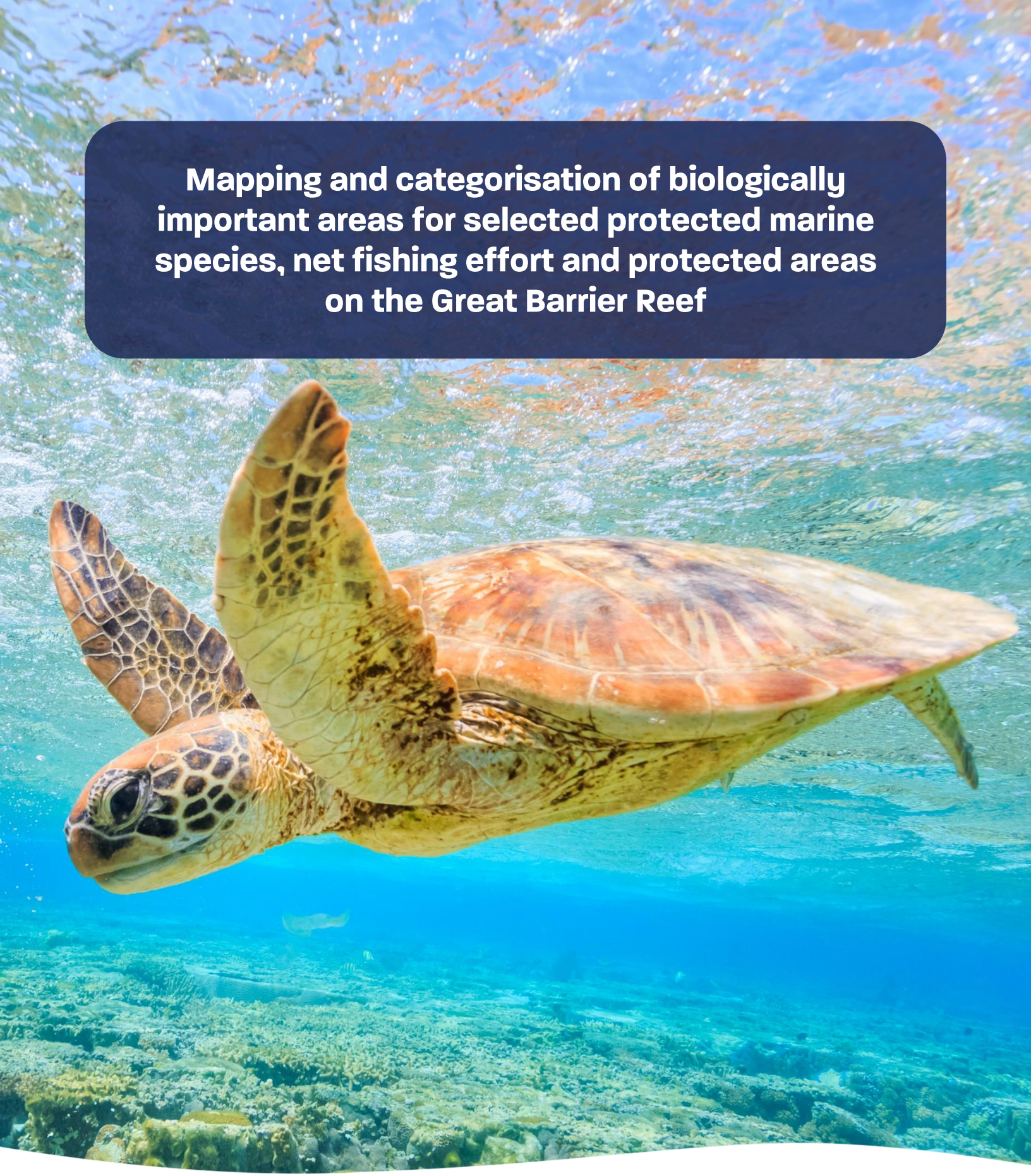
Mapping and categorisation of biologically important areas for selected protected marine species, net fishing effort and protected areas on the Great Barrier Reef



M-DataTech

Australian Marine Conservation Society

Authors

Simon Miller - Great Barrier Reef Fisheries Campaign Manager, Australian Marine Conservation Society. E: simonmiller@amcs.org.au
Caitlin Lennard - Research Assistant, Marine Data Technology Hub, James Cook University.
Carlo Mattone - Postdoctoral Research Fellow, Marine Data Technology Hub, James Cook University.

Mapping and spatial analysis undertaken by **Caitlin Lennard**, Research Assistant, Marine Data Technology Hub, James Cook University.

Contents

Introduction

The Great Barrier Reef World Heritage Area (GBRWHA) is a complex collection of ecosystems, home to a diverse array of fauna and flora, including iconic protected species such as dugongs, marine turtles, inshore dolphins, sharks and rays. Species that are a vital component of the natural and cultural values for which the GBRWHA is known. For many of these species the GBRWHA hosts globally significant populations and is a final stronghold following decline, and in some cases extinction, in other countries.

Decades of published research and monitoring undertaken by University researchers, Queensland and Federal Governments have identified a range of biologically important areas, such as areas used for breeding, foraging, and migration for many of the protected species on the Great Barrier Reef (GBR). Further work has also assessed the conservation status, population size and trends for many of these species in GBR waters. Although much of this work has been collated into resources such as the National Conservation Atlas that identifies biologically important areas for a range of protected marine species, more recent studies contain important information that can be used to build upon and identify important areas for protected marine species.

Due to the complexity and diversity of studies on each of the protected species, this study aims to collate publicly available information to simplify and categorise biologically important areas into high, medium, low or no importance for protected marine species on the Great Barrier Reef.

For some threatened and protected species, national recovery plans exist, such as those for sawfish and river sharks (Commonwealth Department of the Environment, 2015), and marine turtles (Commonwealth of Australia, 2017). These recovery plans, in addition to other studies (e.g. Brooks et al., 2019; GRBMPA, 2020) have identified commercial gillnet fishing as a threat to populations of protected marine species in the Great Barrier Reef.

A level of protection is afforded to protected marine species, particularly within the GBR Marine Park (GBRMP) which encompasses 99% of the World Heritage Area, with most islands, ports and internal State waters not part of the Marine Park. No-take zones encompass 33% of the GBRMP, and further protection from gillnets is provided in areas where large mesh nets are prohibited, including GBR marine park zoning (Pink, Green, Orange, Olive and Yellow Zones), Dugong Protection Zones, and Net-Free Zones. Nonetheless. any areas where gillnetting occurs, still strongly overlap with important areas for a range of protected marine species.

This study aims to bring all of this information together into a single resource that is able to identify areas of high importance to a variety of protected marine species that are subject to high commercial gillnet fishing effort and are not currently offered protection through marine park zoning or other spatial protection. Given the Queensland Sustainable Fisheries Strategy 2017-2027 and the East Coast Inshore Fishery Harvest Strategy and Protected Species Management Strategy aims to reduce interactions with protected species on the Queensland East Coast, we anticipate that this will be a useful resource for guiding actions to reduce the risk to protected marine species.

