Chapter 10: AUSTRALIA

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Regional Findings

Australia: Queensland, Northern Territory, and Western Australia from Shark Bay north.

- Australia is the most important location for dugongs and their seagrass habitats in the world. The vast areas of shallow continental shelf in northern Australia provide extensive areas of seagrass supporting habitat and the human population density of most of this region is very low.
- The total estimated dugong population is ~ 165,000. The total area of seagrass estimated with moderate to high certainty in the dugong's Australian range is ~ 57,500 km^2, including 19.005 km^2 in waters > 20 m deep in the urban coast of the Great Barrier Reef World Heritage Area that has not been surveyed for dugongs.
- The dugong is a Matter of National Environmental Significance under national law and receives protection under the laws of all relevant jurisdictions in their Australian range.
- Ten Important Marine Mammal Areas (IMMAS) with dugongs as a qualifying species are recognised in Australian coastal waters: five in Queensland, one straddling Queensland and Northern Territory waters, and four in Western Australia. Dugongs in most of these IMMAs receive some statutory protection under marine park and/or fisheries legislation.
- The dugong population is explicitly recognised as an attribute of Outstanding Universal Value in both the Great Barrier Reef and the Shark Bay World Heritage Areas.
- The results of the large-scale aerial surveys that have been conducted over dugong habitats in Australia since the 1980s suggest that dugong conservation status varies regionally within Australian coastal waters from stable along the remote coast of the Great Barrier Reef World Heritage Area, the Gulf of Carpentaria coast of the Northern Territory and Shark Bay, declining along the urban coast of the Great Barrier Reef World Heritage, and uncertain in most other parts of their Australian range.
- Confidence in these assessments varies because of regional and temporal differences in survey recency, frequency, and different approaches to assessing trends. Much of the dugong's range in Western Australia and the Northern Territory has only been surveyed once and key areas have not been surveyed for more than ten years including: Torres Strait, which supports the largest dugong population, the Gulf of Carpentaria Coast of Queensland, and the Pilbara coast of Western Australia.
- Dugong hunting by Traditional Owners (Aboriginal or Torres Strait Islander individuals or groups who can prove a traditional or historical connection, attachment, and/or relationship to an area of land or sea) is legal under Australian Law. This situation is unlikely to be having a significant impact on Australia dugong populations.
- Extreme weather events (cyclones, floods, and marine heatwaves) have been the most significant threats to dugongs in their Australian range in recent years. Loss of the seagrasses eaten by dugongs results in dugong life history changes including an increase in mortality, especially neonatal and early juvenile mortality, and a decrease in fecundity. In such circumstances, some dugongs undertake temporary emigration, presumably to locations where seagrass has not been lost.
- As a developed country, Australia has the potential to conduct research and develop monitoring techniques that inform dugong conservation globally and a high proportion of modern dugong research has been conducted in Australia.
- A national Wildlife Conservation Plan could enable a more systematic and prioritized approach to research and monitoring than has occurred to date.

10.1 Regional Setting

10.1.1 Geographic Overview

This chapter considers the status of the dugong around the ~ 36,000 km coastline (including major offshore islands) of northern Australia between Moreton Bay (27.09° S, 152.92° E) in the east and Shark Bay (25.8° S, 113.3° E) in the west. The area of interest includes Torres Strait or Zenadth Kes, which lies between Cape York, the northern most point of the Australian mainland (10.69° S, 142.53° E) and the coastline of Western Province in Papua New Guinea (PNG) (Figure 10.1). The dugongs in Torres Strait waters under PNG jurisdiction are considered here rather than in Chapter 9, because the dugong population of Torres Strait is a transboundary stock.

The dugong's range in the Australian region spans 18 degrees of latitude, ~ 40 degrees of longitude and includes coastal waters in the following Australian marine bioregions: North-West, North, Great Barrier Reef (which includes Torres Strait), and Temperate East Marine (Queensland waters only) (Figure 10.1). These bioregions have been recognised as the basis of large-scale marine planning in Australia, under the *Environmental Protection and Biodiversity Conservation Act, Commonwealth 1999.*

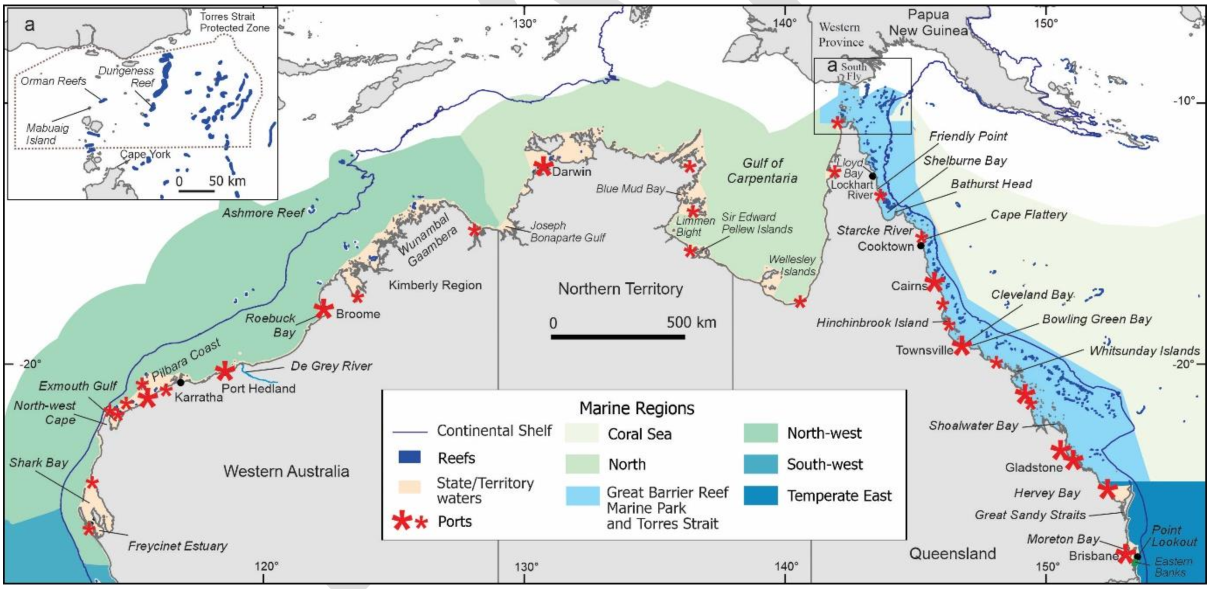
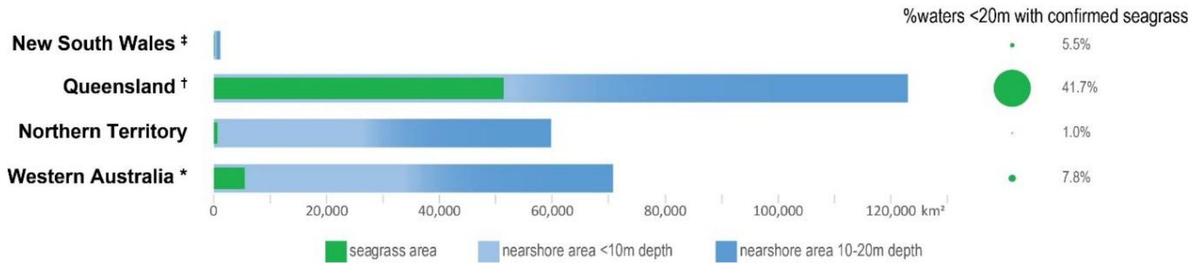


Figure 10.1. The geographic setting of the dugong's range in Australia showing placenames mentioned in the text, major and subsidiary ports, the marine bioregions and the 200 m contour line, which delineates the continental shelf. Top left inset map: Torres Strait. The northern boundary of the Protected Zone follows the jurisdictional boundary between Australia and PNG. Figure created by Adella Edwards; reproduced with permission. The 200 m depth contour generated from GEBCO - The general Bathymetric Chart of the Oceans. GEBCO Compilation Group (2023) GEBCO 2023 Grid (doi:10.5285/f98b053b-0cbc-6c23-e053-6c86abc0af7b).

The continental shelf of northern Australia is extensive (Figure 10.1), and its shallow waters support an estimated 57,498 km^2 of seagrass communities known with moderate to high confidence (Figure 10.2; Astill et al. 2011; Hurley and Ng 2017; Del Deo 2020; McKenzie et al. 2020; Carter et al. 2021; Carter et al. 2023; Lucieer et al. 2023) in the Tropical Indo-Pacific seagrass bioregion (Short et al. 2007). The largest areas of seagrass occur in the Torres Strait and along the east coast of Queensland, where sparse *Halophila* meadows are scattered across the seabed down to 76 m (covering ~ 65% of the total seagrass area) (McKenzie et al. 2020, Table 1; Carter et al. 2021; Carter et al. 2023).

The dugong's winter range spans the coastal waters of Queensland, the Northern Territory, and Western Australia from Shark Bay north (Figure 10.1). Allen et al. (2004) summarised evidence from archaeology, strandings, shark net captures, and anecdotal sightings that confirmed that dugongs also occasionally occurred in New South Wales (NSW) coastal waters in the Austral summer. The NSW coast is characterised by high wave-energy, sandy beaches and the strong south-west flowing East Australian current. Most seagrass occurs in the calmer waters of estuaries, bays, and coastal lakes (MacReadie et al. 2018). The total area of seagrass in the 46 estuaries from Port Stephen in the south to the Queensland border in the north is estimated to be ~ 61 km^2 (Creese et al. 2009; Lucieer et al 2023); most seagrass meadows are small (< 5 ha). In Moreton Bay in Queensland, the southern limit of the dugongs' confirmed winter range on the east coast, some dugongs undertake thermoregulatory movements in winter to the warmer oceanic waters outside that Bay (Marsh and Sinclair 1989a, Lanyon 2003, Preen 1992, Zeh et al. 2018). Thus, winter water temperatures are likely to be too cold for dugongs to be present in NSW year-round (Marsh and Cleguer 2024). In Western Australia, there is no evidence of dugongs occurring south of Shark Bay, although there is evidence of seasonal movements within that bay fort thermal regulation as summarised by Deutsch et al. (2022).

The dugong's Australian range supports 20 species of seagrass (excluding *Ruppia maritima*, which is a brackish water species that also grows in freshwater). All but three species of seagrass (*Posidonia angustifolia, Posidonia australis,* and *Posidonia coriacea*) are likely consumed by dugongs (Marsh et al. 2018). There is no evidence of dugongs eating any species of Posidonia. *Halophila tricostata* (Kuo et al. 1993) and *Cymodocea angustata* (McMillan et al. 1983) are endemic to northern Australia, whereas *P. angustifolia, P. australis*, and *P. coriacea* are all endemic to southern Australia, (Waycott et al. 2014), and mostly occur outside the dugong' range. Apart from *Amphibolis antartica*, most other species are widely distributed or common in the Tropical Indo-Pacific seagrass bioregion. In northern Australia, the number of seagrass species varies with latitude and subregion. For example: Moreton Bay at the eastern end of the dugong's range supports seven species (Maxwell et al. 2019); the Great Barrier Reef supports 15 species (Coles et al. 2015) and Shark Bay, Western Australia, 12 species including three species of temperate seagrasses (*A. antarctica, P. australias* and *P. coriacea*) (Strydom et al. 2020).



** Shark Bay north, † includes Torres Strait, ‡ Port Stephens north*

Figure 10.2. Histogram showing the areas of seagrass known with moderate to high confidence in the coastal waters < 10m deep and < 20 m deep for specified locations within the Australian region. The areas of seagrass are almost certainly underestimates, especially in the Northern Territory and Western Australia. While not all shallow coastal waters are potential seagrass habitat, this figure indicates: (1) the need to undertake additional seagrass mapping in this region; and (2) that New South Wales waters could not support a large dugong population, even if the water was warm enough for dugongs to overwinter there. Figure created by Len McKenzie; reproduced with permission.

10.1.2 Geo-Political and Socio-Economic Overview

This information is provided as an indication of the challenge for each of the Range States in the region to consider the conservation of dugongs and their habitats in the context of their socioeconomic development needs.

Politically, Australia is a federation of six states and two territories. Most of northern Australia is very, sparsely populated (Chapter 1, Figure 1.x). A high percentage of the population occurs in relatively few urban centres, such as the Gold Coast (~ 620,000 people), Brisbane (~ 2.6 million), Sunshine Coast (~ 370,000), all of which are in southeast Queensland (SEQ); Townsville (~ 205,000) and Cairns (~ 164,000), both of which are in north Queensland; and Darwin (~ 171,000), in the Northern Territory (Population Australia 2024).

The South Fly region of Western Province in PNG, the area bordering Torres Strait, had a population of ~ 84,500 in 2021, 37% (~ 31,000) of which live in coastal regions (National Statistics Office 2021).

Australia has a Very High Human Development Index (HDI) (0.951, ranked 5/189) (United Nations Development Programme [UNDP] 2022) and per capita GDP ranked 17/189 (The World Bank 2022). In contrast, PNG's HDI is 0.558 (low end of the Medium range; ranked 151/189) and its per capita GDP is ranked 104/189. McGillivray (see Busilacchi et al. 2018) calculated the HDI for Western Province to be 0.260 in 2007, making it one of the poorest regions in the world. In contrast, the mostly Indigenous inhabitants of inhabitants of Australian Torres Strait, had an estimated HDI of 0.735 in 2011 (Butler et al. 2012), which is close to Yap and Biddle's (2010) calculation of 0.737 for all Indigenous Australians.

The Torres Strait Treaty, which was signed in 1978 and came into effect in 1985, provides the framework for Australia and PNG to collaboratively manage the Torres Strait region, including the dugong population. Western Torres Strait also borders the coastal waters of West Papua, a province of Indonesia (Chapter 8). The framework for regional cooperation is discussed in Section 10.7.

10.1.3 Genetics of dugongs in Australia

For an overview of techniques, relevant genetic studies and general findings, refer to Chapter 1, particularly Figure 1.x.

The Australian region has been the focus of more genetic studies on dugongs than anywhere else. These have cast light on aspects of the dugong's evolution, distribution, and biology.

The earliest genetic work in the region was the PhD thesis by Tikel (1997), largely superseded by work reported in the thesis by McDonald (2005) and published in Blair et al. (2014). Phylogeography and population-genetic inferences based on mitochondrial sequence data (410 bp of partial control region) were the emphases of these works. The presence and interesting spatial distribution of two principal mitochondrial haplogroups in Australian waters were reported (Figure 1.x): the 'restricted' haplogroup found only along the east coast of Queensland (and one report of an example in the Arabian Gulf by Tikel 1997) and the 'widespread' haplogroup occurring throughout the dugong's range in Australia but rare in southeast Queensland. The widespread haplogroup is also the only haplogroup in New Caledonia (Chapter 9) and is present around the island of New Guinea, eastern Indonesia and occasionally further afield (Figure 1.x).

These two haplogroups have strongly contrasting features. Despite many individual dugongs belonging to the restricted haplogroup being included in the network (n=445; Figure 1.x), this group has much less haplotypic and nucleotide diversity than the widespread haplogroup (n=296). In Australia, the restricted haplogroup has been reported only once from west of Torres Strait (Figure 1.x). Baker (2012) presented additional shorter sequences (319 bp) (319 bp: GenBank accession numbers PP331257-PP331356) from 20 bone samples from the Gulf of Carpentaria: all belonged to the widespread haplogroup. A further feature of the restricted haplogroup is the significant genetic differentiation between its representatives in the Torres Strait region versus those in southern Queensland (Blair et al. 2014; McGowan et al. 2023). It is also remarkable that along the ~800 km of coastline extending north from the Whitsunday Islands to Starke River, the restricted haplogroup is greatly under-represented, despite being slightly in the majority in the Torres Strait to the north

(Blair et al. 2014; McGowan et al. 2023). Baker (2012) sequenced 72 additional samples from this stretch of coast, dating back to the 1970s. The restricted haplogroup was represented only by 16 sequences between the Whitsundays and Starke River, as well as further north to Lockhart River, about ~ 300 km from Torres Strait (Figures 10.1, 10.6, 10.7, 10.8). All seven of the sequences reported by Plön et al. (2019) from this coast belonged to the widespread haplogroup.

Explanations of the distribution and structure of the restricted haplogroup have been proposed. Due to low sea-levels for much of the last 400,000 years, Torres Strait has only occasionally been open to transit by marine organisms (Wilson 2013; Ludt and Rocha 2015). The only tropical sea route between the east and west coasts of Australia when Torres Strait is closed is via the north side of the island of New Guinea. Presumably the restricted haplogroup arose in isolation east of Torres Strait. During glacial maxima, members of this haplogroup probably retreated to local refugia and experienced genetic bottlenecks (Blair et al. 2014; McGowan et al. 2023). Tian et al. (2023), using whole-genome data, inferred a considerable reduction in the effective population size of dugongs in eastern Australia around the time of the last glacial maximum and a similar finding was presented by Baker et al. (2024). Further divergence into northern and southern sub-groups (from northern and southern refugia) during such times of separation might explain the observed structure within the restricted haplogroup.

In contrast to the restricted haplogroup, the widespread haplogroup is represented across the entire Australian range of the dugong but is very rare in southeast Queensland. It is possible that there were no representatives of this haplogroup on the east coast of Queensland until the most recent opening of the Torres Strait, around 7,000 years ago. Subsequent dispersal along the east coast failed to establish a major presence in the southern-most dugong habitats in Queensland.

If the above scenarios are correct, questions that arise include: (a) Why did members of the restricted haplogroup not undertake post-glacial dispersal to become common in coastal waters between the Whitsunday Islands and Lockhart River? (b) Why did members of the widespread haplogroup fail to establish in the southern-most dugong habitats in Queensland? Given that mitochondria are maternally inherited, thus tracking only the movements of females, the patterns observed might indicate a high degree of female philopatry. This raises further questions, such as 'why did representatives of the widespread haplogroup become the majority along the mid-north Queensland coast?' There is no immediately obvious answer.

A third haplogroup has been found in Australian waters (Blair et al. 2014). One representative of the northeastern haplogroup was reported from Ashmore Reef on the Sahul Shelf, sympatric with representatives of the widespread haplogroup. Ashmore Reef is closer to Indonesia (~ 150 km) than to mainland Australia (~ 350 km).

