporting services (e.g. primary production, provision of habitat, nutrient cycling, soil formation and retention, production of atmospheric oxygen, water cycling)	Key structural/foundational habitat, and nursery for many species[35,66,69,70,71]. Some species are commercially important, for example in the East Coast Trawl Fishery[72] while others are valued by recreational and Indigenous fishers as catch or bait [65]. Major primary production[73,74,75] Trapping organic nutrients[74] Nutrient cycling[76]
Regulating services (e.g. invasion resistance, herbivory, pollination, climate regulation, disease regulation, natural hazard protection)	Carbon sequestration[77] Baffle waves, reduce current, stabilise sediments, and protect against erosion and sediment re-suspension including during storms[78,79] Hydrodynamic modification[15]

Case study: the ecosystem services provided by shallow water inshore seagrass meadows



Inshore seagrass meadows occur in river estuaries, behind headlands and in the lee of islands often in areas sheltered from the prevailing south easterly winds. There are 15 species within the Great Barrier Reef World Heritage Area with diversity greatest in the north. They can vary seasonally due to changes in light and salt levels driven by seasonal river flows and turbidity fluctuations. Dugong and turtles feed in these areas.

Twenty different prawn species have been recorded in seagrass meadows in the Great Barrier Reef World Heritage Area. Tiger prawns grow to adulthood exclusively in seagrass meadows. They depend on the food and habitat there and would disappear if the seagrass meadows were lost or absent. The gross value of the tiger prawn fishery was $26.8m in 2003 with 1787 tonnes of prawns fished.

One hundered and thirty four fish species have been recorded in seagrass meadows. These include gobies, seahorses, pony fish, leatherjackets and trumpeter. Some fish, such as snub nose garfish feed on the seagrass. Many of these fish are food for larger fish species such as red emperor.

Larger predatory fish species hunt for juvenile fish and prawns sheltering amongst the seagrass. Thinning of seagrass meadows as a result of land based coastal development runoff is reducing the amount of shelter available for juvenile fish and prawns and affects survival rates.

Seagrass meadows also provde food for small herbivores such as copepods, amphipods, mysids and gastropods. These are the staple diet of many fish and prawns that live amongst the seagrass. Some fish species also feed on seagrasses.

Thinning of the seagrass meadows reduces food availability for fish and prawns. As a result there are fewer fish and prawns and greater competition for the food and shelter in seagrass meadows. Fish that use seagrass meadows as refuge on the way to the Great Barrier Reef are also at greater risk of predation.

Pressures influencing seagrass in the Great Barrier Reef Marine Park

Pressures

Catchment runoff, coastal development, and ports and shipping activities, are major pressures. These pressures influence the key drivers that are critical factors in the abundance, distribution and health of seagrass. Three of the key drivers are[15]:

- Light availability
- Water quality (water clarity; sediment, nutrient and other pollutants; temperature)
- Physical disturbance (natural and anthropogenic).

Key seagrass habitats (rivers and inlets, coastal, reef and deepwater)[80] are more, or less, exposed to these pressures: some are exposed at all times, others rarely. Much of the valuable coastal seagrass habitat in the Great Barrier Reef Marine Park and World Heritage Area lies in sheltered coastal bays and estuaries that are also the centres of urban, port and coastal development. While seagrasses are vulnerable to changes in water quality from non-point sources their location in these coastal areas of direct anthropogenic activity and development means they are also under significant pressure from local point source impacts. Assessment of habitats considered most at risk were those in the Cairns/Trinity Inlet, Townsville/Cleveland Bay, Abbot Point, Gladstone, and Mourilyan Harbour regions.[1,2]

Monitoring has shown that light availability is influenced primarily by climatic factors such as day length, rainfall, wind speed and tidal amplitude.[5,7,12,43,44,58,81] However; water quality also affects light, particularly in the high risk area identified in Figure 5. Different species respond to exposures in different ways and with different thresholds for tolerance to disturbance.

A summary of the assessment of pressures is tabled below, however, for the detailed assessment and explanatory notes refer to Appendix 1.

Vulnerability assessment matrix

The *Great Barrier Reef Outlook Report 2009*[14] identified a number of commercial and non-commercial uses of the Marine Park, as well as climate change, coastal development and poor water quality from catchment run off as the key pressures reducing the resilience of the ecosystem.

From the *Great Barrier Reef Outlook Report 2009*[15] it was considered that pressures such as climate change, coastal development, catchment runoff and direct use are the key factors that influence the current and projected future environmental, economic and social values of the Great Barrier Reef. These pressures can impact directly and/or indirectly on habitats, species and groups of species to reduce their resilience. Using the vulnerability assessment framework adapted by Wachenfeld and colleagues[82], this assessment aims to provide an integration of social, ecological, economic and governance information. For each key pressure in the Great Barrier Reef, exposure and sensitivity is assessed in relation to each other to reach a level of potential impact. The potential impact is then reassessed having considered the level of natural adaptive capacity that seagrasses have to respond to the pressure and the adaptive capacity that management has, or can apply, to reduce the potential impact from the pressure.

This provides managers and stakeholders with an understanding of the key elements that each pressure can impose on the habitat, to reach a final assessment of the overall residual vulnerability of seagrasses to that particular pressure. This allows for the formulation of suggested actions to minimise the impact of the pressures which seagrass meadows are most vulnerable to.

Vulnerability assessment matrix summary for seagrass

		Exposed to source of pressure	Degree of exposure to source of pressure	Sensitivity to source of pressure	Adaptive capacity – natural	Adaptive capacity – management	Residual vulnerability	Level of confidence in supporting evidence
Pressures	**Commercial tourism**	Yes; locally	Low	Low	Good	Good	Low	Good
	Defence activities	Yes; locally	Low	Low	Good	Good	Low	Good
	Commercial fishing	Yes; locally	Low	Low	Good	Good	Low	Good
	Recreational fishing	Yes; locally urban coast	Low	Low	Good	Good	Low	Good
	Ports and shipping	Yes; locally (with potential for regional significance)	High within port limits	Very high e.g. for complete meadow removal	Poor e.g. for complete meadow removal	Good. Spatial confinement. Conditional approvals.	High for greenfield proposals and expanding sites	Good – effects of pollutants
			Low outside port limits	Low e.g. distanced from activity	Moderate e.g. for medium density sediment plumes	Moderate. Some concern re removal and cumulative impact.	Low for areas outside port limits and influence of generated plumes	Poor – cumulative effects
	Recreation (not fishing)	Yes; locally urban coast	Low	Low	Good	Good	Low	Good
	Traditional use	Yes; locally	Low	Low	Good	Good	Low	Moderate
	Climate change	Yes, entire region	High intertidal and shallow subtidal meadows	High e.g species close to tolerance limits now	Poor e.g. intertidal species unlikely to compensate for rise in temperature	Poor. Global action needed.	High particularly coastal zone.	Poor. Thresholds not known for many parameters. Uncertainty around climate predictions.
			Low deepwater meadows	Lower e.g. species with wide tolerance ranges or buffered by deep water	Moderate. e.g able to recolonise	Moderate. Planning for shoreline retreat	Low deepwater meadows	
					Good. Growth rate greater than rising seas			
	Coastal development	Yes; developed coast and expanding	High along developed coast	High e.g. where meadows removed	Poor e.g. for complete meadow removal	Moderate. Cumulative impacts difficult to assess	Medium for much of the coast	Moderate
			Low for remainder of coast	Moderate for polluted runoff	Moderate e.g. able to recolonise	Good	Low for remote areas	
				Low for below threshold runoff	Good e.g. for temporary disturbance			
	Catchment runoff	Yes; seasonal flows as well as long term scale chronic pressure	High nearshore	High where pollutants carried by runoff are above thresholds	Poor if long duration, frequent, high pollutant levels	Moderate. Actions underway.	High. Addressing water quality will take many years.	Moderate
			Medium. Distanced from river influence					
			Low dry season	Low for below thresholds	Good if temporary, low pollutant			