Overview and categorisation methodology

To simplify the published research for each of the protected species and translate that onto a spatial map, information on biologically important areas was categorised into high, medium, low, or no importance for protected marine species. This was done by considering the published literature on the species including the species biology, ecology, and habitat use and dependency. In addition, further detail including the conservation status, utilisation of GBR habitats and methodology for categorisation of each species is outlined below.

1. Marine Mammals

1.1 Dugong (*Dugong dugon*)

On the eastern Australian coast, dugongs occur from Torres Strait south to the Queensland/New South Wales border. In the Great Barrier Reef region, dugongs are monitored as two separate populations on the basis of threats, the Northern Great Barrier Reef (Cape Bedford near Cooktown north to the tip of Cape York) and the Southern Great Barrier Reef (Cape Bedford south to the boundary of the GBR Marine Park). Recent work suggests there is a deep genetic break in the Whitsunday region, suggesting two separate stocks (Alexandra McGowan et al. unpublished).

The northern region in particular supports a globally significant population of approximately 7,000 (s.e. 1600) dugongs and has been stable since 2006 (Marsh et al., 2020; Marsh in press). An aerial survey in 2016 from just north of Hinchinbrook to the southern border of the GBR Marine Park indicated that dugong numbers increased significantly in that region since the last survey in 2011 largely due to immigration from outside the region (Sobtzick et al., 2017). However, analysis of the aerial survey data for dugongs in this region from 2005 through 2016 - 2018 suggests that the population declined at 4% (s.e. -8.2% to 0.215) per year during that period (Marsh et al. 2019; Marsh in press; Marsh and Rankin unpublished). The current estimate from Cooktown south is 3,400 (s.e. 600)(Marsh in press).

Dugongs are long lived and slow to breed with a generation time of 22-25 years (Marsh et al, 2011). Dugongs have a broad diet of seagrasses, macro-invertebrates and algae within intertidal and subtidal seagrass communities, with dugong populations and distribution linked closely to seagrass health and abundance. Dugongs are also known to undertake long distance movements within the GBR of over 500km, however this is thought to be individualistic behaviour rather than regular migrations (Marsh et al, 2011). Migration from the northern GBR population is thought to have contributed to recent increases in the southern GBR population (Sobtzick et al, 2017). Dugongs are listed as vulnerable on the IUCN red list (Marsh and Sobtzick, 2019) and are listed as Marine and Migratory on the EPBC Act and Vulnerable on the Queensland Nature Conservation Act.

Extensive efforts have been made to monitor and survey the dugong population of the GBR, the most recent surveys of the northern GBR (Marsh et al, 2020) and the southern GBR (Sobtzick

et al, 2017) estimate dugong densities at a grid size of 1km^2, and categorise them as; low, medium, high, and very high. These density categories have been used in this project, with the exception of high and very high, which were pooled together for the “high” category.

1.2 Australian snubfin dolphin (*Orcaella heinsohni*)

There is currently no national assessment of abundance and data is deficient for Australian snubfin dolphins outside of relatively small study sites. However, Brooks et al. (2019) synthesise a number of studies to present population and sighting information along the GBR coast, with findings indicating the species occurs in small populations of typically fewer than 150 individuals. Knowledge of the species life history characteristics is incomplete, although the species has a low reproduction rate, is late to mature and long-lived (Parra et al., 2017a). Their habitat preferences include inshore, shallow (<20m) habitats within 10km of the coast and within 20km of rivers (Parra, 2006). Little information on migration and movement exists due to relatively small and widely separated study sites (Brooks et al., 2019), however where data exists the species is found to undertake small movements of up to 60km. The species life history characteristics makes them extremely vulnerable to even low rates of human-caused mortality (Parra et al., 2017a). Snubfin dolphins are listed as vulnerable on the IUCN red list (Parra et al., 2017a) and the Queensland Nature Conservation Act, but listed as a Cetacean and Migratory under the EPBC Act.

With the available sighting and population estimates (Brooks et al., 2019; Parra, 2006) sites have been categorised into low, medium or high importance based upon the size of their population; 1-14 individuals or occasional sightings is categorised as low, 15-49 medium and 50+ or a significant population as high.

1.3 Australian Humpback Dolphin (*Sousa sahulensis*)

At present there is no national assessment of abundance, with population estimates only available at a number of relatively small study sites. However, Brooks et al. (2019) synthesise a number of studies to present population and sighting information along the GBR coast, with findings indicating the species occurs in small populations of typically fewer than 150 individuals. There are significant gaps in the species life history, however it is assumed to be long lived, late to mature and have a low reproduction rate [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=87942, Accessed 29/07/2021]. Their habitat preferences include inshore, shallow (<20m) habitats within 10km of the coast and within 20km of rivers (Parra, 2006). Little information on migration and movement exists due to relatively small and widely separated study sites (Brooks et al., 2019), however where data exists the species is found to undertake small movements of up to 130km. The species life history characteristics makes them extremely vulnerable to even low rates of human-caused mortality (Parra et al., 2017b). Humpback dolphins are listed as vulnerable on the IUCN red list (Parra et al., 2017b) and the Queensland Nature Conservation Act, but listed as a Cetacean and Migratory under the EPBC Act.

Biologically important areas for this species have already been identified and mapped in the National Conservation Values Atlas [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021]. Based upon the species life history characteristics, areas that have been identified as biologically important for breeding and calving have been classified as of high importance, while foraging areas have been classified as of medium importance.

2. Reptiles

2.1 Green Turtle (*Chelonia mydas*)

There are three distinct stocks in Queensland, the Northern Great Barrier Reef (North of Cooktown), Southern Great Barrier Reef, and Coral Sea populations. The northern Great Barrier Reef stock has been assessed as being in the early stages of decline, the southern Great Barrier Reef stock recovering, while the Coral Sea stock is unknown (Commonwealth of Australia, 2017). All three stocks utilise the Great Barrier Reef and Australian east coast for key aspects of their life cycle including mating, nesting and foraging. Green turtles aggregate to mate and nest at key nesting beaches which are of critical importance to the species, prior to dispersing amongst a wide range of foraging grounds on the Great Barrier Reef and beyond. Key foraging habitats for green turtles include coral reef, mangroves and rocky reef areas with algal turfs or seagrass meadows present (Commonwealth of Australia, 2017) with a number of these key nesting beaches and foraging grounds (such as Raine Island and Shoalwater Bay) monitored by State and Federal Governments. Green turtles face a variety of threats, in particular climate change reducing hatchling success and altering sex ratios (Commonwealth of Australia, 2017), a threat that is likely to be exacerbated in the future under global warming. Additional threats such as fisheries bycatch or ingesting marine debris are compounding the risk to green turtles. Green turtles are listed as endangered on the IUCN red list (Seminoff, 2004) and listed as vulnerable on the EPBC Act and the Queensland Nature Conservation Act.