Mitochondrial sequence data, as well as nuclear microsatellite (biparentally inherited) data have been used to explore levels of gene flow in Queensland waters. Genetic structure and isolation by distance along the entire east coast of Queensland (extending over 18 degrees of latitude from Moreton Bay to Torres Strait) have been inferred by all relevant genetic studies (Blair et al. 2014; McCarthy 2018; McGowan et al. 2023; Tian et al. 2023). McGowan et al. (2023) used mitochondrial sequences from 639 dugongs, 22 nuclear microsatellite loci and > 10,000 nuclear SNP loci (for a subset of animals), which all confirmed the isolation-by-distance pattern along the Queensland coast as well as a marked "genetic break" in the vicinity of the Whitsunday Islands. Both to the south and the north of the Whitsundays, further subdivision could be identified (McGowan et al, 2023). Tian et al. (2023 in BioRxiv) generated > 16 million SNP loci from whole-genome sequence data for 99 Queensland dugongs. After filtering the SNPs and appropriate analysis, they corroborated the existence of the genetic break near the Whitsunday Islands and dated this at about 10,200 years ago. Suggested reasons for this break include patchy distribution of deep-water seagrasses and/or local current regimes in the Whitsunday Islands inhibiting travel by dugongs through the area in either direction (McGowan et al. 2023). Another possibility, hinted at by Tian et al. (2023), is that local evolutionary adaptations either side of the Whitsunday Islands might discourage breeding movements.

At a smaller, but still substantial, geographical scale, two studies have used microsatellites to investigate gene flow and movement between four shallow bay complexes with large dugong populations along ~ 600 km of coastline in southern and central Queensland: Moreton Bay, Great Sandy Straits, Hervey Bay and Shoalwater Bay. Seddon et al. (2014) genotyped 1293 dugongs at 24 microsatellite loci. They also sequenced a portion of the control region of the mitochondrial genome for a subset of animals. Both types of data indicated a significant departure from random mating expectations in pairwise comparisons among all four bays. A clustering approach showed that the dugongs could be assigned to two major population groups, one confined to Moreton Bay (the southernmost extent of the dugong's winter range in Australia), and the other spread among the three other bays. Moreton Bay is separated from those further north by ~ 200 km of coastline with few seagrass meadows (e.g., Maroochy and Noosa River estuaries, ~ 0.1 ad ~ 2 km^2 seagrass, respectively). Movement of individuals between bays was inferred, with an estimate of 4–5% of individuals moving per generation between Moreton Bay and the major bays to its north. This amount of movement was not sufficient to produce genetic homogeneity (panmixia).

Cope et al. (2015) used pedigrees to investigate contemporary movements between the above bays by analysing 24 microsatellite loci to identify parent-offspring relationships among 1,002 dugongs, many of which had been physically sampled more than once. In their relatively (compared to dugong generation length of 22-25 years; Marsh and Sobtzick 2019) short-term study, physical recaptures of an animal in different locations were rare (six cases), whereas capture of genetically identified offspring in locations different from their parents was more common (about 30% of cases), providing evidence of inter-generational dispersal that could be gathered in no other way. Cope et al. (2015) compared their real-life data with modelled expectations to reach estimates of 1-3% of animals moving between locations per year. However, physical dispersal is not the same as effective genetic dispersal: individuals may not breed in their new location, which might help to explain the genetic distinction maintained among the studied bays (Cope et al. 2015). These results also indicated that genetics should not be the sole basis for determining the scale of management. Animals may move across the boundaries of genetically distinct areas, especially when seagrass is lost due to extreme events as discussed in Section 10.2. This is an important topic that merits further investigation.

Other than gene flow, microsatellite data can provide some indications of levels of inbreeding, estimates of population size and some other parameters. Seddon et al. (2014) inferred low levels of inbreeding for dugongs in southern Queensland, and low levels of relatedness within populations.

The overall picture from studies in Australia is of a degree of local philopatry with relatively limited dispersal, at least by females. Evidence for male-biased dispersal in Australia is equivocal. The failure of the widespread mitochondrial haplogroup to have a substantial presence as far south as Moreton Bay, and the split within the restricted haplogroup mentioned above, might indicate little movement with subsequent breeding by female dugongs but tells us nothing about male-mediated gene flow. Satellite tracking of dugongs has not indicated any difference between movement by either sex (Sheppard et al. 2006). However, both the number of animals tracked and the duration of tracking of individual animals is probably too small for definitive conclusions (Deutsch et al. 2022). McDonald (2005) found preliminary evidence of male-biased dispersal. Seddon et al. (2014) did not find any evidence of this in the southern Queensland populations, whereas Cope et al. (2015) found some support for male-biased dispersal in the same populations based on pedigree analysis.

Evidence of changes in population size through time has been presented by Blair et al. (2014), McCarthy (2018), Tian et al. (2023) and Baker et al. (2024). Based on mitochondrial sequence data, Blair et al. (2014) inferred a recent (effectively post-glacial) population increase in the widespread haplogroup, but little change in the restricted haplogroup. Both Tian et al. (2023) and Baker (2024) used data from one or more whole genomes. The latter used data from a single dugong of the restricted haplogroup sampled in Moreton Bay. This indicated a decline in numbers as sea levels fell after the previous interglacial (which ended around 115,000 years ago) and the consequent reduction in suitable habitat. There was also evidence of some past, but not current, inbreeding. Tian et al (2023) presented very similar findings based on several genomes originating in nine Australian locations, mostly in Queensland. In all cases, there was an inferred reduction in population size as sea levels fell and some increase after the last glacial maximum. The level of inbreeding appeared to be low, and not recent.

At a more local and short-term level, McCarthy (2018) investigated potential changes in genetic diversity in the Cleveland Bay dugong population (Townsville) by comparing dugongs sampled 50 years apart, during which time there had been significant mortality due to cyclone Althea in 1971 (Heinsohn and Spain 1974) and incidental capture in shark nets (Marsh et al. 2005). Mitochondrial DNA sequences from dugongs that had died in the years 1969 to 1981 were compared to those from individuals that had died more recently (1999-2015). Despite the absence of some rare haplotypes in the second time period, the haplotype and nucleotide diversity measures remained constant between the two time periods, possibly a consequence of the short time span investigated relative to the 22-25 year generation length of a dugong (Marsh and Sobtzick 2019).

Tian et al. (2023) considered their sampled Australian dugong populations to be in good genetic health in terms of genetic diversity, population size and low levels of inbreeding. The current data can act as baseline information against which future changes in Australia can be judged. It is unclear whether the same baseline can be applied to other geographical regions where dugongs occur. Ideas for further research are outlined in Section 10.6.6.

- The most detailed genetic studies of dugongs globally have been on populations in Queensland waters.
- This research has revealed a complex phylogeographic history that remains to be fully interpreted and explained. The two, principal mitochondrial haplogroups seem to have had different evolutionary and demographic histories.
- Australian dugong populations appear to be in good genetic health in terms of genetic diversity, population size and low levels of inbreeding. There is some evidence of male-based dispersal and female philopatry.
- Genetics should not be the sole basis for determining the scale of management because, physical dispersal is not the same as effective genetic dispersal: individuals may not breed in their new location. Thus, animals may move across the boundaries of genetically distinct areas, especially when seagrass is lost due to extreme weather events. This is an important topic that merits further investigation.

10.2 Dugong distribution, abundance and trends

At the spatial scale of northern Australia, dugongs are the most abundant marine mammal in coastal waters (Marsh et al. 2011). Unlike much of the remainder of their range, aerial surveys covering tens of thousands of square kilometres are appropriate for studying dugong abundance, distribution and trends in the Australian region as a result of the spatial scale of their range and the relatively large dugong population (Chapter 1). Most of the information presented here comes from standardised strip transect aerial surveys using trained observers, that have been conducted since the 1980s (see Cleguer and Marsh 2023 for a complete list of surveys and links to the relevant references). One of the outputs from these surveys has been the identification of areas of high dugong density, which has served as the basis for management planning, as explained in Section 10.5.

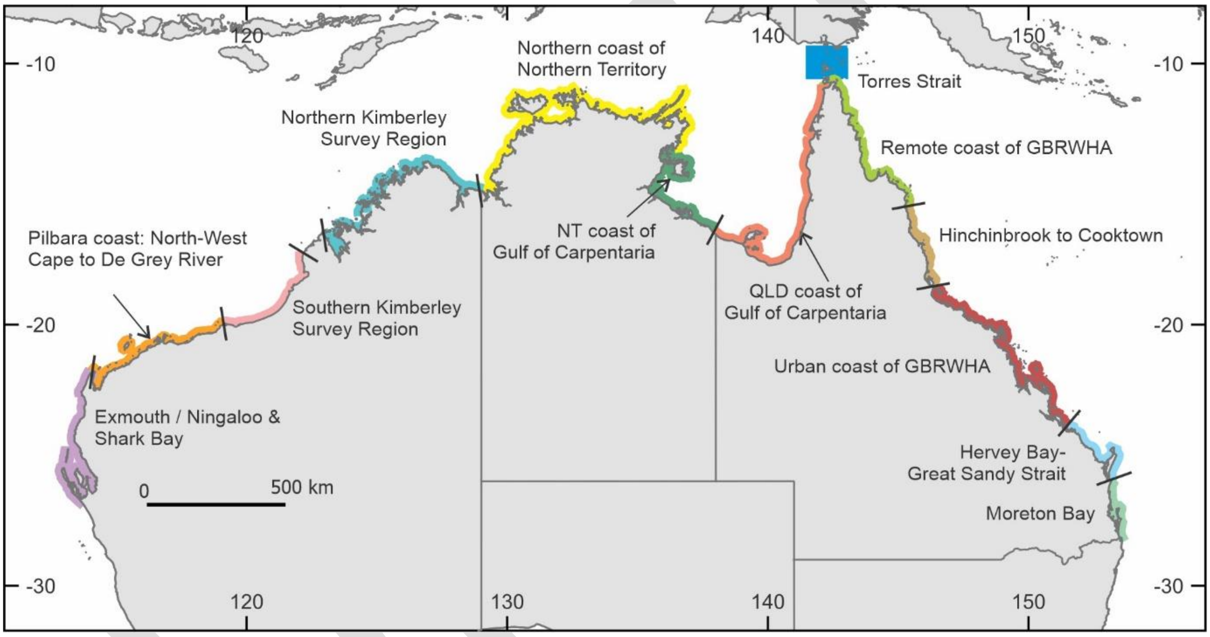


Figure 10.3. The spatial scale of each of the large-scale dugong aerial surveys across northern Australia. Figure created by Adella Edwards; reproduced with permission.

The extent of the large-scale dugong aerial surveys (Figures 10.3-10.11) has largely been determined by jurisdictional boundaries and does not reflect the genetic information outlined in Section 10.1.3. The design of the surveys has remained relatively constant over time and essentially reflects the approach pioneered by Marsh and Sinclair (1989b; *Marsh and Sinclair Method*).

Survey frequency has been variable. Using frequentist power analyses, Marsh and Saalfeld (1989) recommended that each survey be repeated at five-year intervals, an aspirational schedule that was supported by the additional analyses in Marsh et al. (2019), but rarely achieved, even in the Great Barrier Reef Region, where it has been the policy of the Great Barrier Reef Marine Park Authority.

The process for compensating for availability bias (dugong that are present in the survey transect but not available to observers, usually because of water turbidity, has developed over time (Marsh and Sinclair 1989b; Pollock et al. 2006 (henceforth Pollock *Method)*, Hagihara et al. 2014, 2018 *(Hagihara Method*). Consequently, the results of sequential surveys of the same region are not always comparable without reanalysis, which is not possible for earlier surveys because some of the data required for the *Pollock* and *Hagihara Methods* have been collected only since c.2000 and the quality of bathymetric and tidal data is not always adequate. The *Hagihara Method,* which attempts to address the effect of water depth on availability bias, is likely to provide the most accurate estimates to date. However, the effect of correcting for depth-specific detection probability depends on the depth profile and is much greater in areas where dugongs are mostly distributed over extensive deeper water seagrasses (Hagihara et al. 2018) than in areas where dugongs occur only in shallow waters.

The most robust method of detecting trends is the N-mixture Bayesian model technique developed by Rankin and Marsh (2020), which has been applied to surveys conducted on the east coast of Queensland (Marsh et al. 2020; Cleguer et al. 2023). This method integrates various sources of statistical uncertainty and variation, such as stochastically imputing undetected dugongs resulting from availability and perception biases and thus is considered superior to frequentist statistics.

The remainder of this Section provides an overview of the most recent results for the large-scale surveys for each of the various survey regions across the Australian the dugong's range in northern Australia from east to west (Figure 10.3). The method of correcting for availability bias is specified in each case.

10.2.1 Temperate East Marine Region

10.2.1.1 Moreton Bay

Moreton Bay, at the southern end of the dugong's winter range in Eastern Australia, supports the largest dugong population close to a major city (Brisbane; human population of 2.5M). The surface sediments in Moreton Bay are subject to terrestrial runoff (Grinham et al. 2024 a,b) including micro-plastic pollution (Okoffo et al. 2024), exacerbated by floods from the rivers that drain into the bay.

Dugongs have been important to the local First Nations peoples, for at least 2,000 years (McPhee 2017) and were seen by the English explorer Matthew Flinders in 1799 (Bryden et al. 1998), who mistook them for seals. The region has been a focus of modern dugong science since Heinsohn et al. (1978) reported the 'discovery of a large population off Brisbane' and this population is now the most intensively studied dugong population in the world (Lanyon et al. 2019).

Moreton Bay supports an estimated 298 km^2 of seagrass (Lucieer et al. 2023; McKenzie et al. 2020) including 88.7 km^2 on the Eastern Banks (Roelfsema et al. 2014), the area that supports most of the dugongs (Lanyon et al. 2019; Figure 10.4).

Lanyon et al. (2002, 2019) has genetically tagged dugongs in Moreton Bay since 2001 as part of her comprehensive, longitudinal study of the population. As of 2024, more than 800 individual dugongs had been gene-tagged in Moreton Bay as part of this program (J. Lanyon, personal communication 2024), indicating that at least that number of animals used the Bay during the period 2001-2024.

Cleguer et al. (2023) surveyed Moreton Bay in November-December 2022 using the standard aerial survey design that had been used there since the 1980s. The surveys provide snapshot estimates of the relative abundance of dugongs in the Bay at the time of each survey. Moreton Bay is challenging to survey because unlike most other areas in Australia, a large proportion of the dugong population typically occurs in large groups in late spring/summer, when most surveys have been conducted (see O'Shea et al. 2022 for discussion of dugong group size). These groups can significantly influence estimates of dugong population size and density estimates in Moreton Bay but can be inadvertently missed as a result of transect placement.

Cleguer et al's (2023) dugong population estimate for Moreton Bay in December 2022 was 400 ± SE 116 using the *Hagihara Method*, lower than the earlier estimates reanalysed using that method: 453 ± SE 97 in 2005; 696 ± SE 106 in 2011; and 601 ± SE 80 in 2016 (See Cleguer et al. 2023, Appendix 10 for details). The estimated number of dugongs around the Eastern Banks (Figure 10.4) was similar in 2022 to previous survey years, but there was a decrease in the number of sightings in the southern bay preventing the calculation of a meaningful abundance estimate for that area. Some of the decrease in the estimated dugong numbers in Moreton Bay in 2022 could be attributable to a failure to detect additional more large herds over the Eastern Banks during the transect sampling. However, similar to past surveys, the survey was conducted around the peak of high tide (when a larger number of dugongs is likely to be present over the shallow Eastern banks) in excellent weather conditions (low to no wind), and the survey crew checked for additional large herds by flying high over the area after completing the transects (C. Cleguer, personal communication February 2024). The 2022 survey sighted only one herd of 51 dugongs, which is fewer than the five herds (totalling 177 dugongs) detected in 2016, the three herds (totalling 391 dugongs) detected in 2011, and the four herds (totalling 216 dugongs) in 2005.

The dugong population density as a function of transect length was estimated to be 0.274 dugongs km^{-1} ± SE 0.030 in 2022, 30% lower than the 2016 survey, reinforcing a shallow downward trend in density since 2005, estimated to be -1.2% per year using the Bayesian approach (Cleguer et al.

2023). The probability of decline was 0.72 suggesting only weak confidence in a declining trends, and that a zero-trend could not be dismissed.

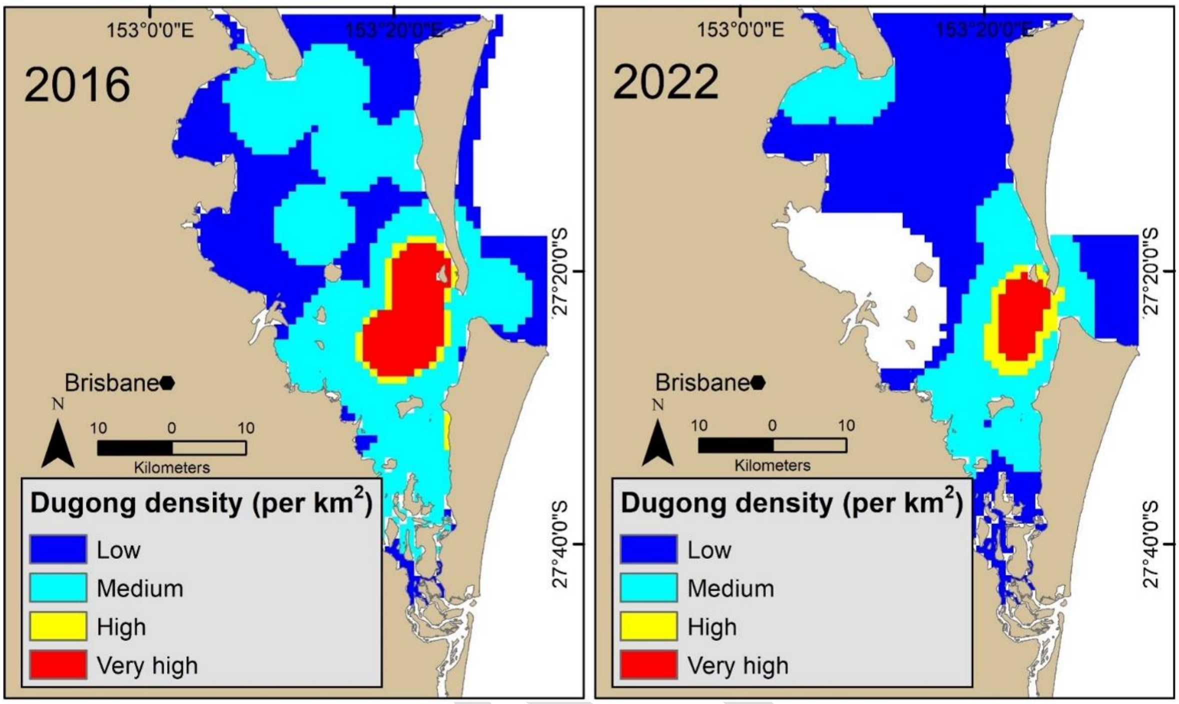


Figure 10.4. Spatially explicit models of dugong density per unit area in Moreton Bay using data from aerial surveys conducted in 2016 and 2022. Dugong density estimations were based on the *Hagihara Method and* classified as Low (0 dugongs per km^2); Medium (0-0.5 dugongs per km^2); High (0.5-1 dugongs per km^2), and Very High (> 1 dugongs per km^2). The Eastern Banks approximates the 2016 high density area. The area in the vicinity of the city of Brisbane could not be surveyed in 2022 so the model did not cover this area, which is in white. Reproduced from Cleguer et al. (2023) with permission.

