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Research Article

Conservation Status of Marine Biodiversity in Oceania: An Analysis of Marine Species on the IUCN Red List of Threatened Species

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Given the economic and cultural dependence on the marine environment in Oceania and a rapidly expanding human population, many marine species populations are in decline and may be vulnerable to extinction from a number of local and regional threats. IUCN Red List assessments, a widely used system for quantifying threats to species and assessing species extinction risk, have been completed for 1190 marine species in Oceania to date, including all known species of corals, mangroves, seagrasses, sea snakes, marine mammals, sea birds, sea turtles, sharks, and rays present in Oceania, plus all species in five important perciform fish groups. Many of the species in these groups are threatened by the modification or destruction of coastal habitats, overfishing from direct or indirect exploitation, pollution, and other ecological or environmental changes associated with climate change. Spatial analyses of threatened species highlight priority areas for both site- and species-specific conservation action. Although increased knowledge and use of newly available IUCN Red List assessments for marine species can greatly improve conservation priorities for marine species in Oceania, many important fish groups are still in urgent need of assessment.

1. Introduction

Spread over approximately 43 million square kilometres of the Pacific Ocean, Oceania is comprised of thousands of small coral atolls and islands surrounded by vast areas of open ocean. Oceania is characterized by areas of high species diversity and endemism, both in the terrestrial and marine realms [1–3].

The Pacific islands of Oceania support an estimated nine million people [4], many of which rely heavily on marine resources for food and income generation. In many small island nations, the entirety of the population lives within the coastal zone, and marine resources may represent the only source of protein for human consumption. This is highlighted by fish consumption statistics, with annual rates estimated at 50 kg per person, as compared to eight kg for people living in continental countries such as Australia [5].

By nature of its small island geography, Oceania is particularly susceptible to changes impacting biodiversity [6, 7]. Depleted populations cannot always be easily replenished by neighbouring areas, and some species may be prone to localized extinctions, such as those with restricted ranges [8] or widespread species with low abundance and high ecological specialization [9]. Threats to marine conservation include habitat degradation, overfishing, invasive species introductions, and climate change. High human dependency on marine resources and increasing population size mean that pressures on coastal ecosystems in Oceania are only expected to increase [7]. An additional challenge is the management of 16 million square kilometres of ocean that fall outside of any country's exclusive economic zone (EEZ). This vast expanse of ocean is only governed under international high-seas legislation of questionable effectiveness [7].

Pacific islanders have traditionally made use of a number of marine conservation methods, including rights-based fishing (restricted entry), closed seasons, closed areas, size restrictions, and gear restrictions [10]. Historically, these traditional systems played an important role in sustaining fisheries in the region. The importance of local subsistence fisheries continues, with landings from this sector accounting for 80% of coastal fisheries production [11]. However, many of the traditional systems have broken down through the process of Western colonization and introduction of cash economies [12] and many coastal areas, including coral reef ecosystems, are threatened by overexploitation and development [13].

Given its remote nature, scientific knowledge of the region is poor, and conservation work is limited and biased towards more developed countries. In a preliminary review of all the plants and animals present in Oceania published on the 2008 IUCN Red List of Threatened Species, almost one-third are in threatened categories [14]. However, the vast majority of these Red List assessments are for terrestrial organisms. Here we provide a more comprehensive analysis of the status of marine biodiversity in Oceania by examining the conservation status of 1190 marine taxa that have been assessed to date under the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species. Our analyses highlight the current state of knowledge of marine species at risk, major threatening processes, and important research and conservation needs within the region.

2. Methods

2.1. Description of Study Scope. For this study, Oceania is defined as all of Micronesia (Palau islands to Wake and Kiribati), Polynesia (Tuvalu, Tonga, Kermadec Islands, north to the Hawaiian Islands and east to Rapa Nui) excluding the main islands of New Zealand, and the Melanesian island chains of New Caledonia, Vanuatu, Norfolk Island and Fiji (Figure 1). The Melanesian areas of New Guinea and the Solomon Islands were excluded because biogeographically these are more similar to the Coral Triangle region [15].

A species was determined to occur in the Oceania region if its range overlapped with any part of the described study area and there existed documented occurrences of the species' presence in the region. To date, the IUCN Red List Categories and Criteria [16] have been applied to 1190 marine species present in the Oceania region, including all marine mammals, sea birds, sea turtles, reef-building corals, mangroves, seagrasses, sea snakes, sharks and rays, and five perciform coral reef fish families or subfamilies (Table S1). IUCN has partnered with numerous institutions and organizations to complete Red List assessments for these species, such as SeagrassNet, BirdLife International, and several IUCN Species Specialist Groups including those for Cetaceans, Pinnipeds, Marine Turtles, Sharks and Rays, Corals, and Groupers and Wrasses.

Since 2002, the IUCN Red List process has moved away from only assessing select species of assumed high vulnerability or ecological importance and has created a number of different global species assessment initiatives to comprehensively assess complete groups or clades of species for inclusion on the IUCN Red List of Threatened Species. For example, all marine mammals were assessed under the Global Mammal Assessment initiative that assessed the world's approximately 5500 species of mammals, all of the world's seabirds were assessed under a comprehensive assessment of the world's bird species through BirdLife International, and over 20,000 marine species, including all key primary habitat producers (mangroves, seagrasses, corals) and all marine fishes, are currently in the process of being assessed through the Global Marine Species Assessment.