Key concerns

Catchment runoff

Catchment runoff and associated poor water quality is identified in the *Great Barrier Reef Outlook Report 2009* as the second most significant pressure on the Great Barrier Reef after climate change. For seagrass it is probably the most significant. Seagrass monitoring at intertidal sites shows many sites are nutrient enriched, with seagrass tissue nitrogen levels in these regions increasing consistently over the last 15 years.[8,9,10,11,12,13]

There are a number of broad categories of contributing factors that can reduce the quality of water entering the Great Barrier Reef, including from agriculture, coastal development, urban runoff, aquaculture, mining, shipping and boating, and changing conditions associated with climate change. Seagrass ecosystems that exist in estuarine and inlet, coastal or nearshore locations are directly exposed to catchment water pollution influences[83,84] and are consequently the most at risk from land-based run-off. This area not only supports significant ecological communities, it is also the area of the Great Barrier Reef most used by fishing, ports, shipping, recreational visitors and commercial tourism operations — all sources of additional pressure.

Whilst excellent progress towards targets for improving the quality of water to the Great Barrier Reef has been reported, it is acknowledged that it will take time for these achievements to translate into improved downstream marine condition. Monitored results are not yet showing evidence of change at the sites sampled within the Great Barrier Reef. This could be due to lag times in the system, natural variability masking any effect, or to insufficient changes to land management practices having yet been made.

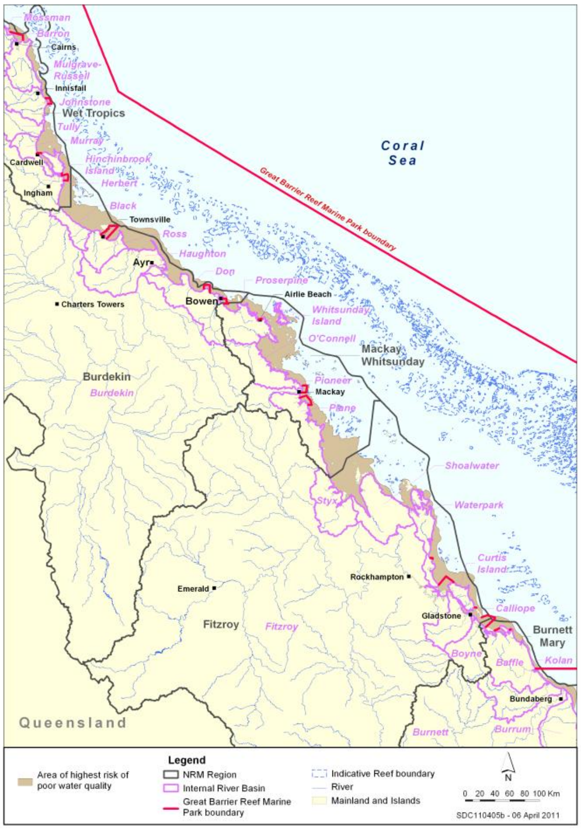


Figure 5: Area most at risk of poor water quality

The marine area most at risk of poor water quality (about eight per cent of the Great Barrier Reef waters) has been estimated by combining flood flow frequency[85] with a ranking of catchment pollutant loads[86,87] (Figure 5).

Coastal Development/Urban/industrial

A growing human population leads to an increase in infrastructure and services and unless well planned and implemented, these constructions can impact and/or modify the coastal environment, changing the flow of water across the landscape, disturbing acid sulphate soils and causing sedimentation, reduced water quality and drainage impacts.[14] Increased boating and fishing, and associated infrastructure and services that support this activity, like marinas, increase the risk of spills and physical damage through, for example, anchoring.

Port and shipping activities

Port development, dredging, marinas, marine facility expansion and increased shipping traffic can cause loss of meadows[53,88,89] through direct removal, and also indirectly through changes to hydrodynamics, generation of sediment plumes that limit light for plant growth, and potentially smothering and/or burial.

Developments are usually closely managed and generally the area of seagrass lost is small.[53] However the resources boom in Queensland has resulted in significant expansion of ports and shipping. Proposals are underway for at least seven ports, or significant port expansions, along the Great Barrier Reef coast.[14] Most involve direct and permanent loss of seagrasses and the cumulative losses in particular are of concern.

Light availability

Reductions in the light available to seagrasses for growth and photosynthesis are implicated in the large scale declines of seagrass that occurred in the Cairns/Trinity Inlet[5], Mourilyan Harbour[4], Townsville[6] and Gladstone[7]. Some of the light reduction is a consequence of a reduced tidal window due to natural cycles in daytime low tides and a reduction in solar irradiation. Turbidity and other factors associated with high rainfall and runoff[90] also contribute. Previous changes in extent and abundance of intertidal meadows of Cairns Harbour and Trinity Inlet were linked to the degree and severity of exposure related stress.[90] The decline is seagrass meadows in Mourilyan Harbour were also thought to be compounded by impacts from Cyclone Larry in 2006 and that these meadows had not yet had time to fully recover.[58]

Research needs
The limits and tolerance of seagrass species to various threats such as reduced light and increased nutrients are still not well understood.

Management of seagrass in the Great Barrier Reef Marine Park

Management agencies with responsibilities for managing this habitat or impacts on this habitat within the Great Barrier Reef World Heritage Area and the statutory and non-statutory tools that influence the conservation management of this habitat.