There are no records of any post-flood, excess dugong mortality. Despite the evidence of genetic structuring of dugong population in southeast Queensland, temporary emigration of dugongs from Moreton Bay cannot be ruled out as an explanation for the lower numbers seen in 2022. Cleguer et al.'s (2023) survey, which extended over ~ 10 degrees of latitude along the southern half of the east Queensland coast, did not identify a destination for any such emigration. However, if displaced animals moved to several different bays in Queensland or NSW that would not have been detected. Seagrass habitats across the Moreton Bay Marine Park (Figure 10.15) were impacted by a flood event in February/March 2022, which transported large quantities of turbid water to Moreton Bay (Udy et al. 2023). Seagrass extent declined by 33.2% between pre and post flood surveys in the portion of the Marine Park covered by Udy et al.'s (2023) surveys, which were conducted between August 2022 and January 2023. While most of the seagrass loss was in subtidal habitats, a post-flood decline in the proportion of all meadow types was also recorded in shallow subtidal areas (< 2 m).

Despite multiple attempts to survey the area in the vicinity of Brisbane city (blank area in the 2022 survey year panel in Figure 10.4) for dugongs, Cleguer et al. (2023) did not receive permission from Air Traffic Control to conduct the survey. Although this area historically does not support many dugongs, some of the variations in dugong estimates found in the 2022 survey could be explained by an increased use of this area by dugongs. The confirmation of the presence of a relatively large seagrass meadow in Waterloo Bay by Udy et al. (2023, see Figures 9, 10, 11 in their report) supports this possibility.

The low dugong calf counts recorded by Cleguer et al. (2023) are also consistent with seagrass loss in the bay (Marsh et al. 2022). Only six mother-calf pairs were detected during the 2022 survey of Moreton Bay. This represents 5.5% of the total number of dugongs detected during this survey, the lowest proportion recorded since 2005 and the third lowest of the 10 estimates since 1976.

The Marine Protected Areas Task Force (MMPATF) (see Chapter 1) declared Moreton Bay to be an Important Marine Mammal Area (IMMA) with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022d; Figure 10.15).

- Moreton Bay supports the largest dugong population close to a major city in the world.
- This population is the most comprehensively studied dugong population globally.
- The most recent aerial survey estimate of the dugong population of Moreton Bay in December 2022 was 400 ± SE 116 (*Hagihara Method*).
- This estimate was 30% lower than the 2016 survey, reinforcing evidence for a shallow downward trend in density since 2005 of -1.2% per year. The probability of decline was 0.72 indicating only weak confidence in a decline, and that a zero-trend cannot be dismissed, and the status of this population is uncertain.
- Moreton Bay has been declared an IMMA with the dugong as a qualifying species.

10.2.1.2 Hervey Bay and Great Sandy Strait (Great Sandy Marine Park)

This region is located north of Moreton Bay and separated from the latter by ~ 200 km of mostly surf coast. The importance of Hervey Bay dugong population has been recognised for many years. The region intermittently supported a cottage industry for dugong oil for a total of almost 80 years between 1860 and 1969 (Daley et al. 2008; Daley 2014). The extent of seagrass in the region can be up to 2,651 km^2 (McKenzie 2017), making this the largest seagrass meadow on the east coast south of Cape York. During the last 30 years, the dugong population has fluctuated because of temporary emigration in response to seagrass loss caused by extreme weather events (see Preen and Marsh 1995, and below).

Cleguer et al. (2023) conducted the most recent survey of Hervey Bay in November 2022 as part of their survey of the Queensland coast south from ~ 18° S. The dugong population size in Hervey Bay was estimated to be 1,533 ± SE 634 animals using the *Hagihara Method.* This estimate was similar to the estimates using the *Hagihara Method* on survey data collected in 2005 1,388 ± SE 323 and 2011 1,438 ± SE 438, but much lower than the 2016 estimate of 2,055 ± SE 382 (see Cleguer et al. 2023 Appendix 10 for details).

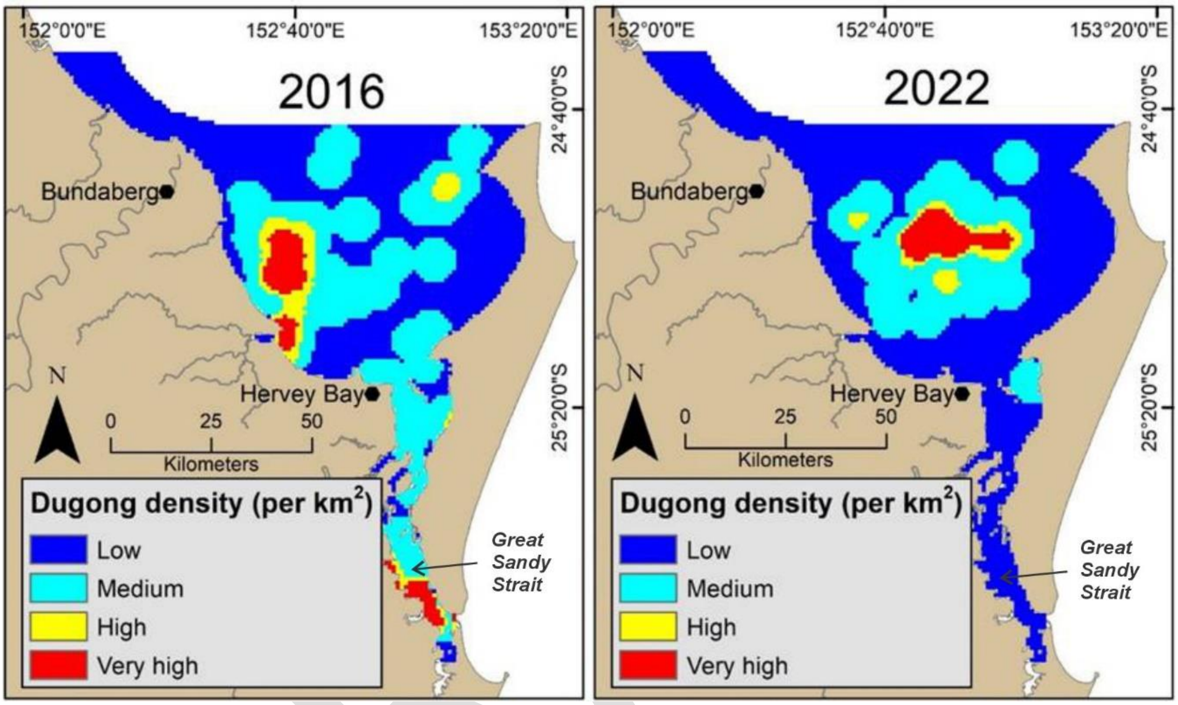


Figure 10.5. Spatially explicit models of dugong density per unit area in Hervey Bay using data from aerial surveys conducted in 2016 and 2022. Dugong density estimations were based on the *Hagihara Method*. Dugong densities were classified as Low (0 dugongs per km^2); Medium (0-0.5 dugongs per km^2); High (0.5-1 dugongs per km^2), and Very High (> 1 dugongs per km^2). Reproduced from Cleguer et al. (2023) with permission.

There was also a marked change in the distribution of dugongs in Hervey Bay in 2022 compared with the previous survey (Figure 10.5). No dugongs were sighted in Great Sandy Strait in 2022. There was a 3.7-fold decrease in the estimated number of dugongs present in the southern section of Hervey Bay and the estimated number of dugongs in the middle, deeper part of the bay increased from an estimated 610 ± SE 272 in 2016 to 1025 ± SE 592 dugongs in 2022 (Figure 10.5).

In 2022, Cleguer et al. (2023) estimated the Hervey Bay dugong population density as a function of transect length to be 0.094 individuals km^{-1} ± SE 0.03, a 69.7% decrease compared to 2016. Using a Bayesian approach, they concluded that the dugong population has been declining (probability = 0.995) at an estimated -5.7% per year since 2005. The 2022 survey data has a strong influence on this trend estimate; the results from the analysis of the data from 2005 through 2016 suggested a slight increase from 2005 to 2016 of + 0.28% and a probability of decline of 0.47 (i.e., < 50%). These results suggest that the two large flood events in early 2022, which resulted in extensive loss of inshore seagrass (McKenzie et al. 2023; Bryant et al. 2023), had a major effect on the population, and that the apparent long-term trend may be confounded by both: (1) inadequate corrections for detection biases, because in 2022 the dugongs were concentrated in the deep water in the middle of the Bay where they are less visible to observers; and (2) temporary emigration from the Bay. In addition, long-term monitoring at sentinel sites throughout the Great Sandy Marine Park had shown a declining trend in seagrass abundance and extent since 2017 (McKenzie et al. 2023), compounding the adverse impact of the major flood events in early 2022.

Although evidence of substantial mortality or temporary emigration from Hervey Bay was not convincingly detected elsewhere in the vast region surveyed by Cleguer and his team in 2022, the estimated number of dugongs in the Gladstone area, located ~ 200km north of Hervey Bay and within the Great Barrier Reef World Heritage Area, was more than twice that of any of the surveys this century (even though it was relatively low; 280 ± SE 129). Low levels of population increase in areas supporting relatively few dugongs are very difficult to detect using large-scale aerial surveys. Nonetheless, Cleguer et al.'s (2023) survey results are consistent with evidence from past aerial surveys (e.g., Preen and Marsh 1995) and satellite tracking work (Sheppard et al. 2006) that some dugongs may move between Hervey Bay and the Great Barrier Reef Region.

Nine mother-calf pairs were detected in Hervey Bay during the 2022 survey. This represents 9% of the total number of dugongs detected during this survey year within the range of the corresponding data from the ten other surveys since 1979 (Cleguer et al. 2023).

Bryant et al. (2023) repeated their seagrass survey in November 2023. Preliminary analysis of the data indicates significant recovery in extent and biomass throughout Hervey Bay and Great Sandy Strait (M. Rasheed, personal communication 2024). The survey team is planning a repeat of the dugong survey in Hervey Bay in late 2024 to determine whether dugongs returned, the timing of this future survey will enable comparison with past surveys.

The MMPATF declared Hervey Bay and Great Sandy Strait to be an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022b; Figure 10.15).

- Hervey Bay is the most significant dugong habitat in eastern Australia, south of Cape York.
- The most recent aerial survey estimate of the dugong population of Hervey Bay, in December 2022, was 1,533 ± SE 634, using the *Hagihara Method.*
- This estimate was almost 70% lower than the 2016 survey, indicating a downward trend of -5.7% per year since 2005. The two large flood events in early 2022, which resulted in extensive loss of seagrass, apparently had a major effect on the dugong population.
- The apparent long-term trend may be confounded by either or both of: (1) inadequate corrections for detection biases, because in 2022 the dugongs were concentrated in the deep water in the middle of the Bay where they are hard to see; and (2) temporary emigration from the Bay. Thus, the dugong status on this survey region is currently uncertain.
- This trend needs to be further investigated with an additional dugong survey when the seagrass has recovered.
- Hervey Bay and Great Sandy Strait has been declared an IMMA with the dugong as a qualifying species.

10.2.2 Great Barrier Reef (GBR) Region

The significance of the GBR region for dugongs was one of the reasons for its World Heritage listing (Great Barrier Reef Marine Park Authority [GBRMPA], 1981). Thus, the status and trends in the distribution and abundance of the dugongs is important information for the management of the GBR World Heritage Area (GBRWHA). Large-scale aerial surveys are scheduled for the waters of the urban (24° S to 15.23° S) and remote coasts (15.23° S to 10.57° S) in separate years for logistical reasons. Whenever possible, the southern surveys of the urban coast have been combined with the surveys of Hervey and Moreton Bays and the northern survey of the remote coast with a survey of Torres Strait, which is biogeographically part of the GBR region but not part of the GBRWHA or the GBR Marine Park (GBRMP; Figure 10.15). However, in some years it has not been possible to complete these surveys as planned as a result of unsuitable weather and/or funding constraints.

10.2.2.1 Southern (urban) coastal waters of GBRWHA

The original survey region extended over the inshore waters from Cape Bedford (15.23° S, 145.21° E) to the southern border of the GBRWHA (24° S) (Figure 10.3), a region estimated to support a total of 25,667 km^2 of seagrass, comprising shallow (1,591 km^2 in waters ≤ 15 m deep) and deepwater (24,076 km^2 in waters > 15 m deep) seagrass (McKenzie et al. 2023). It is not known whether the offshore deep-water seagrass meadows are used by dugongs, and they have not been covered by the dugong aerial surveys for human safety reasons. It has rarely been possible to survey the whole region in a single season and the region from Mission Beach (18° S) to Cape Bedford has mostly been omitted as relatively few dugongs have been sighted there, compared with further north. Marsh et al. (2020) surveyed that region in 2018 and estimated that it supported ~ 550 ± SE 250 dugongs

(*Hagihara Method)*. Because most of this region had not been surveyed for many years using the standard transect technique, they could not evaluate a trend in abundance.

Using the *Hagihara Method,* Cleguer et al. (2023) estimated the dugong population between latitudes ~ 18° and ~ 24° S to be 2,124 ± SE 476. Excluding the region north of Hinchinbrook Island, which was not surveyed in 2016, this estimate decreased to 2,006 dugongs ± SE 466, a 29% decrease in the estimated number of dugongs in the survey region compared to the 2016 survey estimates (2,822 ± SE 600).

In 2022, dugongs were most abundant in the Townsville to Cardwell region (between Hinchinbrook Island and Halifax, Cleveland and Bowling Green Bays), and in Shoalwater Bay, the large bay between Rockhampton and Mackay (Figure 10.6). These regions have consistently supported relatively high numbers of dugongs since the transect surveys began in the 1980s (see Marsh and Saalfeld 1990).

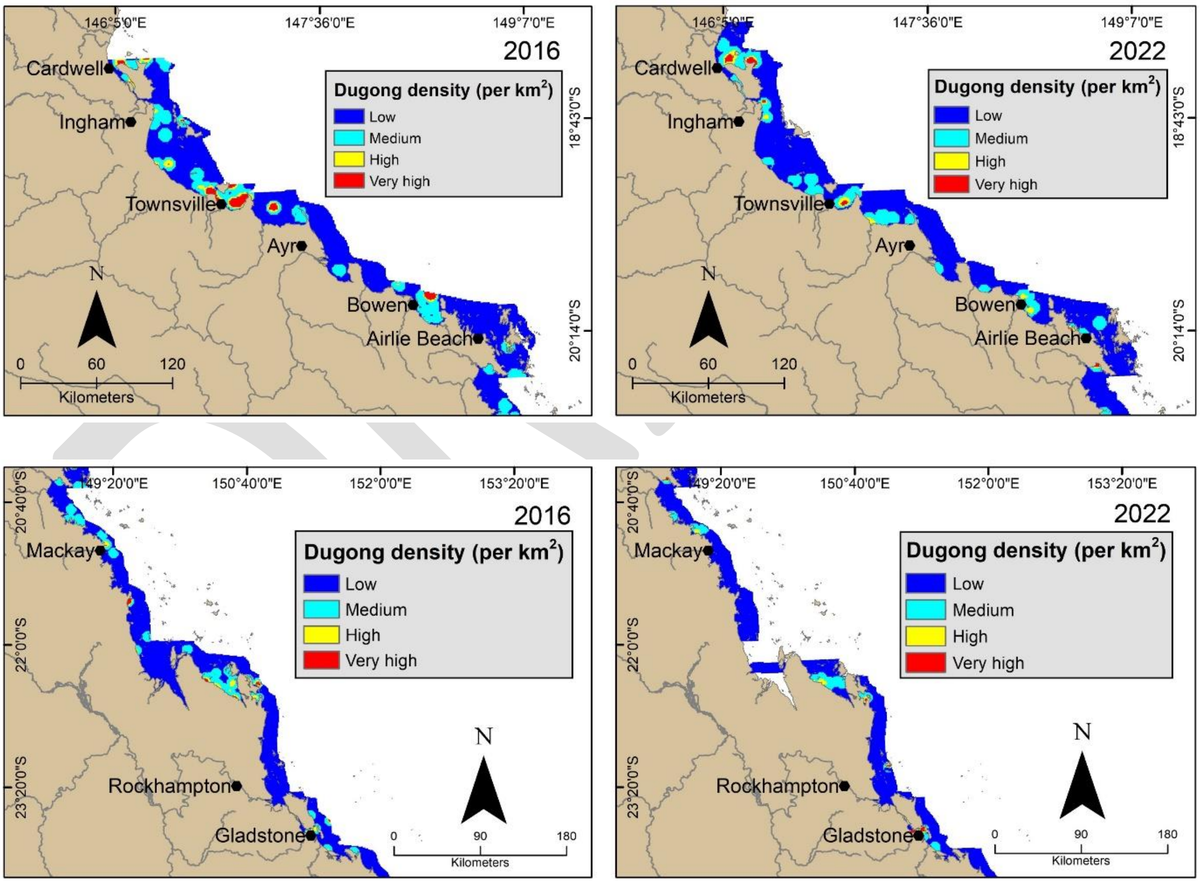


Figure 10.6. Spatially explicit models of dugong density per unit area along the urban coast of the GBRWHA using data from aerial surveys conducted in 2016 and 2022. The upper figures show the northern half of the survey region; the lower figures, the southern half. Dugong density estimations were based on the *Hagihara Method*. Dugong densities were classified as Low (0 dugongs per km²); Medium (0-0.5 dugongs per km²); High (0.5-1 dugongs per km²), and Very High (> 1 dugongs per km²). Reproduced from Cleguer et al. (2023) with permission.

Cleguer et al. (2023) estimated the dugong population density as a function of transect length in the survey region to be 0.086 dugongs km^{-1} ± SE 0.017 in 2022, 40% less than the estimated 2016 dugong densities. Cleguer et al. (2023) estimated a 93.8% probability of decline in dugong numbers in the survey area between 2005 and 2022, with an estimate rate of decline of -2.3% $year^{-1}$. The likelihood of the dugong densities recorded in 2022 being higher than those recorded in 2005 and 2016 respectively were low (< 5%). Nonetheless, the 2022 dugong density was higher than in 2011 after the floods and cyclones of the austral summer 2010-2011 devastated the seagrass meadows in the region (Chapter 1). These figures indicate that the estimates of overall decline may be confounded by temporary emigration but that there is strong and consistent evidence of overall decline in the region since 2005, the reasons for which have not been established.

