Chapter 36

Nauru

Douglas Fenner
Contractor for NOAA and Consultant, Pago Pago, AS, United States

36.1 THE DEFINED REGION

Nauru is one of the world's smallest counties, consisting of a single raised atoll, located about 50 km south of the equator at 0°32′S, 166°56′E in the western Pacific (Fig. 36.1). The island rises 4800 m from the sea floor (UNEP/IUCN, 1988). Nauru is very isolated. The closest island or reef is Banaba Island (Ocean Island) about 300 km to the east, which is a very small (6 km^2), raised atoll like Nauru and is part of Kiribati. Kiribati is the closest archipelago, about 700 km east of Nauru. The Marshall Islands are about 900 km northeast; Kosrae, Micronesia is about 800 km northwest of Nauru; and the Solomon Islands are about 1100 km to the southwest (Fenner, 2015).

Nauru is about 4 × 6 km diameter, about 21.2 km^2, oval and bean-shaped, with a circumference of 16 km (UNEP/IUCN, 1988) and an EEZ of about 431,000 km^2. It is a reef limestone (calcium carbonate) cap on top of a volcanic seamount. Most of the human population lives on a low, nearly flat narrow plain around the island that is 100–300 m wide (Stirnemann, 2015). The interior rises steeply from the outer edge to an average height of about 50 m, with a maximum height of 71 m (McKenna, Butler, & Wheatley, 2015; UNEP/IUCN, 1988). The raised rim and interior are locally called "topside." In places the outer slope is a cliff (designated "escarpment" in Fig. 36.1). The interior is depressed below the rim, and in one small spot reaches sea level and is occupied by a small brackish or anchialine pool named Buada Lagoon, about 400 m long in its longest dimension. The interior of the island from the rim inward is composed of limestone which has a jagged surface called "karst" that resulted from rainwater dissolution of the limestone since it was lifted above sea level (Fig. 36.2).

Before mining, the jagged karst surface was filled with high-grade tricalcic phosphate deposits with a tropical forest growing on it (Stirnemann, 2015). A majority of the land area of the island (70%) is used for phosphate mining. "Over the last 112 years this area has been the focus of extensive mining activity. This has reshaped the land into a mosaic of areas that have been mined both by hand, approximately 80–100 years ago, and more recently (from current to 40 years ago) with heavy machinery" (Stirnemann, 2015). After independence in 1986, Nauru had the highest GDP per capita in the world, but by 2004 primary deposits of phosphate were exhausted and the economy collapsed. In 2006–2007, mining of secondary phosphate in a deeper layer began (Anon, 2017), and continues today. Much of the phosphate deposits have been mined, leaving the jagged karst surface. An effort is underway to smooth the karst surface in mined areas and revegetate it. Seabird colony guano has been suggested as the source of the phosphate—coral reefs, which formed the limestone, generally do not form phosphate. "The low concentrations of rare-earth elements, as well of sulphate and fluoride, support the earlier conclusion of other workers, based on the physical characteristics of Nauru, that the source of the phosphate was bird guano" (Piper, Loebner, & Aharon, 1986).

"The Nauru volcanic base was presumably constructed by hotspot volcanism during the mid-Eocene to Oligocene period (29–47 Ma). It is estimated that the seamount is capped by about 500 m of limestone, with uplift and sub-aerial exposure of the carbonate platform during the Pleistocene, 1.6 Ma…" (McKenna et al., 2015). Since phosphate and limestone karst are highly porous, all rainwater percolates through the karst and enters a freshwater lens on top of the saltwater that occupies pore spaces below sea level. There is no running surface water and thus no estuaries. There are also no bays or natural boat harbors.

Nauru is completely surrounded by reef flats which are just above the level of the lowest tides and about 100–300 m wide (Fig. 36.3). The reef flat was "cut into the original limestone of the island and typified by the presence of numerous emergent coral pinnacles" (UNEP/IUCN, 1988) (Fig. 36.4). It appears that the current level of the reef flat is due to rainwater dissolution of a layer of limestone over it that was several meters thick. This is indicated by the presence in some areas of dolomatized limestone pinnacles (Edwards, 2015) on the reef flat (and structurally continuous with the reef flat), which reach a height of at least 5 m (Skelton, 2015). Such pinnacles on reef flats are rare elsewhere (Edwards, 2015).

World Seas: An Environmental Evaluation. https://doi.org/10.1016/B978-0-08-100853-9.00045-2

FIG. 36.1 Map of the Republic of Naru.

FIG. 36.2 The interior of the island ("topside") is mostly composed of limestone pinnacles left from phosphate mining. *Photo by Douglas Fenner.*

FIG. 36.3 Aerial photo of the coastline, reef flat, and reef crest. The black spots are pinnacles. *Photo by Douglas Fenner.*

FIG. 36.4 Pinnacles on the reef flat. *Photo by Douglas Fenner.*

It seems likely that the present level of the reef flat was produced by the limit of freshwater dissolution, which can only happen when the limestone is exposed to rain above the sea surface. There is no back reef deeper than the reef flat and the reef flat begins at the shore. Gabab channel in the reef flat in the district of Boe on the southwest coast, just north of the airport runway, is man-made and is used for launching fishing and recreational boats. It is about 5 m wide (Skelton, 2015). There is a small boat harbor on the east coast north of the government hotel in the district of Anibare. This small boat harbor was dredged out of the reef flat and is surrounded by breakwaters with a small entrance channel. The harbor has a boat ramp with a winch. The Nauru fisheries department is located across the road from the harbor.

