Seagrass Value Assessment

(Revision 0) **March 2018**

Objective

To provide guidance on assessing impacts to seagrass and seagrass meadows within the permission system.

Target audience

Primary: Great Barrier Reef Marine Park Authority (the GBRMPA) officers assessing applications for permission.

Secondary: Groups and individuals applying for permission for activities that may impact on seagrass; interested members of the public.

Purpose

1. Permission decisions contribute to maintaining and enhancing the condition of seagrass and seagrass meadows within the Great Barrier Reef Marine Park (the Marine Park).

Context

Description of the value

2. Seagrasses are highly specialised flowering plants with roots, leaves and rhizomes. They are not a taxonomically unified group, and not true grasses. Seagrasses vary morphologically and ecologically, ranging from annual short-lived structurally small *Halophila* species to robust, long-lived structurally large species, such as *Enhalus acoroides*. They reproduce either asexually through rhizome growth, or sexually via seeds from flowers fertilised by water-borne pollen.

3. The Great Barrier Reef is one of the most species-rich areas for seagrass in the world.[1] Fifteen species (representing half the number of species found in Australia) occur within the Great Barrier Reef Region.[2,3] *Halphila tricostata* is endemic to the Great Barrier Reef and is a deep water species.[4]

4. Seagrasses grow in a number of habitats, including estuaries (rivers and inlets), coastal waters (intertidal and subtidal), reefal areas (intertidal and subtidal) and deep water. Intertidal and subtidal seagrasses (less than 15 metres deep) in coastal waters are estimated to cover approximately 5700 square kilometres of the Marine Park.[5]

5. Deep water seagrasses (deeper than 15 metres) are estimated to cover approximately 40,000 square kilometres of the Marine Park.[6] At these depths seagrass is often very sparse (less than five per cent cover) although it can form relatively dense and high cover meadows in some locations.[2,6,7,8] Deep water seagrass species in the Marine Park are primarily from the genus *Halophila* and can be highly seasonal or annual.[4,9]

6. Waycott *et al*. 2007[4] (Figure 8.4) in Johnson and Marshall (2007)[11] provides a guide to the dominant seagrass species associated with different habitats and their distribution in the Great Barrier Reef, as well as the recovery strategy of each species.

7. The seagrass distribution in the Great Barrier Reef World Heritage Area produced by TropWater at James Cook University indicates where seagrass is likely to be present. Carter *et al.* 2016[12] also provides Geographic Information System layers of seagrass information in the Great Barrier Reef World Heritage Area.

8. The abundance, condition and resilience of deep water seagrass meadows is not well studied, and few are routinely monitored. A recent study by Chartand *et al.* 2017[10] does provides insight into the light requirements, seasonal change and recruitment strategies of deep water seagrasses in the Marine Park.

9. Species composition of the seagrass meadows influences the resilience of the ecosystem to pressures and hazards. The traits of seagrass species are colonising, opportunistic and/or persistent and vary in

their sensitivity to disturbances.[13] Some species are more resilient to stress than others and if present may recover slowly, whilst other species have the ability to recover rapidly, colonising an area and begin regenerating the meadow.[14] Collier *et al.* 2016[15] (Figure 2) provides a diagram of dominant traits of seagrass species and their sensitivity to disturbances and McKenzie *et al.* 2016[14] (Figure 3) illustrates seagrass recovery after loss and the colonisation of species over time for different habitat types.

10. Generally the growth rate of seagrasses in the Marine Park is seasonally-dependent. The high-growth season is from June to December, with growth (both biomass and cover) peaking September to early December. In December to January, conditions generally become less favourable and growth slows, leading into the wet season (February to April) when conditions can become unfavourable for growth (depending on the severity of the wet season) and growth can even cease, sometimes resulting in losses of whole meadows. Recovery of seagrass meadows can take more than a decade, and is reliant on good conditions in future seasons.

11. Seagrass health is dependent on a number of factors:
    a. suitable light - light is the primary driver for seagrass growth[2]
    b. sediment of suitable depth and stability to anchor roots and rhizomes
    c. appropriate salinity and temperature ranges
    d. suitable nutrient levels
    e. health and availability of propagules (roots, shoots and seeds) for seasonal and annual recruitment and recovery (seeds and or adult plant population)
    f. minimal natural and human disturbance.

12. The Great Barrier Reef Outlook Report 2009 (Outlook Report 2009) noted the overall area of seagrass meadows was considered relatively stable over the proceeding 20 year period. However, in Great Barrier Reef Outlook Report 2014 (Outlook Report 2014) intertidal seagrass meadows declined in the central and southern coast. The broad scale losses of seagrass abundance in the past decade have been primarily due to a number of climatic events, such as widespread rainfall, run-off, and extended periods of high cloud cover, as well as acute disturbances from Tropical Cyclone Yasi in 2011 and chronic impacts, such as poor water quality.[14,19]

13. The Great Barrier Reef Report Card 2016 (2015-16) notes very little change in the overall poor condition of inshore seagrass meadows. Generally reproduction effort, which provides an indication of the ability to recover from disturbance, is in very poor condition across the Reef and has largely been the case since 2006-07. In some regions there has been improvement in seagrass abundance, such as the Fitzroy but reproduction effort is still very poor in this region, as it is in Cape York and in the Wet Tropics regions. Reproductive effort is also poor in Mackay Whitsundays and Burnett Mary regions. In 2015-16, only the Burdekin region is of moderate condition across the three criteria. Additional information can be found in report cards of previous years.

14. Healthy seagrass meadows provide a regeneration source (through seed banks, germination of seeds or from rhizomes) to surrounding or nearby seagrass meadows that may have been degraded or lost.[5] Over recent years, large areas of seagrass meadows in the Marine Park have experienced repeated declines with only partial recovery, resulting in low presence of seed banks, declining seed banks and below average reproduction effort.[14] As a result the capacity of seagrass to recover from the cumulative impacts of past disturbances continues to remain low.[14] The compromised ability for seagrass meadow to regenerate, both locally and regionally, further increases their vulnerability to future pressures and hazards.[5] The Great Barrier Reef Report Card 2016 suggests if there are no further disturbances and pressures, there are signs that reproductive effort and seed bank density may increase in some regions.

15. Further, under a changing climate, seagrass and seagrass meadows are under increasing pressure - refer to Waycott *et al.* 2007[4] in Johnson and Marshall (2007)[11] for further information about the impacts of climate change on seagrass and seagrass meadows in the Great Barrier Reef.

Importance to the Marine Park

16. Seagrass meadows are included in the Statement of Outstanding Universal Value for the Great Barrier Reef World Heritage Area. Seagrass and seagrass meadows support a number of listed migratory and threatened species, such as marine turtle species (particularly green turtles), dugongs, dolphins, and sharks and rays. Bowling Green Bay, and Shoalwater Bay and Corio Bay are classified under the Ramsar Convention as wetlands of international importance which include seagrass meadows.