Legislation or policy	Object as it applies to the habitat	Tools for conservation	Who administers it?
World Heritage Convention	• Four natural heritage criteria with associated conditions of integrity. Criteria focus on: (i)geological processes and phenomena, including the evolution of the earth; (ii) ongoing ecological and biological processes; (iii) linked aesthetic components of the natural world; (iv) the biological diversity and habitats of threatened species. • Natural heritage Criteria iv states that the natural heritage asset must contain the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.	Provides State Parties to the Convention with definitions of natural and cultural heritage, measures for the protection of natural and cultural heritage; the means of administration and obligations of the Convention; funding arrangements, educational programs and reporting obligations.	United Nations Educational, Scientific and Cultural Organization (UNESCO)
Convention on Biological Diversity (CBD)	The three main objectives of the convention are: • The conservation of biological diversity • The sustainable use of the components of biological diversity • The fair and equitable sharing of the benefits arising out of the utilisation of genetic resources.	Provides State Parties to the Convention with global principles, objectives and obligations for the conservation of biodiversity Guides Australia's strategic planning to achieve national priority actions for biodiversity conservation through a range of objectives and targets for each.	United Nations Environment Programme (UNEP) – CBD Secretariat
Environment Protection and Biodiversity Conservation Act 1999	Legislative framework for environmental protection in Australia. There are seven relevant matters of national environmental significance for seagrass in the Great Barrier Reef: • world heritage properties • national heritage places • wetlands of international importance (listed under the Ramsar Convention) • listed threatened species and ecological communities • migratory species protected under international agreements • Commonwealth marine areas • Great Barrier Reef Marine Park	An action will require approval if the action has, will have, or is likely to have, a significant impact on a matter of national environmental significance. Significant Impact Guidelines have been developed as a resource for the support of assessment and approvals process for actions. An action likely to have a significant impact on seagrass could be deemed to be a 'controlled action' and require a greater level of scrutiny through an environmental impact assessment before consideration of approval. Tools include the listing and regulation of threatened and protected species and communities, the preparation of	Department of Sustainability, Environment, Water, Population and Communities (SEWPaC). Actions must be referred to the Minister and undergo an assessment and approval process.

Legislation or policy	Object as it applies to the habitat	Tools for conservation	Who administers it?
		recovery plans for threatened and protected species, the identification of key threatening processes and, where appropriate, the development of threat abatement plans (eg introduced pests). Penalties for non-compliance.	
Great Barrier Reef Marine Park Act 1975	Legislative framework for the management of the marine park.	Regulation of activities and development within the Marine Park. Zoning, assessment, issuing of permits and implementation of plans of management that collectively manage human activities. A planning framework can provide protection for seagrass by recognising areas of seagrass as protected, as marine coastal wetlands, or as areas of high ecological significance, or have desired outcomes for environmental objectives including indirectly by managing runoff and river flows. Special Management Areas can be created. Illegal to discharge waste into the Great Barrier Reef Marine Park without a permit. Fees for sewage water discharges. Policy development. Regular reporting requirements. Penalties for non-compliance.	Great Barrier Reef Marine Park Authority (GBRMPA)
Environment Protection (Sea Dumping) Act 1981	Provides for the protection of the environment by regulating dumping at sea, incineration at sea and artificial reef placements	Assessment, issuing of permits. There are existing approved dumping grounds for spoil within the Great Barrier Reef. Many of these dumping grounds have been used repeatedly for a number of years. Sites were initially selected to minimise impacts on sensitive areas (including seagrass meadows) and are carefully managed to ensure any adverse effects are prevented or minimised.	GBRMPA
Commonwealth Protection of the Sea (Powers of Intervention) Act 1981	Gives force to the Australian Government obligation to prepare for, and respond to, incidents of ship-sourced oil and chemical pollution.	Authorises taking of measures, as the Authority considers necessary to prevent, mitigate or eliminate any relevant danger.	Australian Maritime Safety Authority (AMSA)
Quarantine Act 1908	Management of ballast water Prevention of introduction of marine pests	Reduce the risk of introducing harmful aquatic organisms	Australian Quarantine and Inspection Service (AQIS)
Fisheries Act 1994 (Qld)	The act provides the framework to protect and conserve fisheries resources while maintaining profitable commercial and enjoyable recreational fishing sectors. The destruction, damage or disturbance of marine plants without prior approval from Fisheries Queensland is prohibited.	Provides for declaration of Fish Habitat Areas and their protection from physical disturbance associated with coastal development[91,92]. Notification and permit requirements for marine plant removal. Fish Habitat Management Operational Policy[93] East Coast Otter Trawl plan. Regional plans.	Queensland State Government Coastal local governments and port managers are entering into partnerships with the Queensland Government to manage protected marine plants in their areas. Fish habitat management strategies are developed jointly and enable long-term

Legislation or policy	Object as it applies to the habitat	Tools for conservation	Who administers it?
		Dugong Protection Areas Penalties for non-compliance	management under a self-assessable code.
Great Barrier Reef Protection Amendment Act 2009 (Qld)	Queensland Government Reef Regulations	Requires farmers in high risk catchments (Burdekin Dry Tropics, Wet Tropics and Mackay Whitsundays) to reduce the risk of pollutant runoff from their land. Includes preparation of Environmental Risk Management Plans, as well as increased documentation and reporting requirements.	Queensland State Government
Marine Parks Act 2004 (Qld)	As for *Great Barrier Reef Marine Park Act 1975* complementary management for Queensland waters.	As for Great Barrier Reef Marine Park Act and Regulations.	Queensland State Government
Environmental Protection Act 1994 (Qld)	To protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development). Primary pollution control legislation with definitions of environmental harm. Water quality for the protection of aquatic ecosystems.	Assessment, permits and licensing, conditions for development and environmentally relevant activities. Include mining activities or an activity prescribed under the regulations (where a contaminant will or may be released into the environment when the activity is carried out and the release will or may cause environmental harm). Activities include aquaculture and intensive animal industry activities (feedlots, pig and poultry farming); chemical, coal and petroleum product activities; water treatment services (sewage and water); extractive activities; transport and maritime services; waste management and a series of miscellaneous activities. Many of the activities are sources of wastewater. Best Practice Standards and Guidelines for planning, design and operation of sewage, and wastewater collection, transport treatment, disposal and reuse Penalties for non-compliance	Queensland State Government Local Councils
Water Act 2000 (Qld)	To advance sustainable management and efficient use of water and other resources by establishing a system for the planning, allocation and use of water. Governs matters to do with local Government sewerage and water supply infrastructure.	Water resource plans and Resource Operation Plans. Requires consideration of environmental flow and water quality needs for protection of natural ecosystems in decision making. Licensing and allocation system. Penalties for non-compliance.	Queensland State Government
Plumbing and Drainage Act 2002 (Qld)	Water quality	Deals with plumbing, drainage and on-site sewerage facilities. Specifies design requirements for facilities with a capacity of 21 or less equivalent persons.	Queensland State Government
Environmental Protection (Waste Management Regulation) 2000 (Qld)	To clarify waste management practices in Queensland and provide improved environmental safeguards.	Regulation to prohibit unlawful disposal of waste. Developed in conjunction with local government and industry, the legislation	Queensland State Government

