Matthias Kowasch
Simon P. J. Batterbury *Editors*

Geographies of New Caledonia-Kanaky

Environments, Politics and Cultures

OPEN ACCESS

Springer

Marine Biodiversity in New Caledonia and Contemporary Conservation Challenges

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Dominique Pelletier

Abstract

New Caledonia is internationally renowned for its exceptional marine biodiversity, which has resulted in 80% of the lagoons and reef areas being placed on the UNESCO World Heritage list. This chapter presents the main features of this outstanding marine biodiversity and its ecological significance, highlighting the threats posed by anthropogenic pressures and global drivers, and associated conservation challenges. Oceanic and coastal dynamics determine distinct marine ecosystems. The oceanic ecosystem of the Coral Sea will be described first, and this chapter will focus on the lagoon and reef areas, which are in close relation to human populations.

Keywords

Marine biodiversity · Coral sea · Fishes · Benthic habitats · Iconic species · Conservation · Marine protected areas

4.1 The Marine Components of the New Caledonian Archipelago

Located in the southwestern Pacific Ocean and relatively far from neighbouring islands, New Caledonia includes a large exclusive economic zone (EEZ) of ~1,300,000 km^2 (Fig. 4.1). The EEZ is bounded in the West by the Australian continental shelf, by the Solomon Islands and by Vanuatu in the North and by New Zealand and Australia (due to the presence of Elizabeth and Middleton Reefs) in the South. New Caledonia's EEZ is part of the Coral Sea, which is among the 4% of the global ocean that remain relatively unaffected by human impacts (Halpern et al. 2008). The EEZ forms the Coral Sea Natural Park (CSNP) declared in April 2014 by the government of New Caledonia.[1]

In addition to this extended oceanic area, New Caledonia's main island (Grande Terre) is almost entirely surrounded by a large lagoon delineated by the longest continuous barrier reef area in the world (approximately 1500 km). This reef encloses a lagoon of 24,000 square km. Exchanges between the open sea and the lagoon occur through a number of reef passes described in Breckwoldt et al. (2022), among others. The Loyalty Islands located northeast of Grande Terre comprise two islands without lagoons (Lifou and Maré) and Ouvéa which displays a semi-closed lagoon area. In 2008, six areas in the barrier reef and the enclosed lagoon were declared as a World Heritage serial site owing to their exceptional natural beauty, the diversity of their habitats and their coral and fish species.[2] In addition, they have large populations of iconic and threatened species such as turtles, whales and dugongs.

4.1.1 The Oceanic Ecosystems in the Coral Sea

The attributes of the Coral Sea ecosystems were reviewed by Ceccarelli et al. (2013). They point out that these oceanic ecosystems are generally low in nutrients (oligotrophic), resulting in the dominance of small plankton (picoplankton) and pelagic invertebrates (jellyfish and squid), with mesopelagic fishes such as myctophids. This trophic web supports seasonal and/or ephemeral aggregations of top predators and in particular large pelagic species (mainly tuna, marlin and swordfish). These sustain important commercial fisheries

D. Pelletier (✉)
French Research Institute for Sustainable Development, UMR DECOD, Ifremer, Lorient, France
e-mail: Dominique.Pelletier@ifremer.fr

[1] https://mer-de-corail.gouv.nc/en.

[2] https://whc.unesco.org/en/list/1115 (see map in Chap. 2 by Rodary in this book).

M. Kowasch, S. P. J. Batterbury (eds.), *Geographies of New Caledonia-Kanaky*,
https://doi.org/10.1007/978-3-031-49140-5_4