2.2. IUCN Red List Assessment Methodology. All Red List species assessments are based on standardized IUCN Red List methodology [16]. The vast majority of assessments are conducted in Red List Workshops focusing on a taxonomic group or geographic region that bring together the world's leading scientists to share and synthesize species-specific data, and to collectively apply the IUCN Red List Categories and Criteria. Red List assessments for Oceania species presented here represent the combined work of hundreds of scientific experts in at least 14 global Red List Assessment workshops. During Red List Assessment workshops, species are evaluated one at a time by the group of experts present, with outside consultation and followup conducted when additional information is needed but not available at the workshop. Information on taxonomy, distribution, population trends, ecology, life history, past and existing threats, and conservation actions for each species is recorded and reviewed for accuracy. Under the guidance of IUCN Species Programme scientists, quantitative species information is then used to determine if a species meets the threshold for a threatened category under at least one IUCN Red List Criterion. In order for species accounts to be finalized and published on the IUCN Red List of Threatened Species, each species must have a minimum of two Assessors (e.g., those scientists that provided key data and worked with IUCN Species Programme to create the initial species assessment) and two Evaluators (e.g., those scientists that reviewed the final account for data accuracy and correct application of Criteria); however, in many cases the number of Assessors and Evaluators for many species was much higher. All species data and results of Red List assessments, including the names of the scientists that contributed to the 1190 species assessed in Oceania either as Assessors or Evaluators, are freely and publicly accessible under each species account on the IUCN Red List of Threatened Species [17]. This IUCN Red List process consolidates the most current and highest quality data available and ensures peer-reviewed scientific consensus on the probability of extinction for each species.

The IUCN Red List Categories and Criteria are the most widely accepted system for classifying extinction risk at the species level [18–21]. The IUCN Red List Categories are comprised of eight different levels of extinction risk: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR),

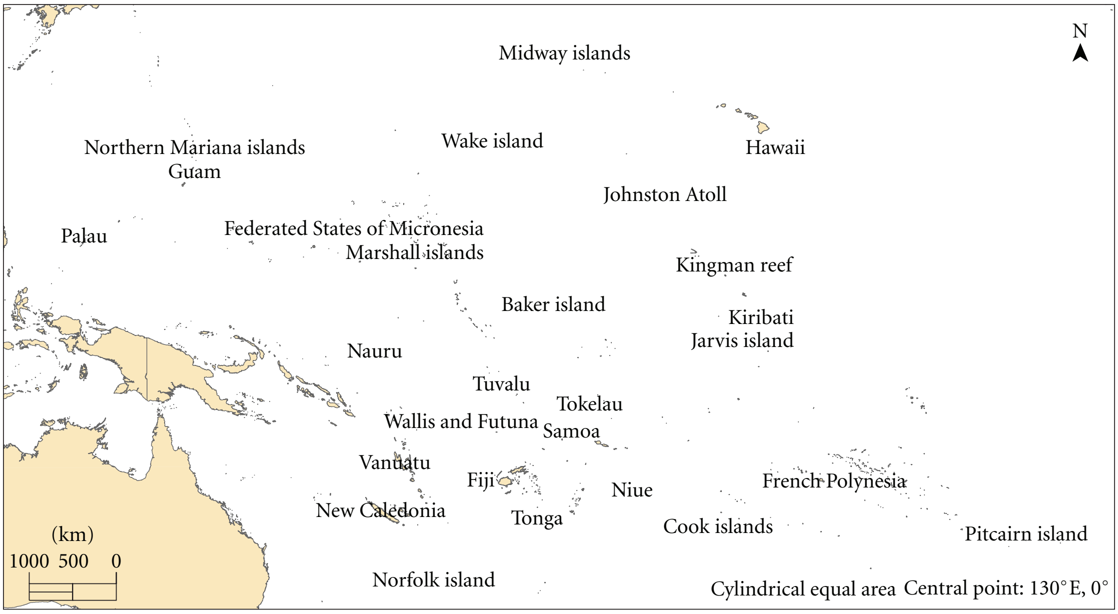

Figure 1: Major islands and regions of Oceania.

Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), and Data Deficient (DD). A species qualifies for one of the three threatened categories (CR, EN, or VU) by meeting a quantitative threshold for that Category in one of the five different available Criteria (A–E). A category of Near Threatened is assigned to species that come close to, but do not fully meet all the thresholds or conditions required for a threatened Category under Criterion A, B, C, D, or E. A category of Least Concern is assigned when there are no known threats to a species, or quantification of known threats for a species does not come close to meeting any of the threatened Category thresholds. A category of Data Deficient is assigned when there is insufficient information available to adequately apply the Criteria, such as taxonomic uncertainty, lack of key biological information, or inability to adequately quantify the impact of known threats.

The IUCN Criteria (A–E) that underpin the IUCN Red List are designed to be transparent, reproducible, and conservatively flexible in the handling of uncertainty [16]. The Criteria are a standardized methodology that can be applied consistently to any species from any taxonomic group [16, 22]. Each of the five Criteria is based on extinction risk theory [22] and fall within one of two paradigms of elevated extinction risk: (1) species with small population sizes that are inherently at higher risk of extinction and/or are undergoing decline, and (2) species with widespread or large populations that are declining faster than they are able to recover.

Criterion A measures extinction risk based on exceeding a threshold of population decline (30% for Vulnerable, 50% for Endangered, and 80% for Critically Endangered) over a timeframe of three generation lengths, a measure of reproductive turnover rate, in the recent past. For species with large, widespread population sizes, this is often the most applicable Criterion. As many marine species have large distributions, compared to terrestrial species, over 90% of species in Oceania that were determined to be in threatened categories were assessed under Criterion A. Taxa-specific methodology for application of Criterion A to species relies on first defining an appropriate generation length for the species group, and then determining the best proxy or surrogate available to estimate population decline over time (e.g., estimates of population size from survey samples, habitat loss, fishery statistics, etc). Generation length, defined as the average age of parents of the current cohort, is a measure of species reproductive turnover and is best calculated from a life table with appropriate age- and sex-specific information on survival and fecundity. However, when these data are not available, other methods can be used to estimate generation length [23]. It is recognized that there are inherent difficulties for calculating generation length in particular for very long-lived taxa, for taxa with age-related variation in fecundity and mortality, or for species with variable reproductive traits under different environmental or population stressors, such as overfishing [23–26].