17. Seagrass meadows are an important part of the Great Barrier Reef ecosystem. They are also critical contributors to human wellbeing and the economy, particularly in coastal communities, and provide important ecosystem services.[5] Important ecological, cultural and economic roles of seagrasses include:
    a. providing nursery grounds and habitat for marine life, including dugong, and are foraging grounds for larger predators
    b. contributing high rate of primary production, nutrient cycling, water filtration, and significant amounts of carbon sequestration
    c. stabilising large amounts of sediment and trapping organic nutrients, reducing currents and sediment resuspension
    d. protecting against erosion and baffling waves, protecting coastlines from storms and other weather events
    e. supporting Traditional Owners cultural practices, for example lore and spiritual connections
    f. supporting commercially important species for fishing (such as fish, crabs, prawns and molluscs) and tourism (particularly charismatic species).

18. Seagrass meadows sequester and store significant amounts of carbon even when compared with terrestrial ecosystems on a per unit area basis.[16] Carbon stored in coastal and marine ecosystems (such as seagrass meadows, tidal marshes and mangroves) is referred to as 'blue carbon'. It is estimated Australia's 92,500 square kilometres of seagrass meadows contain more than 155 million tonnes of carbon and every year sequester another one million tonnes through sediment accumulation (based on sedimentation rate of 1.5 millimetres per year).[17,18] Therefore the seagrass meadows in the Marine Park may store close to 80 million tonnes of carbon. It is also estimated for every loss of one kilometre square of seagrass approximately 1.6 tonnes of carbon is released into the atmosphere.[18]

19. Seagrass meadows also play an important role in maintaining connectivity between marine (including coral reefs) and coastal ecosystems in and adjacent to the Marine Park. Connectivity allows for spawning patterns, larval dispersal, and movement of adult fishes and other animals across ecosystems. Connectivity is an important process to ensure the productive function of the plant and animal species contribute to the overall health of an ecosystem and adjacent ecosystems.[11]

20. Seagrasses represent good bio-indicators of overall marine and coastal health due to their:
    a. widespread distribution
    b. important ecological role
    c. fixed, immobile nature (anchored to the substrate)
    d. measurable and timely responses to environmental conditions and impacts (for example pollution, light, temperature, sediment resuspension, salinity).

Management

21. This section explains the most commonly used legislation, policies and management plans in managing seagrass and seagrass meadows. Also refer to the Policy – Environmental Impact Management – Permission System for a list of legislation, standards and policies used through the permission system.

Zoning and Legislation

22. The main object of the *Great Barrier Reef Marine Park Act 1975* (GBRMP Act) is to provide for the long term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region. The GBRMP Act also allows for ecologically sustainable use.

23. The Great Barrier Reef Zoning Plan 2003 (the Zoning Plan 2003) specifies that the taking of plants (such as seagrass) from the Marine Park requires permission. Queensland's Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004 aligns with the Zoning Plan 2003.

24. The Great Barrier Reef Marine Park Regulations 1983 (GBRMP Regulations) require a permission application to be assessed to determine the potential impacts and risk to Marine Park values, including seagrass and seagrass meadows.

25. There are several Species Conservation (Dugong Protection) Special Management Areas in the GBRMP Regulations designated for species conservation and reflect the requirements of Dugong Protection Areas under Queenland Fisheries legislation. The Zoning Plan 2003 provides for restrictions on access to, or use of, specific areas (such as Special Management Areas) of the Marine Park.

26. Further, the GBRMP Regulations prohibit any amount of capital dredge spoil material that is more than 15 000 cubic metres in volume, prior to its excavation, to be disposed of in the Marine Park (excluding material excavated to create a trench in which a pipe, cable or tube is laid and then used to backfill the trench).

27. Other legislation that aims to protect biodiversity values (such as seagrass and seagrass meadows), include *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act). For further information refer to the Deemed application under the EPBC Act information sheet and *Environment Protection (Sea Dumping) Act 1981* (the Sea Dumping Act). GBRMPA administers the Sea Dumping Act when disposal is proposed in the Marine Park.

28. Queensland state legislation is also in place, such as the *Fisheries Act 1994* (Qld) which provides protection of marine plants, including seagrass and it is a requirement for notification and permission for plant removal. Other relevant Queensland legislation includes *Environmental Protection Act 1994 (Qld)* and the *Marine Park Act 2004 (Qld)*.

Policy

29. Actions focussed to protect seagrass aims to improve the quality of water entering the Great Barrier Reef. The Reef 2050 Water Quality Improvement Plan 2017-2022 (in draft) 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.

30. The Reef 2050 Cumulative Impact Management Policy (in draft) provides a systematic and consistent approach to managing and reducing cumulative impacts on the Great Barrier Reef.

31. The GBRMPA 2010 Water quality guidelines for the Great Barrier Reef Marine Park includes set trigger levels for specific pollutants (such as sediment, nutrients and pesticides) which aim to protect a desired ecosystem state. The water quality guidelines are generally applied to longer-term water quality targets. They were reviewed in 2014 and deemed to be still relevant and up to date. The water quality guidelines are in line with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC).

32. The Queensland Environmental Protection (Water) Policy 2009 (EPP Water) provides catchment-specific water quality objectives for Queensland waters that aim to protect environmental values. Locally applicable data has been used to develop the catchment water quality schedules. Benthic light requirements that support seagrass growth in the Great Barrier Reef are available and are catchment specific.

33. The Dredging and Dredge Spoil Material Disposal Policy provides the approach to managing impacts to the values of the Marine Park from dredging and dredge spoil material disposal activities.

34. The Guidelines on the use of hydrodynamic numerical modelling for dredging projects in the Great Barrier Reef Marine Park (GBRMPA Hydrodynamic Numerical Modelling guidelines) provide the specific procedures, methodologies and frameworks of hydrodynamic modelling and dredge plume modelling expected for dredging and spoil disposal projects in the Marine Park.

35. National Assessment Guidelines for Dredging 2009 (NAGD) sets out the framework for environmental impact assessment (including assessing potential impacts on the marine ecosystems) and permitting of the ocean disposal of dredge material.

Management objectives

36. The Australian and Queensland governments' Reef 2050 Long-Term Sustainability Plan provides an overarching strategy for managing the Great Barrier Reef – it coordinates actions and guides adaptive management to 2050. The actions are intended to fulfil a 2035 objective that "the Great Barrier Reef World Heritage Area retains its integrity and system function by maintaining and restoring the connectivity, resilience and condition of marine and coastal ecosystems".

37. The values of the Marine Park, their integrity and current condition are described in the Outlook Report 2014. The assessment of 'seagrass meadows habitat to support species' was scored 'poor and deteriorated' compared to 'good' in Outlook Report 2009. Similarly, 'populations of species and species groups for seagrass' was also scored 'poor and deteriorated' compared to 'good' in Outlook Report 2009. The Outlook Report is published every five years.