The proportion of calves in 2022 was 6.7% (Clegeur et al. 2023). The proportion of calves in this region has fluctuated between zero (in 2011) and 12.6% (in 1999), since aerial surveys (initially shoreline rather than transect) commenced in 1974.

The MMPATF declared Hinchinbrook to Round Hill to be an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022c; Figure 10.15).

- The estimated dugong population in the urban coastal waters of the Great Barrier Reef World Heritage Area between 18° S and 24° S in 2022 was 2006 ± SE 466, a 29% decrease in the estimated number of dugongs in the survey region compared to 2016.
- The estimates of overall decline are confounded by temporary emigration but there is strong and consistent evidence of overall decline in the region since 2005, the reasons for which have not been established.
- The Hinchinbrook to Round Hill is an IMMA with the dugong as a qualifying species.

10.2.2.2 Northern (remote) waters of the GBR

Marsh et al. (2020) surveyed the waters of the remote coast of the Great Barrier Reef (Cape Flattery 15° S) to southern boundary of Newcastle Bay, 10.95° S) in 2018-19, a region estimated to support 8,964 km^2 of seagrass. The survey had to be conducted in three stages (November 2018, June 2019, November/December 2019) because of weather constraints. The region between Cape Bedford (15.23° S) and Cape Flattery (15° S) was not surveyed because too few dugongs have been sighted in the region on previous surveys to calculate population estimates.

Using the *Hagihara Method*, Marsh et al. (2020) estimated that the dugong population of this region between 15° S and 10.95° S) was ~ 7,000 ± SE 1,600 in 2018–19. Bayesian modelling using the N-Mixture estimator suggested that the dugong population in this region had been stable since 2006, assuming that there was no net movement of animals between the segments surveyed in each of the three stages of the 2018–19 survey. Comparatively few dugongs were sighted in Lloyd Bay in

2019 (Figure 10.7) compared with 2006 or 2013. This region was in the path of a tropical low-pressure system in December 2018 and severe tropical cyclone Trevor in March 2019.

Dugongs were sighted in high densities throughout much of the inshore region between Lookout Point and Bathurst Head and in local regions of some of the bays on the eastern coast of Cape York between Friendly Point and Shelbourne Bay inclusive, and at medium densities in some bays and over many reefs off Cape York (Figure 10.7).

The percentage of calves (8.2%) was slightly higher than but not significantly different to the results for 2006 and 2013 in the region from Cape Flattery north. This percentage was significantly higher for the surveys of this region conducted prior to 2000 (11.6-12.6%) than subsequently and may be a consequence of habitat loss across the region. However, the data on the status of seagrass in the Northern Great Barrier Reef are not adequate to further evaluate this inference, as long-term seagrass monitoring was not established until 2012 (McKenzie et al. 2024).

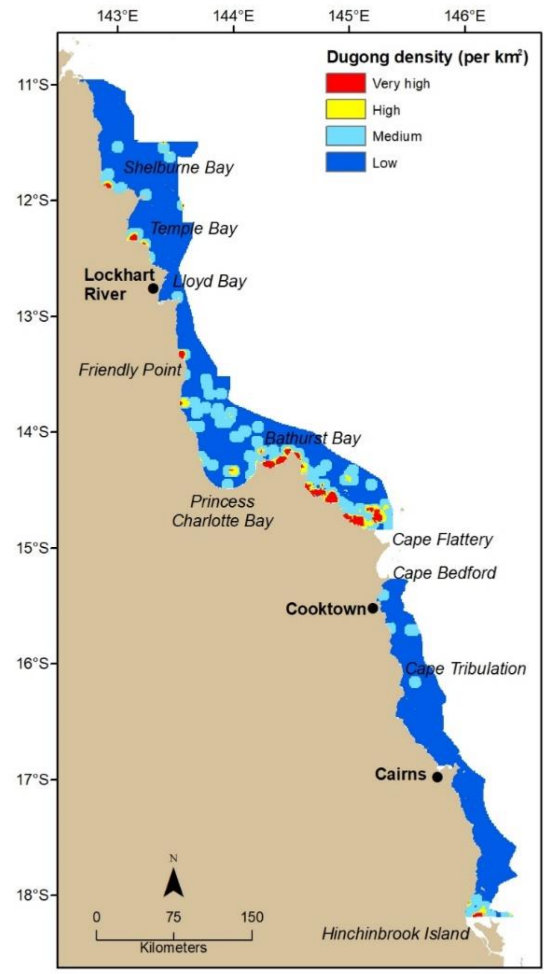


Figure 10.7. Spatially explicit models of dugong density per unit area along the remote coast of the GBRWHA using data from aerial surveys conducted in 2018-2019. The region between Hinchinbrook Island and Cape Bedford on the urban coast was also included in these surveys. Dugong density estimations based on the *Hagihara Method* were classified as Low (0 dugongs per km^2); Medium (0-0.5 dugongs per km^2); High (0.5-1 dugongs per km^2), and Very High (> 1 dugongs per km^2). Figure created by Alana Grech from Marsh et al. (2020); reproduced with permission.

The entire region was surveyed in 2023 (C. Cleguer, personal communication 2024). Preliminary data suggest that the raw (uncorrected) number of dugong sightings was comparable to the 2018/19 survey, with a slight increase in the number of dugong sightings in the northern Great Barrier Reef (nGBR) in 2023 compared to 2018/19. The estimation of dugong abundance and analysis of trends was in progress at the time of writing this chapter (March 2024).

The MMPATF declared the Northern GBR to be an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022f; Figure 10.15).

- The estimated size of the dugong population in the remote coastal waters of the Great Barrier Reef World Heritage Area between ~11° S and 15° S in 2018/19 was ~ 7,000 ± SE 1,600.
- Bayesian modelling suggests that this dugong population had been stable since 2006.
- The Northern Great Barrier Reef has been declared an IMMA with the dugong as a qualifying species.

10.2.2.3 Torres Strait

Torres Strait or Zenadh Kes is the shallow sea between Australia and the Melanesian island of New Guinea (Figure 10.1 inset). It is 150 km wide at its narrowest extent. To the south is Cape York Peninsula, the northernmost extremity of the Australian mainland. To the north is the Western Province of PNG. The jurisdictional boundary between the PNG and Australia waters of Torres Strait is very close to the PNG coastline (Figure 10.1) enabling a large-scale survey of Australian waters to provide a comprehensive picture of dugong distribution and abundance in the region. Torres Strait supports some 13,447 km^2 of seagrass (Carter et al. 2023), most of which occurs in Central and Western Torres Strait. Seven transect aerial surveys for dugongs have been conducted over 41,640 km^2 survey area in this region as funding permitted between 1987 and 2013 (see Cleguer and Marsh 2023 for links to the relevant reports). The survey region extended south to the northern boundaries of the surveys of the Queensland coast of the Gulf of Carpentaria (11.17° S) and the remote coast of the GBRWHA (10.95° S) as outlined earlier in this Section.

Dugongs have been harvested by the Indigenous peoples of Torres Strait between Australia and PNG, for at least 4,000 years (Crouch et al. 2007). The harvest has been substantial for at least the last 400–500 years (McNiven and Bedingfield 2008). Marsh et al. (2004) provided estimates of the catch of dugongs in various Torres Strait communities between the 1970s and the 1990s. The catch estimates reflected differences in monitoring technique as well as spatial and temporal variation. The most accurate records are those of Kwan (2002) who lived at Mabuiag Island, one of the major hunting communities, and recorded a harvest of 170 dugongs over nine months in 1998. Comparable data are not available for the any of 17 other Australian Torres Strait communities and at least 15 PNG coastal communities bordering Torres Strait. Nonetheless, the total harvest across Torres Strait must have been much higher than recorded for Mabuiag, even though not all communities engaged in dugong hunting.

Although Torres Strait Islanders have legal rights to hunt dugongs in their sea country (see Section 10.3), dugong hunting in Australia is controversial and the issue has featured in Australian and Queensland government elections (Delisle et al. 2014). After negotiations with Islanders, a > 13,000 km^2 Dugong Sanctuary, in which hunting is banned was established in Western Torres Strait in 1987 (Figure 10.8).

Heinsohn et al. (2004) and Marsh et al. (2004) used the aerial survey estimates of population size to evaluate the sustainability of the contemporary dugong harvest using two different modelling techniques and concluded that the harvest must be unsustainable, a conclusion disputed by Torres Strait Islanders. Subsequently, Marsh et al. (2015) assembled several lines of evidence that suggested that the harvest was sustainable: (1) dugong relative density was significantly higher in 2013 than in any other survey year; (2) the dugong's Area of Occupancy in the region had trended slightly upward since 1987; (3) the proportion of calves in 2013 was the highest recorded; (4) genetic diversity was high; and (5) comparisons of dugong density maps obtained from the aerial surveys and spatial information on hunting demonstrated that dugongs were caught in only 5.0 % of the 5,268 km^2 of very high dugong density habitat, as the result of the controls on the harvest and socio-economic factors.

Given all this evidence, Marsh et al. (2015) concluded that the data on dugong numbers from aerial surveys (e.g., 15,727 ± SE 2,942 in 2013, using the *Pollock Method)* could not be accurate. Hagihara et al. (2018) hypothesized that the probability of a dugong being available for detection is dependent on water depth and that dugongs spend more time underwater in deep-water seagrass habitats such as in Torres Strait than in shallow-water seagrass habitats. They tested this hypothesis by quantifying the depth use of 28 wild dugongs fitted with GPS satellite transmitters and time-depth recorders at three locations with distinct seagrass depth distributions (New Caledonia, Moreton Bay, and Torres Strait). The fitted instruments were used to measure the times the dugongs spent in experimentally-determined detection zones under various environmental conditions. The estimated probability of detection was applied to the 2013 aerial survey data in Torres Strait and the population estimates increased 6–7 fold using depth-specific availability correction factors, compared with the *Pollock Method* estimates that assumed homogeneous detection probability across water depth and location. The revised population estimate for Torres Strait was 102,519 ± SE 20,146. The differences between the *Pollock* and *Hagihara* estimates were much less for New Caledonia and Moreton Bay, where the bathymetry is different Hagihara et al. (2018) or in the Northern Territory Gulf of Carpentaria, where the *Hagihara* estimates were almost 25% less than the

Pollock Method because the waters are so shallow, and seagrass is mostly restricted to the inter-tidal area (Section 10.2.3).

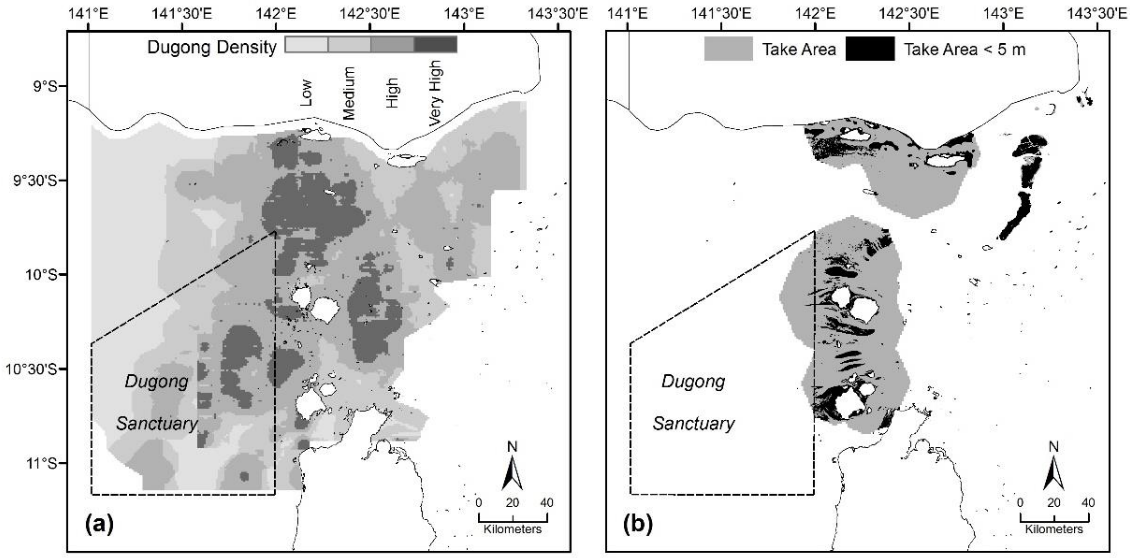


Figure 10.8. Evidence that hunting does not occur in many important dugong areas in Torres Strait: (a) spatially explicit model of dugong relative density per unit area and distribution in Torres Strait based on data from the 2011 and 2013 aerial surveys; and (b) take areas assuming that dugong harvest is: (1) not depth limited and (2) limited to waters shallower than 5 m. Reproduced from *Biological Conservation* with permission.

Torres Strait has not been surveyed for dugongs since 2013 and there are no contemporary data on the dugong harvest, so the status of the dugong population is uncertain. Scientific research and Indigenous Knowledge indicate that there has been another substantial dieback of the deep-water seagrass in Torres Strait that was first noticed in 2019 (Carter et al. 2021). The cause of this dieback is unknown. An apparently similar seagrass dieback in the 1970s was linked to recruitment failure in the dugong population that was still detectable in the age distribution of harvested dugongs in the 1990s (Marsh and Kwan 2008). The most recent report card on the status of seagrass in Torres Strait (Carter et al. 2022) indicated that seagrass condition was variable across the region, but that: (1) the biomass of subtidal seagrasses was very low, and (2) the percent cover at some intertidal sites was also well-below average.

The MMPATF declared Central and Western Torres Strait to be an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022a; Figure 10.15).

- The dugong population estimate for Torres Strait was 102,519 ± SE 20,146 based on the 2013 survey using the *Hagihara Method,* indicating that this region is the most important location for dugongs globally.
- An aerial survey for dugongs in Torres Strait has not been carried out for more than 10 years and there are no contemporary data on the Indigenous dugong harvest. Thus, the status of the population is uncertain.
- The most recent report card on the status of seagrass in Torres Strait indicated that seagrass condition was variable but poor in some areas.
- Central and Western Torres Strait has been declared as an IMMA with the dugong as a qualifying species.

10.2.3 North Marine Region

10.2.3.1 Gulf of Carpentaria: waters off the Queensland coast

The waters off the Queensland coast of the Gulf of Carpentaria (Figures 10.1, 10.3) have not been surveyed for dugongs for > 16 years, so their current status is uncertain. The last survey in October 2007 covered the coastal waters from (11.17° S) on the west coast of Cape York to the Queensland Northern Territory border (17.45° S, 139° E), a region estimated to support 679 km^2 of seagrass (Carter et al. 2023).

Using the *Pollock method*, Marsh et al. (2008) estimated a population of 7,095 ± SE 1,565 dugongs: a higher estimate than the previous comparable estimate for this region. This difference can be partially attributed to changing the method used to correct for availability bias from the original *Marsh and Sinclair method.*

Standardised comparisons of the results for 2007 with the results of previous surveys suggest that overall dugong density was not significantly different between 1997 and 2007, averaged over all regions of the Gulf in the waters off Queensland for which such comparisons could be made. However, density varied substantially among regions between surveys, suggesting movement of dugongs between survey blocks. A plausible reason for the movement of dugongs within the region is the susceptibility of tropical seagrasses to damage from extreme events and diebacks from unknown causes (see accounts of Moreton Bay and Hervey Bay in Section 10.2.1; GBR in Section 10.2.2; Shark Bay and Exmouth Gulf in Section 10.2.4).

The most important dugong area in the region is around the Wellesley Islands (Figure 10.1), where an estimated ~ 80% of the population was sighted. The proportion of dugong sightings that were identified as calves was 10.6%, which is within the range of values recorded for other dugong surveys in other areas of northern Australia.

The MMPATF declared the Southern Gulf of Carpentaria, which includes waters off both Queensland and the Northern Territory, to be an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022i; Figure 10.15).

- The dugong population off the Queensland coast of the Gulf of Carpentaria was estimated to be 7,095 ± SE 1,565 in 2007.
- As no surveys have been conducted since 2007, the dugong population trend in this region is uncertain.
- The Southern Gulf of Carpentaria, which includes waters of both Queensland and the Northern Territory, has been declared an IMMA, with the dugong as a qualifying species.

10.2.3.2 Gulf of Carpentaria: waters off the Northern Territory coast

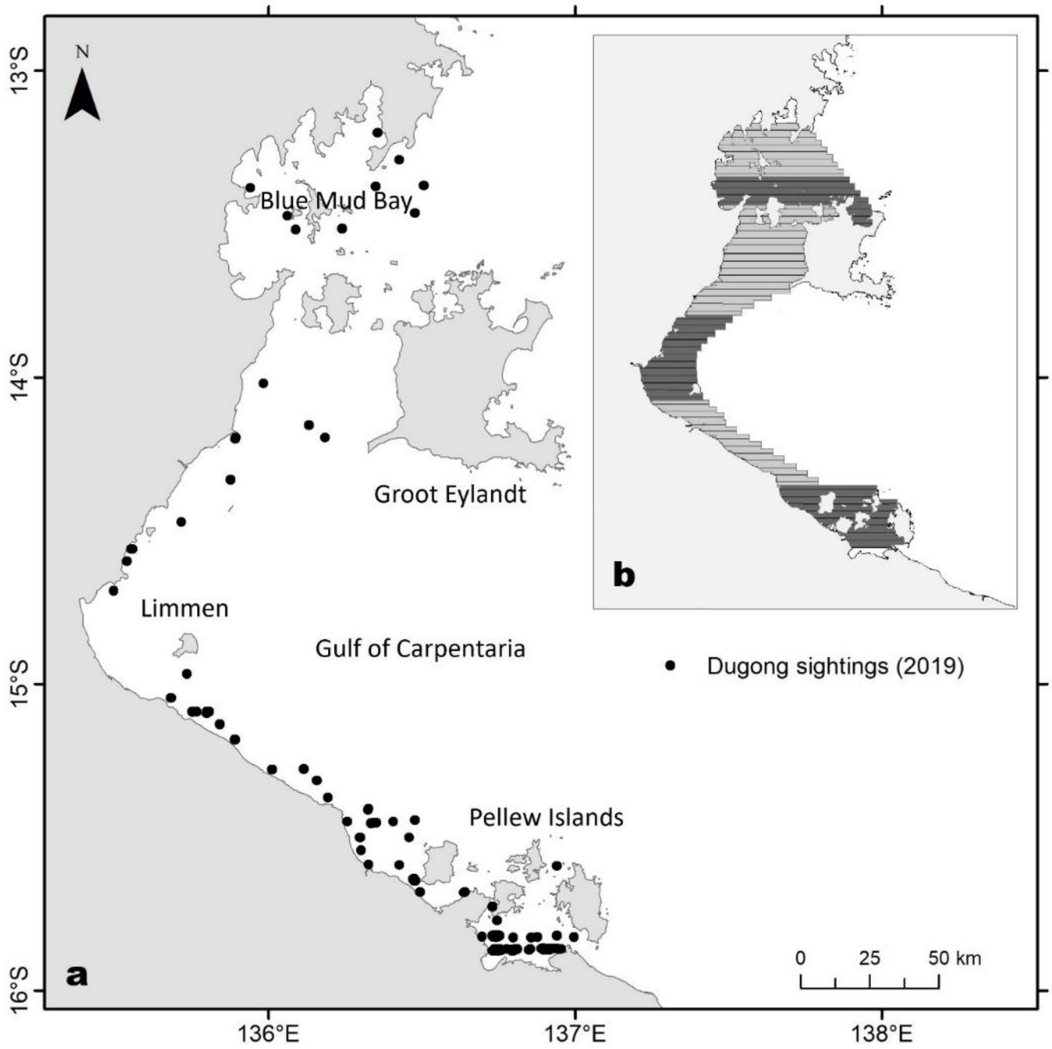


Figure 10.9. Dugong sightings in Northern Territory waters of the Gulf of Carpentaria in 2019 from Griffiths et al. (2020). Redrawn by Mélanie Hamel; reproduced with permissions from Mélanie Hamel and the Northern Territory government.