Criterion B measures extinction risk based on a small geographic range size (extent of occurrence <20,000 km^2 or area of occupancy <2,000 km^2 to meet the lowest threshold for Vulnerable) combined with continued decline and habitat fragmentation. Criterion C is applied to species with small population sizes estimated to be less than 10,000 mature individuals, with continued decline. Therefore, Criterion B and C are most applicable for species with small range sizes or small population sizes, which are also undergoing decline. Criteria D is designed to capture the inherent risk of extinction of species with extremely small population sizes. Under Criterion D, species can qualify for a threatened category if the global population is estimated to be less than 1,000 mature individuals or occupies an area of less than 20 km^2. Criterion E is applied to species with extensive population information that allows for population declines to be appropriately modeled over time. Although few species have this quantity of data available for reliable modeling, it can be appropriate for some species of commercial marine fish [27].

The description and guidelines for the use of IUCN Red List Criteria are publicly available [23]. Details of how the Criteria have been interpreted and applied to different marine groups are described in several recent publications on marine mammals [28], reef-building corals [29], mangroves [30], sharks and batoids [31, 32], groupers [33], sea birds, and sea turtles [34–36].

2.3. Spatial Analyses. Spatial analyses were conducted for all species based on digital distribution maps compiled during IUCN Red List Workshops and from partner organizations. However, distribution maps were not available for all species of sea birds, and therefore all spatial analyses were conducted without the inclusion of sea bird species.

All digital distribution maps were first created based on a minimum convex polygon connecting points of known presence. To improve accuracy and standardize analyses, each polygon was cut to either a shore fish basemap or left as a pelagic species polygon, depending on whether the species is found primarily above 200 m depth or below 200 m depth. In general, the vast majority of shore fish, sea snake, mangrove, coral, and seagrass polygons were cut to the shore fish basemap created from a combined 100 km shoreline buffer and maximum depth of 200 m, based on 2-minute spatial bathymetry data available from NOAA National Marine Fisheries Service (ETOPO1). This "cookie-cutter" method allows for standardization of analyses and better visualization for near shore and shallower water species. Species that could occur in deeper waters, including the vast majority of marine mammals, sea turtles, sharks, and rays were left as entire polygons. Overall, this approach helps to improve the accuracy of subsequent analyses by standardizing species ranges and by excluding large areas of open ocean where a shallow water species would never occur.

For analyses of species richness and proportion maps, all species polygons were stacked and analyzed using a 10 km × 10 km square grid. This grid sizewas chosen as it avoids over-estimation of ranges for small-rangeendemic species. The grid database is a presence or absence record and if a very limited range endemic has a range smaller than the grid size, the species would be recorded in a larger area than it actually occupies and this could skew biodiversity per unit area estimates. Some limited range endemics actually occupy small areas and the 10 km by 10 km grid size is the smallest manageable resolution that was practical. Final maps were converted into a raster of 10 km × 10 km cell size to visualize biodiversity patterns. Presence and percentage of each species range within a marine protected area was estimated based on overlay with the World Database of Protected Areas [37].

3. Results and Discussion

3.1. Summary of IUCN Red List Status of Marine Species. Seventeen percent of all marine species (196 species) assessed to date in Oceania are in threatened (Critically Endangered, Endangered or Vulnerable) categories (Table 1). Of the 196 threatened species, 70% (140 species) are reef-building corals, 13% (26 species) are sharks or batoids, 6% (11 species) are sea birds, 3% (6 species) are shore fish, 3% are marine mammals (6 species), 2% (5 species) are sea turtles, and less than 1% are sea snakes (1 species). Another 16% (187 species) are listed as Near Threatened, indicating that over one-third (383 species) of all species assessed in Oceania are listed in threatened or Near Threatened categories. Fifty-eight percent of all species assessed in Oceania (690 species) are listed as Least Concern, and approximately 10% (117 species) are listed as Data Deficient. It is important to note that species listed as Least Concern or Data Deficient can still be impacted by a number of local and regional threats, but the impact of threats on the species' population was either unknown or unquantifiable (listed as Data Deficient), or if threats were operating on a species, they were determined to be below the threshold required for classification in a threatened or Near Threatened category (listed as Least Concern).

Although approximately 1 in 5 (17%) of marine species in Oceania were classified in a threatened category, it is not clear if this region is more or less threatened than other regions, as comprehensive analyses of marine species in other regions are not yet available. However, a preliminary study of all of the 519 marine bony fishes, sharks, and rays present in the Mediterranean Sea showed that approximately 8% are in threatened categories [38]. Similarly, approximately 9% of all bony fishes, sharks, and rays (108 of 1162 species) assessed in the Eastern Tropical Pacific were preliminarily assessed in threatened categories [39]. Although the vast majority of bony fish species still need to be assessed in Oceania, preliminary results are similar to other regions, with approximately 6% (32 of 512 species) of sharks, rays, and bony fish assessed found in threatened categories.

Although marine species are still vastly underrepresented on the IUCN Red List of Threatened Species (of the 58,000 species currently listed on the 2010 IUCN Red List of Threatened Species less than 7% or 3,800 species are marine), approximately 36% of terrestrial species, 27% of freshwater species, and 19% of marine species are in threatened categories [17]. A preliminary study of threatened species in Oceania found that approximately 28% were in threatened categories [14]; however, this study was not exclusively marine and assessed only five groups (all mammals, amphibians, birds, freshwater crabs, and hard corals). A comprehensive assessment of marine species is necessary for understanding conservation priorities in the region.

With regard to spatial patterns, marine biodiversity is highest in the western portion of Oceania (Figure 2(a)), including New Caledonia, Vanuatu, Fiji, Tuvalu, western Kiribati, and the Federated States of Micronesia. This pattern is consistent with general biogeographic patterns observed in the Indo-West Pacific with species diversity gradually declining with distance from the Coral Triangle [15]. This western Oceania region also has the highest numbers of threatened species assessed to date, with over 100 species

Table 1: Numbers and proportions of species of the different marine groups assessed to date for the IUCN Red List of Threatened Species in Oceania (CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Near Threatened, LC: Least Concern, DD: Data Deficient).