Biologically important areas for this species have already been identified and mapped in the National Conservation Values Atlas [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021], while a comprehensive recovery plan for marine turtles has been developed by the Commonwealth Government and outlines key nesting beaches, foraging grounds and dispersal for all green turtle stocks on the Great Barrier Reef (Commonwealth of Australia, 2017). Key nesting beaches and foraging grounds identified in the marine turtle recovery plan and National Conservation Values Atlas as well as a 20km internesting buffer have been classified as of high importance due to the species aggregation at these sites throughout the year. Minor nesting sites and an internesting buffer of 20km have been classified as of medium importance. Noting that green turtles are the most common turtle on the Great Barrier Reef, their broad dispersal to foraging grounds and their diverse range of habitat preferences, the remainder of the Great Barrier Reef Marine Park has been classified as low importance, although this should not discount the likelihood and negative impact of fisheries interactions with the species.

2.2 Loggerhead Turtle (*Caretta caretta*)

There is one genetic stock in Queensland, the South Western Pacific stock and has been assessed as being in the early stages of decline (Commonwealth of Australia, 2017). Loggerhead turtles utilise a range of habitats within the Great Barrier Reef for key stages of their life cycle, including mating, nesting and foraging. Loggerhead turtles aggregate to mate and nest at key nesting beaches in the Southern Great Barrier Reef which are of critical importance to the species, prior to dispersing amongst a wide range of foraging grounds on the Great Barrier Reef and beyond. Hatchlings are dispersed by the East Australian current out into the south and east Pacific Ocean until returning at an estimated 15-16 years of age (Convention on the Conservation of Migratory Species of Wild Animals, 2015). The species has a broad range of foraging habitat including rocky and coral reefs, muddy bays, estuaries and seagrass meadows with a number of these key nesting beaches and foraging grounds (such as Mon Repos and Heron and Wistari Reefs) monitored by State and Federal Governments (Commonwealth of Australia, 2017). Like other turtle species, Loggerhead turtles face a diverse range of threats, however, international fisheries bycatch of juvenile turtles and historical bycatch of adult turtles in the East Coast Otter Trawl fishery has left loggerhead turtles vulnerable to further depletion. Loggerhead turtles are listed as vulnerable on the IUCN red list (Casale and Tucker, 2017) and listed as endangered on the EPBC Act and the Queensland Nature Conservation Act.

Biologically important areas for this species have already been identified and mapped in the National Conservation Values Atlas [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021], while a comprehensive recovery plan for marine turtles has been developed by the Commonwealth Government and outlines key nesting beaches, foraging grounds and dispersal (Commonwealth of Australia, 2017). Key nesting beaches and foraging grounds identified in the marine turtle recovery plan, Queensland Marine Turtle Conservation Strategy (Department of Environment and Science, 2018) and National Conservation Values Atlas as well as a 20km internesting buffer have been classified as of high importance due to the species aggregation at these sites throughout the year. Noting loggerhead turtle's broad dispersal to foraging grounds and their diverse range of habitat preferences, the remainder of the Great Barrier Reef Marine Park has been classified as low importance, although this should not discount the likelihood and negative impact of fisheries interactions with the species.

2.3 Hawksbill Turtle (*Eretmochelys imbricata*)

The Northern Queensland stock is the only population of Hawksbill Turtles that nests in the Great Barrier Reef region, however other international hawksbill stocks are known to forage within the Great Barrier Reef (Commonwealth of Australia, 2017). The North Queensland stock is assessed as being in decline (Commonwealth of Australia, 2017) with Milman Island nesting population having declined by 58% over a 28 year monitoring period (Bell et al., 2020). Both the North Queensland and international stocks (likely foraging only) utilise the Great Barrier Reef and Australian east coast for key aspects of their life cycle including mating, nesting and

foraging. Hawksbill turtles aggregate to mate and nest at key nesting beaches which are of critical importance to the species, prior to dispersing amongst a wide range of foraging grounds on the Great Barrier Reef and beyond. Key foraging habitats for hawksbill turtles include tidal and subtidal coral and rocky reef habitats on reefs, seagrass meadows and soft-bottom habitats (Commonwealth of Australia, 2017) with a number of these key nesting beaches and foraging grounds (such as Milman Island and Heron and Wistari Reefs) monitored by State and Federal Governments. Hawksbill turtles are listed as critically endangered on the IUCN red list (Mortimer and Donnelly, 2008) and listed as vulnerable on the EPBC Act and endangered on the Queensland Nature Conservation Act.

Biologically important areas for this species have already been identified and mapped in the National Conservation Values Atlas [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021], while a comprehensive recovery plan for marine turtles has been developed by the Commonwealth Government and outlines key nesting beaches, foraging grounds and dispersal (Commonwealth of Australia, 2017). Key nesting beaches and foraging grounds identified in the marine turtle recovery plan, National Conservation Values Atlas and Madden Hof et al., 2021 (in prep) as well as a 20km internesting buffer have been classified as of high importance due to the species aggregation at these sites throughout the year. Minor foraging sites with few individuals sighted (Department of Environment and Science, 2018) have been classified as of medium importance. Noting the hawksbill turtle's broad dispersal to foraging grounds and their diverse range of habitat preferences, the remainder of the Great Barrier Reef Marine Park has been classified as low importance, although this should not discount the likelihood and negative impact of fisheries interactions with the species.

2.4 Flatback Turtle (*Natator depressus*)

Flatback turtles are endemic to Australia. The Eastern Queensland stock nests in the southern Great Barrier Reef and tagged turtles have not left marine park boundaries (Wildermann, 2017). In addition turtles from the Arafura sea stock may forage in the far northern Great Barrier Reef [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021]. The Eastern Queensland stock has been assessed as stable, although the Recovery Plan for Marine Turtles in Australia states that tagging data from the largest rookery on Peak Island has shown a decline in the last three decades (Commonwealth of Australia, 2017). The status of the Arafura Sea stock is unknown. Flatback turtles are the only turtle to stay within the Australian continental shelf throughout all life stages and typically utilise turbid inshore areas with soft sediment (Wildermann, 2017; Commonwealth of Australia, 2017). The species aggregates to nest at key nesting beaches in the Southern Great Barrier Reef which are of critical importance to the species, prior to migrating to a small number of known foraging grounds on the Great Barrier Reef (Wildermann, 2017). Flatback turtles are listed as data deficient on the IUCN red list [IUCN, https://www.iucnredlist.org/es/species/14363/4435952, Accessed 16/09/2021] and listed as vulnerable on the EPBC Act and the Queensland Nature Conservation Act.

Biologically important areas for this species have already been identified and mapped in the National Conservation Values Atlas [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021], while a comprehensive recovery plan for marine turtles has been developed by the Commonwealth Government and outlines key nesting beaches and dispersal (Commonwealth of Australia, 2017). Tagged flatback turtles have also identified a number of foraging grounds on the Great Barrier Reef (Wildermann, 2017). Key nesting beaches, a 60km internesting buffer, and foraging grounds identified in the marine turtle recovery plan, National Conservation Values Atlas and Wildermann's (2017) PhD thesis have all been categorised as of high importance due to the species aggregation at these sites throughout the year. An inshore migration strip between nesting and foraging grounds has been classified as low importance due to the species transiting through the area, however historical trawl captures in these areas (Wildermann, 2017) should not discount the likelihood and negative impact of fisheries interactions with the species.

