Chapter 3
The Oceans Surrounding Papua New Guinea: A Habitat View for Sustainable Fisheries and an Acknowledged Lack of Carrying Capacity Knowledge of the Ocean Ecosystem

Cousteau divers found extraordinary scenes of beauty and diversity in many parts of Papua New Guinea's little-explored waters.
Cousteau and Richards (1999, p. 199).
Parliament has been told that 18 Papua New Guineans working as fisheries observers in seas around PNG have disappeared in the past five years.
Radio New Zealand (2018)

Abstract Papua New Guinea is part of Melanesia and thus consists of a landmass with thousands of islands; it features one of the most diverse cultures on earth. While often not fully recognized PNG actually is an island nation embedded in the sea and its saltwater. The Exclusive Economic Zone (EEZ) of PNG is of major and strategic relevance for the nation; and the ocean wealth is another reason for PNG's diversity and uniqueness. Here the ocean resources surrounding PNG are briefly described and how the geology and biology affects PNG culture and human society in the context of the Anthropocene, which includes colonial, WW1 and WW2 battles, as well as modern gear and subsequent fisheries wars all done with a western and neocolonial oversight. Already 18 fisheries observers in PNG waters disappeared without obvious trace; still a 'cold case' but fully known to the fishing nations in the region like U.S., Japan, and New Zealand. Arguably, the world features a global ocean and coastal crisis, including a crisis of 'The Freedom of the Seas,' and those aspects are reported here also, including seabed mining and decay of sea grass, coral reefs, fish stocks and their connected aspects and collapse.

Keywords Papua New Guinea (PNG) · Pacific Ocean · Melanesia · Coral reef · Marine protected areas (MPAs)

3.1 Introduction

While nations are defined by land, much of PNG is probably better defined by the ocean and its processes and set up; it needs such a mindset for a more proper and more inclusive and effective conservation governance; saltwater matters (Pittmann et al., 2021; Robinson et al., 2022). This is a common-sense concept applied to '*The Earth*'

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also. 'The Earth' actually is more appropriately called '**The Ocean**' simply because its salt water covers easily over 75% of the globe, and thus it dominates the planet and subsequently most of its ecological processes. The dominating ocean concept certainly is true for the app 5,100 km coastline regions of PNG, as much as for the large Melanesian part and for the many estuary regions, e.g. Fly river, Sepik river, Ramu river, and their river/ocean plume systems. It easily applies to the southern sections of PNG connecting geologically under water with Australia (the craton; the connecting Torres Strait is just app. 30 m deep as it presents a flooded land bridge due to sea level rise linked with the world's ancient glaciers and global temperatures; see Flannery, 2002; Beehler & Laman, 2020 for biodiversity and conservation impacts and biogeography).

While tropical waters are kind of nutrient-poor, PNG can beat that in various ways and presents some nutrient-rich hotspots and dispersal systems, e.g. via plumes, sediment wash-outs, currents, ocean floor vents, upwellings and seismic activity all making nutrients more available. Tides in the equator regions tend to be relatively small (c. a 1 m), but they do play a role over time and when 'king tides' and outliers come to the beach (those can have surprising damaging effects on navigating reefs, coastal erosion and brackish water spoiling dirking water).

Broadly speaking, in PNG's seafloor, three major geological plates interact there: the Bismarck Plate, the Australian Plate and the Pacific Plate. And within that geology, PNG comes peppered with many hills above water and subsequent smaller river estuaries and reefs also; it's part of an underwater 'garden of eden' (Stone & Obura, 2013; see for Coral Triangle Atlas at http://ctatlas.reefbase.org/). And thus many of those coastlines are rather remote and just can be reached by 'water taxi' (or bush plane) between major villages or national airports. Traditional outriggers still play a big role; not all are so safe to use and when modern engines are employed (Hoffmann, 2015); life vests or emergency beacons for navigations are often absent (Fig. 3.1).

PNG has easily over 600 larger offshore islands with thousands of smaller ones—most of them located on the shelf. For millennia rural coastal families visit each other on homemade canoes and outriggers (examples shown in Cousteau & Richards, 1999). Much of PNG actually is a coastal ocean nation and islanders intimately understand the high seas and sailing; they can read the environment and navigate for 1000 s of years in that marine universe (see, for instance, Chan, 2016 for the upbringing of the former prime minister and shipping, reef and beach combing experience and subsistence) (Fig. 3.2).

While not given much credit that way, PNG can easily be called a kingdom of islands driven by the ocean-scape and saltwater with a somewhat remote and removed land capitol in Port Moresby. It's a typical setup for (Melanesian) ocean nations, but which is so diverse in many respects. It's a universe in its own rights and it defies western policy (land) minds and governance styles. Already the sea depths of PNG show us no other: Some waters are widely shallow and others are world-record deep and widely untouched (Cousteau & Richards, 1999), and others again are dynamically changing due to sea floor plate dynamics, tsunamis, coral reef successions and some tides. It comes all together connecting with small estuaries,