Kingdom	Phylum	Class	Order	Group	CR	EN	VU	NT	LC	DD	Total Oceania Species	no. of Oceania Endemics	% Oceania Endemism	no. of global species	% Threatened (CR, EN, VU) in Oceania	% DD in Oceania
Plantae	Angiospermae	Monocotyledons	Alismatales	Seagrasses			1		13	1	15	1	7%	72	7%	7%
Plantae	Magnoliophyta	Magnoliopsida	*Multiple*	Mangroves				1	23		24	0	0%	70	0%	0%
Animalia	Cnidaria	Anthozoa	Scleractinia	Corals	1	6	133	141	217	34	532	14	3%	845	26%	6%
Animalia	Chordata	Chondrichthyes	Chimaeriformes	Chimaeras					1	4	5	0	0%	174	0%	80%
Animalia	Chordata	Chondrichthyes	Rajiformes	Batoids	1	2	3	5	8	3	22	2	9%	511	27%	14%
Animalia	Chordata	Chondrichthyes	*Multiple*	Sharks	1	2	17	21	15	19	75	8	11%	357	27%	25%
Animalia	Chordata	Actinopterygii	Perciformes	Groupers (Epinephelinae)			4	10	32	14	60	4	7%	161	7%	23%
Animalia	Chordata	Actinopterygii	Perciformes	Angelfishes (Pomacanthidae)				1	41		42	8	19%	86	0%	0%
Animalia	Chordata	Actinopterygii	Perciformes	Butterflyfishes (Chaetodontidae)				1	55	3	59	9	15%	128	0%	5%
Animalia	Chordata	Actinopterygii	Perciformes	Parrotfishes (Scaridae and Odacidae)			1	2	37		40	4	10%	109	3%	0%
Animalia	Chordata	Actinopterygii	Perciformes	Wrasses (Labridae)			1		191	17	209	44	21%	503	0%	8%
Animalia	Chordata	Reptilia	Squamata	Seasnakes			1	1	15	2	19	4	21%	70	5%	11%
Animalia	Chordata	Reptilia	Testudines	Sea Turtles	2	2	1				5	0	0%	7	100%	0%
Animalia	Chordata	Aves	*Multiple*	Sea Birds	2	1	8	4	31	1	47	6	13%	190	24%	2%
Animalia	Chordata	Mammalia	*Multiple*	Marine Mammals	1	3	2		11	19	36	0	0%	132	17%	53%
				Total	8	16	172	187	690	117	1190	104			17%	10%

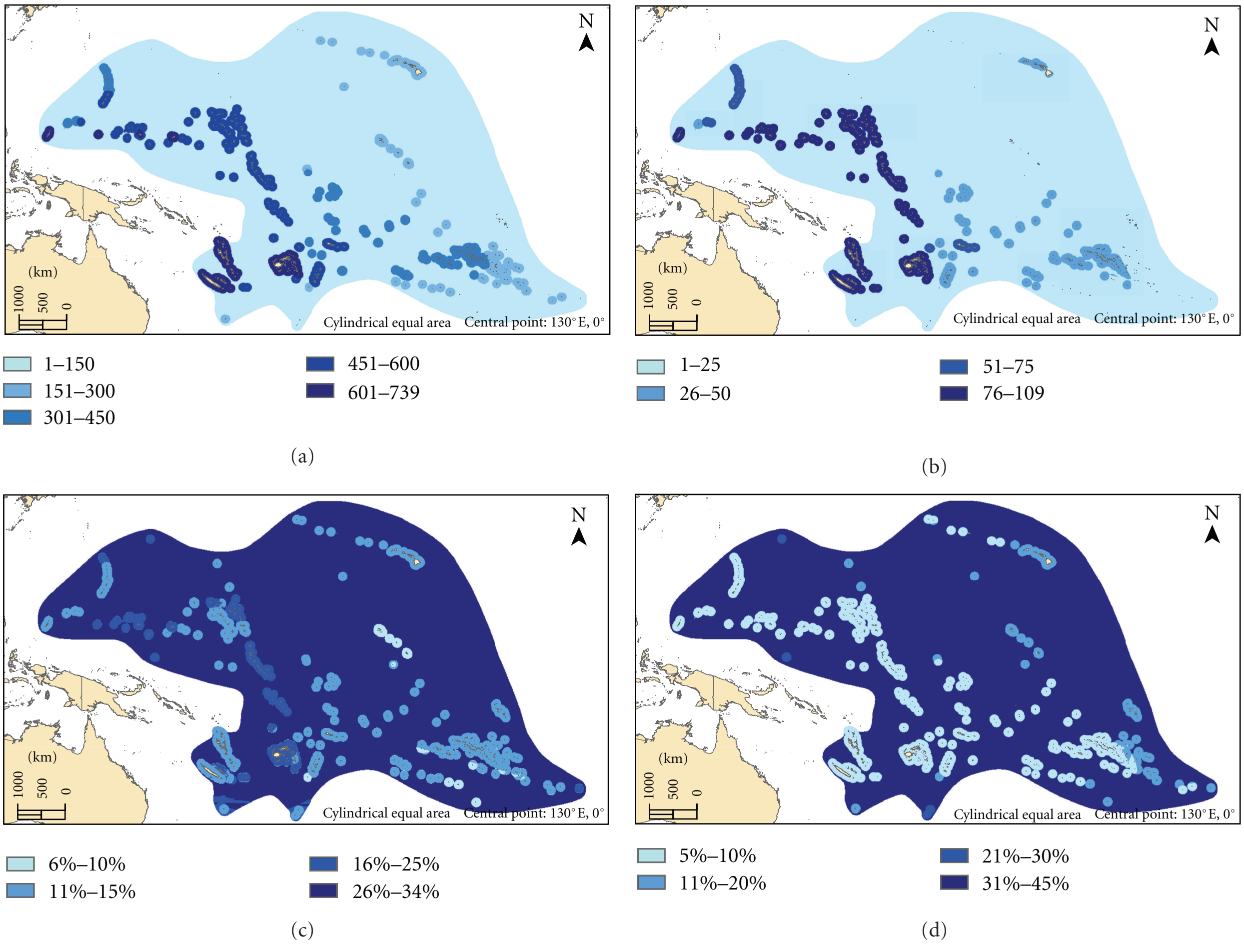

FIGURE 2: (a) Range and number of marine species assessed in this study (species richness), (b) species richness of all marine species assessed in threatened categories: Critically Endangered, Endangered, or Vulnerable, (c) proportion of species assessed in threatened categories, and (d) proportion of all species assessed as Data Deficient. (Sea birds were excluded from all analyses as maps were not available for all species).