Beyond the reef flats, the coral reefs descend at about a 45° angle, without terraces, and below the reefs the slopes continue at a similar slope out of sight below 35 m depth. "Reef area has been estimated to be 10 km^2 (Burke et al., 2011). The total intertidal reef area down to the 200 m isobaths was estimated to be 7.4 km^2 by Dalzell and Debao (1994)" (McKenna, 2015). Water on the reef slopes is clear; offshore waters are oceanic oligotrophic waters as there is no land. Tides are about 2.0 m. All shores of the island are exposed to oceanic waves.

36.2 NATURAL ENVIRONMENTAL VARIABLES, SEASONALITY

The climate is tropical and humid with an average of 1500 mm annual rainfall, and seasons are minimal. The average temperature ranges from 24.4°C to 33°C, and humidity is normally from 70% to 80% (UNEP/IUCN, 1988).

"Nauru is located in the dry belt of the equatorial oceanic zone, with diurnal temperatures ranging from 26°C to 35°C, and night temperatures between 22°C and 34°C. Annual rainfall is extremely variable, averaging 2126 mm per year, with a range of 280–4590 mm. Rains are more frequent between December and April. Prolonged droughts are common and cause severe stress on native ecosystems and species" (McKenna et al., 2015). "Nauru is quite isolated in its oceanic position and has a mild but drought prone equatorial climate. This has made it a natural haven for massive seabird colonies and for development or at least retention of deep phosphate rich soils" (Edwards, 2015).

"During the drier months of May to November, the prevailing wind direction is generally easterly at 5–10 knots. During the wetter months, the winds are generally from the west at 10–18 knots. Nauru does not experience tropical cyclones, although it is occasionally subject to strong winds and sea squalls. The only significant freshwater resource is a lens of often slightly brackish water hydrostatically 'floating' on high density sea water" (McKenna et al., 2015).

The island reef limestone is extremely porous, and there are no surface streams or runoff. Fresh water reaches the sea in submarine vents, and is likely to have little if any sediment in it.

36.3 MAJOR COASTAL AND SHALLOW HABITATS

36.3.1 Coral Reefs

The island is surrounded by a continuous fringing coral reef, which includes a reef flat and a fore reef slope. There are no mangroves or seagrass beds along the coast. There are a few mangrove trees (*Rhizophora* sp.) reported in landlocked ponds in Anabar district (Skelton, 2015), and perhaps a few around Buada Lagoon. The deep-sea benthic habitats have not been explored.

36.3.2 Reef Flat

The Nauru reef flat extends from the shoreline to the reef crest where waves break and the reef slope begins. It is almost completely devoid of corals. A few corals were found in small depressions around the old abandoned cantilevers. "There is no deep lagoon but a number of channels and reef crevices are found scattered throughout the reef flat. Most of the reef flat is exposed during low-tides with a few shallow tidal pools" (Skelton, 2015). The dominant organisms on the reef flat are algae, but in many parts of the reef flat, zones clear of visible algae can be seen. Brown algae dominate the high intertidal area near shore, green algae dominate the mid-intertidal area, and red turf algae is common in the low-intertidal to reef crest area (Skelton, 2015).

36.3.3 Algae

All four of the major algae groups (Chlorophyta—green, Ochrophyta—brown, Rhodophyta—red, Cyanophyta—blue-green) were found on reef flat surveys. "Generally cyanophyte clumps were common adjacent to nutrient rich sources, such as the Meneng hotel and infrastructures with phosphate activities near the main port. In other parts of the islands the low-intertidal zone was dominated by *Padina minor* and *Valonia aegagropila*" (Skelton, 2015). Turf algae are an early successional stage, usually followed by colonization by macroalgae, coralline algae, and/or coral. The dominance of most of the reef flats by turf algae on Nauru probably stems from the fact that the reef flat is high enough for exposure to air during the day, making it difficult or impossible for other organisms to colonize the reef flat. Twenty new algal species records bring the total marine flora known from Nauru to just 58 species. The low number of algal species is due to the small size, isolation, and lack of habitat diversity of Nauru (Skelton, 2015). Further study of reef slope algae and of microscopic algae will likely increase the total number of species known, but it will remain an impoverished flora compared to the nearest islands (Kiribati, Marshall Islands, Solomon Islands) (Skelton, 2015).

36.3.4 Fouling Organisms and Introduced Species

"Introduced marine species were observed in many of the sites surveyed. These were mostly fouling organisms found on pilings and other man-made structures abandoned on the reef flats and slope. Perhaps the most concerning of the introduced species were the bearded fire-worms (*Hermodice carunculata*) abundant at the mid-intertidal area near Gabab channel" (Skelton, 2015). These fireworms have hollow bristles filled with venom which produces a fiery sting from which their name is derived. Barnacles, hydroids, ascidians, and sponges were other fouling organisms seen on the reef flats off the districts of Aiwo, Meneng, and Anabare (Skelton, 2015).