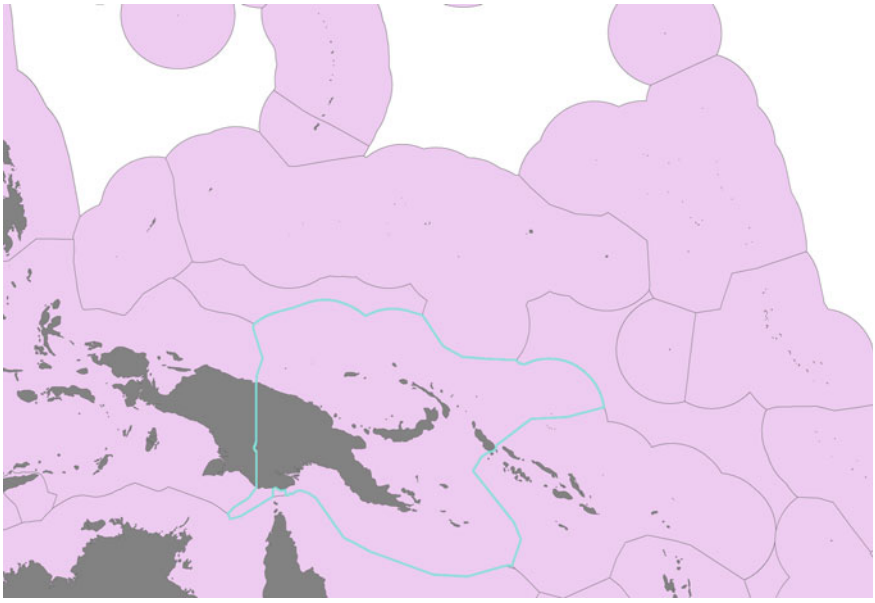

Fig. 3.1 Papua New Guinea Exclusive Economic Zone (EEZ; shown in blue outline). This map indicates what waters PNG has to administer and that there are direct national neighbors (EEZs shown in purple), whereas the international waters (in white) and their no-law zones are quite remote but still have an impact also

sandy and pebble beaches carrying palm trees and even covered with specific orchid species (Orchid Society of Papua New Guinea Inc., 2006). This is what makes already a large section of PNG: the coastline as the ocean–land interface. And not enough, the diverse seafloor extends out of the water and reaches on land up to 4509 m high above sea level (Mt Hagen). The concept of 'Ridge to Reef' is a true PNG feature (Carlson et al., 2019; see Fig. 3.3).

The oceans and coastal zones of this world are in a crisis state (as acknowledged in the UN declaration discussed in The Guardian, 2022a; Cousteau, 1979; Jackson et al., 2013) and so are most coral reefs (see Berzunza-Sanchez et al., 2013 for PNG). The waters of PNG still remain among the world's major destinations for pristine and diverse diving sites (Cousteau & Richards, 1999; Jackson, 2013). PNG is known for the soft corals; and tunicates and polyps are found in abundance. And the Gorgonian stalks are as mind-blowing as the groupers are, or the zebra sturgeon fish, surgeon fish, puffer fish or mother-of-pearls, sea cucumbers, sea shells and giant tridacna clams and their ancient management and human co-evolution (details in Cousteau & Richards, 1999; see also Hyndman, 1993; Jackson, 2013; for overfished mother-of-pearl and its statistics see Simard et al., 2022). But it's arguably the rainbow fishes that PNG is most famous for, and as highly seeked after species in the aquarium markets around the world.

Fig. 3.2 A typical coastal Papua New Guinea coastal set-up

What sometimes is forgotten in this context are the freshwater fish species. Those are often used in biogeography textbooks for their distribution patterns and offer interesting insights according to the Weber Line (Beehler & Laman, 2020 and citations within). On the landscape, the local community in PNG relies on eels for instance as an additional food source of fish found in the rivers, usually in valleys, those are caught in traps (see Fig. 3.4).

3.2 The Northern Ocean Side of PNG

This section of PNG is bordering to Indonesia (Iran Jaya—part of New Guinea), and the mainland coastline is dominated by the Sepik river and its estuary and plume (well described in Cousteau & Richards, 1999 for instance). There is a lot of exploration history in the Sepik river region with (German) colonialists and subsequent missionaries and industry active there for a long time in 'the remote bush' and along that coast. The UN tried the introduce 'exotic fish' in these watersheds but like elsewhere usually, not with good success wiping out endemic species and—in part—entire lifestyles and income systems (Beehler & Laman, 2020). Vanimo and Wewak are the main cities and regional hubs, with an airport and a ferry service for that region but essentially lacking a connecting road to Madang or Lae. There is a mountain

range, and much interior forest landscape is often strongly harvested for its trees (The Guardian, 2015, photos shown in Beehler & Laman, 2020). Not surprisingly, several river headwaters are found there also which contribute the wider oceanic set up and freshwater inflow into this part of the PNG ocean. Some of those rivers are seriously affected by forestry and mining.

Nearby Manam Island has another regional importance as has the Kar Kar Island and Madang with a port. The Bismarck Sea is the central ocean waterbody in the region, surrounded by islands like Manus, more in the east are the New Ireland and New Britain groups. The infamous Wuvulu island described in Cousteau and Richards (1999) north of PNG represents a well-known marine biodiversity hotspot. Orcas are found there in abundance showing peculiar behaviors, apart from the major coral reef ecosystem at its finest. This island group had a diverse history in the colonial times with Spain, France, UK, Germany, and some smaller Swedish and Danish

Fig. 3.3 Ocean spirits and gods are everywhere and to be appeased

Fig. 3.4 Selection of diversity and wealth of a diverse and initially pristine ocean ecosystem

ownerships, also made famous by a Russian anthropologist (Nikolai Nikolajewitsch Miklouho-Maclay; see other chapters of this book). The islanders—who were there first and defending their land—were often described as 'fierce' (https://wuvulu.com/history.shtml#History) resulting into the diverse legacy. Wuvulu island was also famous for its palm tree plantations.

