Chapter 9: PACIFIC ISLANDS

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Regional Findings

Pacific Islands: New Caledonia, Palau, Papua New Guinea, the Solomon Islands and Vanuatu.

- Dugongs persist in locations of local importance in all these Range States. Active engagement with communities and government initiatives to protect dugongs within these areas is crucial.
- Information on dugong habitats, abundance and conservation status is limited outside New Caledonia, especially for Papua New Guinea and the Solomon Islands. Lack of capacity and funding are the main drivers for this persisting gap in investment in research and monitoring.
- IUCN listed the New Caledonia 'subpopulation' as Endangered in 2022.
- The dugong is explicitly cited as an attribute of the Outstanding Universal Value in the 'Lagoons of New Caledonia' World Heritage property.
- The 'New Caledonian Lagoons and Shelf Waters IMMA' was listed as an Important Marine Mammal Area in 2021, with the dugong as a qualifying species.
- The 'Main Solomon Islands IMMA' encompasses the coastal and offshore waters of the main group of Solomon Islands. The dugong is believed to be widely distributed within the IMMA and is one of the qualifying species.
- The Palau dugong population in not only the most isolated dugong population in the world but also appears to have very low genetic diversity.
- An important priority should be to build on the history of regional cooperation to develop a program of coordinated research on and monitoring of the distribution and abundance of dugongs and their seagrass habitats across the region, using techniques that are appropriate to the capacity of each Range State, but which would enable cross-country comparisons.
- Once this foundational work has been established, consideration should be given to understanding the connectivity between dugongs at locations within the region using modern genetics and tracking techniques, especially as genetic diversity appears to be very low for dugongs in both Palau and New Caledonia.

9.1 Regional Setting

9.1.1 Geographic overview

This chapter summarises the status of dugong populations across the Pacific Islands from Palau (7.51° N, 134.58° E) to New Caledonia (20.90° S, 165.62° E). The Pacific Islands are clustered into three distinct ethnogeographic regions: Micronesia (Palau east to the Tungaru (Gilbert Islands of Kiribati), north to Enen Kio (Wake Island) and the Northern Mariana Islands); Melanesia (Papua New Guinea east to Viti (Fiji) and south to Norfolk Island); and Polynesia (Hawai'i south to Aotearoa (New Zealand), east to Rapa Nui (Easter Island) (McKenzie et al. 2021a). There is no evidence of dugongs occurring in Polynesia and the Polynesian islands are not considered further here.

Within the Pacific region, dugongs are reported from the following Range States (ordered north to south): in Micronesia: Republic of Palau (henceforth Palau); in Melanesia: Papua New Guinea (henceforth PNG), Solomon Islands, Vanuatu, and New Caledonia (Figure 9.1). The Range States in the Pacific Islands have a total coastline length of 18,911 km. These countries are mostly surrounded by narrow areas of shallow water with barrier and fringing reefs (Figure 9.2), a very different situation from the habitats of the Australian dugong populations (Cleguer et al. 2024).

Throughout the Pacific Island region, dugong populations are fragmented and at risk of local extinction, posing significant challenges to their long-term viability (Marsh 2017; Pilcher et al. 2017; Cleguer et al. 2020a; Hamél et al. 2023). Summary details are presented below:

- Palau in southwest Micronesia (Figure 9.3), has a 1,519 km coastline comprised of approximately 700 islands and islets surrounded by a barrier and fringing reef complex which forms a vast lagoon spanning over 1,200 km² (Wabnitz et al. 2018; Andrew et al. 2019). Palau is ~ 860 km northeast of Indonesia, ~ 900 km east of the Philippines and ~ 450 km southwest of Yap. The Palau dugong population is the world's most isolated (Marsh et al. 2011; Marsh and Sobtzick, 2019).
- There are very few records of dugongs from the waters of the Micronesian Islands of Yap (Buden and Haglelgam 2010) and Guam (Nishiwaki et al. 1979; Eldredge 2003). There is no evidence of a resident dugong population in Yap and Guam and the very few dugongs recorded there are believed to be vagrants (Buden and Haglelgam 2010).
- PNG, the largest Pacific Island country by area (World Bank 2022c), shares the island of New Guinea with the Indonesian province of West Papua (Chapter 7). PNG has a coastline of 5,152 km and adjoins Australia to the south and the Solomon Islands to the east (Figure 9.4). Dugongs are scattered along the entire mainland coast as well as its outer islands (Hudson

1976; Ligon and Hudson 1977). Dugongs in the Western Province of PNG are part of the Torres Strait population considered in Chapter 10.

- The Solomon Islands (Figure 9.5) has a coastline of 5,313 km and consist of two volcanic island chains: six major islands, plus 1,000 outer islands and atolls. The nation's marine territory exceeds 1.3 million km^2. The dugong population is widely distributed, but crucial aspects regarding population structure, size and ecology remain unknown (WorldFish 2018; Al-Asif et al. 2022).
- Vanuatu comprises 83 high islands, has 3,123 km of coastline, and is the eastern limit of dugong distribution in the Pacific (Marsh 2002; McKenzie et al. 2021a). It is ~ 150 km south of the nearest island in the Solomons. There are few details about the dugong population.
- New Caledonia is separated from the large Australian dugong populations (Chapter 10) by a minimum of 1,230 km of deep oceanic waters to the west. The archipelago of Vanuatu is separated from New Caledonia by a 350 km stretch of open water to the east (Garrigue et al. 2022). New Caledonia has a total coastline length of 2,254 km and is divided into three Provinces: The Southern, Northern, and Loyalty Islands Provinces (hereafter referred to as Province Sud, Province Nord and Iles Loyauté, respectively). Both Province Sud and Province Nord are located on the main island of Grande Terre (Figure 9.7). New Caledonia supports the largest known dugong populations in the region considered in this chapter (Cleguer et al. 2017).
- In 2018, a dugong washed ashore on the eastern coast of Viti Levu, Fiji (Hill-Lewenilovo et al. 2019). Fiji is separated from the nearest established dugong population in Vanuatu by 600 km of deep, open ocean. Although dugongs possess the capacity for such extensive travel, movements over such distances are relatively rare and are usually undertaken by sole, vagrant individuals (Deutsch et al. 2022). The animal reported in 2018 is considered vagrant and Fiji is not discussed further here.

Dugongs are seagrass community specialists (Marsh et al. 2011, 2018). Seagrass ecosystems contribute significantly to the quality of life of the region's traditional inhabitants in material and non-material ways (McKenzie et al. 2021a). The scarcity of seagrass, especially eastward across the Pacific, limits the range of the dugong (Secretariat of the Pacific Regional Environment Programme [SPREP] 2013). Despite the restricted area of seagrass habitat, the Pacific region exhibits a high diversity of seagrass species (McKenzie et al. 2021b). PNG and the Solomon Islands lie within the Coral Triangle (CT), a biodiverse marine ecoregion in the western Pacific Ocean, where up to 19 seagrass species are found (Al-Asif et al. 2022).

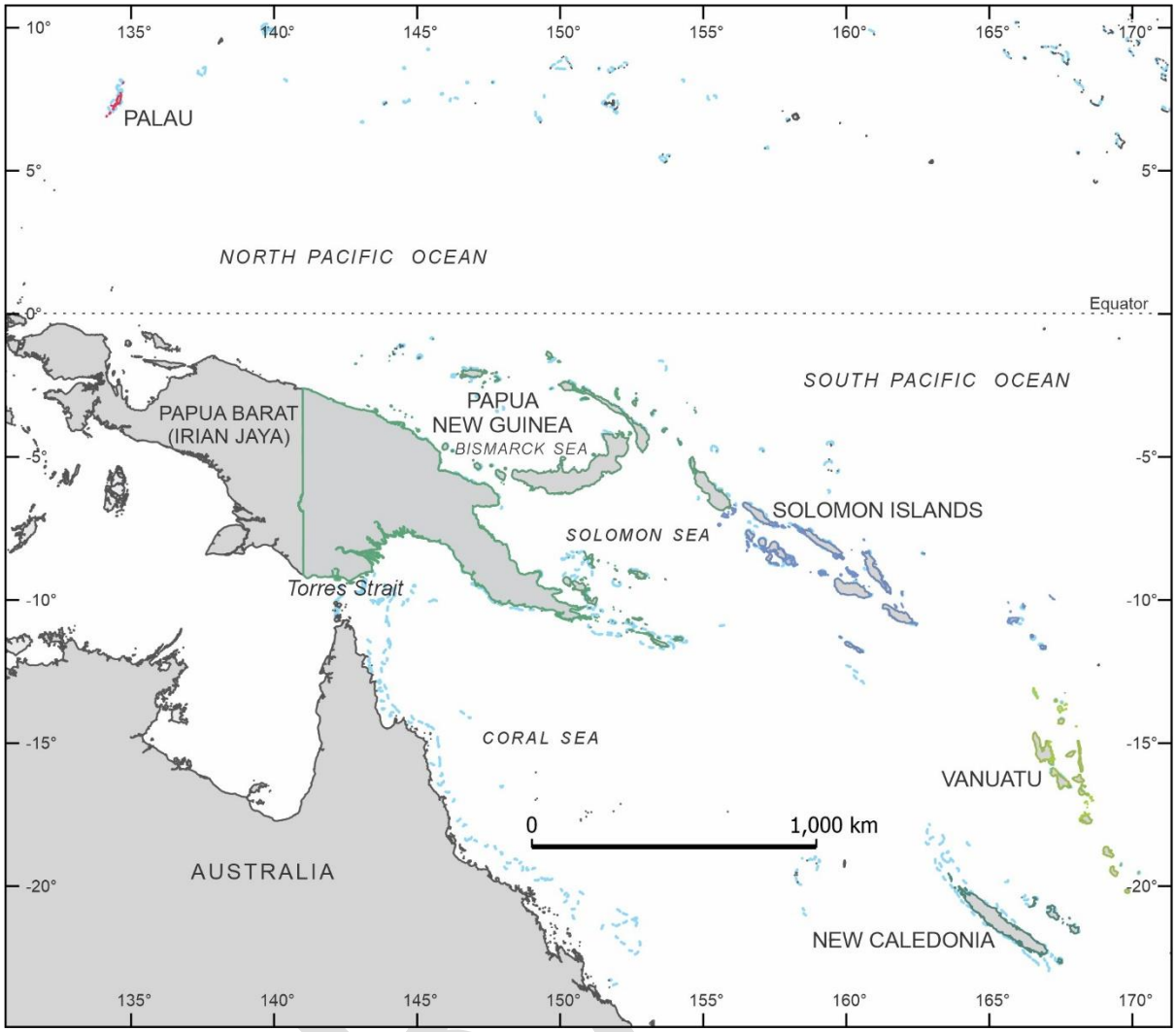

Figure 9.1. Geographic context of the dugong Range States (colored outlines) in the Pacific Islands region. Dugong Range States are ordered north to south with colored coastlines following: Palau (red), Papua New Guinea (PNG, green), Solomon Islands (blue), Vanuatu (orange) and New Caledonia (purple). Coral reefs are shown in blue dashed lines. Figure created by Adella Edwards; reproduced with permission.

Seagrass habitats in the Pacific region primarily occur in shallow waters (≤ 10 m) in five major habitat types: estuaries, bays and lagoons, fringing reefs, barrier reefs, and deep waters. The estimated extent of seagrass in the Pacific Island Countries and Territories (PICTs) is 1,446.2 km^2, ~ 84% (~ 1,219 km^2) of which is in Melanesia; ~ 10% in Micronesia (141.2 km^2) (McKenzie et al. 2020, 2021b). Summary details follow; see also Figure 9.2.

- Palau's seagrass is concentrated around intertidal sand flats along the east coast of the main island of Babeldaob to the sandy shallows of the Rock Islands (Figure 9.3), with the most extensive area (7 km^2) in the north of Peleliu Island (McKenzie et al. 2021b). Palau's seagrass

meadows span approximately 80 km^2 and are in protected lagoons, inshore waters, exposed fringing reef flats, and shallow, sheltered subtidal meadows (McKenzie et al. 2021b).

- Thirteen species of seagrass have been identified in PNG (McKenzie et al. 2021b). Seagrass is mostly concentrated in the southern part of the country. The area of seagrass is less in the eastern regions where meadows occur in sheltered bays, on the protected side of barrier reefs, and behind islands (McKenzie et al. 2021b). Locations with seagrass of note include: Manus Island (Seeadler Harbour), New Ireland, Port Moresby, Milne Bay province, Kavieng, Madang, Morobe, Rabaul, Kimbe, Western Province, and offshore islands like Lihir Island and Mussau Island (McKenzie et al. 2021b). The overall extent of seagrass is estimated to be ~ 573 km^2 (Skewes et al. 2003; Carter et al. 2023; L. McKenzie, unpublished data), however, large areas of potential seagrass supporting habitat remain unmapped (McKenzie et al. 2021b).
- In the Solomon Islands, ten species of seagrass have been recorded across the following locations: Roviana Lagoon (Western Province), Lau Lagoon, Small Malaita (Malaita Province), Tatamba (Isabel Province), Fauro Island, and Wagina Island (Choiseul Province) (McKenzie et al. 2006; McKenzie et al. 2021). *Enhalus acoroides* and *Thalassia hemprichii* are the dominant species throughout the Solomon Islands. The overall area of confirmed seagrass totals an estimated 79 km^2 with just over half occurring in Malaita Province (McKenzie et al. 2021b).
- In Vanuatu, seagrass is restricted to narrow fringing reef areas, sheltered lagoons, bays, and inlets (McKenzie et al. 2021b) over an area of ~ 27 km^2 (estimated from the Allen Coral Atlas 2020). Twelve seagrass species have been identified (McKenzie et al. 2021b).
- In New Caledonia, the total area of seagrass is estimated to be 983 km^2 (942 km^2 in shallow waters, an estimated 41 km^2 in turbid estuaries and an unknown extent in waters deeper than 10 m); 12 species have been reported (Andréfouet et al. 2021; McKenzie et al. 2021b). Most of the shallow seagrass can be found around Balabio, Moindou, Cap Goulvain and North Koné in estuaries, channels, reefs and lagoons (Andréfouet et al. 2021; McKenzie et al. 2021b). Aerial surveys and telemetry tracking conducted on the West coast of Grande Terre have provided insights suggesting the existence of regions with high dugong density (Cleguer et al. 2015) and/or areas extensively utilised by tracked dugongs (Cleguer 2015, Figure 4.8; Cleguer et al. 2020a). These areas likely feature both shallow and deep (> 10 m) seagrasses but had not been mapped as of March 2024. Comprehensive mapping, particularly on the reef/sandy flat lagoon zones located between the inshore intertidal habitats and the barrier

reef encompassing Cap Goulvain, Koné, Ouano, and the lagoon in front of the capital city of Noumea would likely increase the total area of seagrass present in New Caledonia.