Legislation or policy	Object as it applies to the habitat	Tools for conservation	Who administers it?
		will benefit communities through safer disposal practices and cost savings from improved planning and management of waste services. There are particular waste streams which are hazardous to the environment or to human health. These Hazardous Wastes are known in Queensland as Regulated Wastes and are controlled by additional specific legislation.	
Sustainable Planning Act 2009 (Qld)	To seek to achieve ecological sustainability by— (a) managing the process by which development takes place, including ensuring the process is accountable, effective and efficient and delivers sustainable outcomes; and (b) managing the effects of development on the environment, including managing the use of premises; and (c) continuing the coordination and integration of planning at the local, regional and State levels.	Establishes process for land-use planning and development assessments. Identifies state legislation that may be triggered by development assessments and the process by which developments must be assessed against each piece of legislation. Regional plans identify: • Desired regional outcomes • Policies and actions for achieving these desired regional outcomes • The future regional land use pattern • Regional infrastructure provision to service the future regional land use pattern • Key regional environmental, economic and cultural resources to be preserved, maintained or developed. A planning framework can provide protection for seagrass by recognising areas of seagrass as protected, as marine coastal wetlands, or as areas of high ecological significance, or set desired outcomes for environmental objectives including indirectly through managing runoff and river flows. Assessment, permits, licensing and conditions. Penalties for non-compliance	Queensland State Government
Nature Conservation Act 1992 (Qld)	To achieve conservation of nature through an integrated and comprehensive conservation strategy for the whole of the State	Involves (among other things) the following— • Dedication and declaration of protected areas • Management of protected areas • Ecologically sustainable use of protected wildlife and areas. Provides for the preparation of Conservation Plans for native wildlife and their habitat under Ministerial discretionary powers. Penalties for non-compliance.	Queensland State Government
Coastal Protection and Management Act 1995 (Qld)	(a) provide for the protection, conservation, rehabilitation and management of the coastal zone, including its resources and biological diversity;	Provides for development of State and Regional Coastal Management Plans with specific policies for coastal management issues.	Queensland State Government

Legislation or policy	Object as it applies to the habitat	Tools for conservation	Who administers it?
	and (b) have regard to the goal, core objectives and guiding principles of the National Strategy for Ecologically Sustainable Development in the use of the coastal zone; and (c) ensure decisions about land use and development safeguard life and property from the threat of coastal hazards; and (d) encourage the enhancement of knowledge of coastal resources and the effect of human activities on the coastal zone.	Designation of areas of high ecological significance managing coastal use, development and nature conservation. A planning framework can provide protection for seagrass by recognising areas of seagrass as protected, as marine coastal wetlands, or as areas of high ecological significance, or have desired outcomes for environmental objectives including indirectly by managing runoff and river flows. Standards for wastewater discharge	
Transport Operations (Marine Pollution) Act 1995 (Qld)	To protect Queensland's marine and coastal environment by minimising deliberate and negligent discharges of ship-sourced pollutants into coastal waters, and for related purposes. Gives effect to the MARPOL and OPRC conventions.	Aims to protect Queensland's marine and coastal environment from adverse effects of ship-sourced pollution.	Queensland State Government
Vegetation Management Act 1999 (Qld)	Designed to manage broad scale vegetation clearing, one of the key activities responsible for water quality decline.	Progressively reduced clearing rates through to 2006 when broad scale clearing was effectively halted. Legislated buffer distances for different stream orders. Penalties for non-compliance.	Queensland State Government
Local Government Act 1993	Providing a legal framework for an effective, efficient and accountable system of local government in Queensland. Various roles including establishment of laws, planning, waste and stormwater management.	Policies, principles and plans in relation to Local Government operations. Most wastewater (excluding stormwater) in Queensland is treated at sewage treatment plants that are essentially a Local Government responsibility with licensing requirements for quality of discharge water. Planning codes.	Local Councils
Reef Water Quality Protection Plan	Collaborative program of coordinated projects and partnerships designed to improve the quality of water in the Great Barrier Reef though improved land management in reef catchments. Focus is on reducing the load of diffuse agricultural sources of pollutants which account for more than 80 per cent of the load of nutrient and sediment delivered to Great Barrier Reef waters.	Improved land management. Education. Capacity building. Research and monitoring.	Joint Australian and Queensland Government initiative.
United Nations Convention on the Law of the Sea 1982, International Convention for the Prevention of Pollution	Part of the management framework for shipping activities.	A number of international and national management arrangements, conventions and obligations apply to shipping throughout all Australian waters, including the Great Barrier Reef that are implemented through	Various. Nationally – AMSA State - Queensland State Government

Legislation or policy	Object as it applies to the habitat	Tools for conservation	Who administers it?
from Ships 1973 and the 1978 Protocol (MARPOL 73/78), International Convention on Oil Pollution Preparedness, Response and Cooperation (OPRC 90)*, and International Convention for the Control and Management of Ships Ballast Water and Sediments 2004* and others		Australian law.	
National System for the Prevention and Management of Marine Pest Incursions	To reduce the risk of harmful aquatic organisms and pathogens being introduced by ships entering ports		AQIS
National Plan to Combat the Pollution of the Sea by Oil and Other Noxious and Hazardous Substances	Framework for ship-sourced oil and chemical spill response throughout Australia.	Implemented through various national and state level contingency plans, including the Queensland Coastal Contingency Action Plan. Most port authorities have individual Oil Spill Contingency Plans. A Great Barrier Reef and Torres Strait Vessel Traffic Service monitors vessel movements and provides ship traffic information, navigational assistance and maritime safety information to vessels.	Nationally –AMSA State - Queensland State Government
Sewage Discharge Policy 2005	Water quality	Guiding principles and permitting requirements to minimise potential impacts of treated sewage discharges from marine outfalls on the Marine Park.	GBRMPA
Environmental Impact Management Policy and Dredging and Spoil Disposal Policy.	Sensitive environments defined and include seagrass	Dredging and material placement carefully managed to ensure any adverse effects such as degraded water quality, decreased availability light, releasing toxicants and/or smothering[53,88,89] are prevented or confined to areas away from sensitive environments.	GBRMPA
Great Barrier Reef Marine Park Zoning Plan 2003	A multiple-use marine protected area management tool that protects biodiversity by the regulation of activities within the Great Barrier Reef Marine Park	The Representative Area Program that provided the basis for Zoning Plan spatial planning decisions, established 70 broad-scale habitats, or bioregions and as such provides the Marine Park with an approach to ecosystem-based management. 34 per cent of the Marine Park is zoned as Marine National Park (green) or Preservation (pink) in which no extractive activities are permitted. Penalties for non-compliance.	GBRMPA
Environmental Protection (Water) Policy 2009 (Qld)	Achieving water quality fit for purpose including protection of aquatic ecosystems.	Framework for developing environmental values, management goals and water quality objectives. Application through planning, assessment, permits, licensing and conditions.	DERM