This wider part of PNG is truly ocean driven. Rare seabird species like the Heinroth's and Beck's Petrels (Flood et al., 2017) are found there, species like the Aleutian terns connecting from Russia and Alaska can be expected (F. Huettmann unpublished). The diving reports for that region confirm the underwater beauty. But also, fisheries destruction has already left havoc there once again. In those PNG waters local fisheries get used by Asian nations including Taiwan and Indonesia, and it is hardly controllable or enforceable (Cousteau & Richards, 1999, p. 215).

Since ancient times this ocean section connects with China and Asia, and with other parts of the Pacific Rim. This is well exemplified by the shark migration, e.g. Slavador et al. (2010), as well as sea turtles and seabirds (Block et al., 2011). From the human side, among other immigration waves, the relatively recent Lapita culture likely entered app. 3500 years ago along this corridor (see Beehler & Laman, 2020 and citations within) leaving wider impacts in PNG.

3.3 The Eastern Ocean Side of PNG Mainland

The eastern ocean side of PNG's mainland shows a very complex ocean seafloor. It features proximities to one of the deepest ocean trenches in the world (e.g. Challenger Deep c. 11 km deep; Mariana Trench). PNG waters are part of the New Guinea trench, app 10 km deep. Also, it actually is one of the world's most active areas with many sea earthquakes; often those are not so well recognized. Much study has been done there on those topics, e.g. deep ocean waves (Hollar, 2012 for the famous work on internal oceans waves by Walter Munk, etc.).

The coastline of this region is affected—in part—by the Ramu river, and this coast is referred as the Maclay coast with a longer colonial research and collection legacy (discussion in Ball, 1880 and citations within).

Further, the coral reefs and associated seas of this region are among the world's most fascinating, somewhat most pristine and still secretive waters (Jackson, 2013; see http://ctatlas.reefbase.org/ and Berzunza-Sanchez et al., 2013 for assessment).

Lae has a major port connecting with Australia and Asia. Other than that it's worthwhile to mention the lack of major hubs and city centers along the coastline and the Huon peninsula. While the area has ancient human occupation, it still lacks a 'modern' urban development and set up, making such areas attractive for explorers (see Cousteau & Richards, 1999; Hoffmann, 2015, etc.).

Milne Bay is a major section in eastern PNG and presents a bay with a large and deep surrounding culture. It was part of initial 'contact' and much international exploration, and later became a site of intense fighting during WW2 (details in Cousteau & Richards, 1999).

3.4 The Eastern Ocean Side of PNG: Islands

This part of the ocean includes the Solomon Sea and it is another part of true Melanesia, consisting of many small but remote islands, island groups and their diverse and unique cultures such as New Britain and New Ireland. There is a long colonial history for those regions. It's located in the southern part of the Melanesian islands including Bougainville that has virtually all aspects of the Solomon Islands. Just like the northern islands of PNG this part of PNG is truly ocean driven and has connections with Asia.

The Solomon Sea is most influential for this region, with the Trobriand Islands in the south, and Bougainville at the outer edge. New Ireland is just next to it, e.g. famous for coconut palm plantations and coral reefs. Other island groups are Schouten Islands, Vitiaz Strait Islands, and Milne Bay in the south, which includes D'Entrecasteaux Archipelago and Woodlark Islands.

This area is known for its deep human traditions also. Beyond many others, the giant clam is a fascinating species for sustainable management of the publicly shared 'clam gardens' (Lucas, 1988). Many of those ancient 'gardens' are now on the decline,

e.g. due to overharvest and market demand in Japan and Asia. Another unique culture in that region is for instance the 'shark callers.' Shark calling is an ancient ceremony and includes coconut rattles to attract them. Once sharks are attracted and after entangling, the shark gets roped in with a vine noose and one brings the shark on board (details in Cousteau & Richards, 1999, p. 200). Another very interesting aspect of fisheries is found there using the plant-based nerve poison (rotenone) of derri roots; it's similar to what is used in Amazonia (details in Coustau & Richards, 1999, p.197). Those are essentially sustainable fisheries practices which the western world is rather short of (see Pauly et al., 1998 for harvesting down food chains worldwide but mostly carried out by western society and their institutions and agents).

Ecologically, this area is very complex and somewhat related to Guam (Micronesia; Cunningham & Beaty, 2001), and remotely, it connects with Hawaii even. However, albeit the indigenous people in this region are 'brothers,' the Polynesians that occupy these Pacific islands are not really so connected with mainland PNG and do not directly link with that section of Melanesia.

Bougainville, closely related to Solomon Islands, is another part of PNG part in this ocean section. It will be covered in subsequent chapters in more detail. But the politics and economics of such islands in the South Pacific are well documented (e.g. Filer, 1990).

All the islands north of PNG -northwest and northeast—have a deep and complex history including colonialism and during WW2 they were occupied and fought by Japanese troops, and then 'freed' by western allied troops, namely U.S. and Australia during fierce battles (ecological legacy described with photos in Cousteau & Richards, 1999 including subsequent dynamite fishing; first-hand accounts of the area are found for instance in Chan, 2016). The cold war legacy of those islands, including world-relevamt biological warfare experiments and impacts, affecting the ecological balance is described in depth by Rauzon (2016).