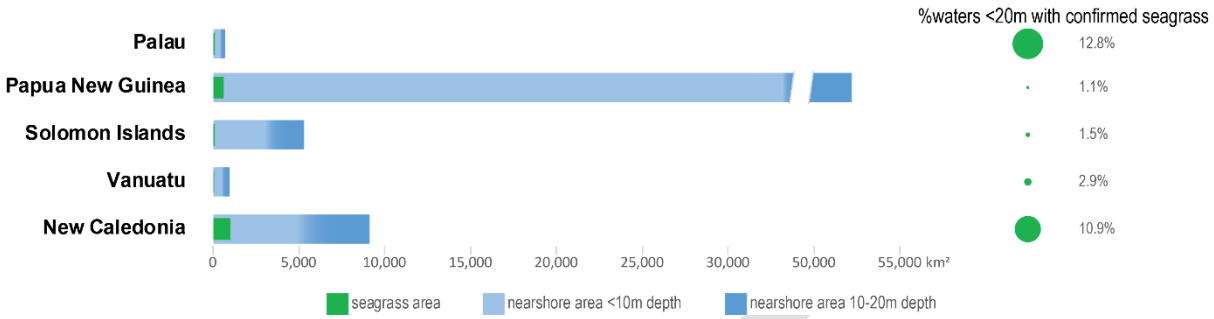

Figure 9.2. Histogram showing the known areas of seagrass and coastal waters < 10m and < 20 m deep for each dugong Range State in the Pacific Islands region. The areas of seagrass are almost certainly underestimates. Figure created by Len McKenzie; reproduced with permission.

9.1.2 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. The Pacific Islands in the dugong's range have an estimated combined human population of approximately 10.8 million people (United Nations, Department of Economic and Social Affairs [UNDESA] (2022a,b). These nations possess significant natural resources and remarkable linguistic and cultural diversity. Fifty-two percent of Pacific Islanders living in dugong Range States in this region reside within 10 km of the coast. They face challenges such as geographical isolation, high local population densities, and extreme vulnerability to the effects of climate change. These nations are among the world's most susceptible to many natural disasters due to their proximity to underwater fault boundaries and reliance on the ocean (Andrew et al. 2019). These challenges are expected to intensify with climate change, profoundly affecting coastal and marine habitats and those dependent on them (Andrew et al. 2019; Johnson et al. 2023).

The region's vulnerability to natural disasters presents formidable constraints to development, including the economic growth required to provide social services, infrastructure and employment for their young populations, at least half of which are aged under 23. China's growing engagement in the Pacific has seen an influx of new international partners and increased access to much-needed finance for Pacific Island countries (Clare 2022).

Palau has a High Human Development Index (HDI) of 0.767 (ranked 80), a gross domestic product (GDP) of USD 218 million and a population of ~ 18,000 in 2022 (World Bank 2022b). The nation relies on its marine resources, which include both subsistence and commercial fisheries as well as tourism,

all of which contribute significantly to its GDP and employment (Wabnitz et al. 2018). Palau has actively pursued conservation initiatives to safeguard marine resources, promote ecotourism, and ensure sustainable revenue generation since 1992 (Wabnitz et al. 2018). In 2009, Palau was the first county in the world to ban commercial fishing of sharks in its Exclusive Economic zone (EEZ) in favour of dive tourism (Ward-Paige and Worm 2017).

PNG has a HDI of 0.558 (ranked 157), a GDP of USD 30.63 billion and a 2022 population of ~ 10.1 million (World Bank 2022c). Since the 1970s, mining has dominated the nation's economy, but has long been criticised for its negative environmental and social impacts (Yamarak and Parton 2023). As a developing country (UNDESA 2022a), PNG is faced with challenges in delivering sustainable livelihoods. Large-scale mining investment allegedly brings employment opportunities, infrastructure development and more advanced education and health services. Nonetheless, many local communities experience the opposite, with mining investments benefiting only a minority (Yamarak and Parton 2023).

The marine resources in PNG are essential for the economic well-being of rural, coastal areas. However, the growing coastal population has led to an increase in subsistence and small-scale fishing, posing a severe threat to the sustainability of coastal fish stocks (Asian Development Bank 2014). Unsustainable fishing methods and inadequate conservation efforts have raised significant concerns (Asian Development Bank 2014). Excessive extraction has led to the rapid disappearance of mangrove forests, particularly in the Gulf of Papua, worsening environmental challenges in the region (Asian Development Bank 2014). The porous international boundaries between PNG, Australia, and Indonesia have worsened these issues, which are expected to be further exacerbated by climate change (Stoeckl et al. 2018).

The **Solomon Islands** has a HDI of 0.564 (ranked 155), a GDP of USD 1.6 billion and a fast-growing population of ~ 724,000 in 2022 (World Bank 2022d). The islands are rich in timber, which contributes 20% to domestic revenue and > 70 % of exports. Timber resources have been over-exploited and are facing depletion. Fisheries, an important source of revenue and employment, now comprises 12% of exports (World Trade Organization 2009). Exploitable mineral resources remain largely undeveloped as low value-added commodity production. The country has a history of internal unrest driven by lingering ethnic conflict and a perceived unequal distribution of resources. These tensions erupted into riots in the capital Honiara in November 2021, from which the country is still recovering (United Nations Committee for Development Policy [UNCDP] 2023a).

Vanuatu has a HDI of 0.607 (ranked 142), a GDP of USD 983 million and a population of ~ 327,000 in 2022 (World Bank 2022e). Tourism is Vanuatu's main source of income, and the country's economy

has suffered greatly in recent years from the combined effects of the COVID pandemic and tropical cyclone Harold in 2020 (UNCDP 2023b).

New Caledonia is an overseas territory of France, a country with a Very High HDI of 0.903 (ranked 23). New Caledonia had a GDP of USD 10.07 billion and a population of ~ 277,000 in 2022 (World Bank 2022a). New Caledonia is a major nickel exporter and a luxury eco-tourism destination and receives considerable aid from France (Central Intelligence Agency [CIA] 2023). The Noumea Accord of 1998 was designed to remedy the disadvantages of the indigenous Kanak population and foster a supportive relationship between the Kanak and French settlers (Blaise 2017). Negotiations between the French state, separatists, and loyalists are ongoing over the institutional future of the territory post-Accord. The territory had been beset by political uncertainty for several years, at the time of writing in March 2024.

Table 9.1. Human Development status and rank and Gross Domestic Product per capita rank of the countries of the Pacific Islands region. Consistent with the remainder of this chapter, the countries in this table are ordered north to south, west to east starting with Palau. The ranks are ordered so that countries with the highest HDI or GDP have the lowest ranks. 189 countries were ranked for both indices.

Range State	HDI	HDI Rank 2023[1]	GDP per capita rank[2]
Palau	High	80	100
PNG	Medium	156	160
Solomon Islands	Medium	155	174
Vanuatu	Medium	140	167
New Caledonia[3]	Very High	23	59

[1] 2023 HDI data from https://hdr.undp.org/data-center/country-insights#/ranks (downloaded from the internet January 2024);

[2] 2023 per capita GDP from https://en.wikipedia.org/wiki/List_of_countries_by_GDP_(PPP)_per_capita (downloaded from the internet January 2024).

[3] France's 2023 HDI data is used as New Caledonia is a Non-Self-Governing Territory of France.

9.1.3 Genetics of dugong sub-populations

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

The only study with a specific focus on the region was conducted in New Caledonia (Garrigue et al. 2022) and identified as a population, which is distinct from all other dugong populations, including those in eastern Australia. The 55 dugongs sampled in New Caledonia exhibited very little diversity in

their mitochondrial control-region sequences: 53 of these shared the same haplotype, which belonged to the widespread haplogroup found around the coast of Australia (Figure 1. X). The remaining two possessed haplotypes differing at a single site from the common haplotype (Garrigue et al. 2022). Similar low genetic diversity was noted based on microsatellite data (Garrigue et al. 2015). The New Caledonian dugongs exhibited very low values for numbers of alleles and for observed heterozygosity and allelic richness, compared to Australian populations. There was no evidence of inbreeding among New Caledonian dugongs, but some evidence of a genetic bottleneck (Garrigue et al. 2015).

Available data suggests that the present-day population of dugongs in New Caledonia arose from a very small, relatively recent founder event (Garrigue et al. 2022), raising the possibility of ice-age refugial bottlenecks. Certainly, habitat suitable for dugongs would have been non-existent or limited at the last glacial maximum, around 20 kya (Ludt and Rocha 2014), suggesting post-glacial dispersal to New Caledonia from elsewhere. This could have been via the Melanesian Island Arc: short mitochondrial sequences from a dugong from Vanuatu and one from Solomon Islands were compatible with the common New Caledonian haplotype (Oremus 2011; Garrigue et al. 2015; Garrigue at al. 2022). Another possibility is direct colonisation from the central part of the Queensland coast (Garrigue et al. 2015), requiring an open water crossing of at least 1,330 km.

Little is known about the genetic structure of dugong populations in PNG. It is very likely that dugongs along most of the southern coast might belong to the same populations as those in northern Australia (Torres Strait, Gulf of Carpentaria and Northern Territory). Those Australian populations belong to the widespread haplogroup (except in Torres Strait, where the restricted haplogroup is also present; see Chapter 10). Some shorter sequences from specimens held in German museums and collected (where known) around 1912 during German administration of the northern half of present-day PNG, were reported by Plön et al. (2019). Three of these, belonging to the Australian widespread haplogroup (Chapter 10), were from New Britain Island. A further two sequences belonging to this haplogroup were from unspecified localities but are likely also from the same area. Interestingly, one specimen (MH704269) from the Berlin Museum für Naturkunde and reported as from New Ireland, belongs to the Western Indian Ocean haplogroup (Chapters 2-4), and therefore represents the easternmost occurrence of this haplogroup. As mentioned in Chapter 7, the only sequence from western New Guinea Island, part of Indonesia, belonged to the northeastern haplogroup (See Plön et al. 2019).

Like New Caledonia, Palau in the tropical Western Pacific is at the periphery of the dugong's range. The usual expectation is that populations at peripheral locations will exhibit limited genetic diversity.

Certainly, that is the case for both New Caledonia and Palau. Seven mitochondrial partial control region sequences are available from Palau. The samples were from salvaged animals found dead or dying in waters around Palau between 2003 and 2013. All sequences are identical to GenBank accession EU835816 and belong to the northeastern haplogroup (Figure 1.x). This haplotype only differs at one site from one of the common haplotypes found on both sides of the Isthmus of Kra (Thailand), about 4,000 km from Palau.

- New Caledonia is the only country in the region where any substantial genetic study has been carried out. All individuals belong to the Australasian widespread haplogroup.
- Both mitochondrial and nuclear genetic data indicate that dugongs in New Caledonia have a very narrow genetic base.

9.2 Dugong distribution, abundance and trends in range states

9.2.1 Palau

Information regarding the ecology and current status of the dugong population is limited (Glover 2023). In a series of shoreline aerial surveys between 1977 and 2007, sections of Palauan waters were surveyed for dugongs (Brownell et al. 1981; Rathbun et al. 1988; Marsh et al. 1995; Marino et al. 2008). Each of these surveys sighted a total of between 26 and 38 dugongs.

Aerial surveys flown between September 2009 and March 2011 covered an estimated area of 292 km^2 in and around Malakal Harbor (Coral Reef Research Foundation [CRRF] 2012). A total of 912 dugongs were recorded during 192 flights over 140 days. Many of these records would have been resightings. Thus, it is certain that this is an overestimate of the dugong population in Palau (CRRF 2012). The highest numbers of sightings were around the following sites: 43% (n=396) offshore Ngederrak, 24% (n=220) in west Malakal Harbor, and 21% (n=187) in the Ngederrak Conservation Area (CRRF 2012). The Report of Pacific Islands Regional Dugong and Seagrass Conservation (Dugong and Seagrass Conservation Project 2018) noted the uncertainty in the size of the Palauan dugong population, estimating it to be ~ 50 to 100 individuals.

Extensive drone flights (n=134) across 539 km in Ngederrak and Lighthouse Reefs (Figure 9.3) in 2018/2019 recorded 521 dugong sightings (Jaiteh et al. 2020) including likely recounts. Seventy-seven percent of the flights (n=103) were flown in the Ngederrak Marine Protected Area (MPA); the remaining 21% (n=31) were flown in adjacent areas including Lighthouse Reef and Malakal Harbor. Only 2% (n=9) of the dugong sightings were recorded in the flights outside the MPA (Jaiteh et al. 2020). The largest observed herd included 59 dugongs; the average group size was seven (Jaiteh et al. 2020).

None of these surveys can be used to estimate the overall population size or trends of dugongs in Palauan waters despite considerable investment over nearly 50 years.