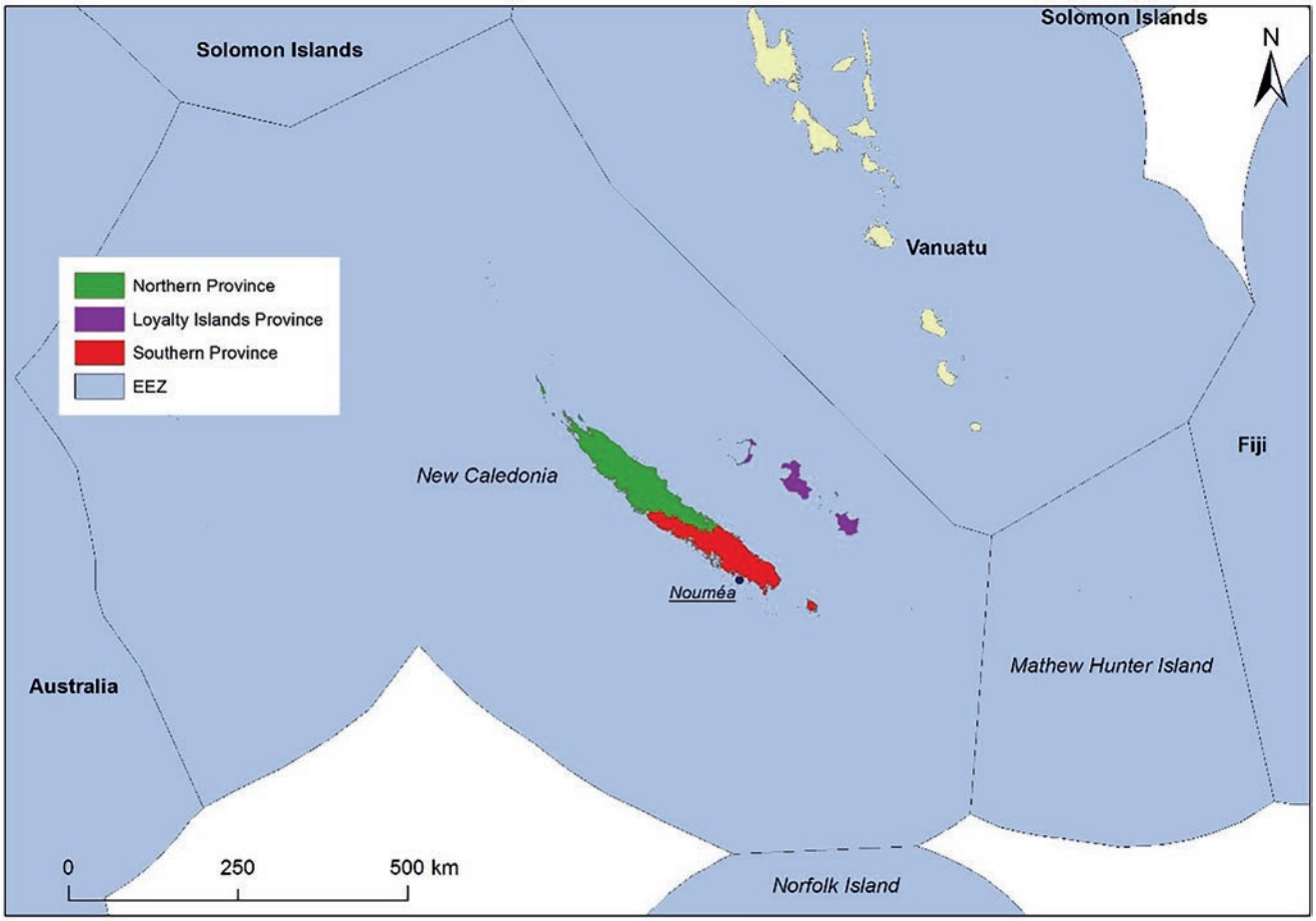

Fig. 4.1 Delineation of provinces and the exclusive economic zone of New Caledonia, located in the Southwest Pacific (17–24° latitude south, 158–172° longitude west). (Source: www.georep.nc, cartography: Kowasch 2021)

and some recreational fishing. Ceccarelli et al. (2013) also identified that we know too little about the underlying productivity (the zooplankton and micronekton that sustain larger species) and associated trophodynamics.

Seamounts are "undersea mountains" (Yesson et al. 2011). Based on bathymetry data, Yesson et al. predicted the presence of more than 500 seamounts in the Coral Sea. They provide habitats for many fish species and invertebrates and can host significant populations of fishes, as a seamount is an attractive biotope for underwater fauna, in the same way as an oasis in the middle of the oligotrophic ocean. They may thus be particularly productive, in particular when they culminate in mid-water (less than 1500 m). A number of ongoing research projects aim at improving the understanding of seamount-associated communities (e.g. led by French and Japanese institutes).

The continental shelf and bathyal (abyssal) habitats were rarely investigated in the past and are relatively poorly known in comparison to other habitats. Between 2016 and 2021, the French Museum of Natural History, Ifremer (National Institute for Ocean Science) and IRD (French Institute of Research for Development) conducted a series of four surveys to explore the deep habitats in the Coral Sea and revise biodiversity inventories.[3] Samples are not yet fully analysed. Observation technologies such as acoustics and imaging should provide additional data in the future.

Marine biodiversity, at least its most conspicuous components, is mainly observed in coastal and reef areas despite the large surface area of the Coral Sea and the EEZ. These areas also correspond to the meeting point between the land and the sea and between human populations and marine ecosystems. They will thus be the focus for the rest of the chapter. Firstly, I summarise the components of marine biodiversity and then the benthic habitats which are home to it. I then focus on components that are the most conspicuous and related to human populations, which are fish and iconic species. Lastly, I examine the

[3] https://www.mnhn.fr/fr/la-planete-revisitee-en-nouvelle-caledonie.

anthropogenic pressures affecting marine biodiversity and the instruments implemented to manage and preserve it.

4.2 What Comprises Marine Biodiversity in New Caledonia?

New Caledonia's reputation as a "hotspot of biodiversity" is justified for terrestrial and marine environments. This section builds on a compendium of marine species established in 2006 (Payri and Richer de Forges 2007) that largely concerns species observed in the 0–100 m range, although some deep species were also listed. Overall, 9300 species were identified, belonging to 1107 taxonomic families (Table 4.1). For many groups, the number of species identified is a gross underestimate, for example, for molluscs where this number could in fact be as high as 8000–10,000 species (Héros et al. 2007). In general, many small species have yet to be fully described, included in collections already sampled but not entirely processed, for example, for molluscs and Foraminifera. Due to varying research efforts, some groups are much more studied than others, like fishes, whereas worms are less researched. In addition, some biotopes were historically less inventoried, like the external slopes of barrier reefs, intermediate lagoon reefs and mangroves. Remote oceanic reef areas were also inadequately sampled in the past but were the focus of several surveys more recently[4] and in particular in the AMBIO project who provided an extensive video-based survey of fishes and habitats in all the remote reefs in the CSNP (see references below).

Table 4.1 Number of species observed in New Caledonia per main taxa group

Taxa	Common names	Number of species
Plants		45
Mangrove flora	Mangrove species	34
Marine angiosperms	Seagrasses	11
Algae	Algae	443
Foraminifera	A group of single-celled organisms	585
Porifera	Sponges	149
Cnidarians		784
Scleratinarians	Stony corals	310
Alcyonaria	Soft corals etc…	173
Gorgonacea	Gorgonians	93
Other groups	Jellyfishes, sea anemones, etc.	208
Lophophorates		415
Molluscs	Bivalves, cephalopods and gastropods	2151
Worms		416
Arthropods	Crustaceans and sea spiders	2043
Echinodermata	Sea urchins, sea cucumbers, starfishes, crinoids (sea lilies and feather stars) and brittle stars	257
Tunicata	Ascidians	290
Vertebrata		1794
Fish		1695
Sea snakes		15
Sea turtles		4
Sea birds		55
Marine mammals		25
Total		**9372**

Only fully identified species were listed. Cyanobacteria were not listed. Figures taken from Payri and Richer de Forges (2007)

In Payri and Richer de Forges (2007), a large proportion of species are microfauna and meiofauna, meaning they are smaller than a few millimetres. For instance, there are 585 species (6% of species) of Foraminifera, which are mostly calcareous species found in shallow lagoonal waters (Debenay and Cabioch 2007). Arthropods also form a vast group (22% of species) with many small taxa, for example, copepods which are tiny crustaceans either planktonic or benthic organisms, sometimes associated with fish or corals.

A second feature of New Caledonian biodiversity is endemicity, that is, the fact that many species are only found there. For several groups, the rate of endemicity is quite high, for example, 40% of sponge species. It is lower for other non-sessile groups, for example, around 50 species for molluscs. The notion of endemicity is closely related to conservation efforts, because if an endemic species disappears from its habitat, it disappears from the planet.

High biodiversity is largely explained by the diversity of ecological niches and habitats found in New Caledonia. The next section describes the main features of these habitats in lagoon and shallow (0–100 m) reef areas.

4.3 Benthic Habitats

Lagoon and reef areas encompass a mosaic of benthic habitats. Habitats are characterised by their geomorphological structure, a simple typology distinguishing the barrier reef with its external and internal slopes, the intermediate reefs located in lagoon areas, the lagoon areas themselves and the fringing reefs. Reef passes are specific areas with strong hydrodynamics entailing a remarkable abundance of fish and the frequent presence of large species such as sharks and rays. Andréfouët and Torres-Pullizza (2004) mapped the geomorphological distribution of reefs and lagoons in New Caledonia and showed the diversity, complexity and intertwining of reef-associated structures. This configuration has

[4] https://mer-de-corail.gouv.nc/fr/missions-du-parc-comprendre/campagnes-scientifiques.

been shaped by strong ancient geological and climatic events.