3.5 The Southern Ocean Side of PNG

The southern ocean side of PNG's seafloor is pretty 'flat' and shallow, and connected with Australia; it is part of the '*sockel*'—the Australian craton. In PNG overall it shows the same geological material than Australia, albeit much more rugged and steeper, even with potential snow coverage (now global warming makes it virtually impossible to occur anymore; as shown early on by Flannery, 1998 for New Guinea. The glaciers in New Guinea—located in the north—were very well and repeatedly studied already last 100 years ago, e.g. by British expeditions; see Beehler & Laman, 2020, p. 46 for overview and details). This part of the ocean—the northern Coral Sea—is often only 30 m deep, or so. There was a very relevant land bridge, app. 15 mio years ago due to Earth's glaciation history affecting the biogeography of the region, the seafloor and coastal zone. The southern section of PNG includes the capitol of Port Moresby (POM), and it's famous for some coral reefs accessible for

tourists. POM is part of a major ocean travel route for PNG connecting with Australia and Asia, this includes crime and human migrants and trafficking.

3.6 The South Western Ocean Side of PNG

The western section of PNG oceans borders to Indonesia. It features the Arufa Sea in the west, the Coral Sea part in the east, and a prominent island group in the Torres Strait; the Torres Islands (e.g. Laffan, 1991). Those are of wider historic value and carry a deep human legacy (Flannery, 2002). By now, those are prime problem areas for climate change due to sea level rise (e.g. Green, 2006 for Torres Islands, and Edwards, 2013 for a PNG-wide example). Noteworthy is that this region is also part of an ancient, as well as a very modern, international travel route, many container ships use this part of the ocean to connect to India, Africa (Cape Horn or Suez Canal) and the Atlantic eventually. It's a certain bottleneck and an alternative to more pirate-infested shipping routes in SE Asia.

This area is a unique section because it has the Fly river estuary, the largest river in PNG (app 1050 km long). Relatively large wetlands are found there, e.g. attracting migratory shorebirds from Australia, Asia and the Arctic. The Fly river has received much attention by western explorers for centuries, including Sir Hillary after his Everest work and his subsequent tragic boating accident there (Gill, 2020). This region is also a source of the 'cannibal narrative' about PNG and of many other stories. Many western people obviously went there because it was quite accessible and it has been perceived as an ultimate adventure to be 'among cannibals.' Nowadays, this region is known for the river contamination caused by mining, e.g. Bolton (2009), Kirsch (2014) for Ok Tedi mine impact overview (Figs. 3.5, 3.6 and 3.7).

3.7 Overall Oceanography

PNG is part of the 'Ring of Fire,' and this also applies to its ocean and the plate boundaries rising and moving. PNG features parts of the Mariana Trench connection, the world's deepest seafloor allowing for many insights about earth and the environment itself (see Peng et al., 2018 for microplastics in the deepest and remotest section far away from humans). In such dynamic ocean seafloor areas therefore, ocean tsunamis are common and create problems for the local communities. The latter are well aware and have adjusted to such a life.

In addition, those 'seaquakes' cause active volcanism. Volcano outbreaks are part of PNG; some of them come straight from the ocean. Rabaul is one of those tragic outbreak legacy sites (see Chan, 2016 for a first-hand evacuation account). The direct impact on the ocean ecosystem remains little studied but the sea floor can quickly change, so does the coral reef ecosystem; the latter is now widely affected by climate change and coral bleaching. There is some good discussion how humans

Fig. 3.5 Handcrafted Papua New Guinea mask with kauri shells

also affect earthquakes, on land and at sea, due to melting glaciers, glacier weights and subsequently changing plate pressure dynamics causing 'tensions and release' between plates (Figs. 3.8 and 3.9).

3.8 A Very Special and Endemic Marine Set Up in PNG, Including Benthos

Papua New Guinea is an acknowledged world-class ocean resource and wilderness; endemism is exceptionally high. PNG is not only affected by the Wallace Line, but also by Weber's line (Beehler & Laman, 2020) as shown by ichthyologists for many decades.

Fig. 3.6 Where precious ocean wealth now is used: cheap house gear. It remotely reminds of a former ocean diversity

PNG reefs are said to be often more diverse and still in a better condition than in Australia (Beehler & Laman, 2020, http://ctatlas.reefbase.org/; see Berzunza-Sanchez et al., 2013 for assessments). Over 2100 species of reef fishes can be found around New Guinea's reefs (Beehler & Laman, 2020). PNG further serves as a resource for endangered marine species, e.g. sharks (three species are typically found: Whitetip Reef Shark, Blacktip Shark and Bull Sharks; the latter even occurs in some freshwater lakes; see White et al., 2015 for river sharks). PNG also has sawfishes (Grant et al., 2021). It also has a very high ray fish diversity (Blaha et al., 2016; White et al., 2019). The historic size of the thuna stock—a predatory species in the food chain—was vast but now crashed due to overfishing (see for details Barcley & Cartwright, 2008), just as the case for whales (at least 15 marine mammal species were detected, Miller & Rey, 2021).

Fig. 3.7 Large shells as a precious ocean sustainability item found widely in-land, distributed on ancient-old trails in interior Papua New Guinea

Fig. 3.8 Sea turtles get fished, poached and offered on domestic markets for meat consumption

Fig. 3.9 Souvenirs for the tourist market showing manatees being hunted and penis bones being sold

Because PNG is so connected with all aspects of the universe, the earth's geology shows as quite accessible to humans, on the interacting surface. The seafloor and the trenches are a unique habitat and allow for a deeper earth insight. While the associated marine seafloor life remains a mystery in the abyss, another unknown, the actual benthos can be studied. While some benthos research has been done, it remains primarily—again—just a species list; much more is to be done and should (see Wei et al., 2011 for global benthos models to start from for PNG). It's a big deal for instance for sea floor mining questions (see chapters in this book and Steiner 2009, 2011) (Figs. 3.10 and 3.11).