38. The Great Barrier Reef Region Strategic Assessment Report 2014 (Strategic Assessment) provides a summary assessment of seagrass condition, trend and overall management objective (refer to Table 1). The projected condition of seagrass meadows and seagrasses is considered to be very poor.

Table 1: Summary assessment of seagrass condition, trend and overall management objective based on the Strategic Assessment (based on limited or very limited evidence or consensus).

Area	Current Condition	Trend	Management Objective
Northern Inshore	Very good	Stable	Maintain
Northern Offshore	Very good	Stable	Maintain
Southern Inshore	Very poor	Declining	Improve
Southern Offshore	Poor	No clear trend	Improve

Common assessment considerations

39. Degradation of ecosystem health and function of seagrass meadows will have negative implications on other values of the Marine Park, in particular biodiversity values, social values and Traditional Owner heritage values.

40. Wherever possible, impacts to seagrass should be avoided by the applicant and prudent and feasible alternatives examined upfront.

41. Where it is not possible to avoid impacts, impacts should be mitigated. If there is any residual impact, a determination should be made whether the impact is acceptable or not. If a permission is granted, appropriate monitoring measures (such as works monitoring and long-term monitoring programs) should be imposed to ensure impacts are adequately monitored and managed. In the context of the overall degraded condition of seagrass populations in the Marine Park even small losses may be critical.[20]

42. There should be an adequate understanding of scale (spatial and temporal), and cause and effect relationship (including direct, indirect and consequential impacts, and cumulative impacts) which may arise from the proposed activity. This understanding should be evidence-based, using the best available information.

43. As seagrass status and condition varies across the Marine Park both spatially and temporally, it is critical to consider impacts in the context of location-specific conditions and their exposure to localised pressures over time (previous and predicted), as well as in the broader, regional context.

44. If the condition of seagrass has been compromised, any impact is likely to be of greater consequence. It is particularly important to ascertain the resilience of seagrass and seagrass meadows and their ability to withstand impacts from the potential exposure to hazards arising from the proposed activity, as well as other pressures and potential future impacts.

45. There should be an understanding of the diversity and the species composition of the habitats potentially exposed to the hazards, and the potential impacts on the most sensitive species present should be assessed. Changes to species composition of seagrass meadows may occur in the short and longer terms. Further, the capacity of a particular species to recover may also differ across locations.[21]

46. It can be difficult to ascertain the cause of impacts to seagrass, as they are subject to a wide range of pressures related to water quality, sea temperature and hydrodynamic changes, and a range of human uses. This is particularly true for near-shore, shallow water seagrass meadows, where they are affected by land based run-off and other non-point sources of pollution. The focus of a risk assessment for public information package, public environment report, and environment impact statement assessment approaches should therefore be to gain an understanding on how a proposed activity may interact with other pressures (such as river runoff). A risk assessment should also determine whether the proposed activity, in the context of the historic and current status of seagrass and the cumulative pressures, will improve or degrade the condition of seagrass locally and regionally (also refer to the Cumulative Impact Management Policy (in draft)).

47. Information on the current and historic condition of seagrass and the threats and impacts at specific Marine Monitoring Program sites can be sourced from detailed technical reports, published annually. If the seagrass under assessment is not located at one of the Marine Monitoring Program sites there may still be relevant regional information which applies. Seagrass-Watch also provides long-term monitoring information at the program's seagrass sites across the Great Barrier Reef.

48. If historic and current condition data is not available, the merits of requiring background monitoring should be considered (refer to Assessment Guidelines for further information about monitoring). The background monitoring should take into account the likely intra and inter annual variability of seagrasses, and water quality and data should be collected over at least three years. The Department of Environment and Heritage Protection Monitoring and Sampling manual includes information on seagrass monitoring, and water and sediment sampling.

49. Light is the main driver of seagrass growth, and water clarity (i.e., turbidity) is the primary influence that determines how much light ultimately reaches seagrass leaves for photosynthesis. This, therefore is the primary influence over the health of the seagrass communities. Potential impacts to seagrass from an activity therefore needs to consider light levels at the seagrass canopy (i.e., benthic light). Light requirements are specified as a Photosynthetic Active Radiation (PAR) moving average, depending on seagrass species.[15,22,23] Regionally relevant PAR thresholds are scheduled in EPP Water. Other water quality parameters relevant to seagrass health, include nutrients and sedimentation.

50. Modelling of sediment transport and sediment resuspension are important tools in predicting potential suspended sediment plumes and sedimentation rates (accretion and deposition), and in assessing the likely exposure of these hazards to seagrass and seagrass meadows (and other ecosystems).

51. Due to their highly seasonal nature, the timing of any seagrass survey is critical as follows:
    a. At least three years of background data is desirable, preferably more
    b. Information should be collected at the peak time for seagrass abundance and distribution where possible (i.e., June to December). Some seagrass meadows are only present as above ground biomass for part of the year or are greatly reduced in their extent during the low seagrass growth season.
    c. Determine risk based on the most sensitive species present.
    d. In the absence of data collected in the peak growth season or where background information is limited, a conservative approach is to use a composite of previous seagrass distributions for the area.
    e. The pertinent consideration for assessment is that like be compared with like. For example, absence in a low growth period should not be interpreted as an impact from any particular activity, nor used as a background comparison for condition in peak season.

Links to other Values

Biodiversity values

52. Seagrass meadows are an important part of the Great Barrier Reef ecosystem and viable connectivity across the Reef depends on intact and healthy coral and non-coral habitats.

53. Seagrass and seagrass meadows are very important foraging and nursing habitats for juvenile fish, dugong and marine turtles. It is estimated seagrass constitutes more than 97 per cent of adult green sea turtle and dugong diet.

54. Seagrass meadows provide 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.[5]

55. It has been recorded that 134 fish species live in seagrass meadows. These include gobies, seahorses, pony fish, leatherjackets and trumpeter. Some fish, such as snub nose garfish feed on seagrass. Many of these fish are food for larger fish species, such as red emperor. Seagrass and seagrass meadows are particularly important for the maintenance and regeneration of fish populations across the Marine Park.[5]

56. Invertebrates like lobsters, crabs and sea urchins also feed on smaller animals, algae and detrital matter caught in seagrass. Twenty prawn species have been recorded in seagrass meadows in the Great Barrier Reef World Heritage Area and tiger prawns grow to adulthood exclusively in seagrass meadows.[5,24]

57. Seagrass-dependant species are likely to be compromised by impacts (such as degradation, loss, or declined ecosystem function) to seagrass and seagrass meadows; with implications for other ecosystems also likely. Further, impacts to seagrass ecosystem function compromises their ability to maintain water quality by trapping sediment, nutrients, organic carbon, and other material suspended in the water column. This can have flow on implications for biodiversity values, social values and Traditional Owner values.