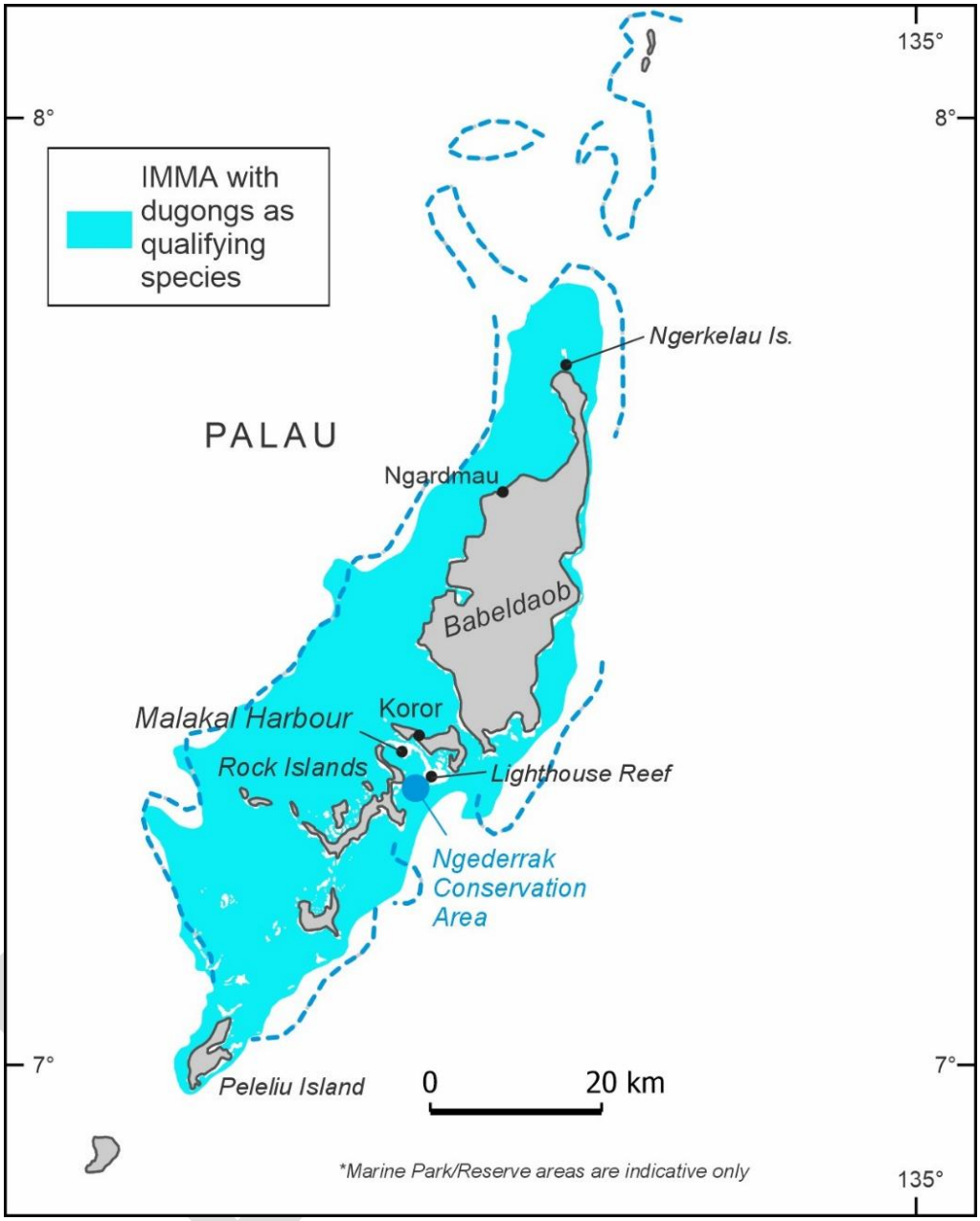

Figure 9.3. Geographic context of Palau with placenames mentioned in the text. Coral reefs are shown in dashed blue lines. Figure created by Adella Edwards; reproduced with permission.

- Palau supports a small, isolated population of dugongs.
- Despite considerable investment over 50 years, information regarding the status of the dugong in Palauan waters is insufficient to estimate the overall population size or trends.

9.2.2 Papua New Guinea (PNG)

Dugongs occur in many coastal locations throughout PNG including the Torres Strait, which is considered in Chapter 10. A postal survey conducted by Ligon and Hudson (1977) in 1973-7 reported dugong sightings along the northern coast from the border with Papua Barat (West Papua) to the Sepik River mouth, around Madang and from the Fly River mouth southwest to the southern border with West Papua, as well as the islands of Manus and West New Britain. Ligon and Hudson (1977) also sighted 186 dugongs (14 calves) in a shoreline aerial survey along ~ 1,200 km of PNG coast (Daru-Warrior Reef area in Torres Strait; the south-Eastern Papuan coast; the Lae area; the northwest coast of West New Britain Province; and the northwest coast) in April 1975. Fifty-six percent of sightings were of solitary animals or small groups; the only large groups (28 and 39 animals) were on the Warrior Reef in Torres Strait (see Chapter 10). Ligon and Hudson (1977) concluded that their sightings were an underestimate of dugong numbers.

Bass (2010) conducted an interview survey in Manus and Bougainville in 2008. In Manus, interviews conducted in 13 locations reported sighting totals of 64 adult dugongs and 18 calves in the first three months of 2008. Respondents collectively reported a total of 187 adults and 48 calves since 2005, with respondents estimating having seen a total of 952 dugongs in the past five years, which must have included many resightings of individual dugongs. In Bougainville, interviews conducted in 25 locations across five survey areas from January to February 2008 reported 20 adults and 10 calves. Overall, from 2007 to 2008, 37 adults and 17 calves were reported. Significant numbers of dugongs were reported from various locations in both Manus and Bougainville provinces.

Beasley and Mavea (2019) conducted interview surveys with the local community and fishers in the Kikori Delta region; the respondents indicated that dugongs occurred there. However, no dugongs were observed during the vessel surveys that the authors carried out between December 2013 and February 2015.

Despite these surveys, the overall population size of the dugong population of PNG is unknown.

The PNG dugong population allegedly began to decline in the late 1970s due to the establishment of the barramundi and lobster fisheries, which brought monofilament gillnets to the country (Kare 1995). However, this has not been confirmed.

Excluding Torres Strait (Chapter 10), the only IMMA in PNG waters relevant to dugongs is the Kikori Delta IMMA. Although the dugong is not listed as a qualifying species, it contributes to the marine mammal diversity of this IMMA (IUCN-MMPATF 2021a).

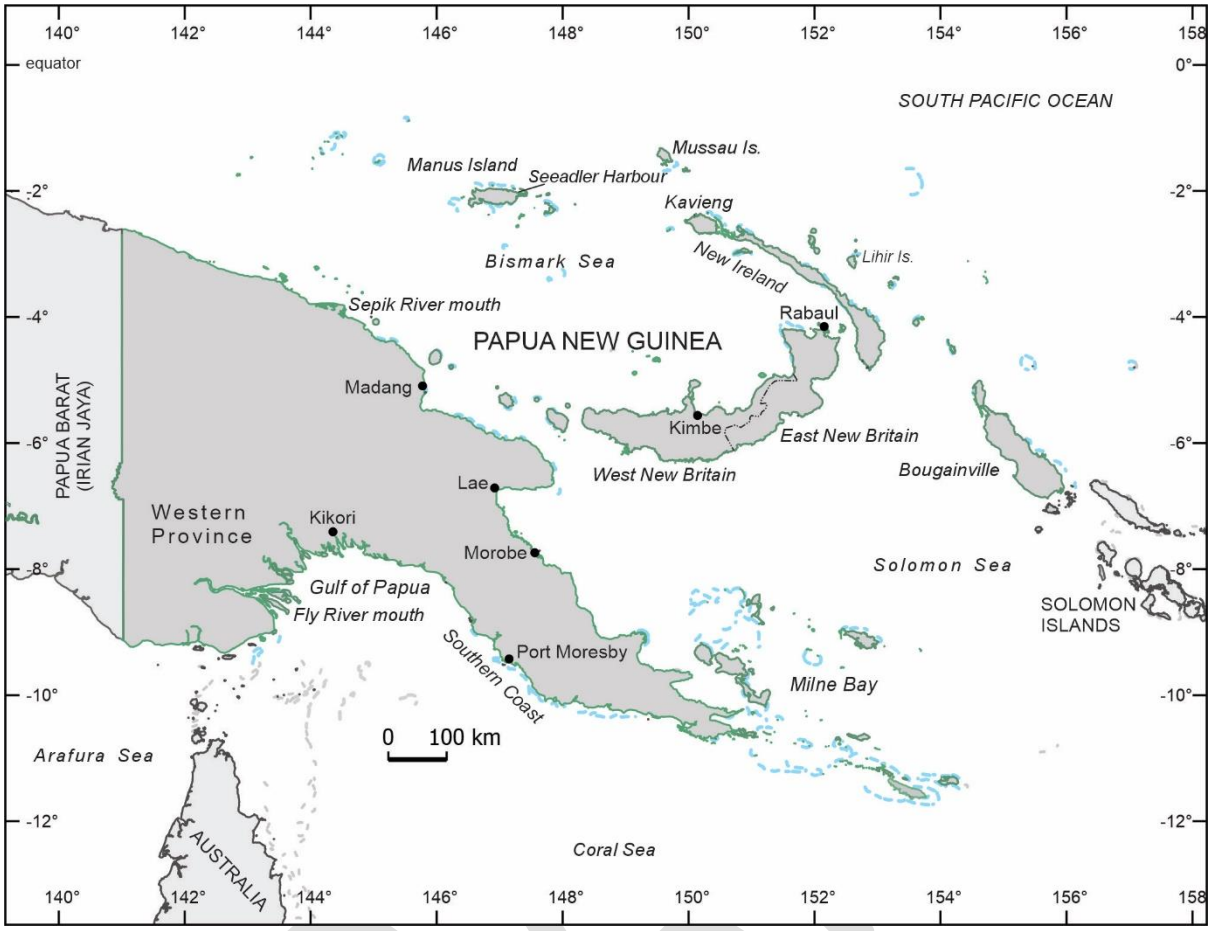

Figure 9.4. Geographic context of Papua New Guinea (PNG) (outlined in green) with locations mentioned in the main text. PNG coral reefs are shown in blue. Figure created by Adella Edwards; reproduced with permission.

- Information regarding the status of the dugong in the waters of PNG is insufficient to estimate its distribution, population size or trends.
- It is likely that dugongs are widely distributed in the coastal waters of PNG.

9.2.3 Solomon Islands

Bass (2010) used interview surveys to obtain basic information on the distribution of dugongs in the Solomon Islands. They conducted 98 interviews across 19 villages in six provinces between January and February 2009. A total of 300 sightings of dugongs (248 adults; 52 calves) were reported in the 12 months prior to the survey (Bass 2010). Western Province had the highest percentage of sightings (29%, n= 91) followed by Malaita (27%, n=82), Isabel (23%, n=69), Guadalcanal (10%, n=30), Choiseul (8%, n=24) and Central Province (2.6%, n=8) (Bass 2010) (Figure 9.5). Fifty-one sightings were reported from Lau lagoon alone (Malaita Province), 38 along the Samasodu coast (Isabel Province), 30 in northeast Malaita (Malaita Province), 37 in Honiara (Guadalcanal Province). The remaining 154

reported sightings were scattered throughout the six provinces. Malaita had the most sightings over the previous 10 years, with 237 total sightings (32%), followed by Isabel (24%, n=175), Western (21%, n=157), Guadalcanal (14%, n=101), Central Province (6%, n=46) and Choiseul (4%, n=26) (Bass 2010). These results suggest that dugongs are widely distributed in the Solomons but cannot be used to estimate abundance or population trends.

The project conducted by the Global Environment Facility (GEF) in the Solomon Islands is considered in Section 9.5.3.

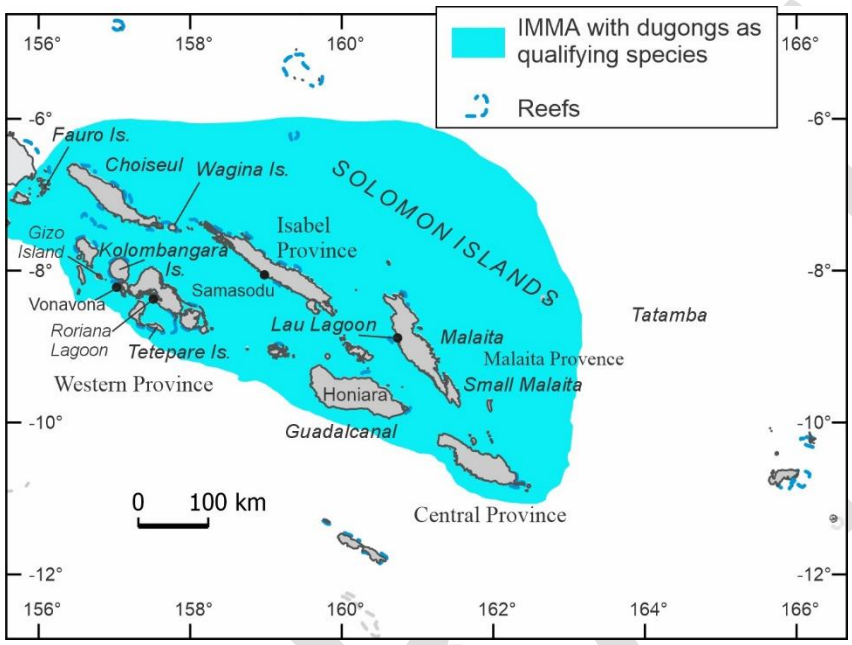

Figure 9.5 Geographic context of the Solomon Islands with locations mentioned in the text and the Main Solomon Islands IMMA is shown in blue. Figure created by Adella Edwards; reproduced with permission.

The Main Solomon Islands IMMA encompasses the coastal and offshore waters of the main group of Solomon Islands. Dugongs are believed to be widely distributed within the IMMA and are one of the qualifying species (IUCN-MMPATF 2021b).

- Information regarding the status of the dugong in the waters of the Solomon Islands is insufficient to estimate its distribution, population size or trends.
- Dugongs are widely distributed within the islands.

9.2.4 Vanuatu

The size and status of the fragmented dugong population in Vanuatu are unknown (SPREP 2011; Dugong and Seagrass Conservation Project 2018). To date, one aerial survey has been carried out to assess the distribution, abundance, cultural importance, and threats faced by dugongs in Vanuatu (Chambers et al. 1989). Only 11 dugongs were sighted: five individual animals, two cow-calf pairs, and one pair of adults. Chambers et al. (1989) concluded that small groups of dugongs occurred in

coastal waters from Aneityum in the south to the Torres Islands in the north, an assessment that accords with the 2016-17 questionnaire findings (Figure 9.6).