3.9 Island Economics, Whales, Fisheries, Estuaries and Sustainable Oceans with MPAs?

The Pacific Ocean is vast, and it includes much of the world's fisheries (e.g. Dalzell et al., 1996). Islands of the Pacific are 'many' and each present their own microcosm. They are seen as a unit in (Island) Biogeography, over water and under water (see Mayr & Diamond, 2001; Steadman, 2006 for an applied example). These natural territories have been recognized early on by colonialists as precious and strategically relevant and they were intensely fought over, e.g. as part of the 'Pacific Theatre' ongoing today.

Fig. 3.10 Children's job in fishing communities consist of bait fishing

Fig. 3.11 Thuna on a local market, not a big one at all as those ones tend to be harvested out and used up by larger extraction industries

However, what is widely misunderstood is that those islands stand in their own, but as well as within wider, global dynamics. They are affected for instance by the Antarctic current, as well as by the Monsoon and the El Nino cycles all interacting in synergy, beside other impacts. Human and Polynesian intrusions and cultures played a big role for their (environmental) modifications. Expert collection of species on islands added further to the pressures. For Melanesian islands the specimen collection peak was achieved in the 1990s already (see in Mayr & Diamond, 2001); so why collecting more still, or even call PNG significantly undercollected as stated by Beehler & Laman, (2020)?

These islands are obviously not really independent or in a balance; see for instance Rauzon (2016) for ticks and invasive species on those Pacific islands deemed to be '*pristine.*' It's part of bioterrorism experiments during the Cold War and the Anthropocene, and it seriously affects the theory and inference for biogeography, and subsequently how we understand live, islands and PNG.

Like most of the world's ocean ecosystem (see UN Crisis Declaration in The Guardian, 2022a), PNG is not really sustainable anymore, nor should it be perceived that way or receive such a PR or management scheme with a static maximum sustainable yield (MSY) concept (Punt & Smith, 2001; which was never really achieved or exactly computed and aimed for anyways; Pauly et al., 1989; Pauly, 2019). Reaching a sustainable fisheries, in remote regions, with multispecies occurrences and interactions—including endemic and undescribed species—in times of climate change, is virtually impossible and almost never shown to have been achieved (Pauly, 1979; Pauly et al., 1989). The Aichi Targets (Sustainable Development Goals (SDGs; www/undp/org)) promoting a win–win for everybody are not helping on this matter as they just implement well-sounding neoliberal concepts and narratives and myths that have no good track record anywhere denying any relevant science for decades, e.g. it's a promoted growth scheme to operate on finite resources instead (see instead Limburg et al., 2011 for generic perspectives in a limited ocean; Safina, 2003 for reality perspectives).

Well familiar with PNG, already in 1979 Cousteau (pp. 411–414) stated the following problems with the oceans, summarized in just a few bullet points ('*The Planet is on Fire*'):

- man the waster.
- sowing less than we reap.
- waste of the world.

These succinct points speak very well to the problems we still have today and which we still have not resolved yet; far from it. It's easy to see that ocean research and marine ecology have not resolved that well for us in PNG (Rooney & Papoutsaki, 2004). The ocean governance in place, certainly for PNG, has not been much effective nor the institutions.

There has been a long, historical and deep shell trade in PNG from the south and coastal areas. It was quite sustainable. However, it went by the way side. The fisheries in PNG waters, or adjacent ones, simply is overharvesting the resource; computations of a sustainable harvest are either not existing, not possible, or not

enforced, hardly monitored precisely. Robust institutions are widely missing in an area that is considered of many 'failing states.' Even basic items like sea cucumbers are not really manageable then (e.g. Purdy et al., 2017 for a required moratorium and impacts in PNG and markets). Relevant number of fisheries observers are not existing, but those who do join that profession get intimidated, or much worse (see The Guardian, 2022b for killed fisheries observers in Tonga; PNG has reports of over 18 dead fishery observers also; Radio New Zealand, 2018).

Shark finning, as a widely unsustainable fisheries method, is widespread also in PNG waters and done for markets in Asia, Canada and U.S. (Beehler & Laman, 2020), some shark products occur in the EU also (Fig. 3.12).

As a typical and still widely unresolved book-keeping problem in tropical nations and fisheries, the 'approved' numbers of fish harvested do not add up well. Noteworthy for most (tropical) fisheries here are the offshore trading quotas, illegal takes, and mislabeling of species on the global marketplace. For instance, PNG sharks are apparently found—and sold—in Greece within the EU and its subsidized efforts (Pazartzi et al., 2019; compare with White et al., 2018).

Instead, and like any ecosystem, PNG and its oceans are finite and delicate, and must not be overused (e.g. Limburg et al., 2011). This includes fish but many other ocean resources and ecological services also, including sea bed mining (Steiner 2009, 2011). Beyond catering international market demands and standards, PNG must look out for itself also: Sustainable ocean communities are real and they have existed fine for over 47,000 years (Hyndman, 1993)! This is clear for most island and ocean nations. Unless islands receive outside support, they struggle on their own for a decent survival while markets from abroad prey on them further till the entire system collapses. Virtually all islands are outcompeted by the bigger 'main land.' Islands become almost always political (e.g. McKenzie, 2021 for a South Pacific example). From deep time till now, the deep sea region of PNG was wilderness; virtually untouched due to sheer remoteness in the three dimensions. Back then, who knew about hydrothermal vents in the Bismarck Sea? Ecological services from the deep sea regions are excessive. Human pressures in that region were relatively small, compared to what we all experience today. This trend likely will change further with more sophisticated gear and deep sea mining plans (see subsequent chapters; Steiner 2009, 2011) while the bulk of the resource biomass just sits at the 0–60 m ocean depth and is already overexploited.