Legislation or policy	Object as it applies to the habitat	Tools for conservation	Who administers it?
State Planning Policy 4/10 for Healthy Waters; Urban Stormwater: Quality Planning Guidelines 2010 and *Codes of Practice* (Qld)	To ensure that development for urban purposes, including community infrastructure, is planned, designed, constructed and operated to manage stormwater and waste water in ways that protect prescribed environmental values.	Seagrass can be identified as areas of high ecological value and hence water objectives are set to achieve their ecosystem protection. Establishes standards and best practice.	Queensland State Government Local Councils
Water Quality Guidelines[94,95] (Cwth & Qld)	Water quality for the protection of aquatic ecosystems.	Trigger values for protection of aquatic environments	GBRMPA Queensland State Government
Water quality improvement plans (WQIPS)	Non legislative	Between 2002 and 2009 many plans were developed along the Great Barrier Reef catchment. These WQIPS or Healthy Waterways Plan's environmental values and water quality objectives are now being scheduled into legislation under the *Environmental Protection (Water) Policy 2009*	Community driven through Natural Resource Management (NRM) Bodies. Townsville City Council. Voluntary practice uptake for improvements.
Queensland Coastal Plan and Regional Coastal Management Plans	Delivers a vision and direction for coastal management in Queensland.	Addresses major challenges associated with protecting the coast for future generations — recognising, planning for and managing the long-term impacts of natural events and human activities. Amongst other things identifying: • Areas of state significance for coastal management • Targets for improving sewage treatment works that discharge to coastal waters Strong support for: • Protecting coastal wetlands • Retaining natural landscape values of the coast • Retaining and managing vegetation in riparian corridors • Rehabilitating, restoring and enhancing degraded coastal resources • Sharing information • Future urban development on the coast to be in existing townships Strong performance criteria and justification for: • New canals and dry land marinas • Further development in erosion prone areas • Reclamation in coastal waters • Planning to adapt to climate change and sea level rise.	Queensland State Government
Regional NRM plans	Management of natural resources.	Community plans, capacity building and education around biodiversity, and partnerships to enhance biodiversity.	NRM bodies
Queensland Wetlands Program	Long-term conservation and management of wetlands	WetlandInfo – a synthesis of information on wetlands and their management Process for setting desired outcomes and management goals Rehabilitation guidelines	Queensland State Government Local Government
Climate Change Action Plan 2007-2012 and	Programs and actions to reduce threats from climate change and improve the resilience of high-risk	Development and implementation of tools (e.g. the emissions calculator) and systems for reef-based industries to	GBRMPA led but partnerships

Legislation or policy	Object as it applies to the habitat	Tools for conservation	Who administers it?
Tourism Climate Change Action Strategy 2009-2012	habitats and species	reduce greenhouse gas emissions, improve efficiencies and assist industry to be more resilient to the impacts of climate change	
Great Barrier Reef Biodiversity Conservation Strategy 2012			GBRMPA
Informing the Outlook for Great Barrier Reef Coastal Ecosystems 2012	Program explores how the inshore marine, coastal and catchment ecosystems are all interconnected and reliant on one another for their functions.	Outcomes will raise awareness and inform decision makers, investors and community on the implications to the Great Barrier Reef ecosystems of decisions made about coastal development.	GBRMPA
Reef Guardian Program - councils, schools, farmers and graziers, Eye on the Reef, Eco certification program for high standard tourism operators, Pro-Vision Reef Stewardship for fisheries	To recognise the role of local governments, industries and community in addressing water quality issues. Programs include elements of understanding the vulnerability of the Great Barrier Reef and helping to build resilience to climate change in the ecosystem and the communities and industries that depend on it	Educating and partnering with people in programs that improve people's understanding of how things they do can affect the Great Barrier Reef, and what can be done to minimise those effects. Program designed to recognise and foster environmental stewardship for the Great Barrier Reef from local government, industries and the general community. Some of the indirect threats to seagrass can be minimised through these types of program. Encourages best management practice in all activities, targeting those that could have effects on the Great Barrier Reef.	GBRMPA/Council, schools, farmers and graziers partnerships, Independent audit for tourism certification program.
Pollution control programs	To reduce the generation or accumulation of pollutants at the source.	Focus on education, prevention and regulation	Various
Seagrass-Watch monitoring program	Raises awareness on the condition and trend of nearshore seagrass ecosystems and provides an early warning of major coastal environment changes	In 2011 there were 58 monitored sites in the Great Barrier Reef World Heritage Area.	Queensland State Government

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OUTLOOK 2014 EVIDENCE: species.

Appendix 1: Vulnerability assessment matrix:

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
Exposed to source of pressure **(Yes/No)**	Yes; localised	Yes; localised, specific locations and times.	Yes; localised	Yes; localised. Mostly nearshore and around urban centres.	Yes; Localised (with potential for regional significance).	Yes; localised. Mostly nearshore and around urban centres.	Yes; localised. Mostly around urban centres south of Yarrabah, on sea country in areas further north.	Yes; Long temporal scale chronic pressure, Great Barrier Reef-wide.	Yes; Long temporal scale chronic pressure, primarily nearshore, developing coast predominantly south of Cooktown.	Yes; Long temporal scale chronic pressure, primarily nearshore although surface plumes can extend 100's of kilometres.
Degree of exposure **(low, medium, high)**	Low. Possible effects from boat propellers, anchors, mooring chains and rope, vessel waste discharge, small spills. High volume visitor access is to reef areas with established infrastructure rather than seagrass	Low. There are six designated defence training areas within or adjacent to the Great Barrier Reef World Heritage Area; the largest of these, with the highest intensity of use, is Shoalwater Bay Defence Training Area; others like Halifax Bay, or	Low. Possible effects from boat propellers, anchors, mooring chains and rope, vessel waste discharge, small spills. Key findings from the East Coast Otter Trawl Fishery ecological risk assessment[96] were that:	Low. Possible effects from bait digging, dragging, boat propellers, anchors, mooring chains and rope, waste, small spills and other physical impacts of boating activity on vegetated bottom.	Variable: Low to High. There are four major ports, six other trading ports and two very small operations. Both ports and shipping activities are focussed around geographically-discrete locations. Low. Where distanced from activity areas.	Low. Principally in estuarine and intertidal coastal habitats* - from bait digging, boat propellers, anchors, mooring chains and rope dragging, other physical impacts of boating activity on vegetated bottom and	Low. Possible effects from bait digging, dragging, gathering, anchor and/or propeller damage, rope dragging, other physical impacts of boating activity on vegetated bottom and possible	Variable: Low to High. Likely to affect all habitats. Intertidal and shallow subtidal meadows will be most exposed: deepwater meadows (>20 metres) will be buffered to some extent, although some predicted changes may make currently viable locations for	Variable: Low to High. Low. Where distanced from urban / developed areas. High. Directly adjacent to population centres. Increasing coastal development and consequent impacts on coastal	Variable: Low to High. Low. In the dry season flows are much lower from many rivers, some even drying completely e.g. the Don River. Low to High. In the wet season some areas receive more runoff than others and more or less polluted waters[97].