58. For information about how impacts to seagrass may create flow-on impacts to other values see the Dugong value assessment guidelines and other value assessment guidelines.

Traditional Owner heritage values

59. Seagrasses and seagrass beds are an essential element of the living maritime culture of the Aboriginal and Torres Strait Islander peoples that live along the coast of the Marine Park, and seagrass meadows are important for cultural traditions. Places of significance, such as seagrass meadows, allow for cultural practices (for example fishing and collection in and adjacent to the area) which greatly strengthens Aboriginal and Torres Strait Islander culture and their connection with traditional sea country.

60. Applicants are encouraged to discuss their proposed activities with the relevant Traditional Owners early, prior to submitting a Marine Parks permission application. Refer to Traditional Owner heritage assessment guidelines for more information. Also refer to the Woppaburra Traditional Owner heritage assessment guidelines for proposed activities in the Woppaburra Traditional Use of Marine Resources Agreement area.

Social values

61. Ecosystem services that seagrasses provide contribute significantly to human wellbeing and are of high economic importance. Refer to the section on 'Importance to the Marine Park' above.

62. Any impacts on seagrass are likely to have flow-on impacts on social values and consideration should be given to any short and longer term impacts and the influence on intra (current generation) and inter-generational (future generations) equity. Ecologically sustainable use allows for activities to occur without compromising the services (such as carbon storage and sequestration) that ecosystems provide into the future. For further refer to Social values assessment guidelines.

Hazards, mitigation and monitoring

63. The Risk assessment procedure lists the most common potential hazards to the values of the Marine Park, as well as permission types able to be granted under the Zoning Plan. Table 2 lists the hazards associated with permitted activities that are most likely to impact directly on seagrass and seagrass meadows, and includes possible avoidance, mitigation and monitoring measures.

64. Primarily, negative impacts to seagrass meadows (and other values of the Marine Park) are to be avoided. Prudent and feasible alternatives (as a requirement under the GBRMP Regulations) are to be identified when considering proposed sites to conduct an activity.

Table 2: Summary of hazards, impacts and mitigation measures for seagrass and seagrass meadows

Hazard	Related permission types (generally)	Impact (effect on value)	Avoidance, mitigation and monitoring measures
Change in light	• Carrying out works (dredging, dumping of spoil, harbour works, reclamation) • Operating a facility	• Any activity that reduces light levels (through physical obstruction of light, sedimentation, or increased turbidity), reduces the light available for photosynthesis which may lead to stress, reduced growth or even death of the plant, depending on the exposure of reduced light. • Seagrass sensitivity (adaptive capacity or recoverability) to dredge-related hazards is considered high-moderate and is depth dependant.[20] • Negative changes to seagrass health and ecosystem function have flow-on implications for biodiversity values, social values, and Traditional Owner values.	• Prudent and feasible alternatives including locations for infrastructure that avoid shading impacts, for example. • Predictive plume models, such as three-dimensional models which consider intra and inter-annual variability of background environmental conditions (refer to GBRMPA Hydrodynamic Numerical Modelling guidelines). • Activities involving carrying out works (such as dredging and dumping of spoil, harbour works) are consistent with the National Assessment Guidelines for Dredging 2009, including a Sediment Sampling and Analysis Plan (SAP) to determine the sediment particle sizes. • Use modelling outputs along with works/operational monitoring (using parameters such as light/PAR and turbidity/Total Suspended Solids) and adaptive management response actions (such as stop works) based on appropriate ecologically relevant thresholds (such as minimum light requirement of seagrass) triggers. • Monitoring program and adaptive management responses are specified in an Environmental Management Plan (refer to Assessment Guidelines).
Change in hydrodynamics	• Carrying out works (dredging, dumping of spoil, harbour works, reclamation) • Operating a facility • Conducting an aquaculture operation	• Changes to hydrodynamics (depth profile, current direction, or current velocity) can influence sediment transport (suspension, sedimentation, re-suspension) - threatening seagrass by causing physical damage to the root system and uprooting the plant, eroding or destabilising the substrate, and burial of seagrass meadows. • Changes to hydrodynamics may also change the sediment suitability (modification of sediment characteristics such as sediment grain size), growth conditions and nutrient availability. • Removal of sediment through works activities (such as dredging) or through erosion from altered hydrodynamics (such as from vessels) can lead to the area no longer being suitable for seagrass growth, by removing sediment around the root system or due to increased depth of substrate and reduced light reaching seagrass. • Increased turbidity due to changes in hydrodynamics may reduce light conditions (see 'change in light' hazard above). • Build-up of sediment can lead to increased periods of low tide exposure and higher temperatures resulting in stress and seagrass mortality. Sediment particles settling on and smothering seagrass, reducing light, thus decreasing photosynthesis (see 'change in sedimentation' hazard below). • Negative changes to seagrass health and ecosystem function have flow-on implications for biodiversity values, social values, and Traditional Owner values.	• Avoid activities that may cause the direct or indirect change in coastal profiles, including long-shore drift, erosion and accretion. Primarily relevant to works-related activities but also to vessel traffic, particularly those vessels accessing shallow areas (such as barges with beach access). • Predictive modelling, such as three-dimensional models which consider intra and inter-annual variability of background environmental conditions (refer to GBRMPA Hydrodynamic Numerical Modelling guidelines). • Test options for minimising changes to hydrodynamics. • Monitor during works to assess any changes to the site (including substrate stability). • Restrict works to certain seasons, times or tidal cycles to reduce the impacts. • A combination of monitoring and modelling during activity to minimise the risk that suspended sediments will cause impacts on any nearby seagrass meadows. • Implement "Go Slow" zones (less than 4 knots planing speed) for shallow areas to reduce stirring up sediments or scouring the seafloor. • Where applicable, monitoring program and adaptive management responses are specified in an Environmental Management Plan (refer to Assessment Guidelines).
Change in ecological processes	• Carrying out works (dredging, dumping of spoil, harbour works, reclamation) • Operating a facility • Research, other than limited impact research	• Direct loss or physical damage to seagrass and seagrass meadows (resulting in habitat loss and degradation) has flow-on implications for reliant species – resulting in altered feeding behaviour, displacement as they move away in search for more abundant seagrass meadows, and become malnourished reducing their fitness. Their resilience to other pressures (for example declining water quality, natural extreme weather events, such as floods and cyclones) can also be compromised. • Changes to species composition may occur in the short and longer terms. Different seagrass species have differing abilities to recover from disturbance and stress. For example *Halophila* species can recover rapidly and is often found colonising disturbed areas, such as dredge spoil disposal sites. Other species have significantly longer recovery times or may not recover at all. • Changes in ecological function of seagrass meadows has flow on implications for the integrity and health of other ecosystems (such as coral reefs, and mangroves) and their values, as all ecosystems are interconnected. • Negative changes to seagrass health and ecosystem function have flow-on implications for biodiversity values, social values, and Traditional Owner values.	• The vulnerability of seagrass species and the capacity of species to recover is understood. Assess the vulnerability and resilience of the overall ecosystem and its values, the sensitivity of the value (based on past, present and foreseeable future pressures) and their adaptive capacity (refer to Cumulative Impact Management Policy (in draft)). • Where applicable, monitoring program and adaptive management responses are specified in an Environmental Management Plan (refer to Assessment Guidelines), including long term monitoring program to ascertain changes to species composition and ecological processes of the exposed seagrass ecosystem. • Refer to other hazards for other applicable avoidance, mitigation and monitoring measures.
Change in	• Carrying out works	• Excess nutrient levels caused by runoff and/or waste discharge can cause	• Also refer to 'change in ecological processes' in this table.