36.4 REEF SLOPE

36.4.1 Ecosystem

The reef also has a fore reef slope descending at about a 45° angle from the outer edge of the reef flat to at least 50–60 m depth. The slope continues on down at a similar angle below 35 m but without significant corals. In the area of the phosphorus loading cantilevers on the west side of the island, the upper reef slope is steep and even overhanging in one area. This allows the phosphate ships to approach the cantilevers closely and the substrate profile may be a man-made feature. These areas have low coral cover. The reef slope around the island appears to have three primary faunal zones. The shallowest zone, down to about 3 m depth, has few if any corals (Fig. 36.5), and in some areas has surge channels (or trenches) that cut into the reef (PROCFish/C and CoFish Team, 2007). The next deeper zone at about 3–7 m depth has plate *Montipora* colonies that are more common in the lower part of the zone than the upper part (Fig. 36.6). In a few places such as the port cantilever area, *Pocillopora eydoui* and *Pocillopora verrucosa* colonies are common. A second zone extends from about 7 m

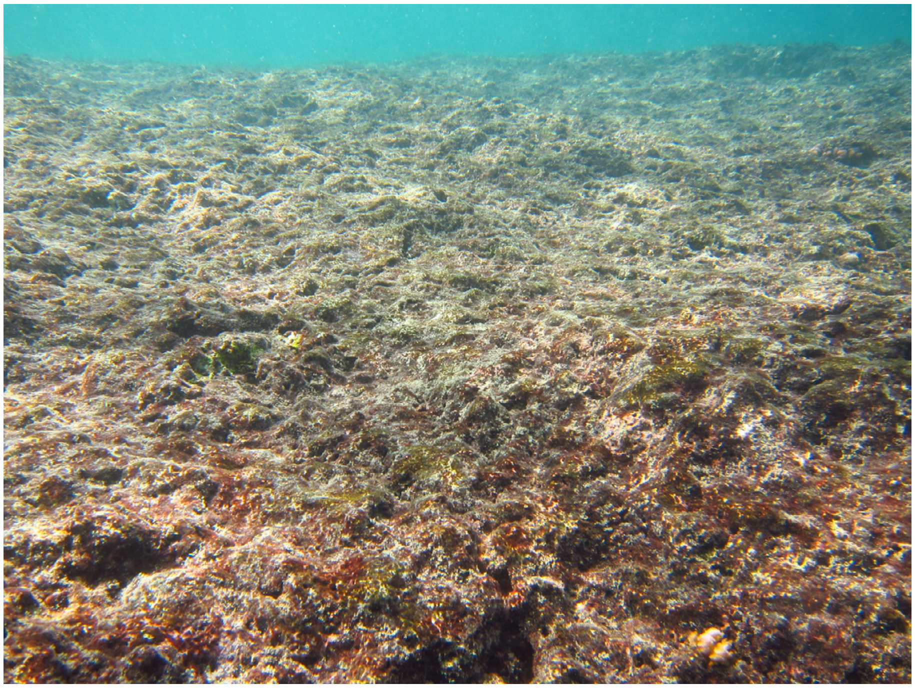

FIG. 36.5 Shallow bare zone. *Photo by Douglas Fenner.*

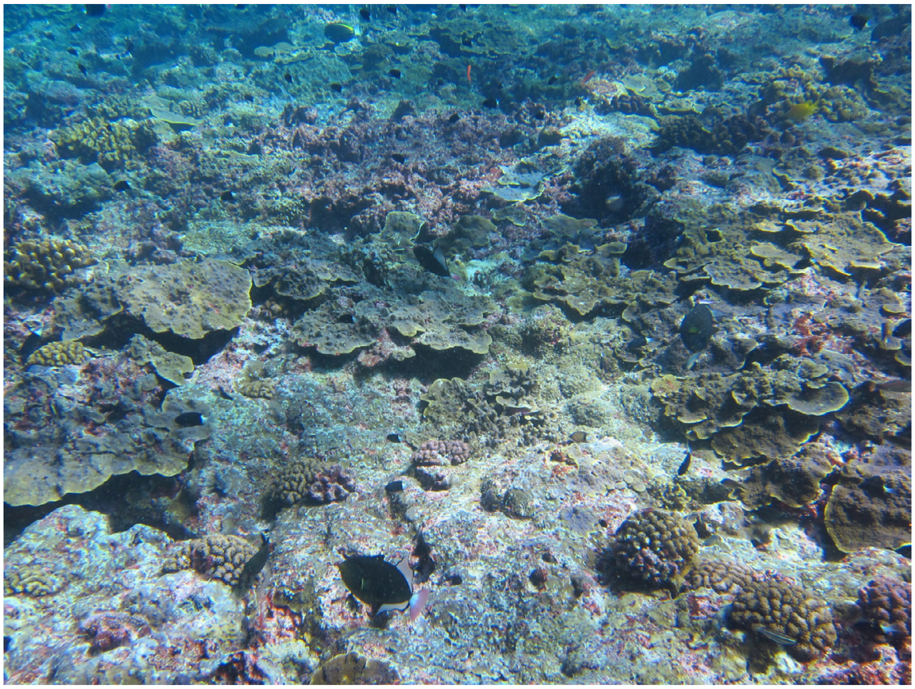

FIG. 36.6 Shallow plate *Montipora* zone. *Photo by Douglas Fenner.*

depth to at least 25 m. This zone is heavily dominated by *Porites rus* Fig. 36.7). The *Porites rus* colonies are a mixture of thin plate bases and small irregular vertical columns. Coral cover gradually decreases from about 20 m depth to 35 m depth, where the green alga *Halimeda* may be common (Fig. 36.8).