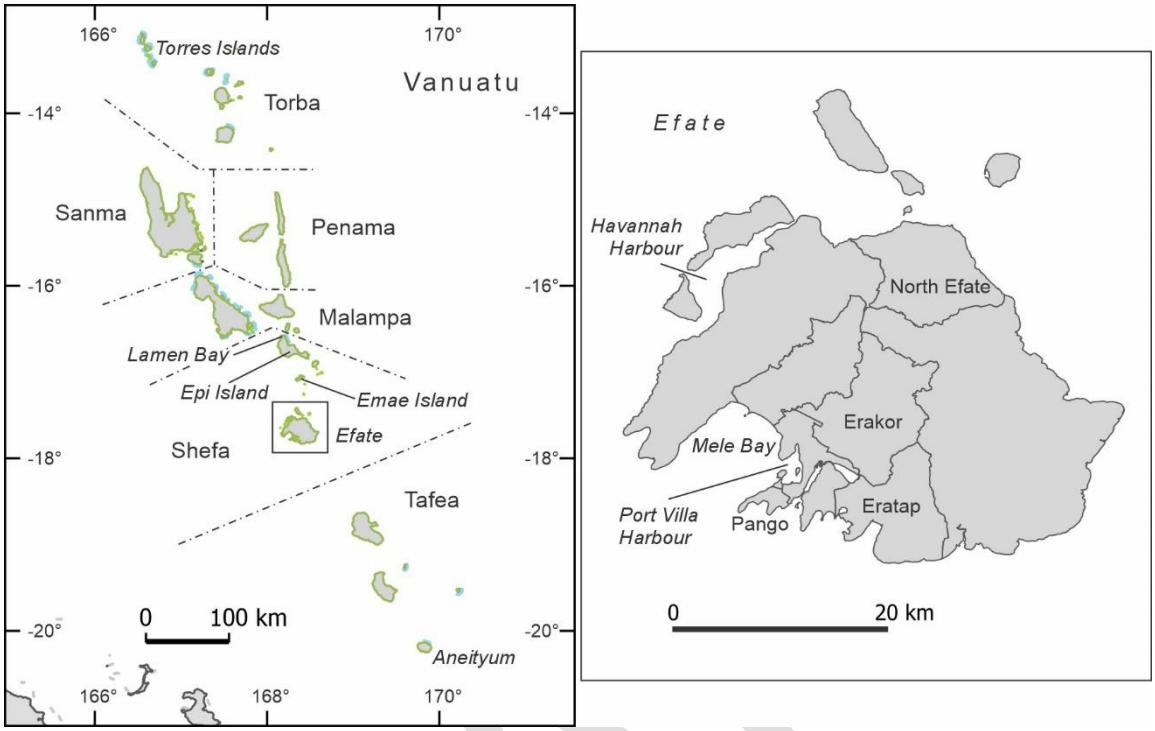

Figure 9.6. Geographic context of the islands of Vanuatu (left) and Efate Island (right, see box in left figure) with placenames mentioned in the text. Coral reefs are shown in blue dashed lines. Figure created by Adella Edwards; reproduced with permission.

The Vanuatu Environmental Science Society used the standardised CMS Dugong MOU catch/bycatch questionnaire to survey fishers over 32 islands across Vanuatu's six provinces in 2016-2017 (Shaw 2017). Five hundred and thirty-seven people were interviewed with most (65%) aged between 25 and 50. Thirty-two percent of respondents reported sighting dugongs every month in the previous year though most agreed that numbers are low with 27% estimating that only a single dugong lived close to their village and 47% estimating only two (Shaw 2017). Twenty dugong areas of local importance were identified based on these reports: five in each of the provinces of Shefa and Torba, three in Malampa, two in Sanma, and one in Tafea (Shaw 2017).

The waters of Vanuatu Archipelago are an Area of Interest (AoI) for a IMMA with the dugong listed as an important species (IUCN-MMPATF).

Section 9.5.3 includes information about the GEF project in Vanuatu.

- The status and size of the dugong population in Vanuatu are unknown.
- It is likely that the population is small, fragmented and widely distributed among the islands.

9.2.5 New Caledonia

Most of the information on the distribution and relative abundance of dugongs in New Caledonia comes from six standardised, large-scale aerial surveys conducted since 2003 based on the techniques developed in Australia (Chapter 10).

The 2003 survey covered 18,128 km^2 across all the lagoons surrounding the main island of Grande Terre, from Iles Bélep in the north, to the Ile des pins in the south (Garrigue et al. 2008) (Figure 9.7). Iles Loyautê were not surveyed due to a lack of evidence of substantial numbers of dugongs using these areas (Garrigue et al. 2008) at the time of the survey. Locals subsequently reported two individuals in 2015, one in Lifou and the other in Ouvéa (Cleguer and Garrigue 2018). Hamél et al. (2023) concluded that the number of dugongs in the Iles Loyauté is likely to be small.

Dugong abundance estimates from all these aerial surveys were originally corrected for availability and perception biases using the *Pollock Method* (Garrigue et al. 2008, 2009; Cleguer et al. 2017). These estimates were revised by Hagihara et al. (2018) using their method, which is considered superior to the *Pollock Method*, because it accounts for differences in the detectability of dugongs based on water depth. The *Hagihara Method* estimates are provided below.

Three hundred and twenty-three dugongs (including 37 calves) were sighted in the 2003 survey: 125 dugongs on transects, 29 dugongs outside the transect, and 169 dugongs during transit flights (Garrigue et al. 2008). The minimum population of dugongs based on the 2003 survey was 1,588 ± SE 407 individuals (*Hagihara Method*). Garrigue et al. (2009) repeated the 2003 survey between January and March 2008 with the aim of investigating seasonal variations in dugong distribution and abundance. The population estimate was 426 ± SE 134 individuals (*Hagihara Method*), much lower than the 2003 estimate, a concerning result.

Four aerial surveys were subsequently flown in June and November 2011 and 2012 (Cleguer et al. 2017) with a view to: (1) understanding the differences between the 2003 and 2008 surveys, and (2) exploring seasonal variations in dugong distribution and numbers. Population abundance for the last two surveys (*Hagihara Method*) were 1,166 ± SE 293 (cool season) and 792 ± SE 212 (warm season) with no consistent seasonal trend.

It is unclear whether the discrepancy between the 2003 estimate and the 2008-2011 estimates is a result of effects of variation in environmental conditions, dugong behaviour, sampling bias, or a real decline in the New Caledonian dugong population (Cleguer et al. 2017). The mean proportion of calves increased from 7.4% in June 2003 to 18.0% in June 2011, before decreasing to 4.7% in November 2012 (Cleguer et al. 2017).

For the first time in New Caledonia, an aerial imagery survey was trialled in 2018 to: (1) detect

dugongs using a semi-automated imagery processing approach (using Artificial Intelligence (AI) and manual reviews of images) and (2) estimate their abundance (Duclos et al. 2019). Differences in the survey design and data analysis hampered the comparison of the imagery survey with previous observer-based aerial surveys. At the time of writing (March 2024), New Caledonia was overdue for a standardised survey to help assess trends in the dugong population (Hamél et al. 2023).

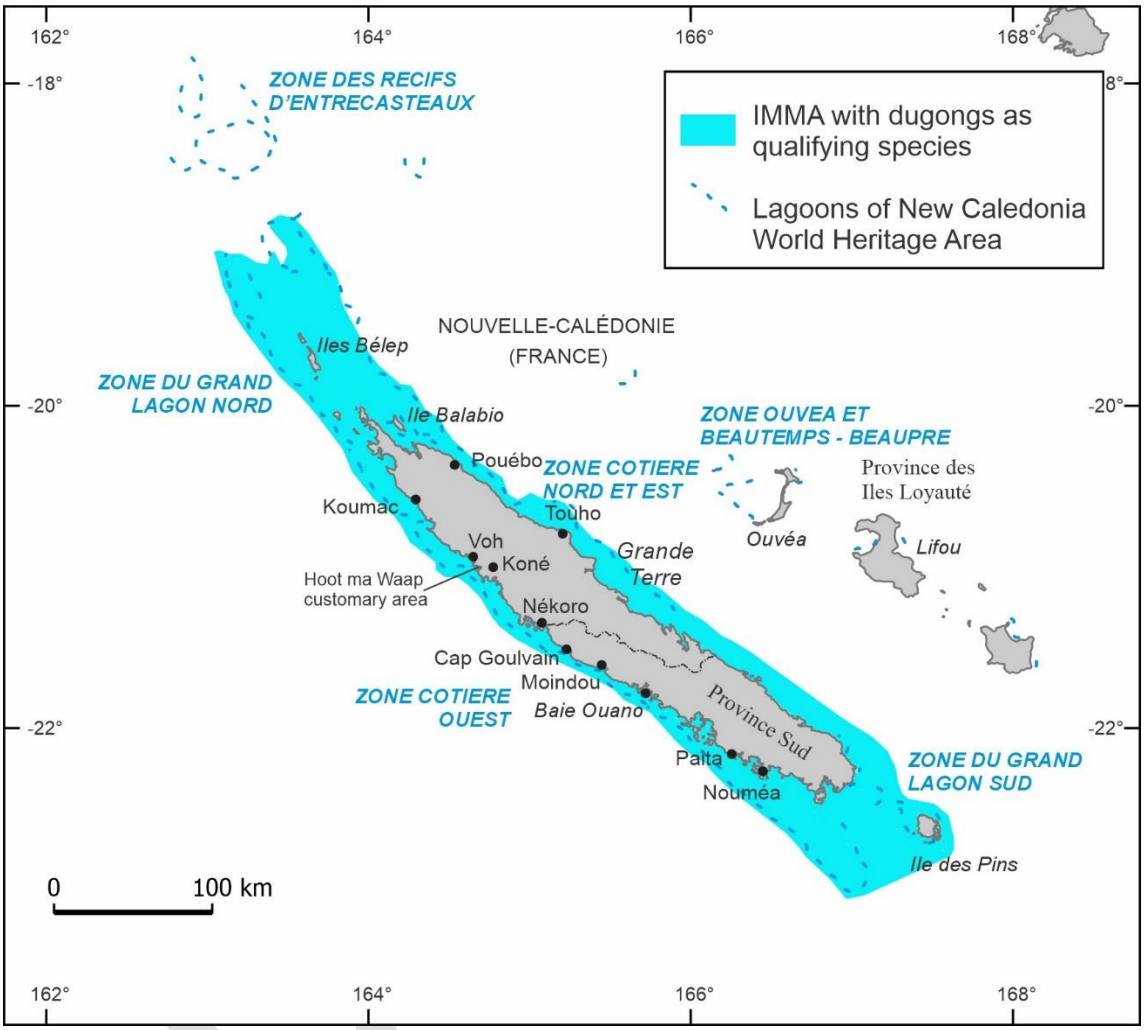

Figure 9.7 Geographic context of New Caledonia with placenames mentioned in the text. The New Caledonian Lagoons and Shelf Waters IMMA is shown in blue. Lagoons of the New Caledonia World Heritage Area are shown in blue dashed lines. Figure created by Adella Edwards; reproduced with permission.

Dugong distribution in New Caledonia reflects the distribution and composition of seagrass meadows on the western coasts of the islands (Cleguer et al. 2020a; Derville et al. 2022). Cleguer et al. (2015) developed a spatial model of dugong distribution and relative abundance in Grande Terre based on the data collected between 2003 and 2012 (Garrigue et al. 2008, 2009, 2011, 2012; see Cleguer et al. 2017). Areas of high dugong relative density were situated: (1) on the west coast including areas near Koumac, north of Voh, near and south of Nékoro, Moindou, and between

Nouméa and Païta, and (2) on the north-east coast between Pouébo and Touho (Cleguer et al. 2015) (Figure 9.). Cap Goulvain, which supports an intertidal seagrass meadow of 17 km^2 (Cleguer et al. 2020a), was identified as an area with a very high dugong relative density, making it the most important location for dugongs in New Caledonia (Cleguer et al. 2015). A retrospective spatial analysis of the network of Marine Protected Areas (MPAs) as of 2015, combined with dugong distribution data, suggested that the species had benefited from a modest level of protection afforded by MPAs (Cleguer et al. 2015).

The New Caledonian Lagoons and Shelf Waters IMMA was listed in 2021 with dugongs as a qualifying species (IUCN-MMPATF 2021c).

- Most of the information on the distribution and relative abundance of dugongs in New Caledonia comes from six dedicated standardised aerial surveys conducted between 2003 and 2011.
- All population estimates have been corrected for detection biases. They surveys suggest that New Caledonian water support several hundred dugongs.
- IUCN listed the New Caledonia 'subpopulation' as Endangered in 2022.
- The 'New Caledonian Lagoons and Shelf Waters IMMA was listed in 2021 with dugongs as a qualifying species.
- The dugong population is explicitly cited as an attribute of the Outstanding Universal Value in the 'Lagoons of New Caledonia' World Heritage property.

9.3 Cultural values

Dugongs are of great importance to many Pacific Islanders and are an essential element of their maritime culture (Dobbs et al. 2012). Dugongs are often featured in paintings, carvings, and other artefacts. Islanders once valued the dugong as an important food source used during the initiation of village chiefs, a totem that maintains many cultural practices, and for the development of the personal identity as hunters. Additionally, dugong body parts are used for making traditional items like drums, spoons, scrapers, and necklaces (Ingram et al. 2022; Glover 2023).

Dugongs are known as *Mesekiu* by Palauans, who have long caught dugongs for consumption and traditional use (Glover 2023). Traditionally, dugong meat was reserved for chiefs of the highest rank, and hunting dugongs was permitted only for select villages, reducing the likelihood of unsustainable harvest (Johannes 1981). Hunting tenure was controlled by chiefs, who often limited harvesting of dugongs and turtle (Putney 2008). Dugong vertebrae were worn as bracelets by high-ranking Palauan men, who sometimes broke their hands in the process of donning them (Glover 2023).

Figure 9.8. Dugong vertebrae worn as a bracelet by a high-ranking Palauan man. ©Juergen Freund/naturepl.com.