now in threatened categories in some of these same areas (Figure 2(b)). This region also has a higher number of Data Deficient species, with between 35 and 50 species listed as Data Deficient in New Caledonia, Vanuatu and Fiji (data not shown). The greater absolute number of threatened and Data Deficient species in the western portion of the study area is partly a reflection of the higher biodiversity in that area.

The proportions (not absolute value) of species in threatened (Figure 2(c)) and Data Deficient (Figure 2(d)) categories offer a different perspective, highlighting regions with more threatened or Data Deficient species relative to the total amount of species present. Areas of open ocean showed the highest proportion of species in these categories, indicating that deeper water or pelagic species (e.g., >200 m), such as marine mammals, sea turtles, sharks and rays are the most threatened and Data Deficient groups. Compared to other taxa assessed to date, these species may be more threatened because they are longer-lived and slower to reproduce. Additionally, many have global or Indo-Pacific distributions, and have experienced widespread population declines throughout their range. Knowledge of the nature and extent of regional threats to these deeper water or pelagic species is essential for their mitigation within Oceania. A higher proportion of deeper water species are also listed as Data Deficient, primarily as these species are generally harder to study in the wild, and less information is known on their population trends, reproductive biology, and impact of known threats.

3.2. Highly Migratory and Wide-Ranging Species. Comprehensive assessments were completed for all sea turtles, sharks and rays, marine mammals, and sea birds in the region. Among these, sea turtles have the highest proportion of threatened species of any group, with all five of the species present in Oceania, Loggerhead (*Caretta caretta*), Green (*Chelonia mydas*), Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricata*), and Olive Ridley (*Lepidochelys olivacea*), listed in threatened categories. Threats to all sea turtle species occur globally and at all stages of their life cycle. Marine turtles lay their eggs on beaches, which are subject to threats such as coastal development and sand mining. The eggs and hatchlings are threatened by pollution and predation by introduced predators such as pigs and dogs, as well as collection by humans. Sea turtles have traditionally been used in the Pacific Island for their meat and eggs, their shells used for decoration, fishing lures and hooks, and for sale and opportunistic by-catch by fishers targeting shellfish and sea cucumbers [40–43]. At sea, marine turtles are faced with threats from targeted capture in small-scale subsistence fisheries, by-catch by long-line and trawling activities, entanglement in marine debris, and boat strikes. Their life history characteristics, particularly late sexual maturity and long juvenile stage, combined with the many threats from human activities in the sea and on land contribute to their high risk of extinction [34]. In addition, global climate change is now considered to be a serious, if not entirely understood, threat that is contributing to the loss of nesting beaches [44], possibly skewed sex ratios [45], and loss of foraging grounds [46].

Approximately one-fourth of all sharks and batoids found in Oceania are in threatened categories. Like sea turtles, the threats to the majority of these species occur globally, and only 10 of the 97 species of sharks and rays present in Oceania are endemic to the region. The primary threat to sharks and rays (batoids) is their capture in nets from both targeted and accidental catch. Most shark species grow slowly, mature late, produce few young, and have low rates of population increase, making them highly vulnerable to depletion with a low capacity for recovery from over-exploitation [32]. Shark fisheries have proliferated around the world during recent decades, in response to increasing demand for shark products and as traditional fisheries come under stronger management. Millions of sharks are caught each year for their fins which are used to make the Asian delicacy shark fin soup [34]. Many subsistence and small-scale fisheries for sharks occur in the Oceania region. Typically, the meat is used for domestic consumption and the teeth and jaws are sold as curios in the tourist industry [47]; however, catches are poorly documented. Sharks are also commonly taken in the Oceania region as by-catch of commercial tuna and other pelagic long-line or purse seine fisheries, which retain primarily shark fins for the international trade [47–49]. The two most threatened shark and ray species found in Oceania, Harrison's Deepsea Dogfish (*Centrophorus harrissoni*) and the Narrowsnout Sawfish (*Pristis zijsron),* both listed as Critically Endangered, have ranges primarily outside of the region, but with records from a few locations within Oceania including New Caledonia and Fiji.

Approximately 25% (19 of 75 species) of sharks and 80% (4 of 5 species) of chimaeras are listed as Data Deficient. For many shark species, little is known about their reproductive biology and quantitative data is lacking on the impact of fisheries on their populations. For example, approximately 50% of the estimated global catch of chondrichthyans is taken as by-catch which does not appear in official fishery statistics and is rarely managed [50]. Most chimaeras are not well-studied, as they are primarily deep-water species that occur in temperate waters. For the few species that are thought to occur in Oceania, little is known about their distribution, reproduction, or the potential impact of fishing activities on their populations.