Overlaying this geomorphological structure, habitat is in addition described by substrate types with varying granularity and organisation. Furthermore, this abiotic substrate is covered with fixed fauna and flora of different sizes, shapes and colours. Hence, the notion of habitat involves a range of spatial scales, from the very fine (a few centimetres) to the large (across a few kilometres) and with a diversity of features. A diversity of shelters in a habitat determines its capacity to host a rich and diverse biodiversity. This diversity of so-called niches and the favourable weather conditions throughout the year likely explain why New Caledonian lagoon and reef habitats exhibit such diverse marine life.

The most common benthic habitats observed in the lagoon and reefs are living coral, sandy bottoms, debris habitats, seagrass beds, macroalgae fields and mangrove areas (Figs. 4.2 and 4.3) (Pelletier et al. 2020).

Mangroves are located at the land-sea interface, in lagoons and estuaries, and are particularly vulnerable to anthropogenic pressures. In New Caledonia, the larger areas are found on the western coast of the Grande Terre, notably from Pouembout to Koné, but they are distributed all around the island. This unique habitat provides four important ecosystem services to human populations: carbon sequestration, water purification, coastal protection and fish biomass production (Trégarot et al. 2021). Because of their intricate root network, mangrove areas are particularly good shelters for animals to avoid predation, for instance, crabs or young fish. Trégarot et al. found that New Caledonian mangroves had a relatively lower vulnerability than in some other French oversea territories.

Seagrass habitats are most frequently found on fringing reefs and on the western coast of New Caledonia (Fig. 4.2, top left), for example, in the Bourail area. By contrast, they are infrequently found in remote reefs across the CSNP. Like mangroves, seagrass habitats limit the erosion of the sea bottom by stabilising the fine-grained substrate. They help trap fine sediments and particles that are suspended in the water column, which increases water clarity. Seagrass also provides food, shelter and essential nursery areas for fish species, including exploited ones, and for invertebrates. Some fish families are more often observed in seagrass habitats than in hard bottom habitats, for example, emperors (Lethrinidae). The green sea turtle (*Chelonia mydas*) and dugongs (*Dugong dugon*) feed directly on seagrass, while the decomposition of seagrass plants releases nutrients in water and food for small invertebrates. Finally, seagrasses provide a safe environment for juvenile and small adult fish and invertebrates to escape from larger predators.

Like mangrove and seagrasses, macroalgae habitats are also found on soft bottoms (Fig. 4.2, top right). Pelletier et al. (2020) found a distribution concentrated in the western

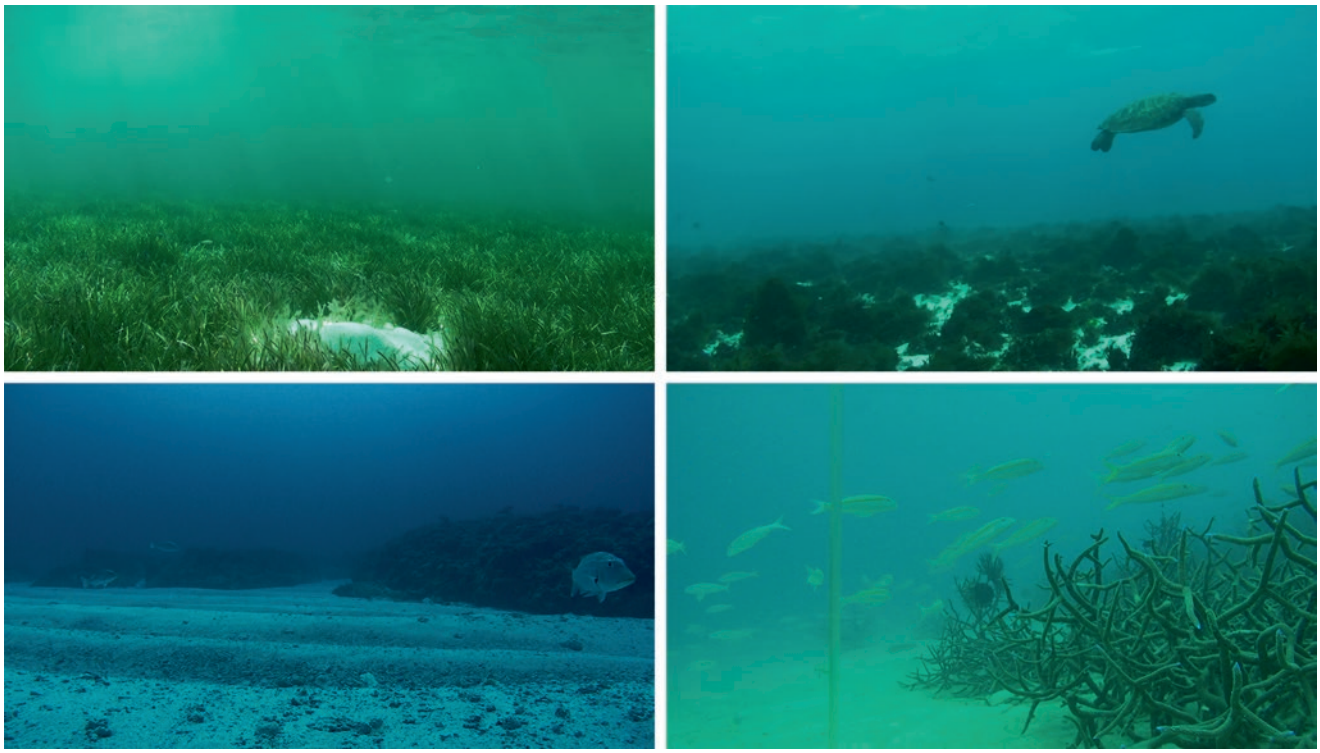

Fig. 4.2 Seagrass habitat in Abore barrier reef (top left), macroalgae habitat in Merlet integral reserve (top right), sandy habitat in Bellona remote reef (bottom left) and sandy habitat with isolated coral patch in Merlet integral reserve (bottom right). (Source: Pelletier 2020)

Fig. 4.3 Live coral habitat (top left), debris habitat on exposed reef flat at Astrolabe remote reef (top right), debris habitat associated with damage from recreative uses and mooring at Mbe Kouen unprotected reef (bottom left) and debris habitat dominated by boulders at the volcanic island Hunter (bottom right). (Source: Pelletier 2020)

coast of the Grande Terre and particularly in the Nouméa area. Macroalgae are primary producers that form the basis of many marine food chains and provide habitat and refuge for a range of organisms. Yet, they appear to support less diversity of animals than seagrasses.