The ocean receives input from many sources. For examples of related river resource declines draining into the oceans, see invasive species in the Sepik river having resulted into a major human population shift due to the ecological collapse (Cousteau & Richards, 1999). For other rivers, the Fly river as the major river in PNG can be seen as a typical example: Fisheries there was affected via the headwaters of the Fly river where the Ok Tedi mine is located. When a tailing dam broke—as a typical and frequent problem in 'sustainable' mining—toxic residues polluted the natural resource with lead, arsenic, mercury and cadmium with ongoing concerns to this very day (Kirsch, 2014 for detailed descriptions). The real impacts are difficult to assess as the wider watershed and food chain is affected in PNG and in the Indonesian border zone as well.

Fig. 3.12 **a** and **b** Protein source for Papua New Guinea citizens straight from the processor and its fleet

And even worse, major game changers in PNG's history came with dynamite fishing; a destructive way of getting at the fish at all costs (Pauly, 1989). It's a leftover of WW2 dynamite—part of one of the largest bombardments in human history (as shown and documented in Cousteau & Richards, 1999). In parallel, the Asian fisheries fleet and their canneries wiped out major resources and devastated coastal zones and communities accordingly (Sullivan et al., 2003, 2011).

But before that, the steam engine and then the combustion engine left already major marks at sea, at land and in the atmosphere. The fishing styles changed over time subsequently. Already with an influx of new people from Asia 1000 s of years ago they brought with them different fishing styles affecting coastalscapes, oceans and PNG (e.g. highly populated highlands trading with the coastal communities). The impact of small engines and available fuel was vast. Major inaccessible remote fishing grounds now were accessible and got harvested without return. Having harpoons (for whales) available and adding never-ending monofilament plastic nets and global market demands did the rest; those net types are now all ubiquitous. And thus in parallel, the ocean decays with many fish stocks lost (Safina, 1999).

And the use of reliable but cheap outboarders changed the reach and intensity of fishing and access to fish stocks even further. More recently, the fisheries effort further increased, so did the gear used, helped with digital tools such as fish finders, sonar, GPS and the internet. All of this is easy to see and to detect in PNG as Asian fleets have almost perfected such skill set to get at the fish harvest and making money essentially at all costs for the fleet. Fisheries policies allowing such fleets now a selective access to PNG waters, e.g. for thuna, contribute dramatically to this problem.

Same can be said for 'winches,' and certainly, the all-dominant floating plastic net; the bigger the better, often measured now in 10 s of miles (= 'walls of death'). Spears are not that new, but gun-powered ones are, and ones that use rubber In PNG one can essentially buy them in any supermarket now (F. Huettmann pers. com.).

For many decades already local fishermen now routinely fasten slings of surgical rubber to their spears, which make it more powerful that way; it's very cheap and has impacts on fish (details in Cousteau & Richards, 1999, p. 205). Considering that in PNG fish and fish supply is provided by children and females (Beehler & Laman, 2020), those 'low-tech' tools are now put at their free disposal, and they are ubiquitously used throughout the tribal society; the fish resource pays the costs.

Even worse, and as found in many parts of the world, including the U.S. National Parks, exotic fish got introduced. In PNG, already since 1949 the UN and other projects introduced exotic fish species in the Sepik river watersheds and elsewhere with the idea to improve food situation for the rural community; arguably a well-sounding idea but with very bad consequences (Beehler & Laman, 2020, p. 159). Overall, in PNG, at least 21 exotic species got introduced already for 'food security,' including species like karp and African tilapia (Beehler & Laman, 2022, p. 148). The Asian Development Bank projects did its share on 'fish ponds' (the author saw several of those start up projects, but that ran dry and afoul). Aquafarming and shrimp ponds are part of that scheme, with similar bad effects. A wild fish stock remains unbeatable; all else gets quite problematic one way or another.

It's difficult to deny that the fish stocks in PNG got compromised and plundered. PNG is part of the 'coastal collapse' described by Jackson et al. (2001) already a decade ago. And now that's all done in an industrial fashion, helped by outside nations, industries and embassies (the latter commonly provide visa support, legal and banking advise, contractual help, and intervene with vessel confiscations and labor questions). It is also clear that the major fish spawning habitats—reefs, mangroves, and seagrass beds—are on the vast decline, that sustainable management is widely absent, and that it continues to dominate in the absence of the western-made and -shaped political nation and EEZ PNG construct (Fig. 3.1). It's another outflow of colonialism gone bad, ignoring science and best professional practice.

Clearly the PNG coast guard cannot police all of the mandated EEZ. The seagrass beds alone are wild and vast, hardly accessible (due to being in very shallow waters). They feature stunning biological insights though as they seem to be often 'one plant' (= perhaps the largest plant in the world; Edgeloe et al., 2022). It is here where not only the framework, set by the new PNG national construct, but as well as by the international oversight, the UN mandate and NGOs have widely failed PNG's environment, ecology and its people, and sustainability at large. Food security in real life has a grim outlook there and consequently refugees are on the rise (Quayle et al., 2019).

PNG waters are certainly affected by humans, and have been so, for millennia (Hyndman, 1993). The human footprint existed but was benign, e.g. due to lack of access to remote areas and depths, and using just soft gear. The status of the giant clam gardens speaks to that situation in powerful terms, so does the recent sea cumber moratorium or widely increased harvest statistics of mother-of-pearls, and the generic decline of sharks and thuna (Fig. 3.13).