In collaboration with partners, the Northern Territory Government has conducted five strip–transect aerial surveys of the waters off its Gulf of Carpentaria coast since 1984 (Figure 10.1, 10.3, 10.9). Griffiths et al. (2020) documented the results of the most recent survey conducted in October 2019, which covered over 13,507 km^2 from the Sir Edward Pellew Islands in the south to Blue Mud Bay in the north (Figure 10.9), a region estimated to support 480 km^2 of seagrass.

The 2019 data were analysed using both the *Pollock* and *Hagihara Methods* and the results compared with previous surveys (1994, 2007, 2014). Based on the *Pollock Method*, the 2019 population estimate was 4,586 SE ± 1,318 dugongs; the *Hagihara Method* estimate was 3,390 SE ± 1,092. The difference between the two methods was attributed to the survey being mostly over relatively shallow water (< 5 m), which increases the availability detection probability compared with the probabilities used in the *Pollock Method*, which relies on consistent water visibility but not water depth. Consistent with previous surveys, the waters surrounding the Sir Edward Pellew Island group and the adjacent Limmen area (Figure 10.9) contained the highest proportion of the population (80%) and calves. These results suggest the dugong population in the Northern Territory portion of the Gulf of Carpentaria is stable, although there appears to be a continual decline in the density of dugongs in the survey blocks north of Limmen. A cross-jurisdictional dugong survey of the Gulf of Carpentaria is scheduled for 2025.

The MMPATF declared the Southern Gulf of Carpentaria, which includes waters off both Queensland and the Northern Territory, to be an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022i; Figure 10.15).

- The population estimate for the dugong population off the Northern Territory coast of the Gulf of Carpentaria in 2019 was 3,390 SE ± 1092 (*Hagihara Method*).
- Comparison of these results with those from previous surveys suggests that this population is stable, although there may be a decline in the density of dugongs in the survey blocks west of Limmen.
- The Southern Gulf of Carpentaria, which includes waters of both Queensland and the Northern Territory, has been declared an IMMA, with the dugong as a qualifying species.

10.2.3.3 Waters off the northern coast of the Northern Territory

In 2015, Groom et al. (2017) conducted the first comprehensive megafauna survey of the coastal waters of the entire Northern Territory from its border with Queensland in the east to the border with Western Australia, using the Marsh and Sinclair (1989b) survey technique (Figures 10.1, 10.3). This was the first such survey of the Northern Region from just north of Blue Mud Bay (13° S, 136° E) to the Joseph Bonaparte Gulf (14° S, 129° E). This Northern Region is estimated to support 121 km^2 of seagrass (Lucieer et al. 2023; Roelofs et al. 2005).

Using the *Pollock Method,* the dugong population estimate for the Northern Region only (~ 44,548 km^2), was 2,648 ± SE 318. Dugong densities per unit area were relatively low in all survey blocks ($\leq$ 0.11 dugong km^{-2}), a result consistent with the reconnaissance survey conducted by Elliot in 1978 (Elliot 1981). As this is the only dedicated dugong survey conducted along this coast, the status of the dugongs in this region is uncertain.

- A 2015 baseline population estimate for dugong population off the northern coast of the Northern Territory was 2,648 $\pm$ SE 318 (*Pollock Method)*.
- As this is the only dedicated dugong survey conducted along this coast, the status of the dugongs in this region is uncertain.

10.2.4 North-West Marine Region

10.2.4.1 Kimberley Region: Western Australian Northern Territory border to Port Hedland

Bayliss and Hutton (2017) conducted the first aerial survey of the coastal waters in the Kimberley Region to the 20 m isobath (Figure 10.10) in September–October 2015 (North Kimberley), and May 2017 (South Kimberley), a survey area totalling 67,163 km^2. Dampier Peninsula was not resurveyed in 2015 or 2017 and the September 2009 Woodside survey data were used to fill this knowledge gap in the assumption that the method used was compatible for the purposes of mapping regional distribution and relative abundances of dugongs.

No estimate of the seagrass area was available at the time of writing.

The North Kimberley survey covered the region between the Western Australian–Northern Territory border in Joseph Bonaparte Gulf to King Sound near Derby; the South Kimberley survey was between Broome and Port Hedland (Figure 10.10). Survey protocols generally followed those developed for the Queensland surveys outlined above. The North Kimberley survey was completed in partnership with Indigenous rangers after a 5-day intensive training course (Bayliss and Wilcox 2015; Bayliss et al. 2015).

Using the *Pollock Method*, Bayliss and Hutton (2017) estimated the dugong population in the entire Kimberley region to be 12,600 ± 601, an average density per unit area of 0.25 ± SE 0.02 km^{-2}. Dugong abundance in the North Kimberley (10,513 ± SE 497) was ~ 5 times that for the South Kimberley (2,087 ± SE 197), most likely reflecting the differences in coastal morphology in the two regions; the southern region has a more open coast. The percentage of calves was 5.8% for the North Kimberley and 8.3% in the South Kimberley.

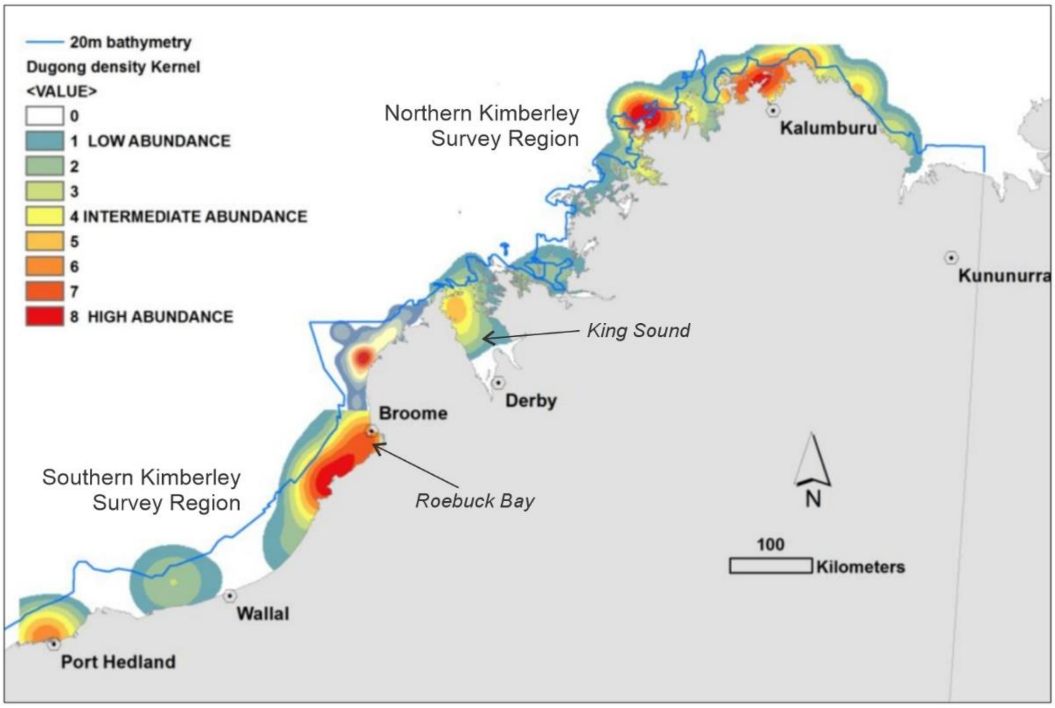


Figure 10.10. Dugong relative density along the Kimberley coast in 2015 and 2017. All sighting data were used to map extrapolated and smoothed Kernel densities across the 5 km aerial survey grid. Within the North and South Kimberley survey areas red colours have the highest relative abundances and blue colours the lowest, with an intermediate colour abundance range (orange, yellow and grey). Reproduced from Bayliss and Hutton (2017) with permission.

The highest densities of dugongs were in areas with extensive seagrass habitat associated with sheltered areas of shallow (< 20 m bathymetry, relatively clear water; Figure 10.10). Many of these areas were within Wunambal Gaambera sea country in the North Kimberley Marine Park (Figure 10.15). Roebuck Bay was identified as an abundance 'hotspot' for dugongs. Comparison between dugong density in the May 2017 component of the survey and an estimate derived from the July 2009 Woodside Petroleum survey (~ 8 years prior) indicated that there has been no significant change in density, suggesting that cultural harvests had been sustainable over that period.

Due to the paucity of dugong data in the Northern Kimberley Survey region, Bayliss and Hutton (2017) developed a Bayesian likelihood model to identify and map important dugong areas. Their work integrated seagrass likelihood data, aerial survey data and seasonal Traditional Ecological Knowledge to identify the probability of dugong occurrence. The key outcome of this approach was a map that can be used as a tool to inform culturally appropriate monitoring and decision support for dugong management. This model allows for new information to be incorporated for adaptive monitoring as Traditional Owner led and partnered research opportunities increase throughout the Kimberley.

The MMPATF declared the Northwest Australian Coastal Waters and Inlets to be an IMMA with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022g; Figure 10.15).

- Baseline surveys were conducted off the Kimberley coast in 2015 (King Sound to Western Australian border) and 2017 (Broome south).
- The resultant dugong population for the entire region was 12,600 ± SE 601 (*Pollock Method)*.
- As this is the only such survey conducted along this entire coast, the status of the dugongs in this region is uncertain.
- Northwest Australian Coastal Waters and Inlets has been declared an IMMA with the dugong as a qualifying species.

10.2.4.2 Pilbara coast: Mouth of De Grey River to North-West Cape

The only transect survey of this coast (Figure 10.3) was in 2000 (Prince 2001). Thus, the status of the dugong in this region is uncertain. Prince (2001) undertook a strip transect aerial survey for dugongs between the mouth of the De Grey River (20° S, 119.25° E) and North-West Cape (21.75° S, 114.17° E) (Figure 10.1, 10.3) to the 20 m isobath in April 2000. He analysed the results using the *Marsh and Sinclair Method* and estimated 2,026 ± SE 376 dugongs in the survey region waters at an average density per unit area of 0.1 km^{-2}. This region is estimated to support at least 188 km^2 of seagrass, however, a greater area of seagrass is likely to be present as mapping efforts across the region have been very limited. As this is the only dedicated dugong survey conducted along this coast, the status of the dugongs in this region is uncertain.

- A baseline surveys was conducted off the Pilbara coast in 2001. The resultant dugong population for the entire region was 2,026 ± SE 376 (*Marsh and Sinclair Method)*.
- As this is the only such survey conducted along this coast, the trend in the dugong population in this region is uncertain.

10.2.4.3 North-West Cape to Shark Bay including Exmouth -Ningaloo

Coastal waters between North-West Cape (21.75° S, 114.17° E) and the southernmost reaches of Freycinet Estuary in Shark Bay (26.6° S, 113.7° E) (Figures 10.1, 10.3, 10.11) have been covered in a single dugong survey on several occasions (July 1989, June 1994, May-June 2007, June 2018 and June 2023). There is some evidence suggesting that some dugongs may have moved from Exmouth Gulf to Shark Bay after cyclone Vance destroyed seagrass meadows in the Ningaloo-Exmouth Gulf region in 1999 (Gales et al. 2004).

The coastal waters of this region include the Shark Bay WHA, which was inscribed in 1991. The Statement of Outstanding Universal Value (OUV) states: 'Shark Bay is one of the world's most significant and secure strongholds for the protection of Dugong'. Dugongs also occur in the Ningaloo Coast WHA (Figure 10.15) but are not listed in the Statement of OUV.

One of the other World Heritage values of Shark Bay is its extensive seagrass meadows. In 2010, before the extreme marine heatwave in the austral summer of 2010/11, Shark Bay supported ~ 4,366 km^2 of both dense (70%) and sparse (30%) seagrass (Strydom et al. 2020). The large temperate seagrasses, *Amphibolis antarctica* and *Posidonia australis,* were historically dominant. The marine heatwave caused the loss of ~ 1,310 km^2 of seagrass, predominantly *A. antarctica*.

The main objective of the 2018 survey by Bayliss et al. (2018) was to assess how the Shark Bay and Exmouth/Gulf dugong populations had responded to the seagrass loss caused by the marine heatwave. Some areas in Shark Bay where *A. antarctica* had been lost had subsequently been colonised by fast-growing tropical seagrass species that are eaten by dugongs (Kendrick et al. 2019).

The estimated numbers of dugongs in Shark Bay and Exmouth/Ningaloo in winter 2018 were 18,555 ± SE 3,396 and 4,831 ± SE 1,965, respectively, using the *Hagihara Method* (Bayliss et al. (2018).

Bayliss et al. (2019) used two different ANOVA models to test for changes in dugong density in each of Exmouth/Ningaloo and Shark Bay between 2007 and 2018. In each region, both models indicated that overall, dugong density had not significantly decreased. Bayliss et al. (2019) concluded that these results: (1) cannot be used to draw conclusions about potential large-scale movements between Shark Bay and the Ningaloo-Exmouth Gulf regions in either direction as a result of the seagrass dieback event in Shark Bay in 2010/11, and (2) suggest that, for Shark Bay at least, dugong populations have been relatively stable between 1989 and 2018, a conclusion supporting Hodgson et al.'s (2008) finding for 1989 to 2007.

In contrast, the trend in the percentage of dugong calves counted during the surveys between 1989 and 2018 inclusive suggested that recruitment likely failed after the seagrass dieback; one calf only was seen in a partial survey of Shark Bay in mid-2012 during which 356 dugongs were sighted (Hodgson et al. 2023). Dugong recruitment failure has also been reported after seagrass diebacks in Torres Strait in the 1970s (Marsh and Kwan 2008) and in the southern Great Barrier Reef in 2011 (Sobtzick et al. 2012).

Another survey of this region was performed in winter 2023; preliminary data indicated that the number of dugong sightings is within the range of previous surveys but detailed analysis of population estimates and trends had not been completed as of March 2024.

Bayliss et al. (2019) modelled the relationship between dugong density from aerial surveys and the estimated areas of dense (> 40% cover) and sparse (< 40% cover) seagrass in Shark Bay obtained from medium resolution satellite images for 2002, 2010, 2014 and 2016. The extent or percentage cover of sparse seagrass habitat were generally the most predictive of all the seagrass mapping variables for dugong distribution and abundance, particularly for 2018 (adjusted R^2=97%). This result accords with current understanding of dugong feeding ecology, which indicates that dugongs prefer to feed by excavating the soft and delicate tropical species, rather than cropping the leaves of high biomass species such as *A. antarctica* (Bayliss and Hutton 2019).

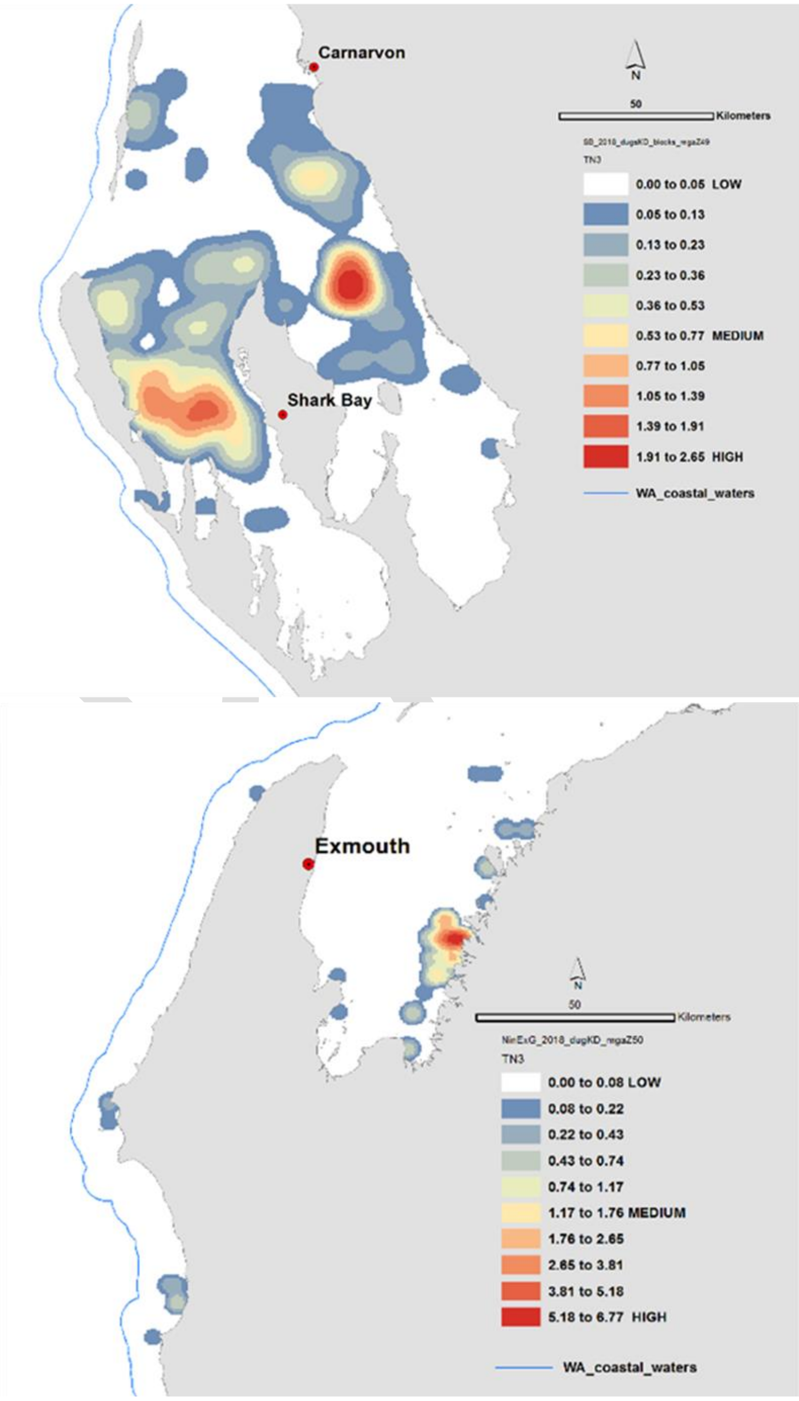


Figure 10.11. Relative abundance of dugongs mapped by Kernel smoothing using all sighting data in Shark Bay (upper figure) and the Ningaloo-Exmouth Gulf (lower) survey areas in June 2018.