Lovell et al. (2004) reported that "Reef development is generally poor and coral communities are either sparse or contain mostly dead corals, especially near the populated and developed areas of Nauru. Small encrusting colonies grow on the reef slope and live coral cover is 0%–20% in areas from Uaboe district to Gahab channel and Boe district." "Nauru Coral

FIG. 36.7 Deeper, high coral cover, *Porites rus* zone. *Photo by Douglas Fenner.*

FIG. 36.8 Whitetip reef shark on the deep reef slope at about 35 m depth. The green algae are *Halimeda*. *Photo by Douglas Fenner.*

Reef Monitoring Network surveyed seven sites in 2004 and recorded live coral coverage between 44% and 78% with sites near the districts of Nibok and Yaren, which had a high percent of dead coral and alga growth. Like other small island countries, the reefs of Nauru are highly threatened by climate change (Chin et al., 2011). Widespread bleaching and dead coral was noted by the Cousteau Nauru expedition in May to June 1991 (King, 1992). From 2002 to 2004, another bleaching event was reported with high mortality of *Acropora* in early 2004 by NCRMN (Deiye in Sulu 2004). Additionally, a massive fish kill occurred in September 2003 hypothesized to be a result of elevated sea surface temperatures with warm water upwelling that led to major drop in dissolved oxygen concentration (Lovell et al., 2004). Localized threats from dredging were documented with the installation of the harbor in the Anibare district (Maharaj, 2003). Overfishing has been identified as a major threat to the reef resources of Nauru (Jacob, 2000; PROCFish/C & CoFish Team, 2007; Vunisea, 2007)" (McKenna, 2015). In 2005, at an average depth of 8.5 m (range 3–16 m), live corals had 21% cover, and 77% was hard bottom (about 70% cover by dead coral). Manta tows found about 34% crustose coralline algae cover (presumably over dead coral) and transects found about 44% crustose coalline algae cover. There was a small amount of other coralline algae, but essentially no macroalgae or turf was reported. (PROCFish/C and CoFish Team, 2007).

In the most recent (2013) survey of 20 sites all around the island, live hard coral cover averaged 48% in deeper water (>12 m depth) and averaged 65.5% in shallow water (<11 m depth). Coral cover ranged from 11.2% to 88.7% in deeper water and 16.9% to 91.2% in shallow water. This is a significant increase in coral cover since 2005 when live coral cover was only 21%. Crustose coralline algae averaged 22.5% in deeper water and 14% in shallower water, a decrease from 2005. Macroalgae averaged 11% in deeper water and 4.3% in shallower water. Turf algae averaged 2.9% in deeper water and 4.5% in shallower water. Cyanobacteria averaged 0.3% in both deep and shallow water. Cover by calcifying organisms (coral and coralline algae) was 70.5% in deeper water and 79.5% in shallow water (McKenna, 2015). Most of the world's coral reefs have declined sharply in coral cover, including in the Pacific (Bruno & Selig, 2007). The coral cover in Nauru has increased since 2005 and is currently outstandingly high on a global basis. Crustose coralline algae cover is moderate, macroalgae cover low, turf algae cover low, and cyanobacteria cover is very low. High coral cover, high coralline algae cover, high calcifying organism cover, and low macroalgal cover are considered signs of a healthy reef.

At the time of the survey in 2013, no signs of coral bleaching were observed, signs of coral disease were rare, only one coralline algae disease was sighted (target pattern disease, which does not threaten the algae), and only one individual Crown-of-Thorns starfish was sighted (and no feeding scars), but a few coral-eating snails (*Drupella*) were sighted (but no outbreak). Standing dead corals were not reported. Signs of fishing activity were observed, and some trash observed on the reef, with high levels of trash at two sites. Only two sea turtles were observed, one a hawksbill and the other unidentified. Most of these indicators point to a currently healthy benthic coral reef ecosystem, though the high density and dominance of one species of coral, *Porites rus*, could make the ecosystem vulnerable to coral disease in the future (McKenna, 2015). The average visibility measured at an average depth of 8.3 m was 14.3 m (Imirizaldu, 2015), but appeared to be greater in deeper water, around 25–35 m.