2.5 Leatherback Turtle (*Dermochelys coriacea*)

Leatherback turtles of an unknown stock and stock status have been recorded sporadically in the Great Barrier Reef Marine Park. The species has been known to nest in low numbers on the Queensland east coast, however, no nesting has been recorded since 1996, with this nesting aggregation likely functionally extinct (Commonwealth of Australia, 2017). Leatherback turtles forage in waters over Australia's continental shelf and are infrequently seen in inshore areas, however, they have been historically caught in the Queensland shark control program (Commonwealth of Australia, 2017). Fisheries bycatch is one of a number of threats to leatherback turtles, however, most interactions with Australian vessels are in Commonwealth longline fisheries (Commonwealth of Australia, 2017). Leatherback turtles are listed as vulnerable on the IUCN red list (Wallace et al., 2013) and listed as endangered on the EPBC Act and the Queensland Nature Conservation Act.

Biologically important areas for this species have already been identified and mapped in the National Conservation Values Atlas [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021], while a comprehensive recovery plan for marine turtles has been developed by the Commonwealth Government and outlines key nesting beaches, foraging grounds and dispersal (Commonwealth of Australia, 2017). Key nesting beaches identified in the National Conservation Values Atlas as well as a 20km internesting buffer have been classified as of high importance due to the species' historic aggregation at these sites throughout the year. A further historical nesting site identified in the marine turtle recovery plan has been classified as of low importance. No known foraging sites exist within the Great Barrier Reef Marine Park.

2.6 Olive Ridley Turtle (*Lepidochelys olivacea*)

There are no known nesting or foraging sites for Olive Ridley turtles on the east coast of Australia, however a low density nesting site exists on the north west of Cape York which is likely to be in decline (Commonwealth of Australia, 2017). The species is known to forage over

soft-bottomed substrates from southern Queensland north through the Great Barrier Reef Marine Park [GBRMPA, https://www.gbrmpa.gov.au/the-reef/animals/marine-turtles/olive-ridley, Accessed 16/09/2021]. The small size of the north-western Cape York genetic stock makes them particularly vulnerable to ghost net and fisheries bycatch, in addition to climate change and other threats. The Olive Ridley turtle is listed as vulnerable on the IUCN red list (Abreu-Grobois and Plotkin, 2008) and listed as endangered on the EPBC Act and the Queensland Nature Conservation Act.

No biologically important areas have been identified for this species on the Queensland east coast [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021. However, as the species is known to be present over soft-bottomed substrates throughout the Great Barrier Reef Marine Park, the region has been classified as of low importance.

3. Sharks and rays

3.1 Green sawfish (*Pristis zijsron*)

In the GBR region, green sawfish are known to be present from the Whitsundays to the tip of Cape York and across northern Australia, and are a distinct genetic population (Commonwealth Department of Environment, 2015), however historic records exist from the southern GBR and into NSW (Udyawer et al., 2021). The species has limited biological productivity, maturing at 9 years and a suspected annual or biennial reproductive cycle (Kyne et al, 2021). Green sawfish have suffered severe population depletions internationally and have experienced range contractions globally and within Australia. The species inhabits both deep (70m) environments (Stevens et al., 2005), as well as coastal estuaries and shallow inshore environments, however they do not penetrate into freshwater (Commonwealth Department of Environment, 2015). Green sawfish are listed by the IUCN as Critically Endangered (Simpfendorfer, 2013) and Vulnerable under the EPBC Act. The recent Shark Action Plan identifies the species as being critically endangered (Kyne et al, 2021). Due to their low numbers, decline in population, and severe data deficiency, all habitats with evidence of breeding, foraging, resting and migrating are seen as critical for species survival (Commonwealth Department of the Environment, 2015).

Noting that green sawfish inhabit both shallow and deep waters, all areas where adults are known to occur, including inshore regions where pupping may occur (Commonwealth Department of the Environment, 2015) have been categorised as of high importance for the species. An area with few contemporary sightings of green sawfish, but containing suitable habitat (Udyawer et al., 2021), from the Whitsundays to the southern boundary of the GBRMP has been categorised as of medium importance due to the ability of green sawfish to travel long distances and the risk of anthropogenic mortality in small isolated populations.

3.2 Largetooth sawfish (*Pristis pristis*)

Highly data deficient, distribution data for largetooth sawfish has been based off juvenile and sub-adult sightings across northern Australia. Evidence from a limited number of individuals suggests that the east coast population may be genetically distinct (Commonwealth Department of Environment, 2015). The species has limited biological productivity, maturing at 8 years with an annual reproductive cycle (Kyne et al, 2021)Juveniles of this species largely utilise the freshwater reaches of rivers with adults found in estuarine and coastal environments, seeming to show preference for large river systems (Richard Pillans, CSIRO, pers. comm). Largetooth sawfish are listed by the IUCN as Critically Endangered (Carlson et al., 2013) and Vulnerable under the EPBC Act. The recent Shark Action Plan identifies the species as being critically endangered (Kyne et al, 2021). Due to their low numbers, decline in population, and severe data deficiency, all habitats with evidence of breeding, foraging, resting and migrating are seen as critical for species survival (Commonwealth Department of the Environment, 2015).

Due to the species habitat preferences and large population depletions, areas where the species is known to exist and where pupping is known to occur (Commonwealth Department of the Environment, 2015) have been categorised as of high importance. River systems in northern Queensland where pupping or juveniles are likely to occur (Commonwealth Department of the Environment, 2015) have been categorised as of medium importance due to the low populations and limited survey effort in some regions. Further coastal waters where adults are known to occur (Commonwealth Department of the Environment, 2015), yet few records exist have been categorised as of medium importance.

3.3 Dwarf sawfish (*Pristis clavata*)

While data deficient on the east coast, a number of confirmed sightings indicate their historical presence in a few locations within the GBRMP (Udyawer et al., 2021), and a likely range that includes the north east of Cape York (Barbara Wueringer, SARA, pers. comm.). The species has limited biological productivity, maturing at 9 years and a suspected annual or biennial reproductive cycle (Kyne et al, 2021). Dwarf sawfish inhabit very shallow coastal and estuarine waters (0-20m) and show site fidelity. Largetooth sawfish are listed by the IUCN as Endangered (Kyne et al., 2013) and Vulnerable under the EPBC Act. The recent Shark Action Plan identifies the species as being endangered (Kyne et al, 2021). Due to their low numbers, decline in population, and severe data deficiency, all habitats with evidence of breeding, foraging, resting and migrating are seen as critical for species survival (Commonwealth Department of the Environment, 2015).