Almost one-fifth of marine mammals present in Oceania are in threatened categories, and over 50% (19 of 36 species) of marine mammals in Oceania are listed as Data Deficient, again because threats to many of these pelagic and/or highly migratory species cannot be adequately quantified [28]. No marine mammals are known to be endemic to Oceania, and major threats to these species are global or historic. The primary threats to marine mammals in Oceania and around the globe are accidental mortality through entanglement in fishing gear, the effects of noise pollution from military and seismic sonar, or boat strikes [28, 51]. In many regions, including Oceania, marine mammals are also threatened by habitat loss from coastal development, loss of prey, or other food sources due to poor fisheries management, and historical or current effects of hunting [34]. Hunting of large whales does not occur in the region, and countries including Cook Islands, Fiji, French Polynesia, Samoa and Niue have declared whale sanctuaries [52]. However, several Pacific Island countries have recently joined the International Whaling Commission and voted with Japan in favor of commercial whaling. Dolphin hunts have occurred traditionally throughout Oceania, and still remain in the Solomon Islands where they are thought to be contributing to population declines [53, 54]. Dugongs, *Dugong dugon*, are also traditionally hunted in many areas for their meat, bones, and skin [55, 56]. Although there are no estimates of the numbers of dugong caught, the species is likely very vulnerable to hunting and other human impacts due to its restricted coastal habitat, dependence on sea grasses, and low reproductive rates [57]. The most threatened marine mammal in Oceania is the Hawaiian monk seal, *Monachus schauinslandi*, listed as Critically Endangered. Mortality rates from birth to maturity of monk seals in the northwestern Hawaiian Islands are very high, and disproportionally impact juveniles. Causes of mortality are thought to include food limitation, predation on suckling and recently weaned pups, and entanglement in marine debris. There are currently less than 600 mature individuals of this species, and declines are expected to continue into the near future despite the species being primarily found within the Northwestern Hawaiian Islands National Marine Monument [58].

Twenty-three percent (11 of 47 species) of all sea birds in Oceania are in threatened categories. Major threats to seabirds across the globe include mortality in long-line fisheries and gill-nets, oil spills, and the impact of invasive species such as rodents and cats at breeding colonies. Additional threats to breeding sites of seabirds are habitat loss and degradation from coastal development, logging, and pollution [59]. In Nauru and Tonga, seabirds have traditionally been caught for food, but it is unclear whether this constitutes a threat [60]. Some sea bird species are vulnerable to by-catch, usually in longline fisheries in the Oceania region. The most common species caught are albatrosses, petrels, shearwaters, and fulmars [61]. Many of these occur only in passage through Oceania and are typically more abundant in temperate areas. However, for those species that are endemic, even infrequent fisheries-related mortality may have a significant effect on populations [61]. Very little information is available on the numbers and species of sea birds that are by-caught [62]. Globally, albatrosses are one of the most threatened families of birds, and both species found in Oceania are listed as Vulnerable. Five of the six Oceania endemic sea birds: Little White Tern (*Gygis microrhyncha),* White-throated Storm Petrel *(Nesofregetta fuliginosa),* Fiji Petrel *(Pseudobulweria macgillivrayi),* Henderson Petrel *(Pterodroma atrata),* Collared Petrel *(Pterodroma brevipes*), and the Hawaiian Petrel (*Pterodroma sandwichensis*) are in threatened or Near Threatened categories. These species have restricted ranges and their nesting sites are threatened by introduced species such as rats, pigs, mongoose, and feral cats. The Fiji petrel, listed as Critically Endangered, is the most threatened sea bird in the region, with the remaining population estimated to be less than 50 individuals [63].

3.3. Sea Snakes. As a group, sea snakes and the impact of perceived threats to their survival are not well understood. Much of what is currently known about sea snakes is from their capture in fisheries by-catch. However, many species of sea snakes prefer near-shore, shallow waters, including estuaries and brackish water habitats, which are areas that are often highly impacted by coastal development and aquaculture. Fifteen of the 19 sea snakes species found in Oceania are also found throughout the Pacific. Of these nonendemics, all are listed as Least Concern except one species listed as Data Deficient. The four species that are endemic to Oceania have relatively restricted ranges, and at least two of these species are exposed to a number of different threats. The Flat-tail Sea Snake (*Laticauda schistorhynchus)* is currently known only from Niue and is listed as Vulnerable. The Yellow-lipped Sea Snake (*Laticauda frontalis)*, listed as Near Threatened, is thought to be endemic to Vanuatu with some records also from the Loyalty Islands of New Caledonia. Both of these species occur primarily in shallow waters and are impacted by coastal development and habitat destruction throughout their small ranges and are especially vulnerable as females of both species need to come onto land to deposit their eggs [64].

3.4. Primary Habitat Producers. Of the coral, seagrass, and mangrove species present in Oceania, corals are by far the most threatened group. Only one seagrass, *Halophila hawaiiana* listed as Vulnerable, is in a threatened category. This shallow water seagrass is endemic to the Hawaiian Islands and is declining due to invasive algal species, shoreline development, and beach replenishment. All of the mangrove species present in Oceania are widespread in the Pacific and are listed as Least Concern, with the exception of *Rhizophora samoensis*, listed as Near Threatened, which is declining due to the loss of mangrove habitat primarily in the eastern Pacific portion of its range [30]. In general, the Oceania region has lower species diversity and few threatened species of mangrove and seagrasses compared to other regions, such as the Coral Triangle or the Eastern Tropical Pacific [30, 39].

As previously mentioned, reef-building corals comprise the highest proportion (70%) of all threatened species currently assessed in the Oceania region. In terms of marine ecosystems, coral reefs harbor the highest concentration of marine biodiversity and are declining worldwide due to a myriad of threats [29] including ocean acidification, coastal development, sedimentation resulting from poor land-use and watershed management, sewage discharges, nutrient loading and eutrophication from agro-chemicals, coral mining, overfishing, and destructive fishing practices. Overall, 25% of all coral species present in Oceania are in threatened categories (133 of 532 species), and another 26% are in Near Threatened categories.