Observed dugong densities per unit area (km^{-2}) were standardised for effort (four observer counts) but uncorrected for detection biases and are considered 'minimum' estimates. Red colours have the highest relative abundances and blue colours the lowest, with a colour-abundance range in between (orange, yellow and green). Reproduced from Bayliss et al. (2018) with permission.

The MMPATF declared the Ningaloo Reef to Montebello Islands and Shark Bay to be IMMAs with the dugong as a qualifying species in 2020 (IUCN-MMPATF 2022e,h; Figure 10.15).

- The estimated number of dugongs in Shark Bay and Exmouth/Ningaloo in winter 2018 was 23,386 ± SE 3,124 (*Hagihara Method*). Shark Bay dugong populations were relatively stable between 1989 and 2018.
- Both Ningaloo Reef to Montebello Islands and Shark Bay have been declared IMMAs, with the dugong as a qualifying species.

10.2.5 Overview of dugong abundance and trends across the Australian region

Collectively, the results of the large-scale surveys indicate that dugongs are far more abundant in the Australian region than anywhere else in their range and that their conservation status varies regionally within Australian coastal waters (Clark et al. 2021). Confidence in this assessment varies because of regional and temporal differences in survey recency, frequency, and different approaches to assessing trends (Figure 10.12, Table 10.1).

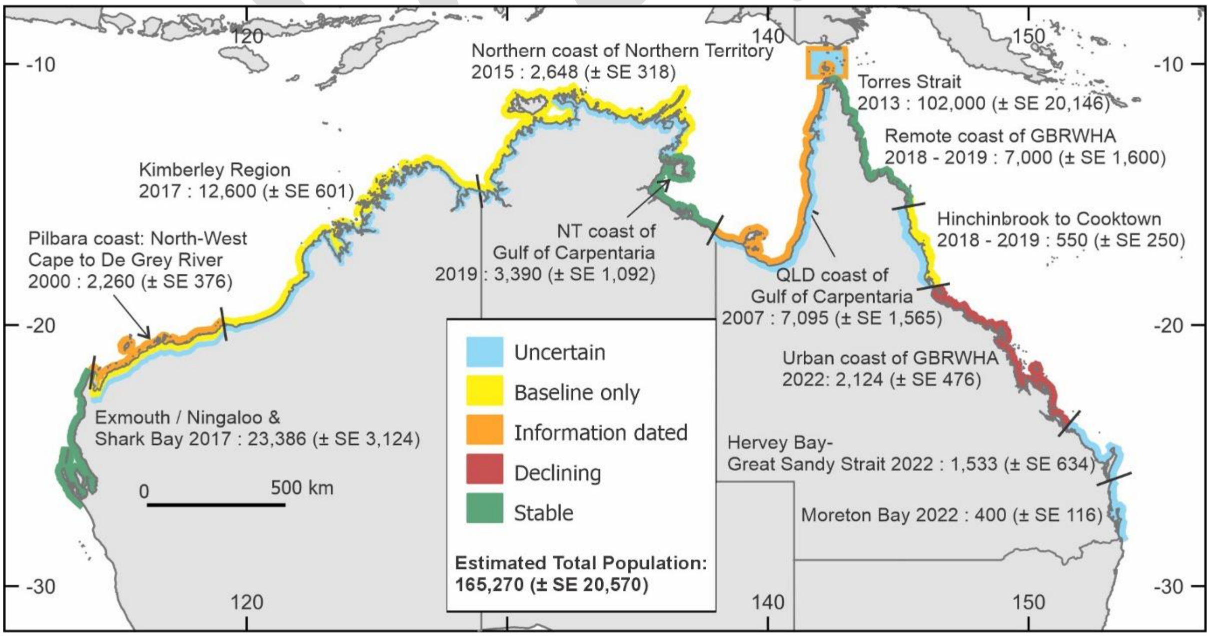


Figure 10.12. Summary of the results of the most recent large-scale dugong aerial survey across northern Australia and the status of the dugong population in each region, based on survey frequency, the timing of the last survey and the likelihood of recent temporary emigration. Figure created by Adella Edwards; reproduced with permission.

Table 10.1. Summary of the most recent dugong population estimates for various surveys, the inferred status of the population in each region and the confidence in that assessment based on survey frequency, timing and the likelihood of recent temporary emigration.

Survey region	Date latest survey	Population Estimate	Correction Availability Bias	Status/Confidence	Reference
Moreton Bay	2022	400 ± SE 116	*Hagihara*	Uncertain, weak trend	Cleguer et al. (2023)
Hervey Bay-Great Sandy Strait	2022	1,533 ± SE 63)	*Hagihara*	Uncertain, possible temporary emigration	
Urban coast of GBRWHA	2022	2,124 ± SE 476	*Hagihara*	Declining	
Hinchinbrook to Cooktown	2018-2019	550 ± SE 250	*Hagihara*	Uncertain; baseline only	Marsh et al. (2020)
Remote coast of GBRWHA	2018-2019	7,000 ± SE 1,600	*Hagihara*	Stable	
Torres Strait	2013	102,519 ± SE 20,146.	*Hagihara*	Uncertain; information dated	Hagihara et al. (2018)
Queensland coast of Gulf of Carpentaria	2007	7,095 ±SE 1,565	*Pollock*	Uncertain; information dated	Marsh et al. (2008)
Northern Territory coast of Gulf of Carpentaria	2019	3,390 SE ± 1,092	*Hagihara*	Stable	Griffiths et al. (2020)
Northern coast of Northern Territory	2015	2,648± SE 318)	*Pollock*	Uncertain; baseline only	Groom et al. (2017)
Kimberley region	2017	12,600 ± SE 601)	*Pollock*	Uncertain; baseline only	Bayliss and Hutton (2017)
Pilbara coast: North-West Cape to De Grey River	2000	2,026 ± SE 376	*Marsh and Sinclair*	Uncertain; information dated and baseline only	Prince (2021)
N-W Cape to Shark Bay including Exmouth-Ningaloo	2017	23,386 ± SE 3,124	*Hagihara*	Stable	Bayliss et al. (2018
Total		**165,271 ± SE 20,570**			

10.3 Cultural values

10.3.1 Indigenous values

Dugongs have been important to the Indigenous peoples of Australia and the Western Province of PNG for thousands of years. Much of the evidence of early contact would now be submerged by the sea level rise since the last glacial maximum. The oldest known rock art depicting a dugong is today located ~ 15 km inland south of the Arafura Sea in the Northern Territory. When it was painted 6,000-9,400 years ago, the rock art site would have been much further from the sea, but within walking distance of it (Taçon et al. 2020).

As explained in Section 10.2.2, there is archaeological evidence from Torres Strait that dugong hunting was occurring there at least 4,000 years ago (Crouch et al. 2007). At that time, the dugong was the largest animal hunted by Aboriginal and Torres Strait Islander peoples and the quality and quantity of its flesh provided a windfall of high-quality meat unequalled by other species (Chase 1981). Kiwai hunters in Western Province of PNG were revered as the greatest hunters of dugongs in PNG (McNiven and Feldman 2003) and being a successful dugong hunter conferred high status and great prestige (Hudson 1986; Parer-Cook and Parer 1990; McNiven and Feldman 2003).

Different techniques were used to catch dugongs in different areas. For example, netting was used to catch dugongs in the Wellesley Islands in the Gulf of Carpentaria (Marsh et al. 1981); Torres Strait Islanders hunted from *gnaths*, platforms built over fresh dugong feeding trails in reef top seagrass beds at low tide in anticipation of a dugong returning to feed on subsequent nights (Nietschmann and Nietschmann 1981; Parer-Cook and Parer 1990), while other groups speared dugongs from bark canoes (Bradley 1997) or in Western Province PNG, from outrigger sailing canoes (Parer-Cook and Parer 1990), using harpoons with a detachable head.

There are numerous totemic sites connected to creation myths about dugongs and human burial sites marked by piles of dugong bones across northern Australia (see, for example, Chase et al. (1981) for the east coast of Cape York; Bradley (1997) for the Sir Edward Pellew Islands and Limmen areas in the Northern Territory, and McNiven and others for Torres Strait (see McNiven 2013 for a review)). It is highly likely that many sites are unknown to archeologists.

Bradley (1997) described sites throughout the Sir Edward Pellew Islands and the coastal margins of the south-west Gulf of Carpentaria (Figure 10.9) where the fecundity of the spirit ancestors is embodied in features of the landscape. An important site is the resting place of the Dugong Spirit Ancestor at Wunubarryi or Mount Young in Limmen, where some of the quartzite outcrops look remarkably like semi-submerged dugongs with the backs and snouts out of the water.

In Torres Strait, bone mounds revealed the ritual treatment of dugong bones, especially skulls, to increase hunting success (Figure 10.13; McNiven and Feldman 2003). These mounds also provided evidence of dugongs being harvested in large numbers for centuries before European settlement in the 1890s (McNiven and Bedingfield 2008).

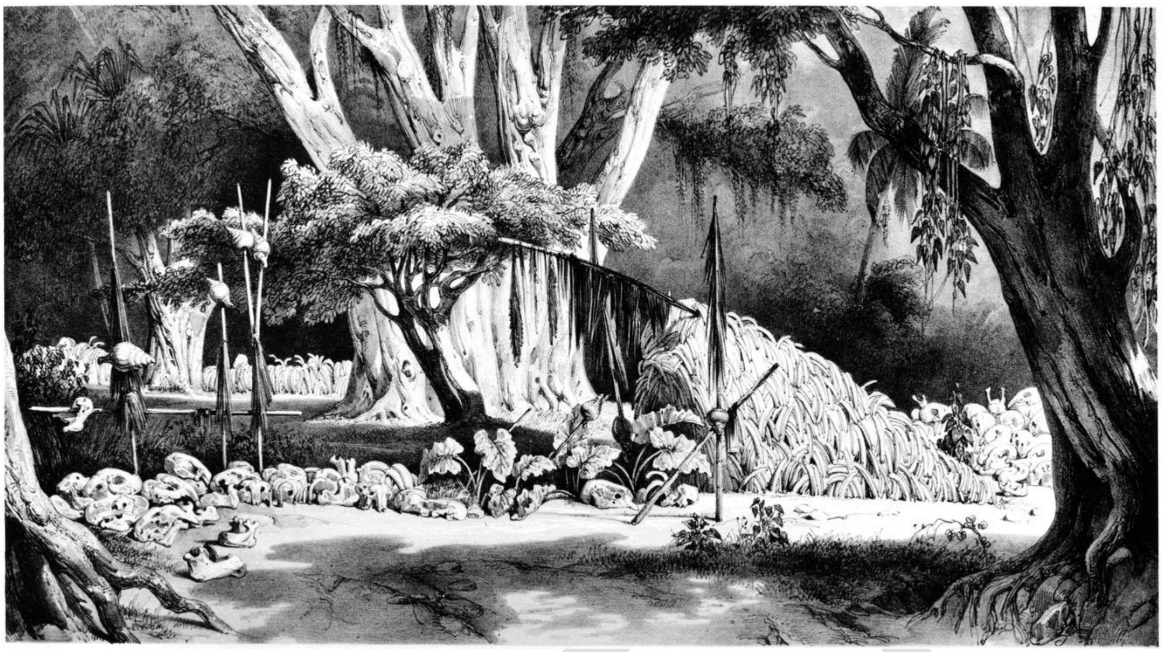


Figure 10.13. A dugong bone mound on Tudu Island, Torres Strait, Australia, in 1840. Note the large number of skulls and rib bones. Dumont D'Urville 1846: pp. 189; out of copyright.

Dugong hunting was a dangerous and difficult activity. Magic and ritual were used with the aim of increasing hunter success. Both Torres Strait Islanders and the Kiwai people used dugong hunting charms (Figure 10.14) to provide supernatural aid in the capture of dugongs. These charms were mounted in the bow of boats or underneath offshore platforms to attract dugongs.

Figure 10.14. A dangal (dugong) charm for harnessing good luck on a dugong hunt collected on Tudu Island by Alfred Cort Haddon in 1888. Measurements: 22x9x11.5 cm. British Museum Oc, 89+194. The animal's protruding vulva suggests that the charm depicted a pregnant female. Helene Marsh photograph; reproduced with permission.

Parer-Cook and Parer (1990) recounted how Kiwai hunters were rubbed with ‘sacred dugong stones’ before a dugong hunt to give strength and bring good fortune, the *Baura* dance was performed after feasting on dugongs, and that Kiwai elders believed that ‘the bounty of the sea was inexhaustible, and the dugong could never disappear’.

The cultural value of the dugong remains of deep significance to many coastal Indigenous peoples in Australia and is represented in their art, music, and dance. Delisle et al. (2017) used cognitive mapping and multidimensional scaling to identify separable groups of benefits (cultural services, provisioning services, and individual benefits) associated with the traditional hunting for communities on two islands in Torres Strait. They demonstrated that the cultural services associated with the traditional hunting of dugongs and green turtles were considered significantly more important than the provisioning services.

Watkin Lui et al. (2016) investigated the contemporary cultural significance of Torres Strait Islanders sharing this ‘marine bushmeat’ with their mainland urban diaspora from the perspective of the diaspora living in three Australian mainland cities. The motivations for sharing dugong and turtle meat were almost exclusively cultural, even though each mainland recipient consumed relatively little dugong and turtle meat (< 1 kg person^{-1} year^{-1}). As one participant in the study explained:

‘*So I think dugong is really important, I know to me it really is, you know, like, people say, they are soul food, our soul food. . . I think it’s our genetic makeup . . . around that connection back to where we’re from, and . . . it nourishes your body, you feel reconnected, you feel like you’re just in that zone . . . and it makes you think of your family then because your mum’s standing over the stove cooking.’* (Female participant, Brisbane).

Section 211 of the *Native Title Act 1993 (Commonwealth)* recognizes that Australian Aboriginal and Torres Strait Islander peoples have common law rights and interests to their lands and waters according to their traditional law and customs, including hunting, gathering, or fishing, rights and interests. Thus, dugong hunting by Traditional Owners (Aboriginal or Torres Strait Islander individuals or groups who can prove a traditional or historical connection, attachment, and/or relationship to an area of land or sea) is legal under Australian Law. The right of Torres Strait Islanders to hunt dugongs ‘traditionally’ with harpoons (*wap*) is also recognised and protected under the Torres Strait Treaty, ratified by the governments of Australia and Papua New Guinea in 1985, and the *Torres Strait Fisheries Act Commonwealth 1984*. The agreements that have subsequently been negotiated with the objective of ensuring that traditional hunting is sustainable are considered in Section 10.5.3.

There are numerous coastal clan groups of Aboriginal and Torres Strait Islander peoples in northern Australia e.g., 70 in the GBR region and at least 15 in northern Western Australia alone, each with their own sea country. These groups often regard 'their' dugongs as a transboundary stock that moves across the boundaries between clan groups.

10.3.2 Non-Indigenous values

10.3.2.1 Historical values: cottage industry for dugong oil

European colonists regarded the dugong and its oil as extremely valuable. Thorne (1876) in his book, *Queen of the Colonies or Queensland as I knew it* p.248 said:

'Of all the resources of Queensland waters, none is more extensive or valuable as its flocks of dugongs, which abound in all its northern waters as far south of Moreton Bay, although they are here in much less profusion that further north.'

Daley et al. (2008) and Daley (2014) outline the history of the dugong oil industry in Queensland, a cottage industry for dugong oil, hides, bones, and meat that persisted intermittently at 10 locations on the east coast of Queensland from Moreton Bay to Torres Strait from 1847 until dugongs were protected in Queensland by an *Order in Council* (subordinate legislation published in the Queensland Government Gazette) on 1 September 1969.

10.3.2.2 Contemporary non-Indigenous values

A variety of artefacts attest to the contemporary value of dugong to non-Indigenous Australians. Examples include a tourist drive with a dugong motif along the western shores of southern Moreton Bay, a giant dugong near Rockhampton, a dugong sculpture on the foreshore at Airlie beach near the Whitsunday Islands, dugong models on the Townsville Strand, and at Monkey Mia in Shark Bay, and a children's playground with a big blue dugong slippery dip and dugong painted on the pavement around the playground on the Cardwell foreshore. There are also displays in the Western Australian and Queensland Museums.

A captive dugong named 'Pig' is a feature of the Sydney Aquarium. This animal was reared in captivity after being found as abandoned neonatal calf in 1998 (Marsh 2022).

Seagrass beds are increasingly valued as a source of Blue Carbon as discussed in Chapter 1.

10.4 Threatening processes

10.4.1 Habitat loss

Despite much of the dugong's range in Australia being in areas with a low human population density (Figure 1.x), habitat loss is the greatest threat to dugongs in this region. Dugongs are seagrass community specialists (Marsh et al. 2011). The most significant threats to dugongs in their Australian range in recent years have been the effects of extreme weather events (cyclones, floods, and marine heatwaves) on seagrass communities. Section 10.2 details these impacts for several of the survey regions (e.g., Moreton Bay, Hervey Bay-Great Sandy Strait, Urban Great Barrier Reef Region, Torres Strait, North-West Cape to Shark Bay including Exmouth-Ningaloo) and explains how loss of seagrass eaten by dugongs results in dugong life history changes an increase in mortality, especially neonatal mortality, and a decrease in fecundity (Marsh et al. 2022; Marsh and Cleguer 2024). In such circumstances, some dugongs undertake temporary emigration, presumably to locations where seagrass has not been lost.

These threats are likely to be exacerbated by climate change (Marsh et al. 2022) as well as the ongoing loss of seagrass caused by anthropogenic pressures in the coastal zone (Waycott et al. 2009). Any reduction in subtidal seagrasses will be particularly important to dugongs in Torres Strait where animals use deeper water than on the east coast (Hagihara et al. 2018). As detailed in Section 10.2, extensive diebacks of deep-water seagrasses of unknown cause have occurred in Torres Strait.