Sandy bottoms (Fig. 4.2, bottom) are habitats where biotic cover is low or absent. A number of mobile fish species can be observed, for example, rays, sharks, jacks and flatfishes and passing sea turtles (Pelletier et al. 2020). Sea cucumbers (a type of echinoderm, like starfish) are commonly observed. In these relatively desert areas, many small species aggregate around isolated coral reef patches that appear as oases (Fig. 4.2, bottom right).

Other types of soft bottom habitats are also present in New Caledonian coastal waters and around shallow reefs. Bays and semi-enclosed zones represent 35% of sediment bottom habitats (Laboute et al. 1991). Sediments and mud are mostly transported by creeks and rivers that wash out from the landmass and accumulate on the lagoon floor. Examples include Prony Bay in the south or Port-Bouquet Bay on the southeast of Grande Terre. In such areas, marine life is mostly endogenous, hidden in the sediment, although some corals, invertebrates and fish species have adapted to this environment.

Hard bottom habitats are the other types encountered in New Caledonian coastal areas. Living coral habitat is the richest and most diversified habitat in terms of marine species, invertebrates and vertebrates. Bioconstructed coral structures yield a diversity of ecological niches and complex habitat morphologies which provide multiple refuges for numerous species. In New Caledonia and in other regions, the macrofauna of this habitat has been researched more thoroughly than others, and corals and fish species have often been used as surrogates in biodiversity assessments (Bellwood and Hughes 2001) because they are comparatively easy to enumerate and are well known taxonomically. According to Pelletier et al. (2020), who established the distribution of benthic habitats at the scale of New Caledonian lagoon and reef areas, the live coral habitat is the most remarkable where reefs are protected from trade winds, for example, on the external slopes of the barrier reef, in the South Lagoon and at several remote reefs of the CSNP (Astrolabe, Chesterfield, Bellona, Entrecasteaux) (Fig. 4.3, top left). Live coral cover is also abundant on some fringing reefs on the eastern coast of Grande Terre, for example, in Pouebo and Borendy.

The debris habitat displays a lower cover of live coral, ranging from 0% to approximately 20%, with diverse facies, either small debris, dead coral, rocks, boulders or slabs. In these habitats, the diversity of fish species is lower than in the live coral habitat. Yet, some species are still quite common here, like triggerfish (Balistidae), surgeonfish

(Acanthuridae) and parrotfish (Scaridae) (Pelletier et al. 2020). This habitat is found in areas where the live coral has been damaged either from natural or anthropogenic forces and in zones exposed to waves (e.g. in reef flats) (Fig. 4.3, top right) or with strong hydrodynamics, for example, reef passes in and out of the lagoon. Where nutrients are abundant or corals have died from bleaching, macroalgae may develop on the substrate or on dead coral, particularly if grazing species (herbivorous species feeding on these macroalgae) are not abundant. The debris habitat is commonly observed in the larger Nouméa area, on the internal slope of the barrier reef and around islands and reefs where frequentation by boat is high (Fig. 4.3, bottom left). It is also found in exposed shallow areas in the remote reefs of Petrie and Astrolabe and in Hienghène and Pouébo on Grande Terre's northeast coast.

Particular hard bottom habitats can be observed in specific areas, for example, around the remote volcanic islands of Matthew and Hunter, northeast of Grande Terre (Fig. 4.3, bottom right). Surprisingly, a substantial cover of live coral was observed on their fringing reefs (Roman and Pelletier 2015).

To summarise, these six main habitats display very distinct features and therefore host distinct species compositions and macrofauna abundances. They may serve as a nursery for some species and a feeding ground for others. Likewise, a given species may spend part of its life cycle in a given habitat and others in different habitats. Therefore, the biodiversity of coral reef ecosystems strongly depends on the coexistence and connectivity of these complementary habitats.

4.4 Fishes and Other Exploited Species

Fish have been well described and illustrated in New Caledonia: the checklist of Fricke et al. (2011) comprises 2320 marine species in 246 families. Laboute and Grandperrin (2016) reported and illustrated 1200 species. The majority of New Caledonian marine species (1860) belong to the Grande Terre group, 1029 to the Loyalty Ridge (including the Loyalty Islands) and 193 to the New Caledonian basin at large (Fricke et al. 2011). These authors list 107 endemic species, that is, 4.6% of the total native species, which is a high rate of endemism (and mainly comprises small species). It is likely that the number of fish species is underestimated because the observation techniques commonly used (underwater visual censuses) cannot reliably capture species that are cryptic, camouflaged, averse to divers or too small (Kulbicki et al. 2010).

The distribution of fish species and their abundance strongly depends on benthic habitat (see above) and on fishing pressures. In many reef passes, in addition to greater abundances, several species form large aggregations, either for spawning or for feeding on spawning species. This is, for instance, the case of the false pass of Bourail, very close to the coast, and the Kouare pass in the South Lagoon, located more offshore from Grande Terre (Fig. 4.4, bottom right). Protecting reef passes from excessive fishing is key to safeguarding the spawning potential of fish populations. The AMBIO (Advanced Nanostructured Surfaces for the Control of Biofouling) project showed that fish abundance and fish diversity were highest in the remote reefs of the CSNP (Fig. 4.4, top left and right) and particularly at Astrolabe reefs (Schohn et al. 2017a) and at d'Entrecasteaux reefs (Schohn et al. 2017b), mainly because of their remoteness and the outstanding health status of these remote coral reefs. The AMBIO project also documented the effectiveness of the marine protected areas (MPAs) implemented on Grande Terre to protect the abundance and diversity of fish assemblages and of exploited fish species; see, for example, the Abore reef marine reserve (Fig. 4.4, bottom right).

4.5 Iconic Species

Iconic species are those with an outstanding social value to humanity; this notion of course being culturally dependent. Iconic species are used to promote New Caledonia and its biodiversity.[5]

A number of fish species are considered as iconic (Fig. 4.5). Most rays (20 species) belong in this category, including the manta ray (*Mobula birostris*), the giant guitarfish (*Rhynchobatus djiddensis*), the round ribbontail ray (*Taeniurops meyeni*) and the whitespotted eagle ray (*Aetobatus ocellatus*). Shark species are included as well (more than 20 species observed) and the humphead wrasse (*Cheilinus undulatus*). Most ray species and the humphead wrasse are endangered. The conservation status of requiem sharks (genus *Carcharhinus*), the great white shark (*Carcharodon carcharias*), the whale shark (*Rhincodon typus*) and the tawny nurse shark (*Nebrius ferrugineus*) range from vulnerable to endangered. Although some of these species are relatively rare, diverless video-based surveys conducted in the AMBIO project evidenced very high frequencies of some shark species (over 40%, that is, they were seen on more than 40% of underwater video stations at a given site) and humphead wrasse (20%) on some remote reefs in the CSNP. Rays were most often observed in lagoon areas, with a frequency up to 10%.