Today, dugong meat is seldom consumed by Solomon Islanders on Gizo and Kolombangara islands (Figure 9.5) due to the practice of the Seventh Day Adventist religion. Nonetheless, Gilbertese people residing on the islands do not share the same beliefs and are reported to actively hunt the dugong (Bass 2010). Islanders residing in the Central Province consider the dugong sacred and do not consume its meat due to the belief that a pregnant woman once committed suicide by jumping from a cliff and was reincarnated as a dugong with a newborn calf (Bass 2010).

Traditional use of dugongs in Vanuatu is not mentioned in the report of the Vanuatu CMS dugong catch/by-catch survey 2015-17 (Shaw 2017), which interviewed 252 people.

In the Melanesian community of New Caledonia, the dugong is considered as a common ancestor (Dupont 2015). It has historically been used in various traditional ceremonies, such as marriages or funerals of important people and traditional customary purposes such as yam feasts (Garrigue et al. 2008). In the Hoot ma Waap customary area in Province Nord, a dugong was required for celebrations marking the wedding or death of a chief or their first brother, as well as the inauguration of a new chief (Garrigue et al. 2008). Dugong hunting is now restricted in New Caledonia by statutory regulations, which prohibit hunting in the province Sud and require special permits in the province Nord and province des Iles Loyauté (Resolution 68 dated 25 June 1963; Province Nord 2008, Province Sud 2009). Such harvest permits can be issued for Melanesian customary ceremonies in the provinces Nord and Iles Loyauté. However, none have been issued since 2003 (Resolution 68 dated 25 June 1963; Province Nord 2008, Province Sud 2009).

9. 4 Threatening processes

Outside New Caledonia, there is a notable gap in the identification and quantification of the threats faced by dugongs in the Pacific region. This deficiency is exacerbated by inconsistent research, survey, and monitoring methods and initiatives (SPREP 2011).

Another challenge is the limited development of public awareness and educational programs, especially in PNG and the Solomon Islands. There is a shortage of local expertise and leadership in marine species research and conservation management. The absence of effective management and prioritisation mechanisms compounds the issue. For example, Cleguer et al. (2015) developed a spatially explicit model of dugong distribution and relative density in New Caledonia based on the 10-year time series of aerial surveys (see Section 9.2.5). The model demonstrated that most (74%) of the areas of high dugong density were not protected by MPAs because information on dugong distribution had not been available at the time of their design and therefore not considered. Adding to these challenges is the scarcity of resources essential for conservation efforts and the limited effective communication and collaboration both nationally and regionally.

Hendriks and Baird (2022) categorised threats to dugong in the Pacific Islands into two types: those that cause direct dugong mortality, and indirect threats that result in dugong habitat loss or degradation, which in turn, negatively affect fecundity. As dugongs are long-lived, slow breeding mammals, threats to mortality and are likely to be more serious than threats to fecundity (Marsh et al. 2011).

Some examples of the threats identified by Hendriks and Baird (2022) are considered below. The impacts of these threats are cumulative. The impact of this threat is spatially variable across the region, but the overall lack of information precludes precise identification of impacted localities, except as identified below.

9.4.1 Direct threats to dugong mortality

- ***Harvesting for food, medicine, artefacts, and trade*:** Dugong have long been sought for their meat, oil, skin, bones, and teeth in the Pacific Islands region as explained above. Hunting is a key threat especially given the low numbers and unknown status of dugong populations in most areas. For most countries, it is unknown whether the level of harvest is sustainable, and there is concern about the increased use of outboard motors and gillnets to capture dugongs (SPREP 2011).

  Despite strict national laws prohibiting dugong capture, an average of five individuals are allegedly lost each year due to poaching and vessel strikes in Palau, with unreported

incidents likely causing additional losses. There are reports of hunters being paid up to USD 2,000 to illegally catch and kill dugongs for traditional uses (Glover 2023).

In the Solomon Islands, dugong hunting occurs within the Kiribati community of the Western Province, although it does not represent a primary food source (SPREP 2011). Reports of targeted dugong hunting for selling meat emerged in early 2017, particularly in Gizo, Western Province. In contrast, other communities, such as those in Lau Lagoon and West Guadalcanal, consider dugongs sacred, prohibiting their capture or consumption (Bass 2010; WorldFish 2018). In August 2018, activities such as fishing, retention, possession, purchase, and selling of dugongs were prohibited, punishable by a substantial fine, imprisonment, or both under the *Fisheries Management (Prohibited Activities) Regulations 2018 (L.N. No. 61 of 2018).*

Although regulations prohibit fishing for dugongs, poaching persists in New Caledonia. Thirteen percent of dugongs stranded between 1991 and 2022 showed traces of poaching, and several cases of poaching were discovered further inland (Garrigue et al. 2023; see IUCN assessment for summary and references).

- ***Incidental by-catch and destructive fishing methods****:* Many traditional fishing methods throughout the Pacific have been replaced by contemporary methods, resulting in negative impacts on Pacific marine ecosystems (Kare 1995; Bass 2010; Glover 2023). Incidental drowning of dugongs caught in fishing nets is now considered to be the predominate threat to dugongs in some Pacific Range States.

  In Palau, customary fishing methods such as spearfishing and the *ruul* (leaf sweep), a communal method fishing involving the use of coconut palm leaves woven together to form a barrier, have been replaced by trawling and long line fishing (Glover 2023). During World War II, dynamite (blast) fishing was introduced to feed military personnel. The practice has been banned, though there are still reports of the method being used illegally (Glover 2023).

  Shaw (2017) reported the results of a rapid assessment survey in Vanuatu based on the CMS Dugong Catch By-catch Standardised Questionnaire (Pilcher et al. 2017). In total, 537 interviews were conducted over a total of 32 islands, spanning each of the six provinces. Most people reported no catch of dugongs. Eighty-seven percent of people thought no one in their village caught dugongs and only 9% of people thought people in other villages catch them. In the year prior to the survey, seven people reported catching 1-2 dugongs. In the previous five years, only four people reported catching 1-2 dugongs and one admitted to catching > 10. In their lifetimes, only 14 fishers report catching one or two dugongs, one

fisher 3 to 10 dugongs and two fishers catching more than 10 dugongs. These figures include accidental by-catch.

- **Vessel-strike**: Occasional deaths of dugongs from collisions with boats have been reported on the west coast of New Caledonia in urban areas such as Nouméa (Province Sud), Voh and Koné (Province Nord), (ESCAL and A2EP 2011), and confirmed from postmortem examination of stranded carcasses (Garrigue et al. 2023). Between 1991 and 2022, collisions with boats were the cause of 11% of dugong strandings recorded whereas entanglements in fishing gear accounted for 3% of the strandings (Garrigue et al 2023). The growth of the tourism industry and associated boating activities is likely to aggravate this risk.

9.4.2 Indirect threats to dugongs

Because of their dependence on seagrass communities (Marsh et al. 2018), dugongs are very vulnerable to habitat loss. There are numerous causes of habitat loss as evidenced by the examples below:

- ***Coastal development, including reclamation***: Development and reclamation activities increase sedimentation and turbidity in coastal waters where seagrasses are found. Sedimentation and turbidity not only smother seagrasses, but also reduce the amount of light reaching them, resulting in the degradation of seagrasses and a reduction in their density and productivity (Short et al. 2018).
- ***Agricultural pollution:*** Nutrient and herbicide runoff from agricultural activities present a potential risk to seagrass habitats and increased sedimentation from poorly managed land practices are cause for concern. Sedimentation, nutrient enrichment from land runoff, and increased turbidity intensify the degradation, resulting in a reduction of seagrass density and productivity (Short et al. 2018; Al-Asif et al. 2022).
- ***Extreme weather events:*** Cyclones and storms can destroy or degrade seagrass meadows. The earthquake and tsunami event in 2010 negatively impacted seagrass cover and diversity in Tetepare Island in the western province of the Solomons (Moseby et al. 2020).
- ***Pollution:*** The deterioration of water quality by sewage, pollutant discharge, the presence of macro and microplastics, and agricultural activities, poses a direct impact on seagrass communities (Unsworth and Cullen 2010; McKenzie et al. 2020; Johnson et al. 2023). In addition, the expanding coastal mining industries pose indirect threats by affecting key locations crucial for dugong survival. (David et al. 2010; Cleguer et al. 2015).

- ***Climate change:*** Human induced climate change is anticipated to result in changes in the availability, production, species composition and distribution of the seagrass communities on which dugongs depend (Marsh et al. 2022). These changes will exacerbate the ongoing loss of seagrass caused by anthropogenic pressures in the coastal zone (Waycott et al. 2009). Fortunately, the Pacific Islands region appears to a global 'bright spot' for seagrasses, where pressures remain relatively low and seagrass more resilient than most other areas (McKenzie et al. 2021). The most relevant unknown is how climate-induced changes in seagrass community composition will affect dugong food quality, biomass, and preferred feeding locations and how in turn, this will affect dugong fecundity and the capacity for calves to learn from their mothers (Marsh et al. 2022).

9.5 Conservation initiatives

9.5.1 International conventions

All dugong range states in the Pacific Islands are signatories to the Convention on Biological Diversity (CBD) the United Nations Framework Convention on Climate Change (UNFCC), and the Memorandum of Understanding on the Conservation and Management of Dugongs *(Dugong dugon*) and their Habitats throughout their Range (Dugong MOU). Palau, PNG, the Solomon Islands, Vanuatu and France are contracting parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Commitment to the conservation of marine mammals, including the dugong, has been ongoing since the South Pacific Regional Environment Programme (SPREP) was established in 1993. SPREP has developed a series of regional action plans for marine species including the dugong, The Dugong Action Plan was last updated in 2022 (Hendriks and Baird 2022).

9.5.2 National laws

9.5.2.1 Palau

In 2010, Palau broadened its commitment to marine conservation by extending protection within its Exclusive Economy Zone (EEZ) to encompass all marine mammals, including dugongs. In the same year, the Marine Division within the Department of Environment and Conservation collaborated with the Coral Triangle Initiative (CTI) to implement Dugong Conservation through the Marine National Action Plan (SPREP 2011). The 2012-2013 Dugong Awareness Campaign, building on the successes of the initial 2010-2011 campaign, aimed to amplify local community awareness regarding the challenges faced by Palau's dugong population, and to enhance understanding of dugong biology and ecology for more effective management (CRRF 2012).

In 2015, Palau designated 80% of its marine EEZ as a National Marine Sanctuary, with the remaining 20% reserved for domestic fisheries (Wabnitz et al. 2018). To support the objectives of this commitment and the Pew Charitable Trusts' Palau Ocean Legacy project, the Palau Pristine Paradise Environmental Fee (PPEF) is applied to all international airline tickets. This fee contributes to ongoing efforts aimed at preserving Palau's marine ecosystems and upholding its commitment to sustainable conservation practices.

9.5.2.2 Papua New Guinea (PNG)

In 1976, the dugong received official recognition as a 'national animal' under the *Fauna Protection Act*, limiting capture to traditional purposes, such as feasts using traditional methods. The law strictly prohibits any commercial exploitation of dugongs. Two years later, in 1978, amendments were made to the legislation, specifically prohibiting the capture of young dugongs and mothers with calves (Hudson 1986).

9.5.2.3 Solomon Islands

Dugongs are subject to regulations enforced by the Ministry of Fisheries and Marine Resources (MFMR). They are officially recognised as protected mammals under the *Fisheries Management (Prohibited Activities) Regulation 2018*. Additionally, the national law on *Wildlife Protection and Management* categorises dugongs as a 'Prohibited Species'; thereby prohibiting any form of wildlife trade (WorldFish 2018).

Tetepare Island is the largest uninhabited island in the South Pacific. The Tetepare Descendants' Association (TDA) plays a crucial role in the management and protection of Tetepare's natural resources, employing community-based monitoring of marine species, including dugongs (Dugong and Seagrass Conservation Project 2018).

9.5.2.4 Vanuatu

In Vanuatu, the dugong is protected by the Vanuatu Whale Sanctuary, established through the *Fisheries Act No. 55 of 2005*. Vanuatu further solidified its commitment to dugong conservation by implementing a national Dugong Action Plan (SPREP 2011).

9.5.2.5 New Caledonia

In 1963, New Caledonia enacted *Resolution 68* (Province Nord 2008; Province Sud 2009), which affords protection to marine mammals (Garrigue et al. 2008). This resolution allows dugong hunting only under special permits. Each of the three Provinces in New Caledonia has independent environmental codes. For example, in Province Sud, the deliberation *03-2004/ APS of 2004* strictly prohibits dugong hunting, with no special permits granted even for customary purposes. In Province

Nord, the deliberation *23-2001/ APN, 85-2001/BPN* and 2006 deliberation *243-2006/APN* allow dugong hunting under special circumstances. In Province Iles Loyauté the dugong is protected under the *1963 Resolution*.

Between 2010 and 2015, a collaborative National Dugong Action Plan (hereafter DAP) was implemented. The DAP committee was coordinated by the French Marine Protected Area Agency and included local environmental managers from Province Nord, Province Sud and Provinces des Iles Loyauté, the French and New Caledonian governments, and NGOs such as WWF New Caledonia and Operation Cétacés. A second action plan, led by the New Caledonian Biodiversity Agency (ANCB – Agence néo-Calédonienne de la Biodiversité) previously named the Conservatory for Natural Landscapes (CEN - Conservatoire des Espaces Naturels) from 2013 to 2016, aimed to enhance governance for addressing critical issues like dugong poaching and bycatch in New Caledonia. This plan also focused on advancing the understanding of dugong ecology to strengthen protective measures, assess the population's status, and evaluate the effectiveness of conservation efforts. In particular, a project has been launched to gather cultural knowledge about the species from seaside tribes. The plan will be reviewed in 2024 with a third action plan set to launch for 2025-2030.

Six marine sites surrounding the main island in New Caledonia and representing the main diversity of coral reefs and associated ecosystems across the territory were listed on the UNESCO World Heritage List in 2008 as a serial nomination (United Nations Educational, Scientific and Cultural Organisation [UNESCO] 2023); the dugong population is explicitly cited as an attribute of the Outstanding Universal Value (OUV)of the site.

9.5.3 Other conservation initiatives

The Pacific Islands have made progress in implementing National Action Plans to undertake conservation programs, managing, and protecting marine and coastal ecosystems. While some of the national plans are still in their early stages or in the process of implementing new policies to safeguard dugongs and the seagrass ecosystems, there is ongoing activity in terms of securing funding and facilitating communication between various entities, researchers, and local communities.