36.4.2 Coral

Surveys in 2013 used a roving diver search method for 60 min from 35 m depth to near the surface, and found an average of 17.2 coral species per dive site and a total of 51 species of coral in the 20 sites surveyed. All but one site were dominated by a single species of coral, *Porites rus*, with the octocoral blue coral *Heliopora coerulea* and the hydrozoan *Distichopora violacea* having the next highest colony abundances, but much lower cover due to smaller colonies. Several earlier surveys did not report that *Porites rus* dominated the reefs, so it appears that the dominance by *Porites rus* is a relatively new phenomenon. It is likely that the large increase in coral cover since 2005 was primarily due to *Porites rus*. *Porites rus* grows in thin fragile plates and thin columns, which increases its ability to fragment. Fragments produced can often attach and grow, and *P. rus* probably grows rapidly. There are several anecdotal reports that the reefs have low coral species richness (King, 1992; Jacob, 2000). Jacob (2000) reported that the low diversity was said to be due to the small size of the island and the great distance from the center of marine diversity. Nauru has much lower coral species richness than all surrounding archipelagos, with the Marshall Islands, Pohnpei and Kosrae, the Solomon Islands, eastern Papua New Guinea, the Gilbert Islands of Kiribati, and Vanuatu having 325–500 species of coral each (Fenner, 2015). Polluted water conditions have been shown to produce lower coral diversity (Edinger, Jompa, Limmon, Widjatmoko, & Risk, 1998). The report from the 1990–91 Cousteau team visit to Nauru (King, 1992) concluded, from the low diversity, the presence of some dead *Acropora*, the presence of phosphate mining, and the observation of bleaching, that the reefs were unhealthy. However, five other small, isolated islands all have 100 species of coral or less (Fenner, 2015). Further, fish, invertebrates, and algae all have relatively low species richness in Nauru and even terrestrial groups such as plants, insects, and lizards have relatively low diversity on Nauru (McKenna et al., 2015). Thus, the low species richness of corals is not a special feature of corals due to some peculiarity of their biology, or to poor marine conditions. Most observers have ascribed the low diversity in Nauru to the small island size, remoteness of the island, and/or low habitat diversity (Jacob, 2000; Edwards, 2015; Feary, 2015; Fenner, 2015; Imirizaldu, 2015; Van Dijken, 2015). Thus, it appears that the small size of the island, remote location, and/or low habitat diversity are likely to contribute to the low species richness. A field guide to the corals of Nauru is nearing completion (Fenner, n.d.).

36.4.3 Fishes

The 2005 SPC survey concluded that "The finfish resource assessment indicates that Nauru has a very high population of surgeonfish and triggerfish, but alarmingly low populations of targeted and commercial species of groupers, snappers, emperors, and scarids" (PROCFish/C and CoFish Team, 2007). The biomass of Acanthurids was nearly three times the average of 13 other countries surveyed by the same program. "The recent 'fish kill' phenomenon experienced in Nauru in 2004 remains a mystery, with algal bloom and/or heat shock triggered by prolonged uncommon elevated water temperature, or an upwelling of de-oxygenated water from depth, as possible explanations" (PROCFish/C and CoFish Team, 2007).

The most recent (2013) survey of reef fish diversity used a roving diver search method and found an average of 73.8 and a median of 79.5 fish species per site. The three sites with the lowest number of fish species were all near the phosphate loading facility and had an average of 52 species per site. One site near the small boat harbor on the east side of the island had just 35 species. A total of 407 fish species are now known from Nauru, including 231 that were found in the most recent survey. Pelagic, deep water, nocturnal, and cryptic (hidden) species are not normally found on diver surveys. Nauru has 34 species of wrasses (Labridae), 30 species of damselfish (Pomacentridae), 21 species of surgeonfish (Acanthuridae), 21 species of butterfly fish (Chaetodontidae), 12 species of triggerfish and filefish (Balistidae), 11 species of groupers and allies (Serranidae), and 10 species of parrotfish (Scaridae). "Mobile invertebrate feeders were the most common functional group found within the reef fish fauna (23.8%), while planktivorous fishes (19.2%), fishes that had a diet comprised of both invertebrates and fishes (12.8%) and piscivores (10.3%) were also relatively diverse" (Feary, 2015). Whitetip reef sharks were seen on all but one dive, down the slope from divers, while other sharks were not sighted. Four to eight individuals were seen per dive. They are not actively fished in Nauru. Squirrelfish and soldierfish (family Holocentridae) were the most abundant fish family, with about 200–300 individuals seen per dive. These fish are taken by fishermen, often 10–15 per fisherman. Fishermen gave no indication that their stocks had declined. There were relatively few large grouper and snapper individuals (Feary, 2015).

The most recent (2013) survey of targeted reef fish surveyed targeted fish in a 500 m^2 area at an 8.4 m average depth at each site and recorded the number of individuals of each targeted reef fish species and the size of each individual fish. A total of 129 targeted species with a mean of 40 species per site were found. The mean biomass of targeted fish (computed from numbers of individuals of each species and length) was 162 t/km^2. The SPC survey in 2005 reported a total mean biomass for all fish of 213 t/km^2 (PROCFish/C and CoFish Team, 2007).