Based on the above understanding of the species and its presence on the east coast, locations with a confirmed sighting (Udyawer et al., 2021) have been categorised as of high importance, while suitable habitat (Udyawer et al., 2021) has been categorised as of low importance to the species.

3.4 Narrow sawfish (Anoxypristis cuspidata)

Narrow sawfish are still found throughout much of their historic range, albeit in lower numbers (D'Anastasi et al., 2019). This species is the most biologically productive of the sawfish, maturing at 3 years and a generation length of 6 years (Kyne et al, 2021). Juveniles are most frequently found in intertidal and subtidal areas, with large bays along the Queensland coast appearing to provide critical habitat for all life stages (Adkins et al. 2016, Colin Simpfendorfer Pers. Comm.). Adults can be found in waters up to 40m and are encountered in offshore waters (Last and Stevens, 2009). Narrow sawfish are listed by the IUCN as Endangered (D'Anastasi et al., 2013) but are only listed as Marine and Migratory under the EPBC Act. However, Narrow Sawfish is currently on the Finalised Priority Assessment List for a proposed listing as Endangered. The recent Shark Action Plan identifies the species as being vulnerable (Kyne et al, 2021).

All major bays within the GBRMP have been categorised as of high importance due to the presence of narrow sawfish of all life stages (Adkins et al. 2016). The remainder of the species range has been categorised as of low importance due to its broad range and relatively productive life history. However, this should not downplay the importance of these areas to narrow sawfish.

3.5 Speartooth Shark (*Glyphis glyphis*)

The speartooth shark is known to inhabit a small number of coastal and estuarine waters in northern Australia (Commonwealth Department of the Environment, 2015). Recent studies have estimated that it's population is between 2,500 and 10,000 mature individuals (Kyne et al, 2021). Little biological data is available for the species but it is suspected to have limited biological productivity (Kyne et al, 2021). While it's understood that juvenile and sub-adults inhabit large coastal river systems, less is known about the key habitats that adults use and it is assumed that adults utilise coastal waters (Stevens et al., 2005). However, more recent research has indicated that suitable habitats are focussed on higher order streams close to the coast, with limited habitat in coastal waters, noting that further data collection is required regarding adult river sharks in the marine environment (Udyawer et al., 2021). The Speartooth shark is listed as Endangered by the IUCN (Compagno et al., 2009) and Critically Endangered under the EPBC Act. Due to their low numbers, decline in population, and severe data deficiency, all habitats with evidence of breeding, foraging, resting and migrating are seen as critical for species survival (Commonwealth Department of the Environment, 2015). For the Great Barrier Reef area, this refers to the Princess Charlotte Bay region where historical records from the 1980's exist, although no recent sightings have been made. However, more recent studies have indicated that the species is wider ranging than previously thought and the species has been assessed as Vulnerable in the 2021 Shark Action Plan (Kyne et al, 2021).

Based on the above understanding of the species, all locations where pupping may occur on the east coast (due to historical records) (Commonwealth Department of the Environment, 2015) were categorised as of high importance for the species . Due to the limited evidence of adult

populations in coastal waters, areas where adult sharks may occur (Commonwealth Department of the Environment, 2015) were categorised as of low importance for the species .

3.6 White Shark (Carcharodon carcharias)

The eastern stock of white sharks inhabits waters from Central Queensland south and is currently assessed to be a stable population of approximately 5,460 individuals following significant historic declines (Bruce et al., 2018). Like other sharks species, white sharks are long lived, late to mature and produce few offspring at infrequent intervals (Kyne et al, 2021). Tracking studies have shown that most white sharks are confined to shelf waters where they utilise rocky reefs and shallow coastal bays, however a number of sharks have been shown to move offshore to oceanic waters (Bruce et al., 2019). White sharks are known to aggregate in the Southern Great Barrier Reef in winter and spring months and migrate between aggregation sites and nursery areas (Bruce and Bradford, 2008). White sharks are listed as vulnerable on the IUCN red list (Rigby et al., 2018) and are listed as vulnerable on the EPBC act, they are not listed under Queensland legislation. The recent Shark Action Plan identifies the species as being vulnerable (Kyne et al, 2021)

Biologically important areas for this species have already been identified and mapped in the National Conservation Values Atlas [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021]. Based upon the species life history and movement trends, aggregation sites for white sharks have been classified as of high importance, with migration pathways between aggregation sites and nursery areas classified as of medium importance.

3.7 Whale Shark (*Rhincodon typus*)

Little is known about whale sharks on the east coast of Queensland, including their genetics, stock status or critical habitats. While little is known about whale shark biology, they are thought to be extremely long lived and late to mature [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl, accessed 16/09/2021], traits which make them extremely vulnerable to even low levels of human induced mortality. Unpublished work suggests that there may be a feeding aggregation in the Coral Sea [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021] as well as a potential aggregation site of Cape Grenville in the northern Great Barrier Reef, following aerial surveys that found 8-13 whale sharks in the area (Mounter, 2019). This is supported by a small number of tagged whale sharks on the Great Barrier Reef remaining local in the Wreck Bay region on the northern Great Barrier Reef [Citizens of the Great Barrier Reef, https://citizensgbr.org/explore/reef-tracks, Accessed 16/09/2021]. Whale sharks are listed as endangered on the IUCN red list (Pierce and Norman, 2016) and are listed as vulnerable on the EPBC act, they are not listed under Queensland legislation.

Biologically important areas for this species have already been identified and mapped in the National Conservation Values Atlas [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021]. Based upon the species life history and the limited knowledge of its occurrence on the Great Barrier Reef, known aggregation sites have been classified as of high importance and potential aggregation sites have been classified as of medium importance. All other areas in its range have been classified as of low importance to reflect the transient nature of whale sharks outside of aggregation sites.

3.8 Grey Nurse Shark (*Carcharias taurus*)

The eastern Australian stock of the grey nurse shark is distributed from central Queensland south to the New South Wales/Victorian border, with an adult population of between 1,686 and 2,167 individuals (based on two differing maturity scenarios), thought to be increasing by 3.4-4.5% per annum (Bradford et al, 2018). Like other shark species, the grey nurse shark is late to mature with a low reproductive output (Kyne et al, 2021). Grey nurse sharks favour inshore waters around rocky reefs and islands in or near deep sandy gutters and occasionally within the surf zone and shallow bays. The species occurs as solitary individuals or in small schools and undertakes seasonal north - south migrations throughout its range. A northerly migration of males in the Capricorn channel off of Yeppoon has been observed over autumn and winter [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl, accessed 16/09/2021], while pregnant females are known to aggregate at Wolf Rock in the Great Sandy Marine Park. A number of key aggregation sites have been identified for the species throughout NSW and southern QLD, however none of these sites are within the GBR marine park. Grey nurse sharks are listed as critically endangered on the IUCN red list (Rigby et al, 2020) and the EPBC act, they are not listed under Queensland legislation.

Biologically important areas for this species have already been identified and mapped in the National Conservation Values Atlas [Commonwealth Department of Agriculture Water and the Environment, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 03/08/2021]. Due to the species critically endangered conservation status, all sites where known aggregations occur have been classified as of high importance.