Hazard	Related permission types (generally)	Impact (effect on value)	Avoidance, mitigation and monitoring measures
nutrients	(dredging, dumping of spoil, harbour works, reclamation) • Operating a facility (including discharge from facility) • Conducting an aquaculture operation	blooms of algae. The algae can be suspended in the water column or occur as epiphytic algal growth on seagrass leaves that can shade seagrass. The reduction in light caused by the algae can decrease seagrass growth (and leaf densities) through reduced photosynthetic rate and in some cases irreversibly kill off whole seagrass meadows. Algae also reduces seagrass health by outcompeting for space and nutrients.[25,26] • An increase in nutrients (up to a tipping point) may benefit seagrass, and can result in increased seagrass growth. However, passing the tipping point can lead to negative impacts, for example high levels of inorganic Nitrogen can cause direct physical impacts (such as reduced growth and mortality) in some species. Seagrass resilience to high nutrient levels is dependent on light availability, temperature, balance of Carbon, Nitrogen, Phosphorus and redox potential.[25] • Seagrass sensitivity (adaptive capacity or recoverability) to dredge–related hazards is considered moderate for nutrient effect.[20] • Negative changes to seagrass health and ecosystem function have flow-on implications for biodiversity values, social values, and Traditional Owner values.	• Avoid or reduce runoff and waste discharge. • Avoid waste discharge, including during extreme weather events, by ensuring appropriate buffering storage and processing facilities for waste. • Enact a robust management and monitoring plan covering habitats within and adjacent to the activity, to ensure nutrient supply is managed in a way that maintains seagrass health and ecosystem integrity. • Conduct hydrodynamic modelling to predict plumes. • Site outfalls, including plume influence areas, away from seagrass meadows wherever possible. • Use modelling outputs along with works/operational monitoring (using parameters such as light/PAR and turbidity) and adaptive management response actions (such as stop works) based on appropriate ecologically relevant thresholds (such as minimum light requirement of seagrass) and triggers. • Monitoring program and adaptive management responses are specified in an Environmental Management Plan (refer to Assessment Guidelines).
Change in salinity	• Operating a facility (including discharge from a facility)	• A moderately low salinity exposure is expected to result in a stress response of reduced shoot growth and reduced flowering.[27] • Very low salinity levels for longer sustained periods can result in reduced health or mortality. • Exposure to high salinity levels for sustained periods can result in reduced health or mortality.[28] • Negative changes to seagrass health and ecosystem function have flow-on implications for biodiversity values, social values, and Traditional Owner values.	• Also refer to 'change in ecological processes' in this table. • Avoid or reduce waste discharge. • Enact a management and monitoring plan covering habitats within and adjacent to the activity, to ensure salinity levels are managed in a way that maintains seagrass health. • Conduct hydrodynamic modelling to predict plumes. • Monitoring program with appropriate ecologically relevant thresholds and triggers (and control sites), as well as adaptive management responses are identified and specified in an Environmental Management Plan (refer to Assessment Guidelines). • Seasonal loss, or reduced growth as a result of exposure to low or high salinity can occur, particularly in estuarine environments. Where relevant this should be considered in the monitoring and interpretation of results.
Change in sedimentation	• Carrying out works (dredging, dumping of spoil, harbour works, reclamation) • Operating a facility	• Sediment build-up over time may result in seagrass growing in more shallow water. This can increase periods of low tide exposure and consequentially higher temperatures, increasing pressure on seagrass which can lead to death. • Sediment particles can settle on and smother seagrass, reducing light and thus decreasing photosynthesis. • Sedimentation is also related to 'change in hydrodynamics' hazard - see above. • Negative changes to seagrass health and ecosystem function have flow-on implications for biodiversity values, social values, and Traditional Owner values. • Seagrass sensitivity (adaptive capacity or recoverability) to dredge–related hazards is considered very high for burial and moderate for deposition, where burial of seagrass resulting in severe impact is generally limited to the footprint of the activity (such as dredge spoil disposal sites).[20] • Also refer to 'direct death or removal of living things' and 'direct injury or disturbance of living things' below.	• Also refer to 'change in ecological processes' in this table. • Avoid activities that may cause the direct or indirect change in coastal profiles, including long-shore drift, erosion and accretion. Primarily relevant to works related activities but also to vessel traffic, particularly those vessels accessing shallow areas (such as barges with beach access). • Activities involving carrying out works (such as dredging and dumping of spoil, harbour works) are consistent with the National Assessment Guidelines for Dredging 2009, and where relevant, includes a Sediment Sampling and Analysis Plan (SAP) to determine the particle sizes of sediments. • Predictive modelling, such as three-dimensional models which consider intra and inter-annual variability of background environmental conditions (refer to GBRMPA Hydrodynamic Numerical Modelling guidelines). • Test options for minimising changes to hydrodynamics. • Monitor during works to assess any changes to the site (including substrate stability). • Restrict works to certain seasons, times or tidal cycles to reduce the impacts. • A combination of monitoring and modelling during activity to minimise the risk that suspended sediments will cause impacts on any nearby seagrass meadows. • Implement 'Go Slow' zones (less than 4 knots planing speed) in and adjacent to the activity to reduce stirring up sediments or scouring the seafloor. • Where applicable, monitoring program and adaptive management responses are specified in an Environmental Management Plan (refer to Assessment Guidelines).
Contamination of water or sediment	• Carrying out works (dredging, dumping of spoil, harbour works, reclamation) • Operating a facility	• Contamination can directly poison, stress and kill seagrass. • Contamination (intentionally or unintentionally) can impact on the water quality of seagrass habitats or directly affect seagrass health. • Contaminants (including freshwater) can stress, disturb or kill seagrass populations through toxicity, growth inhibition, changes to nutrient levels,	• Also refer to 'change in ecological processes' in this table. • Prevent runoff or discharge of turbid or polluted water. • Analyse potential contaminants to understand their short and long-term impacts on seagrass, including chain reactions if released into seawater.