[5] See, for example, dugong and whales featured in advertising material for cruises at https://escales.ponant.com/nouvelle-caledonie-grand-lagon-sud/.

Fig. 4.4 Examples of fish species observed in New Caledonia: Live coral seascape in Chesterfield remote reef (top left), large abundance of fish with jacks and a shark above a coral patch in Astrolabe remote reef (top right), sweetlips in Nouméa barrier reef MPA (bottom left) and aggregation of fish in Kouare reef pass (bottom right). (Source: STAVIRO images from AMBIO project, Ifremer)

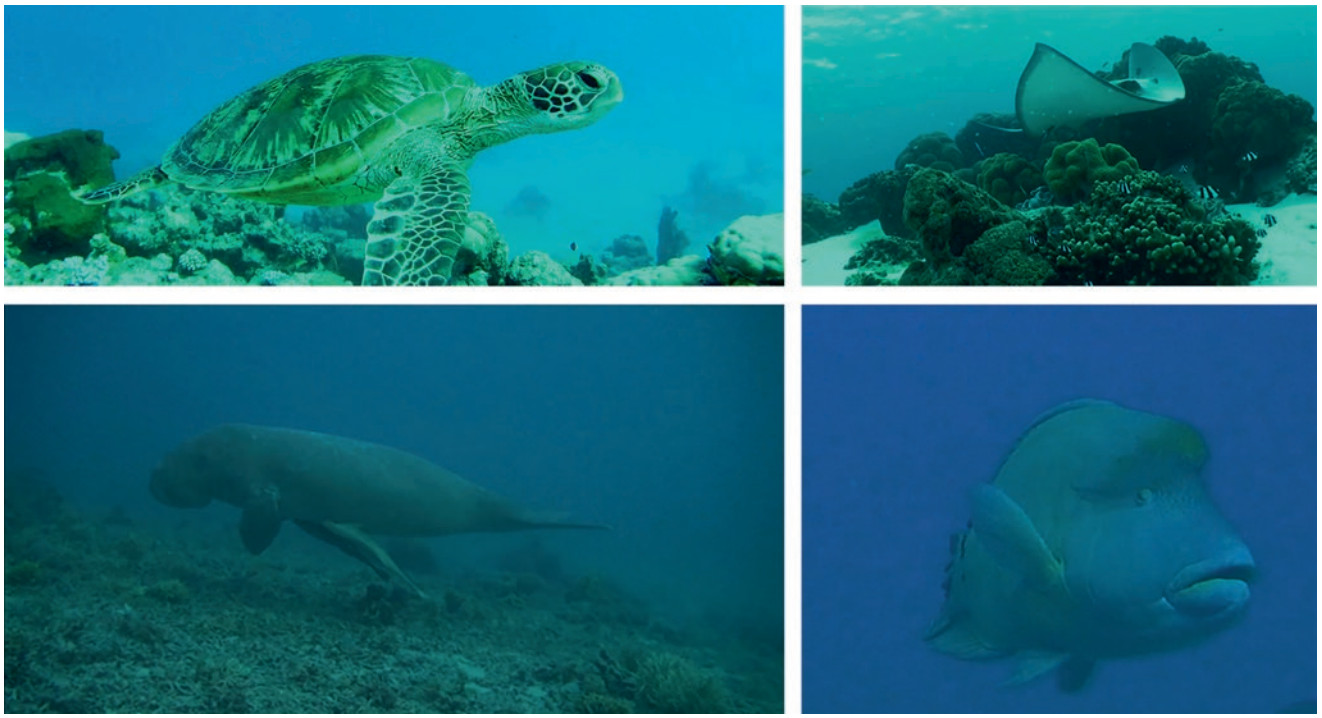

Fig. 4.5 Examples of iconic species observed in the New Caledonian lagoon: green turtle (Kouare pass) (top left), cow tail stingray (*Pastinachus sephen*) (Nouméa barrier reef) (top right), dugong (Signal Islet, Nouméa Lagoon) (bottom left) and giant wrasse (Kouare pass) (bottom right). (Source: STAVIRO, AMBIO project, Ifremer)

Four species of sea turtles (out of seven in the world) are present in New Caledonia. The green turtle (*Chelonia mydas*) is the most abundant (Fig. 4.5). It comes onshore only to breed, and important nesting sites are located at the d'Entrecasteaux reefs and atolls, while a few other sites are distributed on the western and eastern coasts of Grande Terre and across the Loyalty Islands. The loggerhead turtle (*Caretta caretta*) has a main nesting site in the Bourail area and minor sites in the Isle of Pines and Loyalty Islands. The hawksbill turtle (*Eretmochelys imbricata*) can be observed in several places on the northeastern coast, on the Loyalty Islands and across some southern locations on Grande Terre and the Isle of Pines. The leatherback turtle (*Dermochelys coriacea*) is only sporadically observed transiting in New Caledonia (d'Auzon 2007).

Some 59 species of sea birds have been observed in New Caledonia, out of which 28 breed in the territory (Spaggiari et al. 2007). Four breeding species display subspecies that are endemic to New Caledonia: two petrel species (*Pterodroma leucoptera caledonica* and *Pseudobulweria rostrata trouessarti*), the silver gull (*Larus novoehollandiae forsteri*) and the fairy tern (*Sternula nereis exsul*). Petrel species that breed in New Caledonia are classified as vulnerable (*Pterodroma leucoptera*) or endangered (*Nesofregetta fuliginosa*), while two others are considered as near-threatened: *Pseudobulweria rostrata trouessarti* and *Esacus magnirostris*. There is evidence that at least three species were extirpated from regions of New Caledonia where they used to breed: the boobies (*Sula dactylatra* and *S. leucogaster*), the fairy tern and the silver gull.

There are 25 species of marine mammals in New Caledonia. None of them are endemic, as they are widely distributed across the Pacific (Garrigue 2007). The territory hosts the largest population of dugong (*Dugong dugon*) in Oceania. Some 23 species of Cetaceans have been sighted but many only once. The most abundant species is the humpback whale (*Megaptera novaeangliae*), which breeds in the South Lagoon. The minke whale (*Balaenoptera acutorostrata*) is regularly observed too, as is the Indian Ocean bottlenose dolphin (*Tursiops aduncus*).