3.9 Manta rays (Mobula alfredi & Mobula birostris)

Two species of manta ray occur in the GBR marine park, the reef manta ray (*M. alfredi*) and the oceanic manta ray (*M. birostris*). The known distribution of both species in Australia is patchy and here they are grouped together due to this uncertainty. In Australia the majority of sightings are from subtropical locations where the species aggregates seasonally which coincides with ocean-based tourism (Armstrong et al, 2020). Both manta species have limited biological productivity, maturing at 12 years and having a reproductive cycle of 4-5 years, with a single pup (Kyne et al, 2021). While no population estimates are available, the population of reef manta rays in Australia is thought to be stable, while the more mobile and wide ranging oceanic

manta ray is thought to have undergone population reductions of more than 50% in the last three generations (Kyne et al, 2021). The reef manta ray is mostly seen in relatively shallow waters associated with mainland coastlines, offshore islands and reefs, typically associated with feeding and high zooplankton concentrations, the species shows high site fidelity to reef cleaning stations, particularly at Lady Elliot Island (Armstrong et al, 2020). The oceanic manta ray has been photographed at few scattered locations in Australia with most sightings at cleaning stations adjacent to deep water (Armstrong et al, 2020). Both species are highly mobile with the reef manta regularly undertaking movements of 500km and tagged mantas travelling almost 2,500km (Jaine et al, 2014). The reef manta ray is listed as vulnerable on the IUCN red list (Marshall et al, 2019), listed as Marine and Migratory on the EPBC Act and are not listed under Queensland legislation. The oceanic manta ray is listed as endangered on the IUCN red list (Marshall et al, 2020), listed as Marine and Migratory on the EPBC Act and are not listed under Queensland legislation.

Based upon patchy records of the species distribution, known aggregation sites (Armstrong et al, 2020; Jaine et al, 2014) have been classified as of high importance, while areas with known sightings (Armstrong et al, 2020) have been classified as of low importance.

Other data layers

Data layers relating to commercial gillnet fishing effort, spatial protection and areas of conservation interest were also included to aid analysis and identify areas of high importance to a variety of protected marine species that are subject to high commercial gillnet fishing effort and are not currently offered protection through marine park zoning or other spatial protection.

4.1 Gillnet fishing effort

Recovery plans for sawfish and river sharks and marine turtles (Commonwealth Department of the Environment, 2015; Commonwealth of Australia, 2017), in addition to other studies (e.g. Brooks et al., 2019; GRBMPA, 2020) highlight bycatch in commercial gillnets as a key threat to many of the protected species of interest. Commercial gillnet fishing within the GBR Marine Park takes place in the East Coast Inshore Fishery (ECIF) managed by the Queensland Department of Agriculture and Fisheries. Fisheries Management in Queensland is currently undergoing major reforms as part of the Queensland Government's Sustainable Fisheries Strategy 2017-2027. These reforms have coincided with a reduction in the number of active fishers and fishing effort from highs in the early 2000’s.

Commercial fishers record their catch and effort in mandatory logbooks, with fishing effort reported in 30 minute grids. This data is then made publicly available via an online data portal, QFish (Queensland Department of Agriculture and Fisheries, 2022).

A cumulative seven year period (2014 to 2020) was chosen to represent contemporary gillnet fishing effort on the Great Barrier Reef. The time period was considered best to represent current fishing patterns, as the period prior to 2014 had considerably higher fishing effort than

presently seen, which if used may overestimate the current risk to threatened species. Use of a shorter more recent time period may not be reflective of broader fishing patterns and is more likely to be influenced by seasonality.

This data layer has been presented as a heatmap of total days fished within the 30 minute reporting grid in the period 2014 to 2020.

4.2 Great Barrier Reef Marine Park Zoning

The Great Barrier Reef is a multi-use marine park with different activities, including different types of commercial fishing, permitted within the different zones.

Commercial gillnet fishing is not permitted in areas of the marine park including Preservation (Pink), Marine National Park (Green), Scientific Research (Orange), Buffer (Olive) and Conservation Park (Yellow) Zones.

4.3 Dugong Protection Areas

In addition to GBR Marine Park Zoning, Dugong Protection Zones (DPAs) are legislated within the Marine Park. These Special Management areas are designed to reduce the risk of commercial gillnet fishing to dugongs in some areas where commercial gillnet fishing is permitted. Additional gear restrictions apply in DPAs such as net length and mesh size.

DPAs are likely to reduce the risk of bycatch mortality for dugongs and may provide similar benefits to other protected species within the zone.

4.4 Net-Free Zones

Three Net-Free Zones were established in the Rockhampton, Mackay and Cairns regions in 2015. These zones prohibit the use of gillnets and provide protection to threatened species in the region.

4.5 Important Marine Mammal Areas

The Marine Mammal Protected Areas Taskforce of the International Union for the Conservation of Nature (IUCN) has identified Important Marine Mammal Areas (IMMAs) within the Great Barrier Reef Marine Park.

IMMAs are defined by the IUCN as discrete portions of habitat, important to marine mammal species, that have the potential to be delineated and managed for conservation. IMMAs are identified in order to prioritise their consideration for conservation measures by governments, intergovernmental organisations, conservation groups, and the general public.

IMMAs can be established for any marine mammal and some within the GBR may be relevant to species beyond the scope of this study. A number of criteria have been established to identify IMMAs and these are consistent with the concepts of biologically important areas considered within this study. Criteria include:

A) Species or population vulnerability;
B) Distribution and abundance including small resident populations and aggregation sites;
C) Key life cycle activities such as reproductive and feeding areas and migration routes;
D) Special attributes such as distinctiveness and diversity.

The network of Australian IMMAs was established in 2020, and within the Great Barrier Reef include:

- Northern Great Barrier Reef IMMA established for dugongs, Australian snubfin and Australian humpback dolphins under Criteria A and C;
- Great Barrier Ribbon Reefs and Outer Shelf IMMA established for dwarf minke whales under criteria B and C;
- Hinchinbrook to Round Hill Network IMMA established for dugongs, Australian snubfin and Australian humpback dolphins under Criteria A, B and C;
- Southern Great Barrier Reef Lagoon and Coast IMMA established for humpback whales under Criteria B and C;
- Australian East Coast Migration Corridor IMMA established for humpback whales under Criteria C and D.

IMMAs have been included in this study as an indicator of areas that the Marine Mammal Protected Areas Taskforce of the IUCN considers as priorities for conservation.

4.6 50 Reefs Bioclimatic Units

Climate change is the greatest threat to the future of the Great Barrier Reef and initiatives that will halt and reverse the effects of climate change at a global scale are the most urgent to improve the Reef's long term outlook (GBRMPA, 2019).