Hazard	Related permission types (generally)	Impact (effect on value)	Avoidance, mitigation and monitoring measures
	(including discharge from facility) • Conducting an aquaculture operation • Research other than limited impact research	reduced light levels and changes to salinity. • Seagrass habitat may be contaminated with toxic elements and synthetic compounds. • Reduced water clarity leads to reduction in light to seagrass, blocking photosynthesis and growth (refer to 'change in light' hazard above). • Contaminants already in the system can re-enter the water column through resuspension (from activities such as dredging, propeller action and/or vessel movements). • Seagrass sensitivity (adaptive capacity or recoverability) to dredge–related hazards is considered high for contaminants.[20] • Flow-on impacts to the food chain for species that feed on seagrass where toxic elements and synthetic compounds are also ingested. For example, organochlorine compounds and heavy metals have been reported in tissues of dugongs in Queensland from contaminated sediments and seagrass.[29,30,31] The long-term effect of such contamination on species is still mostly unknown, as is any potential impact on human health through consumption of such species. Therefore, there are potential implications for Traditional Owner values and their health and wellbeing. • Negative changes to seagrass health and ecosystem function have flow-on implications for biodiversity values, social values, and Traditional Owner values.	• Avoid or reduce contamination. • Activities involving carrying out works (such as dredging and dumping of spoil, harbour works) is consistent with the National Assessment Guidelines for Dredging 2009, including a Sediment Sampling and Analysis Plan (SAP) to determine if sediment contains contaminants. • Individual contaminants should be assessed on a case-by-case basis. Information on the effects of some toxicants can be found in the Water Quality Guidelines for the Great Barrier Reef Marine Park. Other information sources include the Ecotox database and the Australian Pesticides and Veterinary Medicines Authority. • Enact a robust management and monitoring plan covering habitats within and adjacent to the activity, to ensure contamination of water and sediment is avoided and managed. • Conduct hydrodynamic modelling to predict potential plumes. • Monitoring program with ecologically relevant thresholds and triggers (and control sites), as well as adaptive management responses are identified and specified in an Environmental Management Plan (refer to Assessment Guidelines). • Managing risk of contamination, including during extreme weather events, through appropriate chemical storage, buffering storage and processing facilities. Identify appropriate clean-up strategies, including access to clean-up equipment.
Direct death or removal of living things and **Direct injury or disturbance of living things**	• Carrying out works (dredging, dumping of spoil, harbour works, reclamation) • Operating a facility • Research other than limited impact research	• Any action that physically contacts or uproots seagrass plants may result in death and removal. This is particularly evident during works in and adjacent to seagrass habitats. • Increased vessel activity (associated with works or other activities) creates impacts from propellers, anchors, mooring chains and rope – leading to physical damage (to leaves, stems and roots) and may result in death. • Accidental or intentional groundings of vessels, barges and ships in shallow areas may lead to significant physical damage, including death. • Dredging activities (including the anchoring system) may result in direct physical damage or direct death, and removal of seagrass beds. • Spoil disposal activities may result in direct death by burying or smothering seagrass. • Seagrass sensitivity (adaptive capacity or recoverability) to dredge–related hazards is considered very high for removal and burial, and moderate for deposition. Removal and burial of seagrass resulting in severe impact is generally limited to the footprint of the activity.[20] • Propeller scarring often results in a continuous line of seagrass damage which can fragment the habitat, increase erosion, increase vulnerability to other pressures and disrupt connectivity. • Flow-on effects to dependant species, such as dugong and turtles may include altered feeding behaviour or displacement of animals. This may lead to reduced fitness, resilience, fecundity and even death of those species. • Negative changes to seagrass health and ecosystem function have flow-on implications for biodiversity values, social values, and Traditional Owner values.	• Also refer to 'change in ecological processes' in this table. • Prudent and feasible alternatives (such as alternative location and/or infrastructure design minimising footprint) must be considered to avoid impacts to seagrass habitats (and other habitats). • Reduce footprint of the activity. Although in some cases, depending on the species of seagrass present and the location, disposal of dredge spoil material spread thinly over a larger area may allow seagrass to recover at the disposal site, as opposed to thick layer of material that is likely to result in mortality at the immediate disposal site.[32] • Consider timing of the activity (such as the construction of a facility, or dredging and disposal activities). Restrict seasons and avoid flowering and growing season - typically July to January - to conserve reproduction rates. • Establish exclusion/shut-down zones during works. • Limit physical access to the site. • Moorings may assist in mitigating the amount of anchor damage to a site. Avoid placing moorings within 10m of seagrass and consider using lower impact mooring systems as an alternative to swing moorings. • Establish and maintain a monitoring program to identify changes to seagrass from a permitted activity. • Set triggers for management intervention, for example loss/death of seagrass at specified percentage of reference sites. Where possible, implement monitoring to detect sub-lethal stress levels in seagrass so that management action can be enacted prior to declines or losses.

Consequence

65. Consequences of proposed activities to seagrass and seagrass meadows in and adjacent to the area are determined on a case-by-case basis as regionally-specific factors can influence the consequence rating – such as in areas recently impacted by extreme weather events, flood plumes or past disturbance. They are assessed and evaluated by GBRMPA staff and other experts if required.

66. The risk assessment procedure for the permission system provides information on how to determine risk and consequences and provides examples of consequences of impacts to biodiversity values, generally.

67. Consequences of impacts to other values as a result of impact to seagrass is also to be considered.

Assessment information

68. The information required to be submitted at the time of application is available in the 'checklist of application information'. In some cases (likely when involving a new fixed facility other than mooring), a draft Environmental Management Plan, including proposed works monitoring and long term monitoring programs, may also be required from the applicant at the time of application (see the checklist for further information and also the assessment and decision guidelines).

69. Additional information may be required from an applicant for a permission involving higher risk and/or more complex proposed activities (for example those requiring the use of assessment approaches Public Environment Report or Environmental Impact Statement). Information requirements for the assessment will be specified in the Terms of Reference specific to the proposed activity. Further, as described in the Permission System Policy, permission applications involving Public Information Package, Public Environmental Report or Environmental Impact Statement assessment approaches require the applicant to carry out public consultation.