Sea snakes are abundant in the lagoons of New Caledonia compared to other islands in Oceania, with 14 species inventoried. They are encountered in the reefs and shallow bays fringing the shores of coasts and islets (Ineich and Laboute 2002; Borsa 2008), where they move ashore and also prey on fish on coral reefs. Snakes are also present in remote reefs in the Coral Sea (Goiran et al. 2022). Two species are endemic to the territory: *Laticauda saintgironsi* and *Hydrophis laboutei*.

4.6 Conservation Challenges and Current Management Measures

Marine biodiversity in New Caledonia is subject to several types of anthropogenic pressures (Table 4.2). Most if not all of these are correlated with economic activity and the presence of humans. After several decades of growing populations, the number of human inhabitants of New Caledonia had stabilised by 2019, related to other trends noted in this book.[6]

Urbanisation coupled with rapid demographic increase until 2019 has entailed an extension and densification of the Nouméa agglomeration and the growing urban population anchored by Kone, with consequences in terms of run-off to the lagoon. A different type of run-off occurs due to mining

Table 4.2 Anthropogenic pressures and their impacts on marine biodiversity in New Caledonia

Pressure	Impacts
Fishing	Reduction of fish populations, particularly long-lived and large species (sustainability not evaluated in New Caledonia) Disposal of fish guts and waste in some areas NB: very few habitat-impacting or destructive fishing techniques are used in New Caledonia
Recreational uses (other than fishing) at sea	Disturbance of marine life (birds, mammals) and degradation of benthic habitats (corals, seagrasses, algae) and sessile fauna
Frequentation of islets by visitors	Disturbance of marine birds, some of them are nesting on the islets Habitats and sessile flora and fauna, as well as islet vegetation, are eroded and degraded through repeated trampling, wood collection and light pollution
River run-off including from water treatment plants	Inputs of organic nutrients, pollutants like molecules not treated by water plants, heavy metals from industrial areas and phytosanitary products used by agriculture
Mining activities	Run-off from soil erosion on land, inputs of pollutants Sediment deposit in the lagoon (siltation) Degradation of habitats due to channelisation and other works carried out in the maritime zones
Mooring of boats and cruise ships	Destruction of benthic habitats (corals, seagrasses, algae) and associated sessile fauna through mooring and landings of hundreds of passengers in small areas
Creating artificial shorelines, for example, tourist development	Degradation or destruction of benthic habitats (corals, seagrasses, algae) and associated sessile fauna

[6] https://www.isee.nc/population.

activity, resulting in heavy soil erosion (due to extraction and access roads). For instance, in the Thio area, sediments cover most of the fringing reefs and impair underwater visibility close to the shore (Roman et al. 2015).

Marine recreational activity includes boating, fishing, scuba diving, snorkelling, jet-skiing, sailing small non-motorised craft like kayaks, kitesurfing and surfing. These uses have been growing and diversifying in all coastal areas of New Caledonia over the last three decades, in parallel with demographic increase. Gonson et al. (2016) showed that the number of boat trips in the Nouméa area has more than doubled over a 9-year period (2005–2014), with most operated by local residents. These authors also showed a sharp increase in the number of visitors to the many nearshore islets, aided by a growing traffic to the most popular ones by taxi-boats transporting tourists and residents. In 2013, approximately 157,000 visitors landed on five main islets facing Nouméa (AMBIO project, Gonson et al. 2017). Islets where landing is permitted suffer from substantial degradation due to these landings and leisure activities. Elsewhere, the development of cruise ship tourism over the last 20 years has meant several very large ships anchor off formerly untouched bays on the islands of Lifou, Ouvéa and the Isle of Pines (Île des Pins), as well as in Nouméa harbour. Lifou had 4 landings per year in 1995, increasing to 30 between 2005 and 2008, and 120 in 2016. Pelletier et al. (2016) found a severely damaged reef habitat in Lifou in 2014. That study proved that living coral cover was reduced to zero in a 200 m radius around the mooring point and was badly damaged up to a 400 m distance away from it (Fig. 4.6), often due to the anchor and its chain. Accordingly, the abundance of fish species decreased to a very low level around the mooring sites.

Fishing of course constitutes a major pressure on biodiversity. Fishing is mostly for food but also for stocking aquaria (see Chap. 5 by Sabinot et al. in this book). It is a traditional activity and source of food for Melanesian populations who live by the sea, who have regulated it over thousands of years through customary rules involving territorial fishing rights and closed areas. There are some commercial vessels operating from urban areas, but mostly informal fishing takes place elsewhere, with a mix of subsistence and recreational fishing and with a parallel commercial market (Jollit et al. 2010). Non-commercial fishing pressure is concentrated near the urban centres of Nouméa in the South Province and near the urban agglomeration of Voh, Koné and Pouembout in the North (Gonson et al. 2018). In 2005, the catch in the southwest lagoon was estimated at more than 1100 tons/year from recreational fishing alone (Jollit 2010; Jollit et al. 2010).

The non-commercial catch across the archipelago is substantial. Fishing in the lagoon typically targets grouper (Serranids), surgeonfish (Acanthurids), snapper (Lutjanids), emperor fish (Lethrinids), parrotfish (Scarids), mullet (Mugilids), rabbitfish (Siganids), jack (Carangids) and grunt (Haemulids). Several crustaceans are also prized: the giant mud crab (*Scylla serrata*) caught in mangroves, the coconut crab (*Birgus latro*), spiny lobsters (*Panulirus* sp.) and slipper lobsters (*Scyllarides* sp. and *Parribacus* sp.) Some other invertebrates are targeted too: troca (*Trochus niloticus*), amusium (*Amusium japonica*) and giant clam (*Tridacna derasa* and *Hippopus hippopus*). Unfortunately, the most spectacular seashells may sometimes be sampled for collection. A large number of fish and marine invertebrates (crustaceans and molluscs) are taken. In a survey of recreational fishers conducted in the Nouméa area during the PAMPA project (Pelletier 2011), almost 80 fish species were observed in catches and 15 invertebrate species; among them are spider conch (*Lambis* sp.), giant clam (*Tridacna* sp.), slipper lobster, octopus (*Octopus octopus*) and cuttlefish (*Sepia latimanus*). Note that there is to date no well-established and comprehensive monitoring programme for non-commercial fisheries, and this is not a current political priority. Commercial fisheries (aside from offshore pelagic fisheries) are also not evaluated.