In Oceania there is generally a lower percentage of destroyed or critically declining reef compared to other regions of the world [65], although sedimentation, coastal development and destructive fishing practices are still major threats in the region. The majority of coral species found in Oceania are also found in the Coral Triangle region, which has the highest proportion of threatened coral species and reef decline [29]. Due to a greater absolute number of coral species in the western portion of Oceania, there is also a higher number of threatened species (Figures 3(a) and 3(b)). However, the proportion of threatened coral species is high not only in some western Oceania countries such as New Caledonia, Vanuatu, and Fiji, but also in some eastern regions such as within French Polynesia (Figure 3(c)). There is also higher coral species endemism in eastern Oceania, such as in Hawaii (data not shown). Nine of the 14 coral species endemic to Oceania are in threatened or Data Deficient categories. Of special concern are *Porites pukoensis*, listed as Critically Endangered, and *Montipora dilatata*, listed as Endangered, both of which are only known from a few dozen colonies or less in Hawaii.

3.5. Bony Shore Fishes. Only 410 species of bony fish have been assessed in Oceania to date, all of which belong to fish groups associated with coral reef habitat. Compared to other taxa assessed in Oceania, bony fishes have lowernumbers of threatened species, with only four groupers, one parrotfish, and one wrasse species in threatened categories. Threats to these species are primarily from population declines due to overfishing. Eight percent (34 species) of bony fishes assessed to date are listed as Data Deficient (the majority of which are groupers) as population declines, and the impact of fisheries could not be adequately quantified. Many species of grouper are highly targeted throughout the world, especially for the live fish trade, and have high commercial value. Like many large-bodied fish species [24], groupers are considered to be especially vulnerable to overfishing given their long life span, late sexual maturation, and aggregation-spawning in many species. Many species of parrotfish are also targeted in recreational, artisanal, and commercial fisheries throughout their range. The Green Humphead Parrotfish, *Bolbometopon muricatum,* listed as Vulnerable, is highly sought after in many parts of Oceania, and severe declines in local populations have led to the implementation of improved management measures including minimum size limits, banning of night spearfishing, and required catch permits in US territories in the Oceania region [66].

Like marine species diversity in general, coral reef fish diversity is also higher in western Oceania (Figure 4(a)), especially in New Caledonia, Vanuatu and Fiji, with a trend

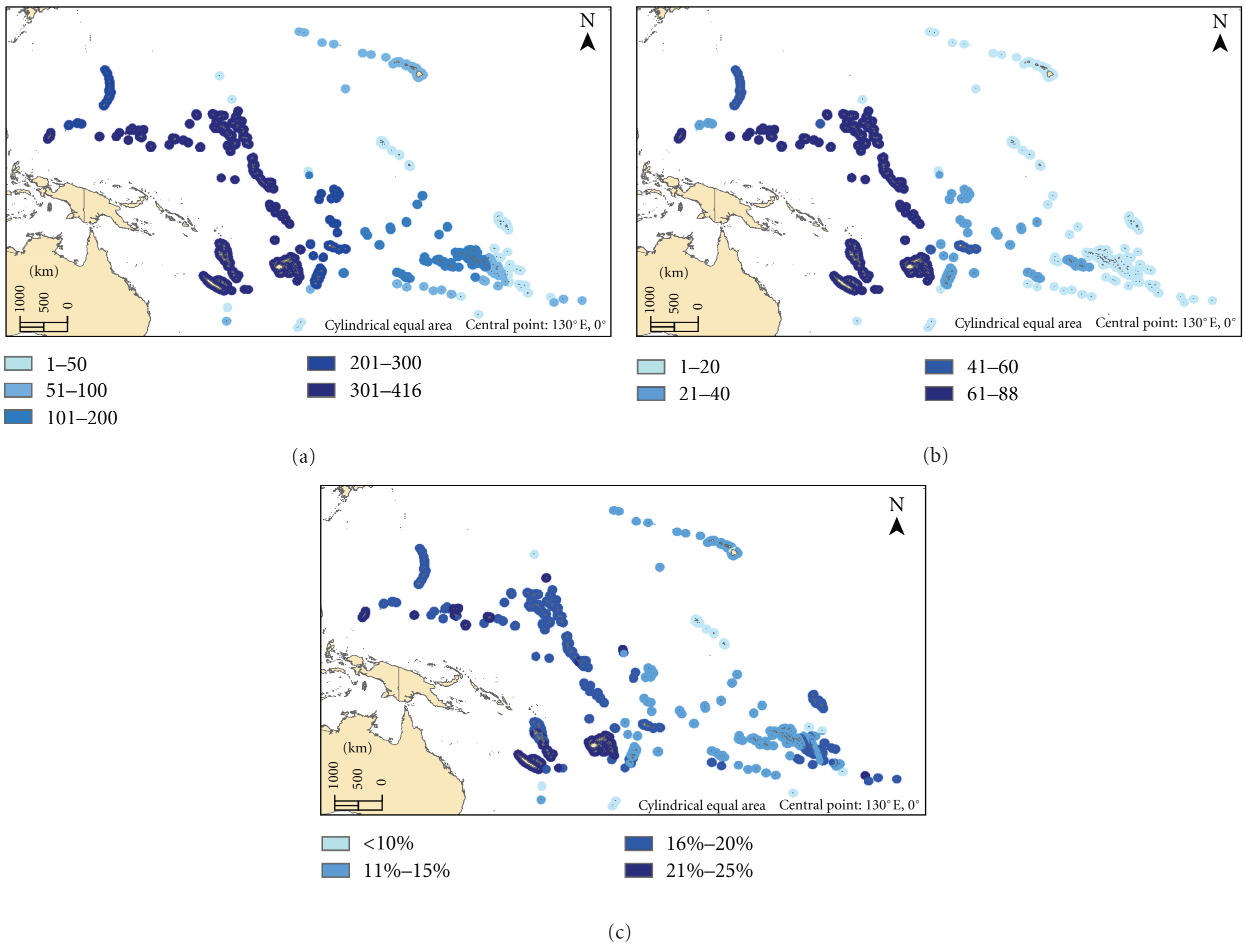

FIGURE 3: (a) Species richness of coral species present in Oceania, (b) species richness of coral species in threatened categories, and (c) proportion of coral species in threatened categories.