70. As a general guide the following information may be required for higher risk proposals (also refer to Cumulative Impact Management Policy (in draft)):

    a. Description of seagrass ecosystem (and other ecosystems) present in the proposed area and in the adjacent areas both potentially impacted (including downstream and consequential impacts), and outside the impact zone. What are the location-specific conditions and their exposure to pressures over time (past, present and foreseeable future)?

    b. The vulnerability of seagrass species and the capacity of species to recover. Assess the vulnerability and resilience of the overall ecosystem and its values, the sensitivity of the value (based on past, present and foreseeable future pressures) and their adaptive capacity.

    c. Background assessment of seagrasses and water quality that account for likely seasonal and inter-annual change and include at least three (3) years of background data.

    d. Bathymetric and topographic surveys before any action is undertaken using at least three (3) years of consecutive data. Surveys should explain the presence/absence of seagrass, extent, cover or biomass, and species composition using methods appropriate to the scale of potential impact and type of seagrass meadows likely to be encountered. Ideally methods should be compatible with previous seagrass assessments conducted at the site or to those at nearby locations to allow historical or regional comparisons. Approaches identified in the Queensland monitoring manual and the Marine Monitoring Program can provide guidance to the design and approach.

    e. Explanation of the possible impacts on seagrass ecosystem for the potential hazards, the exposure and their sensitivity to the hazards (what is the cause and effect relationship between the activity and the impact).

    f. Analysis of the scale (spatial and temporal), and cause and effect (including direct, indirect, and downstream and consequential impacts, and cumulative impacts) from the proposed activity – using the best available information.

    g. Where applicable, hydrodynamic modelling in accordance with GBRMPA's Hydrodynamic Modelling Guidelines to assist in understanding the potential impacts from various hazards including changes in hydrodynamics, light, sediment and sedimentation and potential contamination of water and sediment.

    h. Proposed monitoring program with indicators, thresholds, trigger values and intervention actions. Include real-time monitoring (with trigger values) for likely contaminants or nutrients and environmental indicators (such as light, turbidity, Total Suspended Solids) with consideration for seagrass and other biodiversity values of the ecosystem within seagrass meadows and other habitats within the proposed area and in the adjacent areas both potentially impacted, and outside the impact zone (the control sites).

i. Locally-derived absolute thresholds should be obtained for management of specific activities likely to impact on the light environment and consider general light requirements as covered in Collier *et al.* 2016.[15] Light values should be determined based on the most sensitive species present. Light thresholds should be analysed by experts to determine timing, concentration, and light attenuation periods.

j. Explanation of proposed incident response plan and equipment, and, if deployed, any possible impacts for the considerations listed above.

Implementation

77. These guidelines will be reviewed and updated as required at least every three (3) years.

78. The Permission System Policy and other guidelines are available which provide further detail on how GBRMPA assesses, decides and manages specific aspects of the permission system and the application process.

79. For actions that are wholly or partially outside the Marine Parks, GBRMPA will continue to liaise with the Commonwealth Department responsible for the EPBC Act. Where a bilateral agreement exists between the Australian Government and the Queensland Government, depending on the terms of the agreement, the Commonwealth Department's role may be delivered by the Queensland Government. GBRMPA will work with both levels of government according to agreed procedures, such as a Memorandum of Understanding, to provide advice on matters that may affect the Great Barrier Reef.

Definitions

Refer to the Permission System Policy for a list of general definitions relating to the permission system.

Bathymetric survey

A study of the underwater depth of lake or ocean floors.

Connectivity

Natural links between different habitats, such as reefs, seagrass beds, mangroves that provide dispersal and genetic replenishment. Also refers to links among coastal lands and adjacent catchments, which are sources of freshwater, sediments and pollutants. The mechanisms include ocean currents, terrestrial runoff and watercourses, larval dispersal, spawning patterns, and movements of adult fishes and other animals. Connectivity is an important process to ensure the productive function of the plant and animal species contribute to the overall health of an ecosystem.[11]

Ecosystem services

Are the benefits provided to humans through the transformation of resources (or environmental assets, including land, water, vegetation and atmosphere) into a flow of essential goods and services, e.g. clean air, water, and food.[33] (Ecosystem services definition cited in Department of the Environment, Water, Heritage and the Arts (2009) *Ecosystem Services: Key Concepts and Applications*, Occasional Paper No 1, Department of the Environment, Water, Heritage and the Arts, Canberra).

Topographic survey

A study used to identify and map the contours of the ground and existing features on the surface of the earth or slightly above or below the earth's surface

Turbidity

A measure of the degree to which water loses its transparency due to the presence of suspended particulates. The more total suspended solids in the water, the murkier it seems and the higher the turbidity

Supporting information

1. Coles, R., McKenzie, L.J. and Campbell, S. 2003, The seagrasses of eastern Australia, in *World Atlas of Seagrasses*, eds E.P. Green and T.S. Frederick, United Nations Environment Programme World Conservation Monitoring Centre and University of California Press, Berkeley, California.

2. Collier, C. and Waycott, M. 2009, *Drivers of change to seagrass distributions and communities on the Great Barrier Reef, literature review and gaps analysis. Report to the Marine and Tropical Sciences Research Facility*, Reef and Rainforest Research Centre, Cairns.

3. Waycott, M., McMahon, K., Mellors, J., Calladine, A. and Kleine, D. 2004, *A guide to tropical seagrasses of the Indo-West Pacific,* James Cook University, Townsville.

4. Waycott, M., Collier, C., McMahon, K., Ralph, P., McKenzie, L.J., Udy, J. and Grech, A. 2007, Vulnerability of seagrasses in the Great Barrier Reef to climate change, in *Climate Change and the Great Barrier Reef: a vulnerability assessment*, eds J.E. Johnson and P.A. Marshall, Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Townsville, pp. 193-235.

5. Great Barrier Reef Marine Park Authority 2012, *A vulnerability assessment for the Great Barrier Reef: Seagrass*, GBRMPA, Townsville.

6. Coles, R., Lee Long, W., McKenzie, L.J., Roelofs, A. and De'ath, G. 2000, Stratification of seagrasses in the Great Barrier Reef World Heritage Area, northeastern Australia, and the implications for management, *Biologia Marina Mediterranea* 7(2): 345-348.

7. Coles, R.G., Lee Long, W.J., McKenzie, L.J., Short, M., Rasheed, M.A. and Vidler, K. 1995, *Distribution of deep-water seagrass habitats between Cape Weymouth and Cape Tribulation, northeastern Queensland*, Dept. of Primary Industries (Queensland), Cairns.

8. Lee Long, W.I., Coles, R.G. and McKenzie, L.J. 1996, Deepwater seagrasses in northeastern Australia - how deep, how meaningful? in *Proceedings of An International Workshop on Seagrass Biology,* eds. J. Kuo, R. C. Phillips, D. I. Walker and H. Kirkman. , University of Western Australia, Perth, pp.41-50.

9. McCormack, C., Chartrand, K., Thomas, R., Tol, S., Szabo, M. and Rasheed, M.A. 2013, *Interim Report. Deepwater Seagrass Dynamics: Light requirements, seasonal change and mechanisms of recruitment for deepwater seagrasses*, James Cook University, Cairns.