Fig. 4.6 Snapshots of coral reef habitat in the mooring area, Lifou. Impacted zone (left) and comparable non-impacted zone (right). (Source: AMBIO project, Ifremer)

New Caledonia has, however, been quite a pioneer in France regarding environmental protection, particularly by establishing a number of reasonably sized marine protected areas (MPAs). The first marine reserve, still an integral reserve today, dates back to 1970 (covering 172 km^2), but most of the reserves were declared between 1981 and 1995, in the South Province. Many are located in the lagoon facing Nouméa (174 km^2). In these MPAs, fishing is banned, but there are many recreational vessels and visitors (see above). The largest no-take reserve is formed by the Abore barrier reef offshore from Nouméa city, which was definitively closed to fishing in 1995, after a short reopening between 1993 and 1995. The high catch levels after reopening demonstrated the protection afforded by the MPA (Ferraris et al. 2005).

Other marine reserves were established by the South Province in Bourail on the west coast (in 1993), Ouano (west, in 2004), close to Thio in the east (in 2010) and by the North Province in Hienghene (east coast, in 2007), Pouebo (northeast, in 2009) and a site close to Voh in the west (Kan-Gunu in 2013). The next step in protecting marine biodiversity was placing 80% of the New Caledonian reef and lagoon areas, that is, 15,743 km^2, on the World Heritage list in 2008.[7] The gazetting of these reserves has reinforced the awareness of protective measures within the perimeter of the World Heritage listing and is subject to compulsory periodic monitoring for their "exceptional universal value" (EUV). In this case, EUV is bound up in maintaining marine biodiversity, aided by participatory management of marine areas with local people. The creation by the government of the Coral Sea Natural Park in 2014 has extended protection to the entire EEZ of New Caledonia, outside of the lagoons. It includes several remarkable shallow reefs and atolls: Entrecasteaux, Chesterfield and Bellona, Petrie and Astrolabe, Walpole, Matthew and Hunter. These remote areas are home to quasi-pristine biodiversity, exemplified by abundant fish populations and high coverage of living coral in sheltered reefs (Schohn et al. 2017a). Their remoteness is the first factor of protection, as is also the case for the South Lagoon area (Bockel et al. 2017). In 2023, significant additional protection was agreed bringing the coverage of strictly protected marine areas up to 10% of the EEZ, a plan developed in cooperation with fishers and Indigenous and other government authorities (Oceanographic 2023). The gazetting of these strongly areas within the CSNP perimeter complies with the target 14.5 of the UN Sustainable Development Goal 14 "Life below water".

Another component of management for the marine environment lies in the adoption of Environmental Codes by the North, South and Loyalty Islands Provinces in 2008, 2009 and 2016, respectively. These documents provide frameworks for regulating commercial and non-commercial fisheries. The regulations include constraints on the type and numbers of fishing gear and officially ban several fishing practices such as night fishing and other destructive practices.

[7] https://whc.unesco.org/en/list/1115.

4.7 Conclusion

New Caledonia and its extensive marine territory have been gifted with an exceptional marine biodiversity. The territorial government and the provinces have, over time, implemented several important management instruments to preserve this biodiversity, offering some protection from large foreign fishing vessels operating across the Pacific. In this respect, the territory appears as quite exemplary. It also benefits from a low human population density compared to other tropical islands, and substantial local of marine habitats and species that stretches back thousands of years.

Yet, this is a fragile situation. Environmental policies and controls on commercial exploitation of the ocean and lagoon environments must be sustained over the long term by the different governing bodies, not least because the marine environment is extensive. While the extension of conservation efforts in 2023 are encouraging, they require implementation and funding. This is particularly important as the territory also must face the consequences of climate change which is becoming a major driver and a threat to lagoon and reef socio-ecosystems. Sound management of anthropogenic pressures will contribute to increasing their resilience with respect to local and global change.

References

Andréfouët S, Torres-Pullizza D (2004) Atlas des récifs coralliens de Nouvelle -Calédonie. IFRECOR, IRD

Bellwood DR, Hughes TP (2001) Regional-scale assembly rules and biodiversity of coral reefs. Science 292:1532–1534. Available online at: https://www.science.org/doi/10.1126/science.1058635

Bockel T, Schohn T, Pelletier D, Carpentier L (2017) Video-based baseline assessment of fish communities and habitats in the Corne Sud area, World Heritage property. AMBIO Project, IFREMER. https://doi.org/10.13155/51758

Borsa P (2008) Sea snakes: overlooked predators at an urban fringing reef. Coral Reefs 27(4):743–743. https://doi.org/10.1007/s00338-008-0437-9

Breckwoldt A, Nozik A, Moosdorf N, Bierwirth J, Fache E, Ferse S, Ford A, Mangubhai S, Pelletier D, Piovano S (2022) A typology for reef passages. Front Mar Sci 9. https://doi.org/10.3389/fmars.2022.786125

Ceccarelli DM, McKinnon AD, Andréfouët S, Allain V, Young J, Gledhill DC, Flynn A, Bax NJ, Beaman R, Borsa P, Brinkman R, Bustamante RH, Campbell R, Cappo M, Cravatte S, D'Agata S, Dichmont CM, Dunstan PK, Dupouy C, Edgar G, Farman R, Furnas

M, Garrigue C, Hutton T, Kulbicki M, Letourneur Y, Lindsay D, Menkes C, Mouillot D, Parravicini V, Payri C, Pelletier B, Richer de Forges B, Ridgway K, Rodier M, Samadi S, Schoeman D, Skewes T, Swearer S, Vigliola L, Wantiez L, Williams A, Williams A, Richardson AJ (2013) Chapter four – The Coral Sea: physical environment, ecosystem status and biodiversity assets. In: Lesser M (ed) Advances in marine biology. Academic, pp 213–290. https://doi.org/10.1016/B978-0-12-408096-6.00004-3

d'Auzon J-L (2007) Marine turtles of New Caledonia. In: Compendium of marine species, 2nd edn. IRD Editions, Nouméa, pp 411–414

Debenay J-P, Cabioch G (2007) Recent and quaternary foraminifera collected around New Caledonia. In: Compendium of marine species, 2nd edn. IRD Editions, Nouméa, pp 69–94

Ferraris J, Pelletier D, Kulbicki M, Chauvet C (2005) Assessing the impact of removing reserve status on the Abore Reef fish assemblage in New Caledonia. Mar Ecol Prog Ser 292:271–286. https://doi.org/10.3354/meps292271. http://archimer.ifremer.fr/doc/00000/10970/7574.pdf

Fricke R, Kulbicki M, Wantiez L (2011) Checklist of the fishes of New Caledonia, and their distribution in the Southwest Pacific Ocean (Pisces). Stuttgarter Beiträge zur Naturkunde A, Neue Serie 4:341–463