Loss of deep-water seagrass will presumably result in animals spending more time in intertidal waters where they are more accessible to anthropogenic stressors (Marsh et al. 2022). Contrastingly, in regions with disturbed shallow seagrass beds, dugongs may depend more heavily on deeper-water seagrasses. However, the implications of this shift in habitat use on the energetic requirements of dugongs and their ability to adapt to such changes remain unclear.

Threats from continued agricultural activities and coastal development are also likely to reduce the resilience of seagrass meadows to climate change on the urban coast of the GBR. The effects of sea level rise in the remote regions of northern Australia is expected to ameliorated to some extent by the limited coastal armouring. Nonetheless, the pattern of sea level rise is expected to be geographically uneven, and the local loss of estuarine and coastal seagrass is expected to further reduce the carrying capacity of the Northern Australian coastal waters for dugongs (Marsh and Cleguer 2024).

The most relevant unknown is how climate-induced changes in seagrass community composition will affect dugong food quality, biomass, and preferred feeding locations. The basis for the dugong's food choice is poorly understood, and determinants of food quality are unknown (Aragones et al. 2006, 2012). We do not know whether the dugong's preferred feeding locations reflect environmental parameters, food quality or quantity, socially transmitted knowledge of resources, or some combination of these factors or how changes in food quality and/or biomass change will affect their time budgets.

10.4.2 Incidental capture in nets

Drowning in gillnets is a major threat to dugongs throughout much of their range (Chapters 1-9). In Australia, shark nets set for bather protection were introduced at popular beaches along much of the Queensland coast from 1962 (Marsh et al. 2005). The catch rate in shark nets in six groups of beaches between Cairns 16.5° S and the Gold Coast 28° S, declined at an average of 8.7% per year during this period, presumably because the population of resident dugongs were severely reduced. Shark nets have been replaced by drumlines in the GBRMP and there are few remaining in the rest of the dugong's range in Queensland (Department of Agriculture and Fisheries 2023). Shark nets have not been used for bather protection in the Northern Territory or Western Australia.

Nonetheless, incidental captures in commercial gillnets remains an unquantified threat to dugongs in Australia despite area closures to commercial gillnetting in eastern Queensland in the 1990s, a commitment to phase out commercial gillnetting in the GBRWHA by mid-2027 (see Section 10.5), a Dugong Protection Area in the south-western Gulf of Carpentaria, and area closures to fishing in several marine parks (Figure 10.15). Unknown numbers of dugongs are caught in the Queensland East Coast Inshore Finfish Fishery, the Queensland Gulf of Carpentaria Inshore Finfish Fishery, the Northern Territory Barramundi Fishery, and the Northern Territory Offshore Net and Line Fishery. In the dugong's range in Western Australia, nets including gillnets are deployed in the small-scale commercial finfish fisheries in nearshore and estuarine waters in the Gascoyne Coastal (including parts of Shark Bay and Exmouth Gulf) and North Coast Bioregions (Newman et al. 2023). The Western Australian Northern Shark Fishery has been inactive since 2008/09. No interactions with dugongs were recorded by fishers in their logbooks in 2022. In 2021, Ecological Risk Assessments assessed the impact of commercial fishing on dugongs and their seagrass habitats as a negligible risk (Newman et al. 2023). Without fishery-independent surveys, it is impossible to validate the risk of fishing to dugongs and their habitats in Western Australia.

10.4.3 Poaching and hunting

As explained in Section 10.2.1, dugong hunting by Traditional Owners in their sea country is legal in Australia. There is anecdotal evidence that poaching by Indigenous people in the sea country of others is an unquantified source of dugong morality of concern to some Traditional Owners (H. Marsh and H. Raudino, personal communications 2024). The incidence of poaching by non-Indigenous people in Australian waters is unknown.

10.4.4 Interactions with vessels

There is evidence that dugongs may sometimes fail to flee or evade the approach of fast advancing vessels until an impact is unavoidable (Groom et al. 2004), though there is much less evidence for vessel strike having a serious impact on dugong populations than for Florida manatees as pointed out by Ponnampalam et al. (2022). Along the urban coast of Queensland, the Queensland Stranding and Mortality database recorded four interactions between dugong and vessels between 2013 and 2015; resulting in three dugongs deaths (Meager 2016). Vessel strike has also been confirmed as a source of mortality for dugongs in Exmouth Gulf in Western Australia (H. Raudino, personal communication 2024). Hodgson (2004) believes that vessel speed is the primary factor affecting collision risk due to 'the time available to flee being equal to the time the boat takes to travel the distance from the flee threshold to the dugong'. The risks to dugongs seem greatest in shallow water, especially large intertidal areas with high vessel traffic where: (1) dugongs are forced to spend more time close to the surface; (2) dugongs have little opportunity to escape to deeper water; (3) vessels and dugongs can be constrained to channels during low tide periods and find it difficult to access deeper water, increasing the probability of vessel interaction (Hodgson and Marsh 2007) . Groom et al. (2004) also recorded dugongs responding to an approaching vessel by moving towards deeper water, which again may result in dugongs interacting with vessels in channels. Vessel traffic can also interrupt dugong feeding (Hodgson and Marsh 2007).

There are no data on whether or how the recent increase in the number and size of commodity ports that export Australia's mineral resources has impacted the dugong, which as a Matter of National Environmental Significance (MNES), must be considered in government approvals processes. The dugong's range in northern Australia contains 12 major and numerous subsidiary ports (Figure 10.1) including some of the nation's largest commodity ports, as well as the major cities of Brisbane, Townsville, Cairns, and Darwin (Australian Government 2015), which are all commodity as well as container ports. The Queensland Government reduced the impacts of port development in the GBR region through the *Sustainable Ports Development Act*, *Qld 2015,* which established a legislative framework to balance the protection of the GBR with the development of the state's major bulk commodity ports in that region.

10.5 Conservation initiatives

10.5.1 International conventions

Australia is a signatory to the Convention on Biological Diversity the Convention on Migratory Species and its associated Dugong Memorandum of Understanding (CMS Dugong MOU), the

Convention on International Trade in Endangered Species (CITES) and the United Nations Framework Convention on Climate Change.

10.5.2 National and state laws

The dugong is listed as a marine and migratory species under the *Environment Protection and Biodiversity Conservation Act, Commonwealth 1999*, which makes it a MNES under Australian national law. This Act prohibits the direct use of and domestic (and international) trade in dugongs, their parts, or products, whilst allowing exceptions for traditional subsistence and customary use. The Act also requires any action that has the potential to have a significant impact on the dugong be assessed to determine if approval would be required and if so, what conditions may need to be implemented to ensure minimal impact on the dugong. The protection for dugongs was increased by the *Environment Legislation Amendment Act Commonwealth 2015,* which tripled penalties for killing or injuring them.

The dugong is not listed as threatened at a national scale. Zichy-Woinarski et al. (2012) evaluated it as 'Near Threatened' in their *Action Plan for Australian Mammals 2012,* a document that has no force in law. The dugong is listed as Endangered in New South Wales (*Biodiversity Conservation Act, NSW 2016*), Vulnerable in Queensland (*Nature Conservation Act Qld 1992*), Near Threatened in the Northern Territory, and as Other Specially Protected Fauna in Western Australia (*Biodiversity Conservation Act, WA 2016*). There is no national Wildlife Conservation Plan for the dugong, although as a MNES the dugong is eligible for one.

10.5.3 Statutory restrictions that contribute to dugong conservation

10.5.3.1 Restrictions under fisheries legislation

Under the Torres Strait Treaty between Australia and Papua New Guinea, the Torres Strait Dugong and Turtle fisheries are traditional subsistence fisheries that are restricted to the Traditional Inhabitants of the region. A > 13,000 km^2 Dugong Sanctuary, in which hunting is banned, was established in western Torres Strait in 1987, under the *Torres Strait Fisheries Act Commonwealth, 1984*, after negotiations with Torres Strait Islander leaders (Figure 10.15). In addition, the Statutory Management Regulations associated with that Act place controls on the dugong fishery: (1) dugongs can only be taken by Traditional Inhabitants; (2) dugongs must be caught with a traditional harpoon with a detachable head or *wap*, (3) dugongs must only be caught from a vessel < 6m long; and (4) the sale of dugong meat is prohibited.

Community-based Dugong and Turtle Management Plans, developed by individual Torres Strait Islander communities are implemented on a voluntary basis throughout the Australian waters of

Torres Strait with the assistance of the Torres Strait Regional Authority (TSRA). Each community-based plan includes traditional governance, which supports management arrangements that have been agreed to by the relevant community. The implementation of plans is supported by the Torres Strait Ranger Program, which is funded by the Australian Government. Some Western Australian groups, such as the Bardi Jawi, have also adopted hunting guidelines and are actively involved in the Buccaneer Archipelago Marine Park (H. Raudino, personal communication 2024).

In 1998, the Australian and Queensland Governments agreed to several measures aimed at arresting the decline of dugongs along the urban coast of Queensland. The most significant initiative was to establish a series of Dugong Protection Areas (DPAs) in known high value dugong habitat. The 16 DPAs include seven Zone A DPAs (total area 2,407km^2), where foreshore and offshore set or drift nets were prohibited, and nine DPABs (total area 2,243km^2), where there were less stringent restrictions on commercial gillnetting (Marsh 2000).

Northern Territory Fisheries implemented a gillnet closure area under the Barramundi Management Plan following a significant dugong mortality event (~ 30 dugongs) in Yanyuwa country, near the McArthur River (Bradley 2010). The Dugong Protection Zones are within the Barramundi Fishery Management Plan, under clauses 8 (2)(c) and (e). The implementation of these zones was originally from an agreement between the Barramundi Fishery, the Wurrahaliba Aboriginal Consultative Committee in Borroloola and Northern Land Council. These closures were first implemented into the Barramundi Fishery Management Plan in 2002 and updated in 2012. The Yanyuwa Indigenous people are working to optimise the protection of this area for dugongs by using multiple data layers and cultural knowledge of dugong habitat use. This combined information will be used to delineate a more suitable area of protection for dugongs than under the current arrangements.

Commercial fishing regulations implemented in the 1970s and 1980s preclude the use of large mesh gillnets and long-lines throughout the Gascoyne region in Western Australia, to prevent the incidental entanglement of dugongs and turtles (Newman et al. 2023).

10.5.3.2 Marine Parks

Marine Park protection for dugongs in Australian waters reflects the jurisdictional complexity of the region. In Torres Strait, the dugong is a transboundary stock shared with PNG and possibly West Papua and there are no marine parks. In other areas, individual dugongs live or traverse coastal waters under the jurisdiction of the Australian (Commonwealth) Government and/or state/territory governments.

In jurisdictions other than the GBR, state/territory waters are largely covered by state marine parks and commonwealth waters by commonwealth marine parks, although some areas have joint management plans. Each marine park has its own detailed management plan, which provides varying levels of protection, through an assortment of management zones, typically ranging across the IUCN protected area categories and including zones closed to commercial fishing. Figure 10.15 shows the coastal marine parks in the dugongs' winter range in Australia. The management plan for each marine park provides spatial details of the zoning regime.

The GBR is managed as a partnership between the Australian and Queensland Governments and both governments have direct legislative responsibilities in the region. The GBRMP and the Queensland GBR Coastal Marine Park have mirror zoning because the boundary of the Queensland waters is defined differently by the two jurisdictions. The GBRMP was re-zoned from 2004 to maximise biodiversity protection through a comprehensive and representative multiple-use regime (Fernandes et al. 2005), which increased area closures to commercial netting and trawling. Grech et al. (2008) evaluated the residual impacts of mesh netting to the dugong in the GBRWHA after the rezoning arrangements became law. They concluded that the combined effects of the DPAs and the rezoning (which often overlap) had resulted in bans on commercial gillnetting in ~ 67% of dugong habitats in the GBRWHA and that the accompanying industry restructuring also contributed to the decline in the spatial extent of netting.

This protection is being strengthened from 2024 as part of the Australian Government's response to the UNESCO World Heritage Committee's ongoing consideration of whether the GBRWHA should be listed as Endangered (Australian Government 2024b). The Queensland Government banned commercial gillnets from the northern third of the GBR and all DPAs, with the exception of the rivers and creeks in DPABs; accelerated implementation of the Queensland Sustainable Fisheries Strategy 2017-27, agreed to phase out gillnet fishing in the GBRWHA by mid-2027, and to introduce Independent Data Validation in Queensland's commercial fisheries, so that the incidental capture of protected species such as dugongs would be more likely to be reported.

Consideration of proposed additional closures to gillnets in the Gulf of Carpentaria were on-going at the time of writing. The intent to establish new gillnet-free zones was announced in 2023 by the Australian and Queensland Governments as part of the implementation of the Gulf of Carpentaria inshore fishery reforms under the Queensland Sustainable Fisheries Strategy.

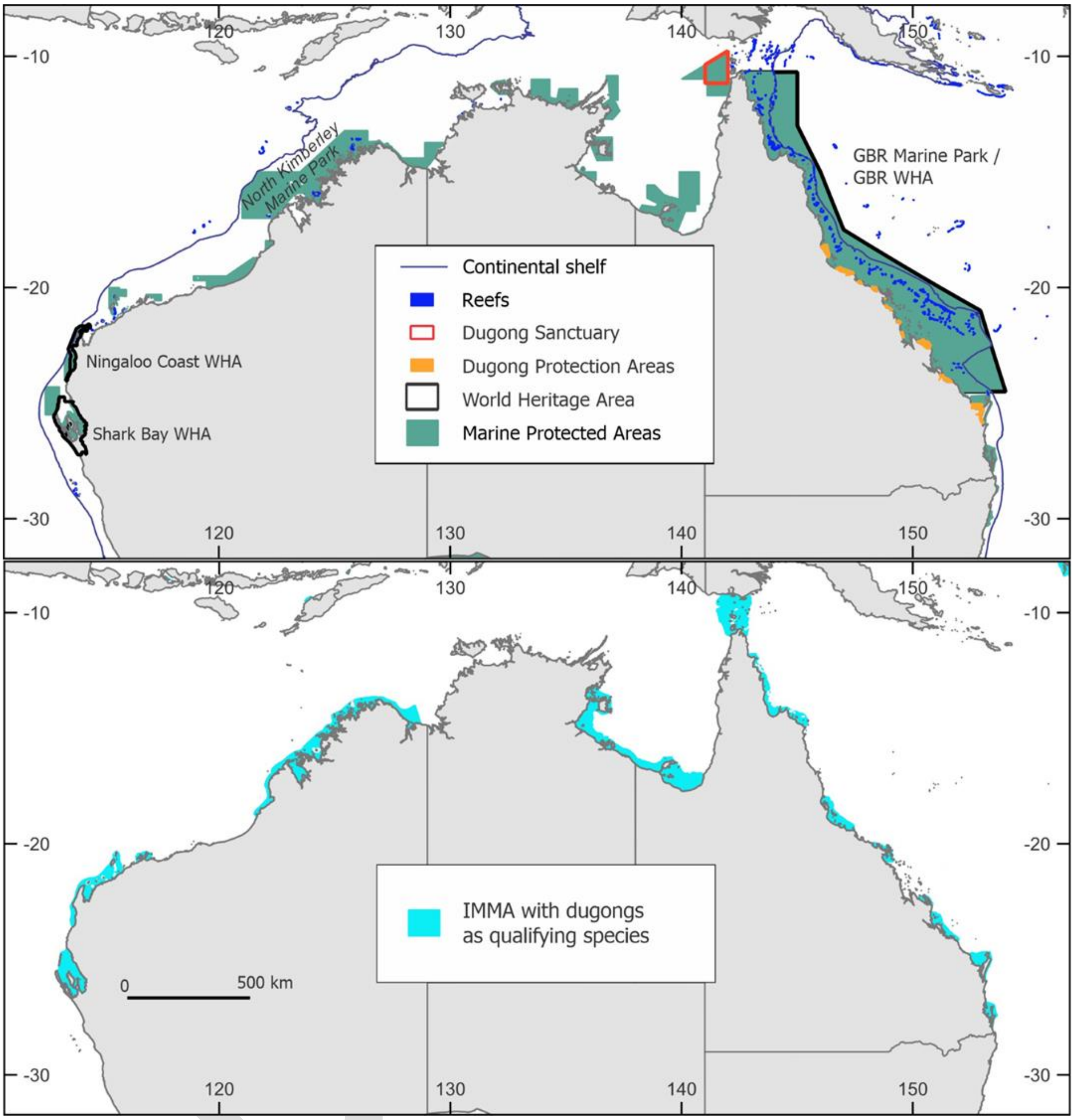


Figure 10.15. ***Upper figure*: The statutory protection areas for dugongs in the Australian region. *Lower figure*: Important Marine Mammal Areas in Australia with dugong as a qualifying species. Comparison of these maps indicates that most of the IMMAs receive statutory protection. Figures created by Adella Edwards; reproduced with permission.**

Marine Protected Areas extracted from The Collaborative Australian Protected Areas Database (CAPAD) 2022 (Marine) Licence: CC - Attribution (CC BY 4.0). This data has been licensed under the Creative Commons Attribution 4.0 International Licence. Dugong Protection Areas licensed under a [Creative Commons - Attribution 3.0 Australia](#) license.© State of Queensland (Department of Agriculture and Fisheries) 2023. Updated data available at http://qldspatial.information.qld.gov.au/catalogue//. Torres Strait Dugong Sanctuary TSRA (2003) ©Torres Strait Regional Authority (TSRA). Marine WHA extracted from Australia, World Heritage Areas, Department of Climate Change, Energy, The Environment and Water. CC BY 4.0 DEED, Attribution 4.0 International. IUCN Important Marine Mammal Area (IMMA) Geographical Information System (GIS) Dataset Version Release Dated: September 2023 Citation: IUCN MMPATF (2023) Global Dataset of Important Marine Mammal Areas (IUCN-IMMA). September 2023. Made available under agreement on terms of use by the IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force and made available at [www.marinemammalhabitat.org/imma-eatlas.](http://www.marinemammalhabitat.org/imma-eatlas)

10.5.3.3 Agreements with First Nations peoples regarding dugongs

10.5.3.3.1 GBRWHA

Within the GBRWHA, Traditional Owners are supported to assert their cultural authority over sea country and voluntarily regulate the dugong and turtle harvest through the Traditional Owners developing formal agreements with the GBRMP. These agreements are called Traditional Resource Use Management Agreements (TUMRAs) (Havemann et al. 2005). In 2024, there were 18 TUMRAs plus an Indigenous Land Use Agreement or ILUA— covering 18 Traditional Owner groups in place. These agreements are developed and implemented through the Indigenous Land and Sea Country Partnerships Program, an AUD 2.3 million (USD 13.4 million) investment in Traditional Owner management of the Reef that currently covers > 43% of the coastline of the Great Barrier Reef Marine Park and World Heritage Area. (GBRMPA 2023b).