Beyer et al (2018) sought to identify global coral reefs that in the absence of other impacts, are likely to have a heightened chance of surviving projected climate changes relative to other reefs. Hypothesising that the protection of less vulnerable but well-connected reefs may then help repopulate degraded reefs should climate change be stabilised. The 50 reefs that were identified in this study are global in distribution, and termed Bioclimatic Units (BCUs). Of these, five are located within the Great Barrier Reef Marine Park - three BCUs in the Whitsunday region, and two in the far northern Great Barrier Reef. .

However, a more recent study by Hughes et al (2021) examined the properties and footprint of recurring climate extremes and coral bleaching on the Great Barrier Reef between 1998 and 2020. The study found that less than 2% of the Reef had escaped coral bleaching and notes that "Following the fifth event in 2020, regions and reefs that were earmarked as candidate

refuges have now also experienced severe or moderate bleaching at least once". Hughes et al (2021) also suggest that the concept of reef refugia rebuilding distant coral reefs is unlikely, stating "As temperatures continue to rise in coming decades, we predict that the patchy local production and dispersal of coral larvae, recovering locally after the most recent bleaching event before crashing at the next, is more likely to rebuild coral populations than the long-distance influence of a dwindling proportion of unbleached or lightly bleached reefs.". However, it does appear that some Reefs in the Whitsunday BCUs have not suffered coral bleaching between 1998 and 2020, while others have only bleached once.

Despite the recent study by Hughes et al (2021), the BCUs were included as a data layer as their properties are likely to give them a heightened chance of surviving climate changes. Addressing local threats such as poor water quality and fishing in the vicinity of these reefs will help maintain ecosystem function and increase the resilience of the Reef.

References

Abreu-Grobois, A & Plotkin, P. (IUCN SSC Marine Turtle Specialist Group). (2008). *Lepidochelys olivacea*. *The IUCN Red List of Threatened Species* 2008: e.T11534A3292503. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T11534A3292503.en. Downloaded on 16 September 2021.

Armstrong, AJ, Armstrong, AO, Bennett, MB, et al. The geographic distribution of reef and oceanic manta rays (*Mobula alfredi* and *Mobula birostris*) in Australian coastal waters. *J Fish Biol*. 2020; 96: 835– 840.

Bell, I. P., Meager J.J., Eguchi T., Dobbs K.A., Miller J.D. , Hof C.M. (2020)
Twenty-eight years of decline: nesting population demographics and trajectory of the north-east Queensland endangered hawksbill turtle (Eretmochelys imbricata)
Biol. Conserv., 241, Article 108376

Beyer, HL, Kennedy, EV, Beger, M, et al. Risk-sensitive planning for conserving coral reefs under rapid climate change. *Conservation Letters*. 2018; 11:e12587. https://doi.org/10.1111/conl.12587

Bradford, R. W. et al. (2018). A close-kin mark-recapture estimate the population size and trend of east coast grey nurse shark. Report to the National Environmental Science Program, Marine Biodiversity Hub. CSIRO Oceans & Atmosphere, Hobart, Tasmania.

Brooks, L., Cagnazzi, D., Beasley, I., and Rankin, R., (2019). Monitoring coastal dolphins within the Reef 2050 Integrated Monitoring and Reporting Program: Final Report of the Dolphins Team in the Megafauna Expert Group , Great Barrier Reef Marine Park Authority, Townsville.

Bruce, B. and Bradford, R., (2008). Spatial dynamics and habitat preferences of juvenile white sharks – identifying critical habitat and options for monitoring recruitment. Final report to the Department of the Environment, Water, Heritage and the Arts

Bruce et al. (2018). A national assessment of the status of white sharks. National Environmental Science Programme, Marine Biodiversity Hub, CSIRO.

Bruce, B, Harasti, D, Lee, KA, Gallen, C, Bradford, R, (2019). Broad-scale movements of juvenile white sharks Carcharodon carcharias in eastern Australia from acoustic and satellite telemetry. Marine Ecology Progress Series Vol. 619: 1-15.

Carlson, J., Smith, K. & Kyne, P.M. (2013). *Pristis (Eastern Pacific subpopulation)*. *The IUCN Red List of Threatened Species* 2013: e.T43508949A43508976. https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T43508949A43508976.en. Downloaded on 23 July 2021.

Casale, P. & Tucker, A.D. 2017. *Caretta* (amended version of 2015 assessment). *The IUCN Red List of Threatened Species* (2017): e.T3897A119333622. https://dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T3897A119333622.en. Downloaded on 15 September 2021.

Citizens of the Great Barrier Reef, https://citizensgbr.org/explore/reef-tracks, Accessed 16/09/2021

Commonwealth Department of Agriculture Water and the Environment, National Conservation Values Atlas, http://www.environment.gov.au/webgis-framework/apps/ncva/ncva.jsf, Accessed 24/09/2021

Commonwealth Department of Agriculture Water and the Environment, Species Profile and Threats (SPRAT) Database, http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl, Accessed 29/07/2021.

Commonwealth Department of the Environment (2015). Sawfish and river sharks multispecies recovery plan.

Commonwealth of Australia (2017). Recovery Plan for Marine Turtles in Australia.

Compagno, L.J.V., Pogonoski, J. & Pollard, D. (2009). *Glyphis*. *The IUCN Red List of Threatened Species* 2009: e.T39379A10221801. https://dx.doi.org/10.2305/IUCN.UK.2009-2.RLTS.T39379A10221801.en. Downloaded on 23 July 2021.

Convention on the Conservation of Migratory Species of Wild Animals (2015). Single Species Action Plan for the Loggerhead Turtle (Caretta caretta) in the South Pacific Ocean.

D'Anastasi, B., Simpfendorfer, C. & van Herwerden, L. (2019). Shark Report Card: Narrow Sawfish, Anoxypristis cuspidata.

Department of Environment and Science (2018). Marine Turtle Conservation Strategy - Queensland, Brisbane: Department of Environment and Science, Queensland Government.

Great Barrier Reef Marine Park Authority 2019, Great Barrier Reef Outlook Report 2019, GBRMPA, Townsville.

Great Barrier Reef Marine Park Authority (2020). Fishing Position Statement. Townsville.Great Barrier Reef Marine Park Authority, https://www.gbrmpa.gov.au/the-reef/animals/marine-turtles/olive-ridley, Accessed 16/09/2021

Great Barrier Reef Marine Park Authority, Olive Ridley Turtle, https://www.gbrmpa.gov.au/the-reef/animals/marine-turtles/olive-ridley, Accessed 16/09/2021.

Hughes, T.P., Kerry, J.T., Connolly, S.R., Alvarez-Romero, J.G., Eakin, C.M., Heron, S.F., Gonzalez, M.A., Moneghetti, J. (2021). Emergent properties in the responses of tropical corals to recurrent climate extremes. Current Biology, 31, 5393-5399.

Jaine, F. R. A., Rohner, C. A., Weeks, S. J., Couturier, L. I. E., Bennett, M. B., Townsend, K. A., & Richardson, A. J. (2014). Movements and habitat use of reef manta rays off eastern Australia: offshore excursions, deep diving and eddy affinity revealed by satellite telemetry. Marine Ecology Progress Series, 510, 73–86.