The surgeonfish family (Acanthuridae) had the highest abundance and biomass of any family, with 22% of the abundance and 39% of the biomass of the recorded fish. The most abundant species was *Ctenochaetus sriatus* (striped surgeon), which is often the most abundant species where found. The second most abundant species was *Acanturus nigricans* (whitecheek surgeonfish). Two species with good numbers of individuals had mean sizes under the length at maturity, a grouper: darkfin hind (*Cephalopholis urodeata*) and another grouper: orange rock cod (*Epinephelus hexagonatus*). Five other species with small numbers recorded also had mean sizes under the length at maturity. A mean size under the length at maturity indicates reduced spawning ability and suggests overfishing of that species. Herbivorous fish as a trophic group had the largest biomass by far (62 t/km^2) among the targeted species, followed by carnivores (22 t/km^2) and planktivores (21 t/km^2), while spongivores (9 t/km^2), piscivores (2.7 t/km^2), and corallivores (1 t/km^2) had low biomasses (Imirizaldu, 2015). Some of the highest reef fish biomass areas in the world have about 5000–7000 kg/ha or 500–700 t/km^2, while low biomass reefs in the Indian Ocean have biomasses of 500–1000 kg/ha or 50–100 t/km^2 (Graham & McClanahan, 2013). High biomass reefs in the Pacific have about 125 g/m^2 or t/km^2 and low biomass reefs (fished) have about 25 g/m^2 (Williams et al., 2015). A review of reef fish biomass and variables that affect it concluded that a biomass of ~1000 Kg/ha (= 100 t/km^2) was a typical figure for unfished reef biomass (MacNeil, Graham, & Cinner, 2015). A total mean biomass for all fish in Nauru of 213 t/km^2 compared to these figures might suggest a moderately or low fished reef fish community at Nauru. Fishing using SCUBA equipment is a common practice in Nauru. There are no fishing regulations. The low abundances of large fish, the small sizes of fish, and the relatively small population of piscivores suggest strong fishing pressure. The reef fish abundance and biomass which PROCFish recorded in Nauru were among the highest recorded in 17 countries in the Pacific (Pinca et al., 2012: Fig. 36.5), suggesting that fishing may have been light in Nauru compared to these other countries. The fact that the 2014 survey found 164 t/km^2 compared to 213 t/km^2 in 2005 suggests that the biomass of reef fish in Nauru may be declining.

36.4.4 Invertebrates

Surveys done in 2005 found that "There is a small lobster fishery, mainly for the restaurant trade, however, anecdotal information indicates this stock is in decline. Six commercial species of sea cucumber were recorded, mainly at low densities. One species, surf redfish, was relatively common (recorded in 92% of broad-scale manta transects and 100% of reef front searches). There is some potential for a small fishery based on this species, however, some locals are starting to eat this species as other marine species become harder to find. Sea urchins in the genus *Echinothrix* (mainly *E. diadema*) "were very common (>95% of manta transects and reef front searches, at a mean density of close to 1000 per ha)." "Anecdotal evidence suggests that a viable *Tridacna* (probably *T. maxima*) population was lost from Nauru as early as the 1980s." Corallivorous starfish were rare (PROCFish/C and CoFish Team, 2007).

The most recent (2013) survey of non-cryptic macro marine invertebrates surveyed 20 reef slope sites and four reef flat sites and found 79 species, including 41 new records of invertebrate species. A total of 248 species of marine invertebrates are now known from Nauru. An average of 10.6 species was found per site. These are relatively small numbers, which may be because of the small number of habitats plus the small size of the island and long distances to other islands. The most common species were the urchin *Echinothrix diadema*, the coralivorous snail *Drupella cornus*, the coral guard crab *Trapezia rufopunctata*, the corallivorous snail *Coralliophila neritoidea*, the sea cucumber *Actinopyga varians*, and the urchin *Diadema setosum*. Two individuals of the giant clam *Tridacna squamosa* were found. Previous surveys had failed to find any giant clams and they were thought to be locally extinct on the island. A few individuals of two species of soft coral were found, *Sarcophyton* sp. and *Cladiella* sp. There were low abundances of species targeted in fisheries. Only five species of sea cucumber were found, low abundances of *Turbo* snails, and no *Trochus* snails in spite of habitat availability, suggesting overexploitation (Van Dijken, 2015). The reefs in Nauru are all very exposed and steeply sloping, and there is very little sandy substrate, the substrate favored by most sea cucumbers which ingest sand.

36.5 OFFSHORE SYSTEMS

Nauru has 431,000 km^2 of Exclusive Economic Zone (EEZ). "The large amount of tuna caught by foreign fishing vessels in the Nauru zone, about 41,000 mt in 1999, is all landed outside of Nauru. Sixty per cent of the fish in 1999 was taken by Taiwanese and Korean purse seiners and was transshipped to canneries in either Asia or American Samoa. The Japanese catch, about 15%, was landed in Japan while the US catch, 15%, was taken directly to American Samoa" (FAO, 2002). In 2007, foreign-based offshore fisheries produced 69,236 tons (FAO, 2010). Locally based boats were reported to land 475 tons of tuna in 1999 (FAO, 2002) and 650 tons in 2007 (FAO, 2010). "The most important fishing activity is trolling for tuna from small outboard-powered boats. A study undertaken by the Forum Fisheries Agency in 1989 indicated that these boats catch an average of 70 kg of fish per day while trolling around Nauru. The most important finfish species are the skipjack tuna *Katsuwonus pelamis*, yellowfin tuna *Thunnus albacares*, and rainbow runner *Elagatis bipinnulata*" (FAO, 2002).