In the Western World, ocean zoning is now often practiced, based on marine protected area (MPA) optimizations. A MPA network is to be assessed and designed (e.g. Hamilton et al., 2009), while it's not so clear how it is to be funded, enforced and effective even (Klein et al., 2015), and by when it comes truly into action (e.g. Green et al., 2007). See for northern PNG for instance the Bismarck Sea Task Force (https://www.marinemammalhabitat.org/portfolio-item/bismarck-sea/). MPAs are not always providing the best protected biodiversity solution because they are biased by the input and contractor NGO. An example found in WAITTS (Ocean Protection Waitt Foundation and its aims to balance the environment AND the economy but catering economy the most (https://www.waittfoundation.org/ocean-protection). Something good and sustainable is to be done about PNG oceans, and here is some action then: The role of sperm whales and killer whales are used as criteria for protection, and it looks good in public. However, it's not very effective when considering that those are moving and migratory, virtually unsurveyed, and they are not so well indicating the small pocket endemics which are famous in PNG. Using indices is always an indirect and coarse approach missing many details. Arguably, PNG waters are more complex and bigger than just handling a few marine mammals. Similar to National Parks, the MPA idea is a brain child from The West, heavily supported now by Australia, perceived as the last 'cry' in ocean management (see, for instance, Halpin et al., 2022 for nearby ocean areas and Gadlflies. Those

are endangered seabirds and are to be 'zoned out' into areas that are to be protected, but ecologically cannot), another typical western approach to ocean resources and failing. It's widely behind trying to protect anything, and anything relevant with a meaningful concept while we are in a world and PNG ocean crisis of a public good embedded in deep ecology (Figs. 3.14, 3.15 and 3.16).

In the meantime, the MPAs are usually just political compromises, and primarily consist of biologists circling areas on maps (as stated Beehler & Laman, 2020) in various shapes and forms, often based on aided optimization algorithms driving it (see Halpin et al., 2022, see Figs. 3.8, 3.9, 3.10, 3.11 for examples and realities in PNG waters). Whereas, the real issues like poverty, economic growth promotion, profit motive and good governance are not mentioned certainly not reached or resolved and almost never part of the 'modern' conservation equation.

Fig. 3.13 Shark calling and shark fishing is a long but sustainable practice in Papua New Guinea; but now taken over by commercial Asian efforts

Fig. 3.14 Inland fishing adds to fisheries views: photo of a fish trap

Last but not least, the biggest issue now comes from man-made climate change as the ultimate outcome of those synergies that were not addressed early on. Aqua-farming will not fix it (Fig. 3.17). There is little good outcome from this situation—no winners and just a few losers—because the world's ocean currents, the water quality itself and coral reefs are all affected and the climate refugia are breaking down (Dixon et al. 2022) with implications beyond ocean ecosystem but affecting human well-being, globally. Without ocean, PNG as we know it, is 'toast.'

Textbox 1: Why is being a fisheries observer in PNG a deadly job, with 18 bodies missing and still counting? Troubles in the EEZ and with Freedom of the Seas

On the one hand, one cannot answer that question easily. While many fisheries observers report intimidation during their job, PNG fisheries observing would not differ from any other fisheries, observing or assessment job. But on the other hand, knowing that PNG is a dangerous place for crime to start with, why would the fisheries be any different?

It simply differs because PNG has the largest thuna fisheries area in the Pacific, and the PNG fisheries observers are treated by foreign vessels; their lives are essentially in their hands, out there in the wider PNG EEZ.