10. Chartrand, K.M., Bryant, C.V., Sozou, A., Ralph, P.J. and Rasheed, M.A. 2017, *Final Report: Deep-water seagrass dynamics - Light requirements, seasonal change and mechanisms of recruitment*, Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication, James Cook University Report No 17/16. Cairns, 67 pp.

11. Johnson, J.E. and Marshall, P.A. (eds) 2007, *Climate change and the Great Barrier Reef: a vulnerability assessment,* Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Townsville.

12. Carter, A.B., McKenna, S.A., Rasheed, M.A., McKenzie, L. and Coles, R. 2016, *Seagrass mapping synthesis: a resource for coastal management in the Great Barrier Reef World Heritage Area: report to the National Science Programme*, Reef and Rainforest Research Centre Limited, Cairns.

13. Kilminster, K., McMahon, K., Waycott, M., Kendrick, G.A., Scanes, P., McKenzie, L., O'Brien, K.R., Lyons, M., Ferguson, A., Maxwell, P., Glasby, T. and Udy, J. 2015, Unravelling complexity in seagrass systems for management: Australia as a microcosm, *Science of the Total Environment* 534: 97-109.

14. McKenzie, L.J., Collier, C.J., Langlois, L.A., Yoshida, R.L., Smith, N. and Waycott, M. 2016, *Marine Monitoring Program - Inshore Seagrass, Annual Report for the sampling period 1st June 2014 – 31st May 2015*, TropWATER, James Cook University, Cairns.

15. Collier, C., Chartrand, K., Honchin, C., Fletcher, A. and Rasheed, M. 2016, *Light thresholds for seagrasses of the GBRWHA: a synthesis and guiding document: including knowledge gaps and future priorities. Report to the National Environmental Science Programme.*, Reef and Rainforest Research Centre Limited, Cairns.

16. International Union for Conservation of Nature 2017, *Issues brief: Blue Carbon,* IUCN, viewed 13 December 2017, < https://www.iucn.org/resources/issues-briefs/blue-carbon>.

17. Lavery, P.S., Mateo, M., Serrano, O. and Rozaimi, M. 2013, Variability in the Carbon Storage of Seagrass Habitats and Its Implications for Global Estimates of Blue Carbon Ecosystem Service. *PLoS ONE* 8(9): e73748.

18. Lavery, P. 6 September, 2013, *Seagrass is a huge carbon store, but will government value it?* The Conversation, viewed 12 December 2017, < http://theconversation.com/seagrass-is-a-huge-carbon-store-but-will-government-value-it-17878?utm_medium=email&utm_campaign=Latest+from+The+Conversation+for+6+September+2013&utm_content=Latest+from+The+Conversation+for+6+September+2013+CID_0b9a89f55969c9435c955efdb5e9d379&utm_source=campaign_monitor&utm_term=Seagrass%20is%20a%20huge%20carbon%20store%20but%20will%20government%20value%20it>.

19. Collier, C., Langlois, L., Zemoi, R., Martin, K. and McKenzie, L. 2016, *Developing and refining biological indicators for condition assessments in an integrated monitoring program. Report to the National Environmental Science Programme.*, Reef and Rainforest Research Centre Limited, Cairns.

20. McCook, L., Schaffelke, B., Apte, S., Brinkman, R., Brodie, J., Erftemeijer, P., Eyre, B., Hoogerwerf, F., Irvine, I., Jones, R., King, B., Marsh, H., Masini, R., Morton, R., Pitcher, R., Rasheed, M., Sheaves, M., Symonds, A. and Warne, M.S. 2015, *Synthesis of current knowledge of the biophysical impacts of dredging and disposal on the Great Barrier Reef: report of an independent panel of experts*, Great Barrier Reef Marine Park Authority, Townsville.

21. Rasheed, M.A., McKenna, S.A., Carter, A.B. and Coles, R.G. 2014, Contrasting recovery of shallow and deep water seagrass communities following climate associated losses in tropical north Queensland, Australia, *Marine Pollution Bulletin* 83: 491-499.

22. Chartrand, K.M., Bryant, C.V., Carter, A.B., Ralph, P.J. and Rasheed, M.A. 2016, Light Thresholds to Prevent Dredging Impacts on the Great Barrier Reef Seagrass, *Zostera muelleri* ssp. *capricorni* , *Frontiers in Marine Science* 3: 106.

23. Chartrand, K.M., Ralph, P.J., Petrou, K. and Rasheed, M.A. 2012, *Development of a light-based seagrass management approach for the Gladstone Western Basin dredging program*, Department of Agriculture, Fisheries and Forestry (DAFF), Cairns.

24. Department of Environment and Heritage Protection 8 September, 2016, *Seagrass,* Queensland Government, viewed 25 January 2017, < https://www.ehp.qld.gov.au/coastal/ecology/marine-habitats/seagrass.html>.

25. Ralph, P.J., Tomasko, D., Moore, K., Seddon, S. and Macinnis-Ng, C.M. 2006, Human impacts on seagrasses: Eutrophication, sedimentation and contamination, in *Seagrasses: Biology and Ecology and Conservation*, eds A. Larkum, R.J. Orth and C. Duarte, Springer, Dordrecht, pp. 567-593.

26. Burkholder, J.M., Tomasko, D.A. and Touchette, B.W. 2007, Seagrasses and eutrophication, *Journal of experimental marine biology and ecology* 350(1–2): 46-72.

27. Collier, C.J., Villacorta-Rath, C., van Dijk, K., Takahashi, M. and Waycott, M. 2014, Seagrass proliferation precedes mortality during hypo-salinity events: a stress-induced morphometric response, *PLoS ONE* 9(4): 1-11.

28. Koch, M.S., Schopmeyer, S.A., Kyhn-Hansen, C., Madden, C.J. and Peters, J.S. 2007, Tropical seagrass species tolerance to hypersalinity stress, *Aquatic Botany* 87(1): 14-24.

29. Vos, J.G., Bossart, G.D., Fournier, M. and O'Shea, T.J. 2003, *New Perspectives: Toxicology and the Environment. Toxicology of Marine Mammals. Vol. 3 Systems,* Taylor and Francis, New York.

30. Haynes, D., Carter, S., Gaus, C., Muller, J. and Dennison, W. 2005, Organochlorine and heavy metal concentrations in blubber and liver tissue collected from Queensland (Australia) dugong (*Dugong dugon*), *Marine Pollution Bulletin* 51(1-4): 361-369.

31. Haynes, D. 2001, *Pesticide and heavy metal concentrations in Great Barrier Reef sediment, seagrass and dugongs (Dugong dugon),* PhD,University of Queensland, St. Lucia,Brisbane.

32. Hirst, A.J., McGain, S. and Jenkins, G.P. 2010, The impact of burial on the survival and recovery of the subtidal seagrass *Zostera nigricaulis*, *Aquatic Botany* 142: 10-15.

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

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