36.6 CLIMATE CHANGE IMPACTS

The reefs at Nauru are projected to begin experiencing temperatures conducive to annual summer mass bleaching about 5 to 16 years before the median (van Hooidonk, Maynard, & Planes, 2013). Rising sea level should flood the reef flat at low tide in the future, allowing coral to begin growing there (Fenner, 2012); if this happens before mass bleaching events cause major coral mortality.

36.7 HUMAN POPULATIONS AFFECTING THE AREA

In 1983, there were just over 8000 people in Nauru, with 62% being Nauruans and the remainder being mainly Kiribatese, Tuvaluans, and Solomon Islanders (UNEP/IUCN, 1988). "A lack of land for urban development and an unsecured ground water supply are serious issues for Nauru. The lack of land is further exacerbated by the rise in population from 9919 (1992 statistics) to 10,084 in 2011 (Nauru Bureau of Statistics)" (McKenna et al., 2015). The population is concentrated on the narrow nearshore lowland that forms a rim around the island. The island has few resources other than phosphate, which has mostly been mined and thus has a limited future for supporting the country. In 2005, 86% of employment was in government. Some foreign workers have returned to their countries (Kiribati and Tuvalu), and the population may have declined some. Estimates from 2003 indicate that 38.9% of the population was <19 years old, a very young population, with a high population growth rate (PROCFish/C and CoFish Team, 2007).

Over 70% of the forest on the island was removed to mine the phosphate. Although this had major effects on terrestrial flora and fauna, it has had little effect on marine ecosystems because there is no surface runoff and all rainwater percolates through the porous limestone substrate.

The primary pollutant is phosphate dust which is released into the air in the process of being loaded onto ships. However, algal blooms have not been observed in the ship loading area. Suspicion that phosphate may have damaged the reefs led a Cousteau group in 1990–1991 to collect samples of corals and fish and have them tested for cadmium, a toxic contaminant of phosphate, but unhealthy levels were not found (Fenner, 2015; King, 1992).

36.8 RESOURCES

The fisheries of Nauru can be divided into the commercial fishing of tuna, carried out in the EEZ by distant water fishing fleets of other countries under license from the Nauru government, and the nearshore fisheries carried out by residents. In turn, the nearshore fisheries can be divided into fishing for pelagic fish around nearshore FADs (fish attraction devices), bottom fishing, and coral reef fisheries. As of 2005, 95% of land-based fishing was in the coastal reefs and passages, and the remainder was for pelagic species. Also, 97% of households fished, with an average of 3.7 fishers per household. Fresh fish is eaten an average of 3.8 times per week. Per capita consumption of fresh fish is about 47 kg/person/year. About 55%–72% of the catch by people in Nauru was for subsistence. Most fishing for invertebrates occurs on the reef flats. Although many small boats were engaged in fishing previously, there were few in 2005 because fuel was unaffordable for most residents (PROCFish/C and CoFish Team, 2007). For more details on fishing, see PROCFish/C and CoFish Team (2007).

"There are plenty of skipjack tuna in Nauru waters. Oceangoing fishing vessels catch around 50,000 tons a year here—a catch which the best scientific minds of the Pacific reckon is fully sustainable—and the income from which contributes in a major way to the Nauru economy. It's not just foreign consumers and the Nauru government budget that benefits from this healthy tuna resource. Small boats and canoes fishing in the blue water just outside the Nauru reef can bring in plenty of tuna on a good day. But talk to Nauru fishermen about the fish on the Nauru reef and they turn pessimistic. "Things were better in the old days," they will say. "We used to be able to catch big coral trout and groupers, but nowadays we hardly see them. We used to catch plenty of lobsters. We used to see giant clams." Also, unlike some other Pacific Islands, which put the blame on tourists or climate change, Nauru fishermen are clear-sighted about where the problem lies: too many people fishing in too small an area" (SPC, 2012). Nauru sells the right to fish tuna in its EEZ for over US$3 million per year to foreign fishing vessels (Anon, 2017).

Nauru wants to protect reef fish spawning aggregations (NFMRA, 2011a, 2011b). However, "Nauruan fishermen stated that they would typically dive to depths deeper than ~50 m to collect fish" (Feary, 2015).

"Bottom fishing by hand-line is conducted along the outer reef slope targeting both shallow and deep demersal species. Shallow-water snappers dominate the catch from this fishery. Expatriate workers also conduct an active scoop-net fishery for flying fish. Nauruans fish on the reef flats with cast nets and gill nets. A dive fishery using spear guns, commonly conducted with the aid of SCUBA, is also active, targeting snappers, groupers, squirrel fish, jacks, surgeonfish, and soldier fish. Reef gleaning for octopus, turban shell, and other invertebrates is also common. Recent declines in activity associated with phosphate mining, have resulted in a significant retrenchment of workers. Many of these people have increased their fishing activity, especially in inshore areas and declines in abundance of popular fish and invertebrates have been noted" FAO, 2002. Ninety-seven percent of households surveyed were engaged in fisheries (FAO, 2010).