Garrigue C (2007) Marine mammals of New Caledonia and the Loyalty Islands. Checklist of the species. In: Compendium of marine species, 2nd edn. IRD Editions, Nouméa, pp 429–435

Goiran C, Mallet D, Lanos N, Shine R, Udyawer V, Wantiez L (2022) Sea snake diversity at the Entrecasteaux atolls, Coral Sea, as revealed by video observations at unbaited stations. Coral Reefs 41(6):1551–1556. https://doi.org/10.1007/s00338-022-02307-x

Gonson C, Pelletier D, Gamp E, Preuss B, Jollit I, Ferraris J (2016) Decadal increase in the number of recreational users is concentrated in no-take marine reserves. Mar Pollut Bull 107(1):144–154. https://doi.org/10.1016/j.marpolbul.2016.04.007

Gonson C, Pelletier D, Alban F, Giraud-Carrier C, Ferraris J (2017) Influence of settings management and protection status on recreational uses and pressures in marine protected areas. J Environ Manag 200:170–185. https://doi.org/10.1016/j.jenvman.2017.05.051

Gonson C, Ferraris J, Pelletier D, Jollit I (2018) The lagoon: a natural heritage and recreational space. In: New Caledonia: world of corals. IRD Editions, Editions Solaris, Marseille, pp 211–215. Available online at: https://www.documentation.ird.fr/hor/fdi:010076917

Halpern BS, Walbridge S, Selkoe KA, Kappel CV, Micheli F, D'Agrosa C, Bruno JF, Casey KS, Ebert C, Fox HE, Fujita R, Heinemann D, Lenihan HS, Madin EMP, Perry MT, Selig ER, Spalding M, Steneck R, Watson R (2008) A global map of human impact on marine ecosystems. Science 319(5865):948. https://doi.org/10.1126/science.1149345

Héros V, Lozouet P, Maestrati P, von Cosel R, Brabant D, Bouchet P (2007) Mollusca of New Caledonia. In: Compendium of marine species, 2nd edn. IRD Editions, Nouméa, pp 199–254

Ineich I, Laboute P (2002) Sea snakes of New Caledonia. IRD Éditions. Institut de Recherche pour le Développement. Muséum national d'histoire naturelle

Jollit I (2010) Spatialisation des activités humaines et aide à la décision pour une gestion durable des écosystèmes coralliens: la pêche plaisancière dans le lagon sud-ouest de la Nouvelle- Calédonie. Retrieved from http://www.theses.fr/2010NCAL0047/document

Jollit I, Léopold M, Guillemot N, David G, Chabanet P, Lebigre J-M, Ferraris J (2010) Geographical aspects of informal reef fishery systems in New Caledonia. Mar Pollut Bull 61(7):585–597. https://doi.org/10.1016/j.marpolbul.2010.06.033

Kulbicki M, Cornuet N, Vigliola L, Wantiez L, Moutham G, Chabanet P (2010) Counting coral reef fishes: interaction between fish life-history traits and transect design. J Exp Mar Biol Ecol 387(1):15–23. https://doi.org/10.1016/j.jembe.2010.03.003

Laboute P, Grandperrin R (2016) Guide des poissons de Nouvelle-Calédonie. Editions Catherine Ledru, Nouméa

Laboute P, Feuga M, Grandperrin R (1991) Nouvelle-Calédonie: Le plus beau lagon du monde. Editions Alizés, Nouméa

Oceanographic (2023) New Caledonia protects 10% of its ocean. Oceanographic Magazine 19/10/2023. Available online at: https://oceanographicmagazine.com/news/new-caledonia-protects-10-of-its-ocean/

Payri C, Richer de Forges B (2007) Compendium of marine species, 2nd edn. IRD Editions, Nouméa

Pelletier D (2011) INDICATORS – constructing and validating indicators of the effectiveness of marine protected areas. In: Marine protected areas: effects, networks and monitoring – a multidisciplinary approach. Cambridge University Press, pp 247–289. Available at: https://archimer.ifremer.fr/doc/00177/28834/

Pelletier D (2020) The diversity of shallow habitats in New Caledonia reefs and lagoons. https://doi.org/10.17882/73937

Pelletier D, Bockel T, Carpentier L, Schohn T, Raillard B, Roman W, Powell A (2016) Video-based assesment of the impact of cruising activity on the habitat and fish communities of the Bay of Easo-Xepenehe Lifou. 2014 STAVIRO survey. AMBIO Project, Ifremer. https://doi.org/10.13155/47348

Pelletier D, Selmaoui-Folcher N, Bockel T, Schohn T (2020) A regionally scalable habitat typology for assessing benthic habitats and fish communities: application to New Caledonia reefs and lagoons. Ecol Evol 10(14):7021–7049. https://doi.org/10.1002/ece3.6405

Roman W, Pelletier D (2015) Video-based baseline assessment of fish assemblages and habitats of the volcanic islands Matthew and Hunter in the Coral Sea Natural Park. 2014 STAVIRO Survey. AMBIO Project, Ifremer. https://doi.org/10.13155/38084

Roman W, Pelletier D, Powell A (2015) Video-based baseline assessment of fish assemblages and benthic habitats in the Borendy area, New Caledonia 2012 STAVIRO survey. AMBIO Project, Ifremer. https://doi.org/10.13155/38523

Schohn T, Bockel T, Carpentier L, Pelletier D (2017a) Video-based baseline assessment of fish assemblages and habitats at Astrolabe, Petrie and Walpole remote islands and reefs in 2014, Coral Sea Natural Marine Park. AMBIO Project, Ifremer. https://doi.org/10.13155/51738

Schohn T, Pelletier D, Carpentier L (2017b) Video-based baseline assessment of fish assemblages and habitats of Entrecasteaux atolls, World Heritage and Coral Sea Marine Park. 2015 STAVIRO survey. AMBIO Project, Ifremer. https://doi.org/10.13155/51760

Spaggiari J, Barré N, Baudat-Franceschi J, Borsa P (2007) New Caledonian seabirds. In: Compendium of marine species, 2nd edn. IRD Editions, Nouméa, pp 415–428

Trégarot E, Caillaud A, Cornet CC, Taureau F, Catry T, Cragg SM, Failler P (2021) Mangrove ecological services at the forefront of coastal change in the French overseas territories. Sci Total Environ 763:143004. https://doi.org/10.1016/j.scitotenv.2020.143004

Yesson C, Clark MR, Taylor ML, Rogers AD (2011) The global distribution of seamounts based on 30 arc seconds bathymetry data. Deep-Sea Res I Oceanogr Res Pap 58(4):442–453. https://doi.org/10.1016/j.dsr.2011.02.004