Members of SPREP in the Pacific region declared 2011 ‘the Pacific Year of the Dugong’. The primary objectives of this initiative were to increase awareness regarding fishing activities, minimise dugong mortality resulting from human activities, improve information dissemination, advocate for sustainable management practices, and establish partnerships while securing resources to actively support dugong conservation in the region (SPREP 2011).

The Palau Coral Reef Research Foundation launched a dugong awareness campaign *I Love Mesekiu* in

2010-2011, engaging in a variety of outreach activities such as the distribution of educational materials to all schools in Palau, newspaper press releases to increase awareness of illegal poaching and the erection of dugong statues and carvings in the capitol building, among others (CRRF 2012).

Both the Solomon Islands and PNG are part of the Coral Triangle Initiative (CTI), which aims to conserve and sustainably manage marine resources within the CT region (Coral Triangle Initiative 2014). In 2013, The PNG LNG Community Investment Program conducted a comprehensive assessment of dolphins and dugongs (locally known as *Pidu*) in the Kikori Delta region of southwestern PNG. Subsequently, additional funding was allocated to establish a scholarship program, facilitating the pursuit of higher education by selected PNG Nationals at the University of Papua New Guinea, PNG or James Cook University, Australia (Beasley and Mavea 2019). This ongoing project focuses on the conservation of inshore dolphins and dugongs in the Kikori Delta, working with local communities. Collaborating with NGOs such as Conservation International, The Nature Conservancy, the Wildlife Conservation Society, and WWF, these entities contribute significantly to PNG's marine conservation initiatives (Asian Development Bank 2014). Additionally, the PNG Department of Conservation, along with the Government of the Solomon Islands, has invested resources in understanding the ecology and environment associated with seagrass meadows.

Supported by the Global Environment Facility (GEF), the Mohammed bin Zayed Species Conservation Fund, the United Nations Environment Program (UNEP), and the Dugong MOU, the 2014-2018 GEF Dugong and Seagrass Conservation Project (GEG Project) focused on mitigating both direct and indirect threats to dugong population and their seagrass habitats in eight countries including the Solomon Islands and Vanuatu (Dugong and Seagrass Conservation Project 2018, no date(a), no date(b); SPREP 2014).

The GEF Project worked with the Vanuatu Environmental Science Society (VESS) to undertake two projects to: (1) improve policies for dugongs and seagrasses in Vanuatu through research and awareness raising, and (2) create a national facilitating committee for the GEF Project. Maps generated using data collected through questionnaires and expert elicitation identified 20 locations where dugongs were considered locally important. VESS created two documents to aid in education and outreach: (1) Guidelines for Interacting with Dugongs and, (2) a Code of Conduct for Tourism Operators Interacting with Dugongs (Dugong and Seagrass Conservation Project no date(b)).

In the Solomon Islands, the GEF Project funded seven projects, working with numerous stakeholders. The projects included strengthening provincial and national capacity for project implementation by establishing a National Facilitating Committee to support the government and issuing a National Dugong and Seagrass Conservation Strategy for reference of implementing partners and

stakeholders. Programs were established to promote habitat preservation through alternative livelihoods such as aluminium recycling in Gizo and spirulina cultivation, as well as awareness and educational campaigns in Northwest Vonavona Lagoon. The Project committed to mapping critical seagrass fisheries habitats in Lau Lagoon in partnership with WorldFish (Dugong and Seagrass Conservation Project no date(a)). No reports on the outcomes of these projects were available as at March 2024.

Provinces Sud and Nord of New Caledonia declared a Year of the Dugong between May 2023 and May 2024. On this occasion, a workshop bringing together all the stakeholders made it possible to reflect on public policies that could be implemented to facilitate the conservation of dugongs. An artistic competition as well as a dugong day were organized offering games, exhibitions and conferences. An update of the dugong booklet made it possible to integrate the new knowledge acquired. A training package on what to do in the event of a stranding made it possible to train 117 people (firefighters, nature rangers, police, veterinarians, volunteers).

9.5.3.1 Traditional laws

In Palau, village councils oversee the management of land and sea (Glover 2023). In the past, it was reported that traditional leadership was transparent and all laws pertaining to marine resources were followed without question (Putney 2008). Law making power now resides with the central government however traditional knowledge is becoming increasingly integrated into conservation strategies and decision making to aid conservation (Glover 2023).

9.5.4 Conservation status

Although its assessments of conservation status are usually conducted at a global scale, IUCN allows assessments of isolated regional 'subpopulations' for species with a heterogeneous regional status such as the dugong. The global dugong population is currently listed as Vulnerable on the IUCN Red List (Marsh and Sobtzick 2019), but the New Caledonian dugong 'subpopulation' was listed as Endangered in 2022 (Hamél et al. 2023). The 'subpopulation' qualified for listing as Endangered under criterion C2a(ii) due to the number of mature individuals being < 2,500 with continuing decline inferred and more than 95% of the subpopulation at a single location, the lagoons within the barrier reef surrounding Grande Terre. The New Caledonian subpopulation was also eligible for listing as Vulnerable under criterion B (VU B2ab(v)) and criterion D (VU D1). Criterion B was supported by the following evidence: 1) the Area of Occupancy is < 2,000 km², 2) more than 90% of the region's mature individuals occur at a single location, and 3) there is evidence for continuing decline in the number of mature individuals. An estimation of < 1,000 mature individuals supported

the eligibility for listing under Criterion D. Currently, there are insufficient data to assess the eligibility of this dugong subpopulation under criteria A or E.

The status of the other dugong 'subpopulations' in the Pacific Islands region has not been assessed by IUCN.

9.5.4.1 Seagrass status

All seagrass species in the Pacific Island Countries and Territories (PICTs) are listed as "Least Concern" on the IUCN Red List of threatened species, and the global status of only 13% of PICT species are listed as "decreasing", with the majority (69%) "stable" and the remainder "unknown" (McKenzie et al. 2021).

9.6 Research and monitoring initiatives

9.6.1. Techniques used to date

9.6.1.1 Distribution and abundance of dugongs and their habitats

As outlined in Section 9.2. diverse survey methods, such as aerial surveys using occupied aircraft (Garrigue et al. 2008, 2009; Cleguer et al. 2017), unoccupied aerial vehicle (UAV) surveys (CRRF 2012), and satellite tracking (Cleguer et al. 2020a,b) have been used to understand dugong distribution, status, abundance, and behaviour in New Caledonia. A large knowledge gap in other Pacific Island nations remains. Complementing these methods, questionnaires administered to fishermen, locals, and indigenous communities have been employed to document dugong distribution as outlined in Section 9.2. This multifaceted approach has enabled the assessment of habitat and protection on marine mammal densities (Heudier et al. 2023). Additionally, innovative tools such as deep learning using film accumulated on social media and video surveys in New Caledonia have contributed to the detection of rare megafauna species in the field (Mannocci et al. 2022). Telemetry tracking and systematic aerial surveys have been integrated to provide information about dugong spatial use (Derville et al. 2022). Deep learning implemented in aerial video surveys has also become a useful tool (Mannocci et al. 2022; Heudier et al. 2023). Additional survey tools that could be implemented include camera-mounted occupied planes, GPS satellite tags, and fine-scale dive profiles.

9.6.1.2 Dugong habitat use (New Caledonia)

Studies on dugong movements in the waters of Grande Terre, New Caledonia, suggest that dugongs remain within the lagoons, utilising the lagoons' full width, from close to the shore to the back reef (Cleguer 2015; Cleguer et al. 2020a; Derville et al. 2022).

Cleguer et al. (2024) conducted extensive local-scale surveys (n=62) over Cap Goulvain in New Caledonia using an ultralight aircraft from February 2012 to August 2013 to investigate how dugongs in New Caledonia used a high conservation value coral-reef lagoon system during different seasons and tides to support local management. The surveys were conducted fortnightly over 18 months in different seasons and at different tides. Temperature loggers and existing local footage of dugong herding behaviour were used to study the habitat use and behaviour of the animals in the area. The researchers found that more dugongs were sighted in Cap Goulvain during the cool season than during the warm season. As tides restricted access to the intertidal seagrass meadows and during the cool season, more dugongs were sighted in the warmer waters of the fore reef shelf outside the lagoon. Dugongs were resting in large aggregations during their use of this non-seagrass habitat. The study emphasised the importance of non-seagrass habitats for dugongs in spatially restricted coral reef environments as well as the importance of considering outer lagoon habitats as key dugong management areas. This study also adds to evidence of behavioural thermoregulation in dugongs from other areas at the high –latitude limits to their range.

9.6.1.3 Seagrass mapping (New Caledonia)

Mapping seagrass areas in the Pacific Islands poses challenges, given data gaps in models like MaxEnt (Jayathilake and Costello 2018). However, the integration of diverse technologies, such as satellite sensors, drones, remote sensing platforms, and acoustic tools, enhances mapping accuracy in both shallow and deep waters. In New Caledonia, seagrass distribution has been part of mapping projects since 2004, incorporating various datasets. Andréfouet et al. (2021) applied a multi-scale hierarchical framework, providing valuable insights for conservation and management decisions concerning seagrass beds and marine mammals like dugongs.

Seagrass inventories and community maps have been developed in New Caledonia since 1984, applying a multiscale hierarchical framework (Andréfouet et al. 2021). Nonetheless, the condition of seagrass in New Caledonia is not monitored regularly. A regional analysis conducted by McKenzie et al. (2021) at one site in New Caledonia did not reveal any specific trends. To address this gap, a workshop organised by the French Initiative for Coral Reefs (IFRECOR) took place in 2022 in New Caledonia to establish indicators for future seagrass monitoring. In 2024, a post-doctoral project will focus on developing indicators and a service is underway to propose a sampling plan (C. Garrigue, personal communication 2024).

9.6.1.4 Dugong feeding ecology (New Caledonia)

Thibault et al. (2024) used C and N stable isotope values in dugong skin to make a preliminary assessment of the feeding ecology of dugongs in New Caledonia. The feeding niche of calves overlapped with that of females, presumably reflecting the long period of material care. Differences

between adult male and female dugongs suggest sex differences in foraging with females consuming a wider variety of foods than males. Pregnant females may minimize their energy expenditure by focusing their foraging efforts in smaller areas and using a wider range of food resources.

9.6.2 Additional research techniques that may be applicable

An important priority should be to develop a program of coordinated research on the distribution and abundance of dugongs and their seagrass habitats across the Pacific Islands using techniques that are appropriate to the capacity of each country, but which would enable cross-country comparisons. Once this foundational research has been completed, consideration should be given to understanding the connectivity between dugongs at locations within the region using the modern genetics and tracking techniques.

Much of the research and monitoring initiatives on dugongs and their habitats (seagrasses) to date have been conducted in New Caledonia, and that there is a considerable gap in other Pacific countries. Lack of capacity and funding are the main drivers for the persisting gap in research and monitoring in other Pacific Island nations. Legislation and enforcement also contribute.

9.7 Regional co-operation

The foundations for regional co-operation are well-developed. SPREP spans 21 Pacific Island member countries and territories, including Palau, PNG, Solomon Islands, Vanuatu and New Caledonia. SPREP provides assistance protecting and improving the Pacific region's environment to ensure sustainable development for present and future generations. SPREP has launched several campaigns to spread awareness of dugongs and their seagrass habitats across the Pacific as outlined in Section 9.5.3.

The Pacific Islands Regional Dugong and Seagrass workshops, organised by the Dugong and Seagrass Conservation Project (2018) and supported by GEF, have also been instrumental in advancing plans and discussions on dugong and seagrass conservation in the Pacific Islands region. Participants from four range states—Palau, Solomon Islands, Vanuatu and New Caledonia–engage in reporting on the status of dugong and seagrass, discussing initiatives to address threats at both national and regional levels, strategizing the survival of dugong and seagrass ecosystems. Key focal points in these workshops include the importance of long-term community engagement, where community needs are considered at both national and regional levels. Additionally, the workshops emphasise the essential role of government and international support, as well as the participation of various stakeholders, in structuring MPAs (Cleguer et al. 2015; Glover 2023). As highlighted by Glover (2023), traditional ecological knowledge of fishing methods and dugong populations is crucial for

implementing successful monitoring and fisheries management. This knowledge has proven to be pivotal in informing sustainable management of marine resources for the future.

9.8 Regional summary

In the Pacific Islands region, dugongs persist in locations of local importance (Table 9.2) , necessitating active engagement with communities and government initiatives to protect them within these areas (Marsh et al. 2002; WorldFish 2018). The commitment to regional protection and action plans holds the potential for addressing dugong population declines and the uncertainties surrounding the sustainability of traditional harvests. It is crucial to utilise a multi-faceted approach which will provide alternatives that minimise illegal hunting and poaching to ensure the survival of dugong populations (Glover 2023).

The following initiatives would enhance the conservation of dugongs and their habitats:

- Engaging local communities in nearshore resource management and the curbing of destructive practices to enhance the resilience of seagrass ecosystems.
- Empowering communities to facilitate the development of culturally-sensitive solutions to support conservation efforts.
- Strengthening legislation to specifically address both direct and indirect impacts on the ecosystem at regional and national levels within each Range State.
- Prioritising genetic research on samples from Palau and New Caledonia, where mitochondrial diversity is low.
- Assessing the conservation status of the Palau ‘subpopulation’.
- Increasing efforts in data deficient areas, especially PNG, the Solomon Islands, and Vanuatu, to inform national and regional conservation strategies.

Table 9.2. Summary of confirmed and possible areas of local importance for the dugong in the Pacific Islands. This list is likely to be incomplete due to inadequate information about some Range States, especially PNG and the Solomon Islands.