Owing to the decline in the economy, starting in about 2004, the ability to purchase package food decreased, and the diet shifted from imported and processed packaged foods to traditional foods, the opposite of current trends in most places in the Pacific. Backyard gardening increased, seabirds which were eaten only as a delicacy on ceremonial occasions became widespread, and fishing and gleaning pressure increased dramatically, with seafood being the main source of protein for 98% of households. Extended families gathered to share resources (Vunisea, 2007). These trends appear to have eased in recent years as the economy recovered somewhat.

For a more detailed history of fishing in Nauru, see PROCFish/C and CoFish Team (2007).

36.8.1 Aquaculture

Aquaculture is limited by space. Milkfish are reared in small quantities in ponds, most of which are bomb craters from World War II. Fry are collected from the reef at low tide, acclimated for 2–3 weeks, and then released into the ponds. "… production is limited because of introduced *Tilapia* which could outcompete the milkfish" (UNEP/IUCN, 1988).

36.8.2 Oil and Gas, Minerals

Phosphate mining produces the main economic support for this tiny island nation. Traditional landowners receive payment for phosphate mined on their land. Mining is done by machinery removing vegetation and topsoil, then removing phosphate down to the limestone substrate which commonly is in the form of karst "pinnacles." The phosphate is taken to a facility where it is processed and then stored. Large cantilevers on the reef flat then use conveyor belts to carry the phosphate to the ships which are moored very close to the reef crest. "Phosphate dust causes few problems during loading at the cantelevers because of the constant oceanic current upwelling around the island" (UNEP/IUCN, 1988). The recent reef surveys (McKenna et al., 2015) did not detect upwelling, and the ocean volume is so vast that minor currents could easily dilute the phosphate dust greatly.

At one point, the island government was considered wealthy and it invested in a variety of ventures in other countries, but it has fallen on hard times due to problems with investments. There is no oil or gas. For a history of phosphate mining in Nauru and social issues stemming from the decline of the economy, see PROCFish/C and CoFish Team (2007).

36.8.3 Tourism

There is very little if any tourism to Nauru. Most visitors come to work on construction projects at the Australian detention facility. The Australian government has built and operates a facility for asylum-seekers who land in Australia, and pays the Nauru government for being allowed to have this facility on Nauru. The Australian government invests in construction, maintenance, and operation of the facility, and the Nauru government hotel has been expanded with portable units to house their contract workers.

36.8.4 Threats to Sustainable Use of Resources

On the land, there is little or no agriculture other than kitchen gardens. Seabirds are caught and eaten, and some species are locally threatened by unsustainable exploitation, predation from dogs, and destruction of habitat (Stirnemann, 2015). As of 2005, "The people of Nauru are going through difficult times with the current economic crisis, low wages and purchasing power for those with jobs, high fuel costs when fuel is available, and the need to put food on the table for themselves and their families. The increased focus on harvesting marine resources to address the food security issue, has the potential to devastate the inshore resources unless appropriate measures are put in place to ensure sustainable harvesting of the resource" (PROCFish/C and CoFish Team, 2007).

36.9 MANAGEMENT REGIMES

There are currently no limits on coral reef fish catch (FAO, 2010), the taking of sea turtles or seabird catch, and no Marine protected areas. Owing to the lack of traditional authority, there are no customary regulations and fishing is open-access (Vunisea, 2007). Nauru sells the right to fish in its EEZ to distant water fishing nations. Legislation gives the power to regulate fisheries to the Minister of the Nauru Fisheries and Marine Resources Authority. However, "Aside from fisheries development efforts, there is little government intervention in the inshore fisheries" (PROCFish/C and CoFish Team, 2007).

36.10 RECOMMENDATIONS

Recommendations from the 2005 SPC survey were for the government to monitor fishing effort and fish catch, and implement management measures to affect catch and fishing practices. They also recommended that fishing be managed to rebuild and sustain fish and invertebrate stocks, and management controlled by communities. They recommend awareness programs for any management that the government undertakes. They recommend that SCUBA spearfishing be controlled as it is the most powerful fishing method. They recommend the government work to shift fishing pressure away from reefs and toward pelagic fish, and that reef fishing be shifted toward abundant herbivorous Acanthurids. They recommend that the government consider implementing a few Marine Protected Areas.

Restoration or maintenance of seabird nesting habitat, control of feral dogs, and regulation of seabird catch to attain sustainability appear to be the most urgent management need in Nauru (McKenna et al., 2015; Stirnemann, 2015). Regulations need to restrict catch to less than sustainable catch levels. Stocks need to be rebuilt to levels that can maximize sustainable yields. Seabird species that are subject to local extinction need to be completely protected, and at least part of the nesting areas used most by the most threatened species need to have protected areas that are no entry zones and are patrolled during nesting seasons.

Larger coral reef fish such as sharks, humphead wrasse, and bumphead parrotfish need to be totally protected from fishing until their stocks recover, at which time regulated fishing may be allowed and could provide sustainable yields higher than current yields. Sea turtles and giant clams need to be protected as they are now very rare. Species in all groups which are rare in Nauru could easily become locally extinct and should be protected. Since Nauru is so remote, the loss of any species is not likely to be reversed by the arrival of propagules from other areas within anything but long periods of time (with the possible exception of seabirds). Marine protected areas in the pelagic EEZ may not be needed for tuna if tuna stocks in the EEZ are well managed.

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