Kyne, P.M., Rigby, C. & Simpfendorfer, C. (2013). *Pristis clavata* (errata version published in 2019). *The IUCN Red List of Threatened Species* 2013: e.T39390A141790455. https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T39390A141790455.en. Downloaded on 23 July 2021.

Kyne, P.M., Heupel, M.R., White, W.T. and Simpfendorfer, C.A. (2021). The Action Plan for Australian Sharks and Rays 2021. National Environmental Science Program, Marine Biodiversity Hub, Hobart.

Last, P.R. and Stevens, J.D. (2009). Sharks and Rays of Australia. Second Edition. CSIRO Publishing, Collingwood, Australia.

Madden Hof, C., Smith, C., Miller, S., Ashman, K., Townsend, K. (2021). Delineating spatial use and threat exposure for critical recovery management of the endangered hawksbill turtle in northeast Australia, one of western Pacific last stronghold. Manuscript in preparation.

Marsh H (in press) Status and trends of the dugong, *Dugong dugon*, in Australia. 2021 State of the Environment Report.

Marsh, H. & Sobtzick, S. 2019. *Dugong dugon* (amended version of 2015 assessment). *The IUCN Red List of Threatened Species* 2019: e.T6909A160756767. https://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T6909A160756767.en. Downloaded on 30 September 2021.

Marsh, H, O'Shea, TJ, Reynolds, JE III (2011) The ecology and conservation of Sirenia: dugongs and manatees. Cambridge University Press. 521pp.

Marsh, H., Hagihara, R., Hodgson, A., Rankin, R., and Sobtzick, S. (2019). Monitoring dugongs within the Reef 2050 Integrated Monitoring and Reporting Program: final report of the Dugong Team in the Megafauna Expert Group, Great Barrier Reef Marine Park Authority, Townsville.

Marsh, H., Collins, K. Grech, A., Miller, R. and Rankin, R. (2020). An assessment of the distribution and abundance of dugongs and in-water, large marine turtles along the Queensland coast from Cape York to Hinchinbrook Island. A report to the Great Barrier Reef Marine Park Authority, May 2020

Marshall, A., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Herman, K., Jabado, R.W., Liu, K.M., Pacoureau, N., Rigby, C.L., Romanov, E. & Sherley, R.B. 2019. *Mobula alfredi*. *The IUCN Red List of Threatened Species* 2019: e.T195459A68632178. Downloaded on 01 October 2021.

Marshall, A., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Derrick, D., Herman, K., Jabado, R.W., Liu, K.M., Rigby, C.L. & Romanov, E. 2020. *Mobula birostris*. *The IUCN Red List of Threatened Species* 2020: e.T198921A68632946. Downloaded on 01 October 2021

Mortimer, J.A & Donnelly, M. (IUCN SSC Marine Turtle Specialist Group). 2008. *Eretmochelys imbricata*. *The IUCN Red List of Threatened Species* 2008: e.T8005A12881238. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T8005A12881238.en. Downloaded on 08 October 2021.

Mounter, B., (2019). Whale shark expedition on Great Barrier Reef uncovers great mysteries of world's largest fish, ABC News, 6 December. Available at: https://www.abc.net.au/news/2019-12-06/whale-sharks-in-great-barrier-reef-hotspots/11767218. Accessed 16/09/2021.

Parra, G. J., Schick, R. and Corkeron, P. J. (2006). Spatial distribution and environmental correlates of Autralian snubfin and Indo-Pacific humpback dolphins. Ecography 29: 396406.

Parra, G., Cagnazzi, D. & Beasley, I. (2017a). *Orcaella heinsohni* (errata version published in 2018). *The IUCN Red List of Threatened Species* 2017: e.T136315A123793740. https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T136315A50385982.en. Downloaded on 28 July 2021.

Parra, G., Cagnazzi, D., Perrin, W. & Braulik, G.T. (2017b). *Sousa sahulensis*. *The IUCN Red List of Threatened Species* 2017: e.T82031667A82031671. https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T82031667A82031671.en. Downloaded on 29 July 2021.

Pierce, S.J. & Norman, B. (2016). *Rhincodon typus*. *The IUCN Red List of Threatened Species* 2016: e.T19488A2365291. https://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T19488A2365291.en. Downloaded on 16 September 2021.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M.P., Herman, K., Jabado, R.W., Liu, K.M., Lowe, C.G, Marshall, A., Pacoureau, N., Romanov, E., Sherley, R.B. & Winker, H. (2019). *Carcharodon carcharias*. *The IUCN Red List of Threatened Species* 2019: e.T3855A2878674. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T3855A2878674.en. Downloaded on 16 September 2021.

Rigby, C.L., Carlson, J., Derrick, D., Dicken, M., Pacoureau, N. & Simpfendorfer, C. 2021. *Carcharias taurus*. *The IUCN Red List of Threatened Species* 2021: e.T3854A2876505. https://dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T3854A2876505.en. Downloaded on 30 September 2021.

Queensland Department of Agriculture and Fisheries, QFish, https://qfish.fisheries.qld.gov.au/, accessed 14/04/2021.

Seminoff, J.A. (Southwest Fisheries Science Center, U.S.). (2004). *Chelonia mydas*. *The IUCN Red List of Threatened Species* 2004: e.T4615A11037468. https://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T4615A11037468.en. Downloaded on 15 September 2021

Simpfendorfer, C. 2013. *Pristis zijsron* (errata version published in 2019). *The IUCN Red List of Threatened Species* 2013: e.T39393A141792003. https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T39393A141792003.en. Downloaded on 23 July 2021.

Sobtzick, S., Cleguer, C., Hagihara, R., and Marsh, H. 2017. Distribution and abundance of dugong and large marine turtles in Moreton Bay, Hervey Bay and the southern Great Barrier Reef. A report to the Great Barrier Reef Marine Park Authority. Centre for Tropical Water & Aquatic Ecosystem Research (TropWATER) Publication 17/21, James Cook University, Townsville

Stevens, J. D., Pillans, R. D. & Salini, J. P. (2005). Conservation assessment of Glyphis (speartooth shark), Glyphis garricki (northern river shark), Pristis microdon (freshwater sawfish) and Pristis zijsron (green sawfish). Report to Department of Environment and Heritage. Canberra. Australia. 84 pp.

Udyawer, V., Thums, M., Ferreira, L.C., Tulloch, V. & Kyne, P.M. (2021). Distribution and habitat suitability of Threatened and Migratory marine species in northern Australia. Report to the National Environmental Science Programme, Marine Biodiversity Hub. 102 pages

Wallace, B.P., Tiwari, M. & Girondot, M. (2013). *Dermochelys coriacea*. *The IUCN Red List of Threatened Species* 2013: e.T6494A43526147. https://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T6494A43526147.en. Downloaded on 16 September 2021.

Wildermann, NE. (2017). Flatbacks at sea: understanding ecology in foraging populations. PhD thesis, James Cook University.