TUMRAs are community-based plans for management of traditional resources, which are accredited in legislation, and describe how Traditional Owner groups work in partnership with the Australian and Queensland Governments to manage traditional use activities in their Sea Country. Each TUMRA is managed by a committee. Management applies to all traditional use of marine resources in their Sea Country, including any traditional take of dugongs, and is based on both cultural lore and contemporary science. Formal agreements have not yet been accredited for several major hunting communities adjacent to the NGBR, such as Lockhart River, Hope Vale and the Northern Peninsula Area. Several of the TUMRAs provide Traditional Owners with the powers to limit illegal take of dugongs, usually by poachers, who are not Traditional Owners of the area where the TUMRA applies. GBRMPA has a dedicated Indigenous Compliance Team which delivers targeted training and development of Compliance Management Plans to support indigenous Rangers, Traditional Owners and Indigenous Communities and provides career pathways for Aboriginal and Torres Strait Islander people in land and sea management. Some Indigenous rangers have been appointed as Marine Park inspectors and this program is being extended on a national level (Australian Government 2024a)

10.5.3.3.2 Other regions

In northwestern Western Australia, Kimberley Indigenous Turtle and Dugong Initiative 2022–2032 (Lincoln et al. 2021) is a regional, long term, partnership approach to the conservation and management of those species. The Initiative was designed and led by local Indigenous saltwater managers as a tool for the Kimberley Indigenous Saltwater Advisory Group (ISWAG) to use to guide their activities and obtain funding for implementation.

10.5.3.3.4 Management of interactions with vessel traffic

The Australian National Strategy for Reducing Vessel Strike on Cetaceans and other Marine Megafauna (Australian Government 2017) notes the risk to of vessel strike to dugongs but is largely silent on practical measures, regarding what should be done about it, except at a very superficial level. Measures to mitigate the risk are implemented as part of government approvals for capital dredging campaigns at major ports for example, the Channel Upgrade Project in Townsville (Port of Townsville 2023). In the Moreton Bay Marine Park near the major city of Brisbane, there are two types of turtle and dugong go slow areas: (1) in five areas in the Bay, all vessels, including jet skis, must be operated off-the-plane or in displacement mode, and motorised water sports are prohibited; while (2) applies in southern Moreton Bay, where vessels larger than 8 m are restricted to a maximum speed of 10 knots (Department of Environment, Science and Innovation [DESI] 2024). In the GBRMP, the Hinchinbrook Plan of Management complements zoning and other management strategies by establishing transit lanes and go-slow areas to minimise the impacts of vessel traffic on dugongs (GBRMPA 2023a).

10.5.4 Other Conservation Initiatives

10.5.4.1 Education

- GBRMPA, Queensland, the Northern Territory and Western Australia have educational information available on the dugongs, their habitat, and conservation in association with their materials on MPAs (Australian Government 2024a).
- The captive dugong at Sydney Aquarium is used to raise awareness and educate the community about dugongs. This Aquarium attracts a large number of visitors each year and the dugong is one of the flagship attractions.

10.5.4.2 Water Quality

The Reef 2050 Water Quality Improvement Plan, launched in July 2018, was developed by the Australian and Queensland Governments to encourage industry, government, and the community to work to together to improve the quality of water flowing to the GBR, including to the seagrass habits vital to dugongs. Nonetheless, progress in achieving the targets has been of ongoing concern to the World Heritage Committee (Australian Government 2024b)

10.5.4.3 Marine debris

Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris is listed as a key threatening process under the *Environmental Protection and Biodiversity Conservation Act, Commonwealth 1999*. Harmful marine debris includes land-sourced garbage, fishing gear from recreational and commercial fishing abandoned or lost to the sea, and vessel-sourced, solid, non-biodegradable floating materials disposed of or lost at sea. A statutory threat abatement plan incorporates the actions needed to address this threatening process and binds the Commonwealth and its agencies to respond to the impact of marine debris on vertebrate marine life, including dugongs (Australian Government 2018).

10.6 Research and monitoring

A significant proportion of pure and applied research on dugongs and their habitats has been performed in Australia. Topics investigated include research on their abundance and population trends, anatomy, anthropology, archaeology behavioural ecology, contaminants, cultural values, distribution, foods and feeding, genetics, habitat, health, life history, movements, and physiology. Both this chapter and Chapter 1 summarise research relevant to dugong distribution, abundance, status and trends and genetics. In addition, as summarised in Section 10.2, there has been significant research into monitoring techniques, particularly the correction of detection biases.

Some of this research is ongoing. Nonetheless, additional multidisciplinary approaches will be required to progress our understanding of the distribution, abundance, status, and trends of Australia's dugong populations. Marsh and Cleguer (2024) developed ideas for such research for dugongs in the GBR region. Their suggestions are further elaborated below in no particular order.

10.6.1 Modelling

The results of the large-scale aerial surveys have been used to identify IMMAS with dugongs as the qualifying species throughout its Australian range (Figure 10.15). These assessments were based on dugong density data and expert scientific opinion but do not take cultural values into account. Bayliss and his co-workers (Bayliss and Wilcox 2015, Bayliss et al 2015, Bayliss and Hutton 2017) integrated survey data and Traditional Ecological Knowledge to identify dugong areas important to local Indigenous peoples in the North Kimberley region. Given that the dugong is a such a culturally important species for Indigenous peoples throughout their range in Australia (Section 10.3), it will be important to extend this transparent and culturally respectful approach to other areas and to work with the relevant Traditional Owners to undertake vulnerability assessments of key locations, including their susceptibility to climate change.

Extensive spatial datasets are available for both seagrasses and dugongs in large portions of its Australian range. Bayliss et al. (2019) modelled the relationships between the distribution and relative abundance of dugongs in Shark Bay and seagrass density. Parallel research is underway in the GBR region conducted by the dugong and seagrass groups at James Cook University (JCU). This exploration of the relationship between seagrass presence, community type, species, and their physical determinants has the potential to increase understanding of habitat choice in dugongs and the prediction and interpretation of temporal changes in dugong population size and distribution.

10.6.2 Field studies of the dugong seagrass interactions

Field experiments using enclosures and/or simulated feeding have provided important information on the effects of dugongs and other megaherbivores on seagrasses (e.g., Preen 1995; Aragones and Marsh 2000; Scott et al. 2020, 2021). Replicating these experiments in important dugong areas has the potential to provide important new information on the interactions between dugongs and seagrasses. Many of the experiments to date have been in meadows where excavating is the dominant form of dugong feeding, and priority should be given to areas where cropping is also used.

Rasheed et al. (2017) mapped dugong feeding trails in intertidal areas in the Gladstone region using photogrammetry. Extending this work across intertidal habitats in a range of locations would provide insights on the spatial pattern of dugong excavating behaviour within intertidal meadows. Similar research is planned for Yawuru sea country in the Kimberley (H. Raudino, personal communication 2024).

Across the Pilbara region, Said et al. (unpublished) has developed a novel approach for rapidly assessing dugong-habitat associations, integrating innovative aerial survey and imagery technology as in Cleguer et al. 2021 (N. Said and C. Cleguer, personal communication 2024), and comprehensive in-water habitat assessment to determine the environmental drivers of dugong occurrence in the region. Three locations identified as dugong hotspots (Exmouth Gulf, Mangrove Passage, and Regnard Islands) were surveyed using relatively small drones. A standard area was surveyed in each location (~ 30 km^2) using either a standard line transect survey or a gridded, randomised approach and this was repeated up to three times in 2018/2019. From these surveys, a rapid assessment was performed to identify sites within each location where dugongs were present, named 'presence' sites, and absent, named 'possible absence' sites. Each of these sites (200 m^2) was then surveyed using drop-down cameras and environmental loggers to characterise the benthic habitat, habitat quality and the environmental features that could influence the distribution of dugongs. These datasets were analysed using generalised linear models (GLMs) to predict the drivers of dugong occurrence and distribution at the local scale. The study highlighted fine-scale patterns of habitat association in dugongs across the Pilbara region, with cover of seagrass, particularly the abundance of small colonising species, as well as the nutritional content of one of these species identified as best predictor of either the presence or abundance of dugongs over mother environmental factors.

10.6.3 Application of new technologies

The dugong is a relatively cryptic animal that in northern Australia mostly occurs in turbid waters and is therefore difficult to study. In a collaboration between JCU and Murdoch University, custom-designed, animal-borne, multi-sensor tags are being used to improve understanding of the dugong's fine-scale, three-dimensional diving behaviour, diel patterns in activity budgets, buoyancy, habitat use, movement corridors, animal interactions, and the biophysical drivers influencing these aspects of the dugong's behavioural ecology. The resultant information also has the potential to improve the corrections for availability bias. Multi-sensor tags remain attached to the animals only for hours to days and must be retrieved to access data.

GPS-satellite tags have been used in different regions of Australia to study the movements and habitat use of dugongs across variable spatial and temporal scales (see Deutsch et al. 2022 for a complete and recent summary). Because of the necessary weak-link integrated in the GPS-satellite tag attachment apparatus (to ensure dugongs can break free off the tag should they get entangled), most GPS-satellite tags have remained attached for periods of only 3-6 months. Thus, long-term studies of individual dugongs based on satellite tracking will be very difficult. Nonetheless, such studies, particularly of mothers and their dependant calves, have the potential to provide new insights into dugong movements and socially transmitted knowledge. Lanyon et al.'s longitudinal study of gene-tagged dugongs in Moreton Bay has the potential to provide key insights, which will become more revealing over time.

Environmental DNA (eDNA) is a promising tool for both species' detection and biodiversity monitoring (Sigsgaard et al. 2020). Dugongs leave a 'footprint' in surface waters including genetic materials from their skin, mucus, and/or faeces. eDNA could be used to detect dugong presence in estuarine areas which are difficult to survey and local areas that have not been surveyed from the air, such as bays in northern NSW.

Off-the-shelf small drones, which are relatively cheap and easy to use, are increasingly used by citizen scientists and communities to conduct local scale assessments of dugong presence and distribution (Cleguer et al. 2021). Using small drones for to conduct 'backyard surveys' are limited in spatial coverage (and thus are not an adequate tool for dugong population assessments over 100s of km^2) but they empower their trained users in conducting independent surveys at a relatively low cost and they are enhancing collaborations among Traditional Owners, TUMRA representatives, land and sea ranger programs, and scientists conducting local scale seagrass and dugong surveys. This approach, which is being rolled out multiple places around Australia (C. Cleguer, personal communication) has the potential to inform the understanding of the relationship between the dugong's fine-scale habitat use and their biophysical environment as demonstrated by Cleguer et al. (2021).

10.6.4 Health assessment

Lanyon et al. (2002, 2019) and her University of Queensland researchers have conducted a longitudinal study of dugongs in Moreton Bay for more than 20 years. This study has provided many important insights into dugong biology as outlined in Chapter 1.

As part of this study, health assessments of wild dugongs in Moreton Bay have been conducted annually since 2008 (Lanyon et al. 2010; Walsh et al. 2018). These comprehensive assessments involve the capture of wild animals and take advantage of the proximity of dugongs in Moreton Bay to the infrastructure and expertise available in a major city. Such an approach could not be used in remote locations.

Images from small drones are being used to estimate the body condition of marine mammals. These methods have been used to study manatees (e.g., Ramos et al. 2022) and are being developed for dugongs by scientists in collaboration with local sea rangers, and citizen scientists including members of the Indigenous communities across Australia.

10.6.5 Acoustic behaviour

Acoustic receivers have been used to record dugong vocalizations and investigate the functions of the calls, especially in Thailand, where 'vocal hotspots' have been identified (Tanaka et al. 2017, 2023). The functions of different types of vocalisations remains unclear. If such hotspots also occur in Australia, this approach could provide new insights to inform dugong management. In association with animal-borne acoustic transmitters, acoustic receivers also have the potential to provide new information on the dugongs' use of three-dimensional space and their interactions with biophysical and anthropogenic environments, especially near ports (Zeh et al. 2015). Similar work is planned using the acoustic array in Roebuck Bay near Broome, Western Australia (H. Raudino, personal communication 2024).

10.6.6 Genetics

Most of the Australian research on dugong genetics to date has been carried out in Queensland as outlined in Section 10.1.2. More samples are being obtained by JCU scientists from its range west of Torres Strait to increase understanding of genetic population structure across the dugong's range in Australia. More whole-genome data will increase our understanding of genetic health and diversity, changes in population size and levels of inbreeding.

10.6.7 Monitoring

For the last 40 years, most of the advances in dugong monitoring using large-scale aerial surveys have been in attempting to improve: (1) the corrections for detection biases, and (2) statistical techniques for detecting trends (Marsh et al. 2019). A technological step-change is underway to transition to the use of aerial imagery surveys and Artificial Intelligence (AI) with a resultant increase in survey accuracy and human safety and a decrease in cost. Research has been progressing for several years to support this transition, which is occurring in two stages by: (1) fitting cameras to light aircraft, an approach that is under development in Queensland, the Northern Territory and Western Australia (C. Cleguer, A. Hodgson and H. Raudino, personal communication 2024), and (2) replacing light aircraft with large drones (Hodgson et al. 2013, 2017, 2023). In the future, integrating the outcomes of aerial surveys with these complementary methods for assessing dugong population health will be important. This approach adopts a jigsaw paradigm, where the combination of diverse monitoring methodologies forms a cohesive and comprehensive framework for population assessment, thereby harnessing the strength of several lines of evidence.

10.6.8 National Wildlife Conservation Plan for the Dugong

In Australia, the dugong is a Matter of National Environmental Significance (MNES). Australia has by far the largest dugong population in the world. As a developed country, Australia has the potential to conduct research and develop monitoring techniques that inform dugong conservation globally. A national Wildlife Conservation Plan for the dugong would enable a more systematic and prioritized approach to is conservation than has occurred to date.

10.7 Regional co-operation

The Australian Government currently engages with its northern neighbours on the management of dugongs as a transboundary species through two fora: the Torres Strait Treaty and the Arafura and Timor Seas Ecosystem Action (ATSEA) Programme. For over 30 years, the management of dugongs within and in the vicinity of the Torres Strait has been a standing agenda item for the Torres Strait Treaty Environmental Management Committee (EMC) represented by government officials and traditional custodians from Australia and PNG. Arafura and Timor Sea Ecosystem Action (ATSEA) is a long-standing partnership between Australia, Indonesia, Papua New Guinea, and Timor-Leste for transboundary cooperation on marine values and threats in the shared waters of the Arafura and Timor Seas (Figure 10.1). The conservation of regional populations of endangered, threatened, and protected species and their critical habitats is a major strategic objective of ATSEA (N. Montgomery, Australian Department of Climate Change, Energy, the Environment and Water [DCCEEW] personal communication 2023).

10.8 Regional summary

- Australia is the most important location for dugongs and their seagrass habitats in the world. The vast areas of shallow continental shelf in northern Australia provide extensive areas of seagrass supporting habitat and the human population density of most of this region is very low.
- Australian dugong populations appear to be in good genetic health in terms of genetic diversity, population size and low levels of inbreeding.
- The total estimated dugong population is ~ 165,000 ± SE 21,000. The total area of seagrass estimated with moderate to high certainty in the dugong's Australian range is ~ 57,500 km^2 including 24,076 km^2 in waters > 15 m deep in the urban coast of the Great Barrier Reef World Heritage Area (GBRWHA) that has not been surveyed for dugongs.
- The dugong is a Matter of National Environmental Significance (MNES) under national law and receives protection under the laws of all relevant jurisdictions in their Australian range.
- Table 1.2 lists confirmed areas of high dugong concentration in the Australian region. Ten Important Marine Mammal Areas (IMMAS) with dugongs as a qualifying species are recognised in Australian coastal waters: five in Queensland, one straddling Queensland and Northern Territory waters, and four in Western Australia. Dugongs in most of these IMMAs receive some statutory protection under marine park and/or fisheries legislation.
- The dugong population is explicitly recognised as an attribute of Outstanding Universal Value (OUV) in both the Great Barrier Reef and the Shark Bay World Heritage Areas (WHAs).
- The results of the large-scale aerial surveys that have been conducted over dugong habitats in Australia since the 1980s suggest that dugong conservation status varies regionally within Australian coastal waters from stable along the remote coast of the GBRWHA, the Gulf of Carpentaria coast of the Northern Territory and Shark Bay, declining in the urban coast of the GBRWHA and uncertain in most other parts of their Australian range.
- Confidence in this assessment varies because of regional and temporal differences in survey recency, frequency, and different approaches to assessing trends. Much of the dugong's range in Western Australia and the Northern Territory has only been surveyed only once and key areas have not been surveyed for more than ten years including: Torres Strait, which supports the largest dugong population, the Gulf of Carpentaria Coast of Queensland, and the Pilbara coast of Western Australia.

- The dugong is a culturally significant species for coastal Indigenous peoples across their range in northern Australia, where they have been hunted for thousands of years.
- Dugong hunting by Traditional Owners (Aboriginal or Torres Strait Islander individuals or groups who can prove a traditional or historical connection, attachment, and/or relationship to an area of land or sea) is legal under Australian Law.
- Extreme weather events (cyclones, floods, and marine heatwaves) have been the most significant threats to dugongs in their Australian range in recent years. Loss of the seagrasses eaten by dugongs results in dugong life history changes including an increase in mortality, especially neonatal and early juvenile mortality, and a decrease in fecundity. In such circumstances, some dugongs undertake temporary emigration, presumably to locations where seagrass has not been lost.
- As a developed country, Australia has the potential to conduct research and develop monitoring techniques that inform dugong conservation globally and a high proportion of modern dugong research has been conducted in Australia.
- A national Wildlife Conservation Plan would enable a more systematic and prioritized approach than has occurred to date.

Table 10.2. Summary of confirmed areas of high dugong concentration in the Australian region.

REGION	KEY LOCATIONS
Temperate Queensland	Moreton Bay; Hervey Bay -Great Sandy Strait,
Great Barrier Reef southern border to Cape Bedford	Shoalwater Bay; Townsville -Cardwell region: Bowling Green Bay, Cleveland Bay, Halifax Bay, Hinchinbrook
Great Barrier Reef Cape Bedford North	Lookout Point to Bathurst Head; bays between Friendly Point and Shelbourne Bay; large reefs, especially in Princess Charlotte Bay
Torres Strait	Central and Western Torres Strait
Gulf of Carpentaria; Queensland coast	Wellesley Islands
Gulf of Carpentaria: Northern Territory Coast	Sir Edward Pellew Islands; Limmen Bight
Kimberley region of Western Australia	North Kimberley; Roebuck Bay
Gascoyne coast of Western Australia	Shark Bay; Exmouth Gulf

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