COUNTRY	REGION
PALAU	Malakal Harbour
	Ngardmau Bay
	Offshore from Ngerkeklau Island
	Koror
	Rock Islands
	Ngederrak
PNG	Southern coast (for Torres Strait see Chapter 10)
	Manus Island
	West New Britain
	Bougainville
SOLOMON ISLANDS	Western Province
	Malaita
	Isabel
	Guadalcanal
	Choiseul
	Central Province
	Lau Lagoon
VANUATU	Shefa (Port Villa Harbour, Mele Bay, Pango, Erakor, Eratap, Havannah Harbour, northern Efafe, northwest Epi, Lamen Bay and Emae Island)
	Torba
	Malampa
	Sanma
	Tafea
	Torres Islands
NEW CALEDONIA	Cap Goulvain
	West coast areas near Koumac, north of Voh, near and south of Nekoro, Moindou, and between Noumea and Paita
	North-east coast: between Pouebo and Touho

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9.10 References

Al-Asif, A., Kamal, A.H., Hamli, H., Idris, M.H., Gerusu, G.J., Ismail, J., Bhuiyan, M.K., Abualreesh, M.H., Najiah, M., Wahid, M.E. and Manoranjan, M. (2022). Status, biodiversity, and ecosystem services of seagrass habitats within the Coral Triangle in the western Pacific Ocean. *Ocean Science Journal* 57(2), 147-143. https://doi.org/10.1007/s12601-022-00068-w.

Allen Coral Atlas (2020). Imagery, maps and monitoring of the world's tropical coral reefs. Vulcan Inc. https://doi.org/10.5281/zenodo.3833242. Available: allencoralatlas.org. Accessed 17 January 2024.

Andréfouet, S., Derville, S., Buttin, J., Dirberg, G., Wabnitz, C.C., Garrigue, C. and Payri, C.e. (2021). Nation-wide hierarchical and spatially-explicit framework to characterize seagrass meadows in New-Caledonia, and its potential application to the Indo-Pacific. *Marine Pollution Bulletin* 173, 113036. https://doi.org/10.1016/j.marpolbul.2021.113036.

Andrew, N.L., Bright, P., de la Rua, L., Teoh, S.J. and Vickers, M. (2019). Coastal proximity of populations in 22 Pacific Island Countries and Territories. *PLoS One* 14(9), 1–15. https://doi.org/10.1371/journal.pone.0223249.

Asian Development Bank (2014). *State of the Coral Triangle: Papua New Guinea*. Mandaluyong City, Philippines: Asian Development Bank. https://www.adb.org/publications/state-coral-triangle-philippines.

Bass, D.K. (2010). Status of dugong *Dugong dugon* and Australian Snubfin Dolphin *Orcaella heinsohni,* in the Solomon Islands. *Pacific Conservation Biology* 16(2), 133–143. https://doi.org/10.1071/PC100133.

Beasley, I. and Mavea, W. (2019). *Looking for Pidu (dolphins and dugongs) in the Kikori Delta of Papua New Guinea: Public Report.* Pidu Project. https://pngdolphinproject.org/wp-content/uploads/Looking-for-dolphins-in-Kikori_PIDUPublic_FINAL.pdf.

Blaise, S. (2017). The 'rebalancing' of New Caledonia's economy. *The Journal of Pacific History* 52(2), 194-216. https://doi.org/10.1080/00223344.2017.1349532.

Brownell, R.L., Anderson, P.K., Owen, R.P. and Ralls. K. (1981). The status of dugongs at Palau, an isolated island group. In *The Dugong: Proceedings of a Seminar /Workshop held at James Cook University.* Marsh, H. (ed.). Department of Zoology, James Cook University, Townsville, Australia, 8-13 May 1979. 11-23.

Buden, D.W. and Haglelgam, J. (2010). Review of crocodile (Reptilia: Crocodilia) and dugong (Mammalia: Sirenia) sightings in the federated states of Micronesia. *Pacific Science* 64(4), 577–583. http://hdl.handle.net/10125/23128.

Carter, A., McKenna, S., Rasheed, M., Taylor, H., van de Wetering, C., Chartrand, K., Reason, C., Collier, C., Shepherd, L., Mellors, J., McKenzie, L., Duke, N., Roelofs, A., Smit, N., Groom, R., Barrett, D., Evans, S., Pitcher, R., Murphy, N., Carlisle, M., David, M., Lui, S., Rangers, T.S. and Coles, R. (2023). Seagrass spatial data synthesis from north-east Australia, Torres Strait and Gulf of Carpentaria, 1983 to 2022. *Limnology and Oceanography Letters*. https://doi.org/10.1002/lol2.10352.

Chambers, M.R., Bani, E. and Barker-Hudson, B.E. (1989). *The status of dugong (Dugong dugon) in Vanuatu. Tropic Review No. 37. South Pacific Regional Environment Program*. New Caledonia: South Pacific Commission.

Central Intelligence Agency [CIA] (2023). World fact book: New Caledonia. https://www.cia.gov/the-world-factbook/countries/new-caledonia/summaries/#economy. Accessed 12 November 2023.

Clare, A. (2022). Pacific Islands – key issues. In *Briefing Book: Key Issues for the 47th Parliament.* Australia: Commonwealth of Australia. 281-287.

Cleguer, C. and Garrigue, C. (2018). Dugongs: endangered lagoon mermaids. In *New Caledonia World of corals*. Payri, C.E. (ed.). Marseilles, France: IRD Editions. Chapter 41. 239-242.

Cleguer, C., Grech, A., Garrigue, C. and Marsh, H. (2015). Spatial mismatch between marine protected areas and dugongs in New Caledonia. *Biological Conservation* 184, 154–162. https://doi.org/10.1016/j.biocon.2015.01.007.

Cleguer, C., Garrigue, C., Fuentes, M.M., Everingham, Y., Hagihara, R., Hamann, M., Payri, C. and Marsh, H. (2017). Drivers of change in the relative abundance of dugongs in New Caledonia. *Wildlife Research* 44, 365-376. https://doi.org/10.1071/WR16133.

Cleguer, C., Garrigue, C. and Marsh, H. (2020a). Dugong (*Dugong dugon*) movements and habitat use in a coral reef lagoonal ecosystem. *Endangered Species Research* 43, 167–181. https://doi.org/10.3354/ESR01061.

Cleguer, C., Derville, S., Kelly, N., Lambourne, R. and Garrigue, C. (2020b). *Programme SIREN: Suivi à fine échelle de la fréquentation et du déplacement des dugongs dans la zone Voh-Koné- Pouembout, pour une gestion améliorée de l'espèce.* Unpublished report, KNS SA. (In French).

Cleguer, C., Garrigue, C., Fuentes, M.M., Hamann, M., Payri, C. and Marsh, H. (2024). Temporal changes in habitat use by dugongs in a spatially restricted coral reef environment. *Pacific Conservation Biology* 30. https://doi.org/10.1071/PC23036.

Coral Reef Research Foundation [CRRF] (2012). *Palau Dugong dugon awareness campaign 2010-2011.* Technical report.

David, G., Leopold, M., Dumas, P.S., Ferraris, J., Herrenschmidt, J.B. and Fontenelle, G. (2010). Integrated coastal zone management perspectives to ensure the sustainability of coral reefs in New Caledonia. *Marine Pollution Bulletin* 61(7–12), 323–334. https://doi.org/10.1016/j.marpolbul.2010.06.020.

Derville, S., Cleguer, C. and Garrigue, C. (2022). Ecoregional and temporal dynamics of dugong habitat use in a complex coral reef lagoon ecosystem. *Scientific Reports* 12, 552. https://doi.org/10.1038/s41598-021-04412-3.

Deutsch, C.J., Castelblanco-Martínez, D.N., Groom, R. and Cleguer, C. (2022). Movement behavior of manatees and dugongs: I. Environmental challenges drive diversity in migratory patterns and other large-scale movements. In *Ethology and Behavioral Ecology of Sirenia*. Marsh, H. (ed.). Berlin: Springer. Chapter 5. 155-232.

Dobbs, K., Lawler, L. and Kwan, D. (2012). Dugongs in Australia and the Pacific. In *Sirenian Conservation: Issues and Strategies in Developing Countries.* Hines, E.M., Reynolds III, J.E., Aragones, L.V., Mignucci-Giannoni A.A. and Marmontel, M. (eds.). Gainesville, Florida: University Press of Florida. Chapter 11, 99-105.

Duclos, G., Aubert, C., Dambreville, R., Le Moguedec, G. and Roux, B. (2019*). Étude de la distribution de la population de dugongs de Nouvelle-Calédonie par survol aérien, 2019. Rapport d'analyse des données de la campagne de novembre 2018.* (In French).

Dugong and Seagrass Conservation Project (2018). *Report of the Pacific Islands Regional Dugong & Seagrass Conservation Workshop. Munda Island, Solomon Islands, 5-8 March 2018.* Solomon Islands: SPREP and Dugong and Seagrass Conservation Project.

Dugong and Seagrass Conservation Project (no date(a)). Where we work: Solomon Islands. https://www.dugongconservation.org/where-we-work/solomon-islands/. Accessed 27 March 2024.

Dugong and Seagrass Conservation Project (no date(b)). Where we work: Vanuatu. https://www.dugongconservation.org/where-we-work/vanuatu/. Accessed 27 March 2024.

Dupont, A. (2015). *Evaluation de la place du dugong dans la société néo-calédonienne. Mémoire de stage.* Plan d'Actions Dugong 2010-2015. (In French).

Eldredge, L.G. (2003). The marine reptiles and mammals of Guam. *Micronesica* 35-36, 653-660.

ESCAL and A2EP (2011). Enquête sur les pressions exercées par les activités nautiques sur la population de dugongs en Nouvelle Calédonie. Agence des Aires Marine Protegées. http://www.aires-marines.fr/Documentation/Plan-d-action-Dugongs-Nouvelle-Caledonie. (In French).

Garrigue, C., Patenaude, N. and Marsh, H. (2008). Distribution and abundance of the dugong in New Caledonia, southwest Pacific. *Marine Mammal Science* 24(1), 81–90. https://doi.org/10.1111/j.1748-7692.2007.00173.x.

Garrigue, C., Oremus, M., Schaffar, A. and Patenaude, N. (2009). *Etude du statut de la population de dugongs en provinces Nord et Sud 2008. Zoneco, Nouméa, Nouvelle-Calédonie, Avril 2009.* (In French).

Garrigue, C., Cleguer, C. and Schaffar, A. (2011). *Etude de la distribution de la population de dugongs de Nouvelle-Calédonie par survol aérien, 2011. Rapport de mission de la campagne de juin 2011.* (In French).

Garrigue, C., Cleguer, C., Schaffar, A. and Oremus, M. (2012). *Etude de la distribution de la population de dugongs de Nouvelle-Calédonie par survol aérien, 2011. Rapport de mission de la campagne de novembre 2011.* (In French).

Garrigue, C., Cleguer, C., Oremus, M. and Schaffar, A. (2015). *Etude génétique complémentaire sur le statut de la population de dugongs de Nouvelle-Calédonie Rapport final*. Nouméa: Opération Cétacés. (In French).

Garrigue, C., Bonneville, C.D., Cleguer, C. and Oremus, M. (2022). Extremely low mtDNA diversity and high genetic differentiation reveal the precarious genetic status of dugongs in New Caledonia, South Pacific. J*ournal of Heredity* 113(5), 516–524. https://doi.org/10.1093/jhered/esac029.

Garrigue, C., Derville, S., Bonneville, C. D., Brisset, M., Bustamante, P., Cleguer, C., Clua, E.E., Fiat, S., Justine, J.-L., Machful, P., Mai, T., Plichon, P., Portal, A., Sidobre, C., Steel, D., Vivier, J.-C. and Vourey, E. (2023). Marine mammal strandings recorded in New Caledonia, South West Pacific Ocean, 1877 to 2022. *Pacific Conservation Biology* 30, PC23016. https://doi.org/10.1071/PC23016.

Glover, M. (2023). *An exploration of Palauan fishing methods and fisheries: A study for the conservation of dugongs.* Master's Thesis presented to the Faculty of the College of Arts, Humanities, and Social Sciences, University of Denver.

Hagihara, R., Jones, R.E., Sobtzick, S., Cleguer, C., Garrigue, C. and Marsh, H. (2018). Compensating for geographic variation in detection probability with water depth improves abundance estimates of coastal marine megafauna. *PLoS One* 13(1), 1–15. https://doi.org/10.1371/journal.pone.0191476.

Hamél, M.A., Marsh, H., Cleguer, C., Garrigue, C. and Oremus, M. (2023). *Dugong dugon (New Caledonia subpopulation).* The IUCN Red List of Threatened Species 2022: e.T218582754A218589361. https://dx.doi.org/10.2305/IUCN.UK.2022-2.RLTS.T218582754A218589361.en. Accessed 10 December 2023.

Hendriks, H. and Baird, K. (2022). Dugong Action Plan. *In Pacific Islands Regional Marine Species Programme 2022–2026*. Apia, Samoa: SPREP. 29-42. 4242https://library.sprep.org/sites/default/files/2022-05/PIRMSP-2022.pdf.

Heudier, M., Mouillot, D. and Mannocci, L. (2023). Assessing the effects of coral reef habitat and marine protected areas on threatened megafauna using aerial surveys. *Aquatic Conservation: Marine and Freshwater Ecosystems* 33(3), 286–297. https://doi.org/10.1002/aqc.3923.

Hill-Lewenilovo, R., Vuiyasawa, R. and Piovano, S. (2019). First record of a dugong (*Dugong dugon* Müller, 1776) in Fiji. *Pacific Conservation Biology* 25, 324–325. https://doi.org/10.1071/PC18059.

Hudson, B.E. (1976). Dugongs: distribution, hunting, protective legislation and cultural significance in Papua New Guinea. *Scientific Consultation on Marine Mammals*. 31 August–9 September 1976. Bergen, Norway.

Hudson, B.E. (1986). The hunting of dugong at Daru, Papua New Guinea, during 1978-82: community management and education initiatives. In *Torres Strait fisheries seminar, Port Moresby.* Haines, A.K., Williams, G.C. and Coates, D. (eds.)., February 1985. Canberra, Australia: Australian Government Publishing Service. 77-94.

Ingram, D.J., Prideaux, M., Hodgins, N.K., Frisch-Nwakanma, H., Avila, I.C., Collins, T. Cosentino, M., Keith-Diagne, L., Marsh, H., Shirley, M.H., Van Waerebeek, K., Djondo, M.K., Fukuda, Y., Glaus, K.B., Jabado, R.W., Lang, J.W., Lüber, S., Manolis, C., Webb, G.J. and Porter, L. (2022). Widespread use of migratory megafauna for aquatic wild meat in the tropics and subtropics. *Frontiers in Marine Science* 9. https://doi.org/10.3389/fmars.2022.837447.