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
	habitats although there is small scale visitation and operation in and around seagrass meadows generally near urban centres. Associated marina development to moor vessels.	Cowley Beach, are used far less often. Possible impacts primarily on shallow coastal or intertidal habitat within those limited areas. Most relevant in Shoalwater Bay Training Area.	• overall ecological risks from trawling in the Great Barrier Reef are relatively low, with most species, habitat types, species assemblages and ecosystem processes at low risk from the fishery; • overall footprint was lower in 2009 compared to 2005; and • protection afforded through zoning significantly contributed to the relatively low ecological risks from the fishery.		Possible groundings. Medium. Possible exposure to exotic species; oil and chemical spills. including ballast water discharged by commercial shipping, bio-fouling on hulls and inside internal seawater pipes of commercial and recreational vessels. Shipping traffic is generally confined to specified channels and holding areas. High. Within port development, direct loss of habitat, impacts from dredging, marinas, marine facility expansion.	possible small spills.	small spills.	growth of seagrass meadows shift outside of tolerance ranges[23]. Exposure to direct/indirect impacts including increased air and sea temperature, sea level rise, ocean acidification, storm and flood intensity, and altered ocean currents.	ecosystems remains an ongoing factor (particularly for nearshore habitats)*. Increased populations mean increased use with consequent potential impacts.	Where seagrass meadows are distanced from rivers they are less exposed to runoff. High. The marine area most at risk of poor water quality is nearshore waters from Cooktown south to around the Burnett River. This area was estimated by combining flood flow frequency[85] with a ranking of catchment pollutant loads[86,87] (refer to Figure 5). Within this area pollutants are found at different loads and concentrations. For example, waters off the Wet Tropics and Mackay

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
										Whitsunday regions receive higher nutrient concentrations, while waters off the Dry tropics (Burdekin and Fitzroy) receive higher loads of sediment[85,98,99,100,101]. Hence, degree of exposure is parameter specific.
Sensitivity to source of pressure **(low, medium, high, very high)**	Low. Although disturbances from anchoring and boat propellers do occur[27,36] it is not reported other than small scale, within meadow scarring. Not attributable to any one source.	Low. Adaptive management of training areas has demonstrated a successful approach with no recognisable major environmental impacts to date[102]. Small scale disturbances from traversing, anchoring and boat propellers	Low. Although disturbances from anchoring and boat propellers do occur[27,36] it is not reported other than small scale, within meadow scarring. Not attributable to any one source. Trawl	Low. Although disturbances from anchoring and boat propellers do occur[27,36] it is not reported other than small scale, within meadow scarring. Not attributable to any one source.	Low to Very High. Potential sources of pressure from port and shipping activities are varied, hence sensitivity follows suit. Low. Where activity generates little potential harm to seagrass e.g. if sediment plumes are infrequent, of short duration,	Low. Small scale disturbances from anchoring and boat propellers do occur[27,36] it is not reported other than small scale, within meadow scarring. Not attributable to any one source.	Low. Small scale disturbance from anchoring and boat propellers do occur[27,36] it is not reported other than small scale, within meadow scarring. Not attributable to any one source.	Variable: Low to High. Lower for species that have a wide tolerance range for the parameters predicted to change: high for species that survive close to the limits of their tolerance range, both in range as well as location. Predicted air and sea	Variable: Low to High. Low. Where activity generates little potential harm to seagrass e.g. a change to land use that does not involve removal of seagrass or affect the quality of water that runs off the land. High. Where there is loss of meadows	Variable: Low to High. Some species are more sensitive than others, and also depends on duration, frequency and level of contamination. The response to nutrients varies depending on the season and the species. Additional nutrients sometimes favour seagrass

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
		possible.	damage is to vegetative plant section rather than uprooting of the rhizome.		contain low concentrations of total suspended solids, or other toxicants, seagrass species are likely to be able to tolerate them easily. If a ship were to ground within a seagrass meadow, which has a low likelihood, it would most probably cause only minimal disturbance in a whole of meadow context. If the seagrass meadow was small, or the ship very large, and/or toxicants were spilt the sensitivity may increase to medium or even to high. Potential ongoing impact,			surface temperatures have a number of likely consequences including[104] drying out intertidal plants; stress from decreasing photosynthesis, increasing microbial activity and depletion of oxygen in the sediments[105]; seagrass burn-off[106,107]; changed growth rates, metabolism or reproductive success[23,107,108,109]; changed distribution of species[23,109]; damage (long-term exposure to 33 °C or greater)[109]; destruction of proteins and irreparable damage to tissues (above	through direct removal, and also indirectly through changes to hydrodynamics, and generation of poor water quality discharges. Some species are more sensitive than others. Refer to catchment runoff for indirect pressures of poor water quality. Moderate to High. Where development affects connectivity between seagrass, saltmarsh and mangrove ecosystems.	growth[121,122,123] and in other cases have negative effects (e.g. leaf size reduced in high nutrient treatments)[8,123] or can favour the growth of epiphytes on the leaves of seagrasses which can shade the leaves from light[8,115,124]. Some herbicides block photosynthesis in seagrass at concentrations as low as 0.1 µg/L, and there are concerns about their possible chronic threat[115,125,126,127,128,129,130,131,132,133,134,135,136]. High organic nutrient content in sediments

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
					for example from release of antifoulant may increase sensitivity. Operational discharges from ships such as sewage and ballast water, as well as potential oil spills[103], can threaten water quality and can also introduce marine pests. Discharge release locations are limited however, and not expected to occur at levels that would be above low sensitivity. Potential sensitivity to introduced pests would depend on what the pest was. High. Activity can cause loss of meadows			about 38-42°C)[23]; effects on seed germination[110]. Temperature tolerances are species specific[107,109]. Few studies have been done however to determine what the tolerance ranges, or thresholds are. With predicted increases in storm intensity[104] intertidal and nearshore subtidal seagrasses may experience lower salinities, and for longer periods, which may cause species shifts and habitat		inhibits the growth of seagrass[120]. Different species can tolerate different sediment, minimum light and salinity regimes[31,111,112,113,114,115,116,117,118,119]. Few studies have been done however to determine what the tolerance ranges, or thresholds are.

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
					through direct removal, and also indirectly through changes to hydrodynamics, generation of sediment plumes that limit light for plant growth, and potentially smothering and/or burial[53,88,89]. Large oil spill or chemical spill could be locally signficant. Very High e.g. if whole meadows are removed permanently.			loss[111]. It is also likely that periods of reduced light will occur for longer — primarily through increased water quality runoff pollutants. Sensitivity will depend on duration of reduced light as well as minimum light requirements. Scouring and erosion of substrate is also possible. Greater energy at shallower depths means intertidal and shallow meadows will be most sensitive[23]. Different species can tolerate different		

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
								sediment, minimum light and salinity regimes[31,111,112,113,114,115,116,117,118,119]. Changes in ocean circulation could affect where seagrass grows[23]. Predictions are that there will be an increase in magnitude to present day inshore northward moving currents[23] which may threaten the continued suitability of some existing habitable areas, although new areas may become suitable[120]. Sea level rise will mean		