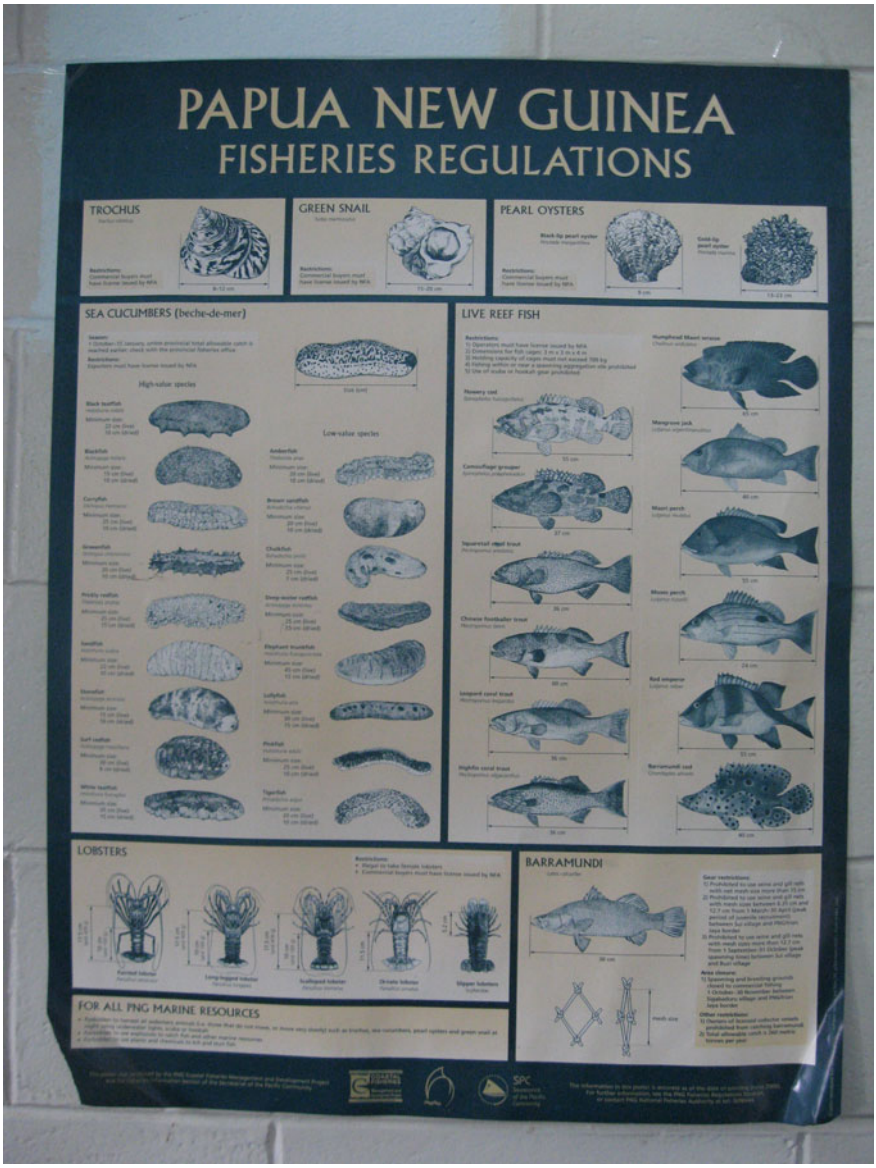

Fig. 3.15 Papua New Guinea's fisheries regulations for practitioners

PNG grants fishing access to resources in PNG waters of the EEZ through international agreements with Taiwan, Korea, the Philippines and China, as well through a multilateral treaty with the USA. Fisheries observers are then

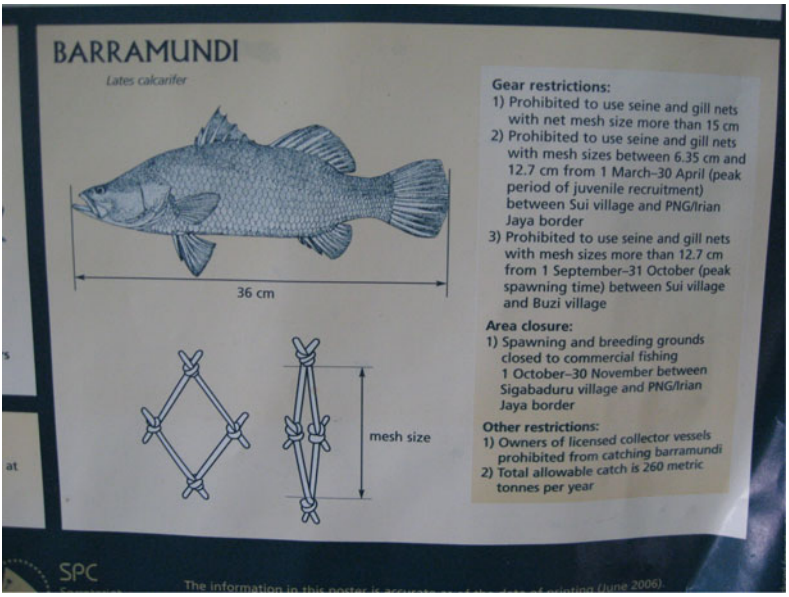

Fig. 3.16 Some details on Papua New Guinea's fisheries regulations for Barramundi

Fig. 3.17 Aquafarming as the solution to what?

affected by the laws of those nations; not 'just' PNG legislation. Certainly the U.S. customers of fish are very sensitive by now.

Globally speaking, fishing observers have a tough job and might not necessarily be well liked for their task by some exploitive industry members. After all, they can expose bad reality details and their reports can shut down the entire fishing task at hand; it's money off the table for some

Similar to whistle-blowers (Kennedy & Cuomo, 2000), fisheries observers do indeed make fisheries better and can help to show problems that otherwise would not be really visible, e.g. (Smart et al., 2016).

However, PNG seems to be specifically deadly and a warfare rages at sea centered around fishing observations. Radio New Zealand (2018) - not Australia or U.S. that usually have often the PNG oversight - exposed 18 missing PNG citizens in such a job without solution or good answers by the PNG government (see PNGAttitude, 2019 for more details and lack of progress).

The EEZ is supposed to serve anybody in PNG and allow for national protection and jurisdiction. The Coast Guards provide such a service…Well, if they are around, if their gear exists and is adequate, if all items line up well, and if a case can be made. Realities in the world fisheries show us a different picture though.

The EEZs tend to be too vast and too complex, with just a few coast guards—ships and helicopters—to really be on the ground and to enforce 'anything.' The EEZs are a real security and surveyance problem, certainly for PNG. Reality is, outer and wild areas of the EEZ - where some of the precious fish actually is located - are not enforceable.

In addition, the international sea, where the 'Freedom of the Ocean' sits, remains an utterly absurd concept: In times of legal regulation and governance, why should unregulated, criminal behavior be allowed at sea, anywhere? By now, the international seas are an international place of labor violations, of crime, a global place of war for everybody who can engage there. Money drives it, and always has.

From an environmental perspective, this applies specifically to fishing and following fishing regulations and contamination, e.g. bilge water cleaning (chronic oil pollution), drilling (oil spills), and ballast water (invasive species). Who wants observers there to expose cheap operations and bad practices affecting industrial income? While this dispute is usually fought in court, in many nations it's also fought on the ground, on the ships and with the fleets. The environmental outcome remains the same regardless: The ocean gets destroyed further, and that's precisely what we all see but should avoid if a claimed sustainability is the overall aim and best practice, the law!

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