IUCN-MMPATF. IMMA Searchable Database. Marine Mammal Protected Areas Task Force (MMPATF). https://www.marinemammalhabitat.org/immas/immas-searchable-database/. Accessed 12 March 2024.

IUCN-MMPATF (2021a). Kikori Delta. IMMA Brochure. IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force, 2021. PDF made available for download at https://www.marinemammalhabitat.org/. Accessed 12 March 2024.

IUCN-MMPATF (2021b). Main Solomon Islands. IMMA Brochure. IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force, 2021. PDF made available for download at https://www.marinemammalhabitat.org/. Accessed 12 March 2024.

IUCN-MMPATF (2021c). New Caledonian Lagoons and Shelf Waters. IMMA Brochure. IUCN Joint SSC/WCPA Marine Mammal Protected Areas Task Force, 2021. PDF made available for download at https://www.marinemammalhabitat.org/. Accessed 12 March 2024.

Jaiteh, V., Lindfield S., Bell Colin, L.J., Colin, P. and Swords, J. (2020). *Behavioral observations and habitat use of dugongs (Dugong dugon) in the Rock Islands Southern Lagoon, Palau*. Koror, Palau: Coral Reef Research Foundation for GEF Small Grants Programme.

Johannes, R.E. (1981). *Words of the lagoon: Fishing and marine lore in the Palau District of Micronesia.* California, USA: University of California Press.

Johnson, J.E., Welch, D.J., van Hooidonk, R., Tracey, D., Chandrasa, G., Molinari, B., Triani, D., Tania, C. and Susanto, H. (2023). Climate change implications for the Arafura and Timor Seas region: assessing vulnerability of marine systems to inform management and conservation. *Climatic Change* 176(88). https://doi.org/10.1007/s10584-023-03554-9.

Kare, B.D. (1995). A review on the research and fisheries of barramundi, reef fish, dugongs, turtles and spanish mackerel in the Papua New Guinea side of the Torres Strait. *Joint FFA/SPC Workshop on the Management of South Pacific Inshore Fisheries*. June – July 1995. Noumea, New Caledonia.

Ligon, S. and Hudson, B.E. (1977). *Aerial survey of the dugong Dugong dugon in Papua New Guinea. Wildlife in Papua New Guinea*. Papua New Guinea: Wildlife Division, Department of Lands and Environment 77, 53-76.

Ludt, W.B. and Rocha, L.A. (2014) Shifting seas: the impacts of Pleistocene sea-level fluctuations on the evolution of tropical marine taxa. *Journal of Biogeography* 42(1), 25-38. https://doi.org/10.1111/jbi.12416.

Mannocci, L., Villon, S., Chaumont, M., Guellati, N., Mouquet, N., Iovan, C., Vigliola, L. and Mouillot, D. (2022). Leveraging social media and deep learning to detect rare megafauna in video surveys. *Conservation Biology*, 36(1). https://doi.org/10.1111/cobi.13798.

Marino, E., Bauman, A., Miles, J., Kitalong, A., Bukurou, A., 4, Mersai, C., Verheij, E., Olkeriil, I., Basilius, K., Colin, P., Patris, S., Victor, S., Andrew, W., Miles, J. and Golbuu, Y. (2008). The state of coral reef ecosystems of Palau. In *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008.* Waddell, J.E. and Clarke, A.M. (eds.). Silver Spring: NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Chapter 16. 511-540.

Marsh, H. (2002). *Dugong: Status Reports and Action Plans for Countries and Territories.* UNEP Early Warning and Assessment Report Series. UNEP.

Marsh, H. (2017). Dugong: *Dugong dugon*. In *Encyclopedia of Marine Mammals Third Edition.* Wursig, B., Thewissen, J.G. and Kovacs, K.M. (eds.). London, UK: Elsevier. 274–277.

Marsh, H. and Sobtzick, S. (2019). *Dugong dugon* (amended version of 2015 assessment). The IUCN Red List of Threatened Species 2019: e.T6909A160756767. https://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T6909A160756767.en. Accessed 10 December 2023.

Marsh, H., Rathbun, G.B., O'Shea, T.J. and Preen, A.R., (1995). Can dugongs survive in Palau? *Biological Conservation* 72(1), 85–89. https://doi.org/10.1016/0006-3207(94)00068-2.

Marsh, H., O'Shea, T.J. and Reynolds III, J.E. (2011). *Ecology and conservation of the Sirenia: Dugongs and manatees.* Cambridge, UK: Cambridge University Press.

Marsh, H., Grech, A. and McMahon, K. (2018). Dugongs: Seagrass community specialists. In *Seagrasses of Australia: Structure, Ecology and Conservation*. Larkum, A.W., Kendrick, G.A. and Ralph, P.J. (eds.). 629-661. Cham, Switzerland: Springer.

Marsh, H., Albouy, C., Arrau, E., Castelblanco-Martínez, D.N., Collier, C., Edwards, H., James, C. and Keith-Diagne, L. (2022). How might climate change affect the ethology and behavioral ecology of dugongs and manatees? In *Ethology and Behavioral Ecology of Sirenia*. Marsh, H. (ed.). Berlin: Springer. Chapter 8. 351-391.

McKenzie, L. J., Campbell, S. J. and Lasi, F. (2006). Seagrasses and mangroves. In *Solomon Islands Marine Assessment: Technical report of survey conducted May 13 to June 17, 2004.* Green, A., Lokani, P., Atu, W., Ramohia, P., Thomas, P. and Almany, J. (eds.). TNC Pacific Island Countries Report No 1/06. Brisbane, Australia: The Nature Conservancy, 401-444.

McKenzie, L.J., Nordlund, L.M., Jones, B.L., Cullen-Unsworth, L.C., Roelfsema, C. and Unsworth, R.K. (2020). The global distribution of seagrass meadows. *Environmental Research Letters* 15(7), 074041. https://doi.org/10.1088/1748-9326/ab7d06.

McKenzie, L.J., Yoshida, R.L., Aini, J.W., Andréfouet, S., Colin, P.L., Cullen-Unsworth, L.C., Hughes, A.T., Payri, C.E., Rota, M., Shaw, C., Tsuda, R.T., Vuki, V.C. and Unsworth, R.K. (2021a). Seagrass ecosystem contributions to people's quality of life in the Pacific Island Countries and Territories. *Marine Pollution Bulletin,* 167, 112307.

McKenzie, L.J., Yoshida, R.L., Aini, J.W., Andréfouet, S., Colin, P.L., Cullen-Unsworth, L.C., Hughes, A.T., Payri, C.E., Rota, M., Shaw, C., Skelton, P.A., Tsuda, R.T., Vuki, V.C. and Unsworth, R.K. (2021b).

Seagrass ecosystems of the Pacific Island Countries and Territories: A global bright spot. *Marine Pollution Bulletin* 167, 112308. https://doi.org/10.1016/j.marpolbul.2021.112308.

Moseby, K.E., Daniels, A., Duri, V., Tropa, W., Welma, S., Bero, A. and Soapi, K. (2020). Community-based monitoring detects catastrophic earthquake and tsunami impacts on seagrass beds in the Solomon Islands. *Marine Pollution Bulletin* 150, 110444. https://doi.org/10.1016/j.marpolbul.2019.07.032.

Nishiwaki, M.T., Kasuya, T., Miyazaki, N., Toboyama, N. and Kataoka, T. (1979). Present distribution of the dugong in the world. S*cientific Reports of the Whales Research Institute* 31, 133-141. https://www.icrwhale.org/pdf/SC031133-141.pdf.

Oremus, M., Garrigue, C., Cleguer, C. and Opération Cétacés (2011). *Isolement Et Diversité Génétique Des Dugongs De Nouvelle-Calédonie. Rapport final (2011).* (In French).

Pilcher, N.J., Adulyanukosol, K., Das, H., Davis, P., Hines, E., Kwan. D., Marsh, H., Ponnampalam, L. and Reynolds, J. (2017). A low-cost solution for documenting distribution and abundance of endangered marine fauna and impacts from fisheries. *PLoS One* 12(12), e0190021. https://doi.org/10.1371/journal.pone.0190021.

Plön, S., Thakur, V., Parr, L. and Lavery, S.D. (2019). Phylogeography of the dugong (Dugong dugon) based on historical samples identifies vulnerable Indian Ocean populations. *PloS One* 14(9), https://doi.org/10.1371/journal.pone.0219350.

Province Nord. (2008). Code de l'environnement de la province Nord. www.juridoc.gouv.nc. Accessed 11 March 2024.

Province Sud. (2009). Code de l'environnement de la province Sud. https://www.province-sud.nc/codenv. Accessed 11 March 2024.

Putney, R. (2008). *Customary marine tenure and traditional ecological knowledge in Palau*. Master's thesis submitted to the San Jose State University, United States of America.

Rathbun, G.B., Brownell, R.L., Ralls, K. and Engbring, J. (1988). Status of dugongs in waters around Palau. *Marine Mammal Science* 4, 265-270.

Secretariat of the Pacific Regional Environment Programme [SPREP] (2011). *Dugongs: Respect and protect. Dugong profile for range states in the Pacific Islands.* Apia, Samoa: SPREP.

Skewes, T., Kinch, J., Polan, P., Dennis, D., Seeto, P., Taranto, T., Lokani, P., Wassenberg, T., Koutsoukos, A., Sarke, J. and Manson, F. (2003). *Distribution and abundance of reef resources in Milne Bay Province, Papua New Guinea: Analysis of environmental data.* Cleveland, Australia: CSIRO Division of Marine Research.

SPREP (2013). *Pacific Islands Regional Marine Species Program [PIRMSP] 2013-2017*. Apia, Samoa: SPREP.

SPREP (2014). Funding for Pacific dugong conservation announced, 17 August. https://www.sprep.org/news/funding-pacific-dugong-conservation-announced. Accessed 11 March 2024.

Shaw, C. (2017) *Report on the Vanuatu CMS Dugong catch/by-catch questionnaire survey 2015 to 2017.* Vanuatu: Dugongs and seagrass conservation project and the Vanuatu Environmental Science Society [VESS].

Short, F.T., Short, C.A. and Novak, A.B. (2018). Seagrasses. In *The Wetland Book: II: Distribution, Description, and Conservation.* Finlayson, C.M., Milton, G.R., Prentice, R.C. and Davidson, N.C. (eds.). Dordrecht, Netherlands: Springer. 73–91.

Stoeckl, N., Larson, S, Thomas, J., Hicks, C., Pascoe, S. and Marsh, H. (2018). Socioeconomic impacts of changes to marine fisheries and aquaculture that are brought about through climate change. In *Climate Change Impacts on Fisheries and Aquaculture: A Global Analysis*. Phillips, B.F. (ed.). Chichester, UK: Wiley Blackwell. 925-958.

Thibault, M., Letourneur, Y., Claguer, C., Bonneville, C., Briand, M., Derville, S., Bustamante, P. and Garrigue, C. (2024). C and N stable isotopes enlighten the trophic behaviour of the dugong (*Dugong dugon*). *Scientific Reports* 14, 896. /doi.org/10.1038/s41598-023-50578-3.

United Nations Committee for Development Policy [UNCDP] (2023a). Monitoring of countries graduating and graduated from the LDC category: Solomon Islands. New York: United Nations. CDP2023/PLEN/9.a.

UNCDP (2023b). Monitoring of countries graduating and graduated from the LDC category: Vanuatu. Virtual Meeting: United Nations. CDP2021/PLEN/5A.iii.

UNDESA (2022a). World economic situation and prospects 2022 statistical annex. https://desapublications.un.org/file/728/download?_ga=2.109353536.47777887.1710448383-1365005936.1709849289. Accessed 11 March 2024.

UNDESA (2022b). World Population Prospects 2022, online edition. https://population.un.org/wpp/. Accessed 12 December 2023.

UNESCO (2023). The World Heritage List. https://whc.unesco.org/en/list/. Accessed 10 December 2023.

Unsworth, R.K. and Cullen, L.C. (2010). Recognising the necessity for Indo-Pacific seagrass conservation. *Conservation Letters* 3(2), 63–73.

Wabnitz, C.C., Cisneros-Montemayor, A.M., Hanich, Q. and Ota, Y. (2018). Ecotourism, climate change and reef fish consumption in Palau: Benefits, trade-offs and adaptation strategies. *Marine Policy* 88, 323–332. http://dx.doi.org/10.1016/j.marpol.2017.07.022.

Ward-Paige, C.A. and Worm, B. (2017). Global evaluation of shark sanctuaries. *Global Environmental Change* 47, 174-189. https://doi.org/10.1016/j.gloenvcha.2017.09.005.

Waycott, M., Duarte, C.M., Carruthers, T.J., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck Jr, K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Short, F.T. and Williams, S.L. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences* 106(30), 12377–81. https://doi.org/10.1073/pnas.0905620106.

World Bank (2022a). New Caledonia. https://data.worldbank.org/country/NC. Accessed 10 December 2023.

World Bank (2022b). Palau. https://data.worldbank.org/country/palau. Accessed 10 December 2023.

World Bank (2022c) Papua New Guinea. https://data.worldbank.org/country/papua-new-guinea. Accessed 10 December 2023.

World Bank (2022d). Solomon Islands. https://data.worldbank.org/country/solomon-islands. Accessed 10 December 2023.

World Bank (2022e) Vanuatu. https://data.worldbank.org/country/vanuatu. Accessed 10 December 2023.

WorldFish (2018). *Conservation strategy for dugongs and seagrass habitats in the Solomon Islands. Strategy: 2018-22*. Penang, Malaysia: WorldFish. https://hdl.handle.net/20.500.12348/1987.

World Trade Organization (2009). Trade policy review report by the secretariat: Solomon Islands. WT/TPR/S/215/Rev.1.

Yamarak, L. and Parton, K.A. (2023). Impacts of mining projects in Papua New Guinea on livelihoods and poverty in indigenous mining communities. *Mineral Economics* 36, 13–27. https://doi.org/10.1007/s13563-021-00284-1.