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
								some intertidal sites will become shallow subtidal, potentially resulting in species shift. Sites below water will experience increased light attenuation and some currently viable sites may become unviable.		
Adaptive capacity natural (Poor, moderate, good)	Good. Ability to regrow or recolonise small areas following disturbance.	Good. Ability to regrow or recolonise small area following disturbance. Time between activities that may cause impact is generally long. Poor if impacts of activities render substrate no	Good. Ability to regrow or recolonise a small area following disturbance.	Good. Ability to regrow or recolonise a small area following disturbance.	Variable. Capacity depends on nature, duration and frequency of disturbance. Poor: if habitat is permanently removed, or is regularly impacted. Variable: Effects of sediment deposition on seagrasses are species-specific	Good. Ability to regrow or recolonise small area following disturbance	Good. Ability to regrow or recolonise a small area following disturbance .	Variable. The capacity for adaptation is not well understood. Poor. Some tolerance thresholds are likely to be exceeded beyond capacity for adaptation. Temperature rises, in	Variable. Poor: if habitat is permanently removed, hydrodynamic changes make habitat unsuitable, is regularly impacted or receives water quality with pollutants above tolerance levels.	Variable. Capacity depends on duration, frequency and level of contamination. Poor: if pollutants levels are delivered above plant tolerances, and/or reduce light availability below thresholds and for extended

	Pressures									
	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
		longer viable as a habitat surface e.g. bomb craters alter depth of bottom.			and strongly size-dependent. Small intertidal seagrasses such as *Halophila* and *Halodule* can be smothered, while the larger *Zostera* and *Enhalus* have greater tolerance[112]. Minimum light requirements vary between species[111,113,114,115,116,117,118,119]. Ability to resist or outcompete potential pests or invasive species is not known. Poor – if sediment loads smother meadows too deeply to allow regrowth, or seed banks are not available, or if light is reduced below			particular on intertidal and shallow subtidal meadows, are not likely to be able to be adapted to. Some changes to ocean circulation and sea level are not likely to be able to be adapted to. For example, where newly inundated substrate is not suitable for growth of seagrasses no inland migration of meadows will be possible. Moderate to Good. Some species have wider tolerance ranges than others for the parameters predicted to	Good: if disturbance is temporary, light levels are sustained to the meadow, sediment loads do not smother meadows completely, and pollutant levels are within tolerances. Ability to regrow or recolonise small areas following disturbance or for a large area is seed bank dependent.	time periods. The specific role of nutrients as a driver remains poorly understood[15]. Losses of 300 hectares of seagrass in Pioneer Bay (Whitsundays) were linked to nutrient inputs and algal blooms[143]. Good: if pollutant levels are within plant tolerances, and minimum light requirements for plant growth are met. Some adaptations can be made that affect tolerance levels to light limitations created by runoff[61,141,144]. Changing photosynthetic

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					the tolerance range of minimum light requirements for long enough duration to cause mortality.			change and conditions may remain tolerable. Newly inundated areas may provide new suitable colonising habitat[120]. Where vegetative material, recruitment stock and/or viable seed banks remain, recovery from storm damage is feasible following return of minimum light requirements for growth. Some species can store carbohydrate to use during low light periods[23]. If change is		characteristics[31,62,145,146,147] including: rates of photosynthesis, light saturating irradiances, photosynthetic efficiency and effective quantum yields; and/or adjusting pigment ratios; in shaded or high turbidity areas. Although responses are variable. Changing plant morphology eg reduced biomass or other related metric, such as shoot density, leaf dimensions, leaves per shoot, in response to lower light intensity[114,137,138,139,140,141,142] can allow colonisation of
					Good - if disturbance is temporary, light levels are sustained to the meadow, and/or sediment loads do not smother meadows completely, or with only a fine layer of sediment.					

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								sufficiently slow, and does not surpass tolerances completely, some adaptations may be able to be made e.g. the rate of vertical growth of most seagrasses is greater than the predicted rate of rise in sea level[23]. Changes of species distributions and community compositions to those that tolerate new conditions may occur. Changing plant morphology eg reduced biomass or other related metric, such as shoot		an area that might otherwise not be viable. Some species have the capacity to build up a persistent seed bank in the sediment enabling recovery from large scale vegetative loss[148].

	Pressures									
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								density, leaf dimensions, leaves per shoot, in response to lower light intensity[114,137,138,139,140,141,142] could maintain viability at some sites.		
Adaptive capacity-management (Poor, moderate, good)	Good. Planning, education and partnering programs are applied to minimise physical disturbance. Activities require assessment and permission which allow conditions for management to be legislated. Regulation of access to meadows, provision of	Good. Activities are well managed, limited in extent, duration, and geographic location. Defence has a number of policies and management plans that together contribute to a robust environmental management plan within the World Heritage Area including the *Defence Environmental Policy* and the	Good. Trawling activities are regulated. Large areas of the Great Barrier Reef are protected from trawling activity through zoning, Fish Habitat Areas, or through low level of effort in General Use zones[132]. Planning, education and partnering programs are	Good. Planning, education and partnering programs are applied to minimise physical disturbance. Regulation of access to meadows, provision of mooring points. The Great Barrier Reef Marine Park Zoning Plan 2003 and complementary State plans provide some	Moderate to Good. Moderate. New port proposals for greenfield sites are not supported by the GBRMPA. However, applications can still be made and whilst they are subject to rigorous assessment concern exists about the ability to adequately consider their cumulative impacts. A Strategic Assesment has commenced that will	Good. Planning, education and partnering programs are applied to minimise physical disturbance. Regulation of access to meadows, provision of mooring points. The Great Barrier Reef Marine Park Zoning Plan 2003 and complementary State	Good. Planning, education and partnering programs are applied to minimise physical disturbance. Regulation of access to meadows, provision of mooring points. The Australian Government under the Caring for	Poor to Moderate. Extent and persistence of the damage from climate change depends on the success of international efforts to curb the rate of accumulation of greenhouse gases in the atmosphere, and on the resilience of the ecosystem to the changes in climate that manifest over coming decades. Given current	Good. Through integrated coastal management decision making, policies and legislation there is potential to explicitly recognise the intrinsic value of seagrass habitat and implement protection. Developments are subject to assessment, licensing and conditions that can protect	Moderate. Through integrated coastal management decision making, policies and legislation there is potential to explicitly recognise the intrinsic value of seagrass habitat and implement protection. Significant actions are already underway to halt and reverse the decline in water quality entering the Great Barrier Reef including

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	Commercial marine tourism	**Defence activities**	**Commercial fishing**	**Recreational fishing**	**Ports and shipping**	**Recreation (not fishing)**	**Traditional use of marine resources**	**Climate change**	**Coastal development**	**Catchment runoff**
	mooring points. The Great Barrier Reef Marine Park Zoning Plan 2003 and complementary State plans provide some protection. Penalties for non-compliance.	*Maritime Activities Environmental Management Plan*[131]. Further management could be applied as required.	applied to minimise physical disturbance. Regulation of access to meadows, provision of mooring points. Penalties for non-compliance.	protection.	consider cumulative impact. Good. Ports are confined to specific locations. Port expansions and major dredging proposals or other activities associated with ports generally require environmental impact assessment and permits or approvals. A combination of monitoring and modelling during dredging activity is used to minimise the risk that suspended sediments will cause impacts on any nearby seagrass meadows.	plans provide some protection.	our Country initiative, committed $10 million over five years towards the Reef Rescue Land and Sea Country Indigenous Partnerships Program. The program actively engages Aboriginal and Torres Strait Islander communities in the management and protection of the reef's marine resources and cultural diversity.	trajectories of greenhouse gas emissions, strategies that build resilience and reduce vulnerabilities of seagrass habitats will be increasingly crucial to their prognosis. Management will only be able to implement actions to address other sources of pressure to enhance ecosystem resilience, not mitigate the impacts of climate change directly. Moderate. Planning and legislative frameworks can factor in the potential for shoreline	seagrass. Waste water discharge quality is legislated. Codes of Practice and Water Sensitive Urban Design are in place to manage stormwater in local areas. Erosion and sediment control plans are legislated requirements during construction phases of development. Penalties for non-compliance. Cumulative impacts are however difficult to assess.	implementation of the Reef Water Quality Protection Plan, development and implementation of Healthy Waters Management Plans and precursor products) Implementation of water quality guidelines into permitting and decision making processes. A degree of uncertainty surrounds several elements of water quality management including thresholds, models of runoff, and effectiveness of strategies to minimise runoff from agricultural lands.

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					Dredging and material placement are carefully managed to ensure any adverse effects such as degraded water quality, decreased availability light, releasing toxicants and/or smothering[53,88,89] are prevented or confined to areas away from sensitive environments. Issues such as operational ship-sourced pollutants, discharge and disposal of waste, exchanges of ballast water, oil spills and potential antifoulant paint effects are covered by various regulations,			retreat and provide for subsequent movement of seagrass habitat inland, to ensure the long term viability of these habitats. Where substrate has been hardened and will not support growth of seagrass e.g. rock walls, concrete surfaces, this will be more difficult.		

	Pressures									
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					conventions and policies applied in the Great Barrier Reef.					
Residual vulnerability (Low, medium, high)	Low.	Low.	Low.	Low.	Low - for areas outside port limits and the influence of plumes generated, primarily by dredging. Existing meadows within port limits are colonised by species that tolerate conditions experienced. High – if proposals to open new areas where meadows exist are successful (although impacts would be local) they are likely to result in losses. Also for existing port expansions that include reclamation and new berths there are meadow losses. Cumulative impacts are difficult to assess.	Low.	Low.	Low for deepwater. High in the coastal zone.	Low for remote areas. Medium for much of Great Barrier Reef coast. There are issues with capacity to control population growth to coastal areas and urban sprawl. Cumulative impacts are difficult to assess.	High. Addressing the poor water quality entering the Great Barrier Reef is not a short-term problem with a simple solution. It will take many years to improve practices that affect water quality throughout the catchments adjacent to the Reef, and then to see these improvements realised in the Reef lagoon itself[149].
Level of confidence in	Good.	Good[12,14,15,131].	Good.	Good.	Good – for effects of	Good.	Moderate.	Poor.	Moderate.	Moderate.

	Pressures									
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supporting evidence (Poor, moderate, good)			An ecological risk assessment of the East Coast Otter Trawl Fishery in the Great Barrier Reef was undertaken in 2010-11[96].		pollutants. Poor – for consideration of cumulative effects.		Evidence of use or any associated potential impact is minimal. New information expected from the Reef Rescue Program.	High uncertainty surrounds predictions for the effects of climate change. Specific thresholds for parameters that are predicted to change are not known for Great Barrier Reef seagrasses[15]. Analysis of potential shoreline retreat and subsequent movement of seagrass habitat inland is not done.	Cumulative impacts are difficult to assess. Knowledge of thresholds of tolerance to pollutants, as well as light limitations is poor.	Knowledge of end of catchment loads good but transport pathways uncertain. Knowledge of thresholds of tolerance to pollutants, as well as light limitations is poor. A degree of uncertainty surrounds effectiveness of strategies to minimise runoff from agricultural lands.

The pressures addressed in this Vulnerability Assessment were identified in the *Great Barrier Reef Outlook Report 2009*.[14]
* Coastal habitats (rivers, estuaries, seagrasses, mangroves and wetlands) are under increasing pressure from human activities. More than 85 per cent of Queensland's population live on the coastal fringe. Predicted strong population growth means the intensity of activity and development in coastal zones is likely to persist.[150]

The purpose of the vulnerability assessment process is to provide a mechanism to highlight key concerns and make assessments of the vulnerabilities that species, groups of species or habitats have to known sources of pressure within the Great Barrier Reef World Heritage Area (the World Heritage Area) using a standardised and transparent process. This was undertaken using a standard approach to assess exposure and sensitivity and adaptive capacity to potential impacts (Figure 1) based on the best-available information on that particular habitat, species or group of species.

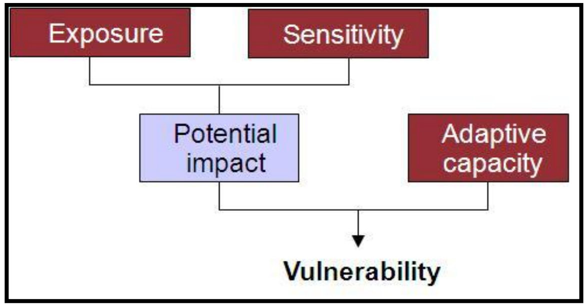

Figure 1. The key components of vulnerability assessments (Adapted from Wachenfeld *et al*., 2007)

To achieve this objective it has been necessary to apply a linear relationship to comparisons that are sometimes non-linear by nature. For example, when applying the potential impact matrix[1] to create a combined score for exposure and sensitivity, if a species, group of species or habitat has a very high level of exposure to a pressure but low sensitivity to it, it is scored as having a medium-high potential impact score. This medium-high score may be the same as determined for another assessment where there may be a low level of exposure but a very high level of sensitivity. This implies a linear relationship for the sensitivity a species or habitat has to a given level of exposure, which may not necessarily be the case. However, it does provide managers with the required level of resolution on these relationships for the purpose of the vulnerability assessments that inform the *Great Barrier Reef Biodiversity Conservation Strategy 2012*.

The methods used to determine the degree of exposure or sensitivity of sea snakes of the World Heritage Area against each source of pressure are described within the vulnerability assessments page of the GBRMPA website.

The natural capacity of sea snakes to adapt to pressures in the Great Barrier Reef, and the capacity of management to intervene (which in turn may assist sea snakes to adapt to these pressures), are considered as two dynamics that affect their residual vulnerability to any of the identified pressures. These two dynamics are then combined to produce an overall rating for adaptive capacity and then applied to the potential impact rating to provide a score for the residual vulnerability that sea snakes may be expected to experience for the given pressure. An explanation of the procedure by which this process has been applied and qualifying statements for the assessment of adaptive capacity (natural and management) scores are provided within the vulnerability assessments page of the GBRMPA website.

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[1] The potential impact matrix is described within the vulnerability assessments page of the GBRMPA website.