of declining number of species moving eastward from the Coral Triangle [15]. The number of threatened bony fishes assessed to date is therefore also higher in these areas (Figure 4(b)). However, the proportion of threatened and Data Deficient bony fishes show a different pattern with slightly higher proportions of threatened shore fishes outside of western Oceania such as around Kiribati and Micronesia (Figure 4(c)) and higher proportions of Data Deficient shore fish in other areas such as around French Polynesia (Figure 4(d)). This apparently random pattern is most likely because of the very low proportion of total shore fishes that have been assessed to date, particularly groups with high numbers of species endemic to Oceania. Compared to the widespread or primary habitat producing species, bony fishes assessed to date have a relatively higher proportion and number of endemic species in Oceania, with 69 of the 410 species (17%) considered endemic to the region. Of these, the wrasses and angelfish have the highest endemism with approximately 20% of Oceania species endemic to the region. None of the assessed endemics have been placed in a threatened category because they mostly appear to be present in high abundances and with few major threats. However, large numbers of small, limited range endemic shore fishes that may be threatened have not yet been assessed. This includes species groups with high numbers of endemic shore fishes in Oceania, such as damselfishes, gobies, and blennies. In general, species with small range sizes and/or population sizes are inherently more at risk for extinction than more widespread species [22], and the highest rates of extinction have been recorded for endemic species on isolated islands [67, 68]. However, widespread species that are low in abundance and exhibit some degree of specialization can also have a greater risk of local extinction [9], especially in areas of intensive localized threats such as overfishing, pollution, or habitat loss. It will be important to assess all shore fishes in order to get a complete picture of conservation status of bony fishes in Oceania.

3.6. Threatened Marine Species Conservation in Oceania. The Oceania region is politically and culturally complex, with 10 independent island nations, 3 self-governing or autonomous territories, and 10 territories or jurisdictions with varying degrees of autonomy and association with one of five metropolitan countries (Australia, France, New Zealand, the United Kingdom, or the United States). Independent island nations in Oceania with specific national laws or ordinances

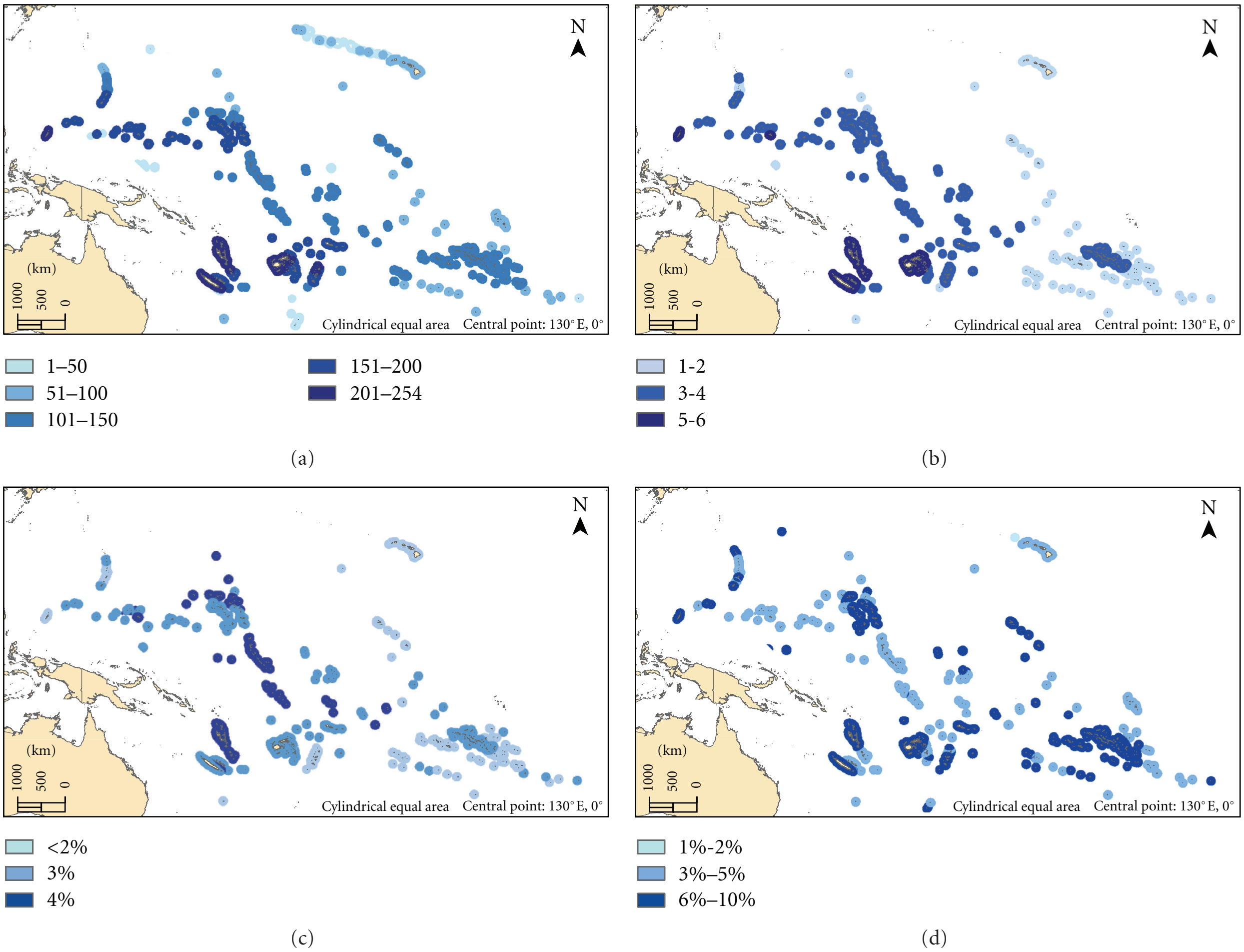

Figure 4: (a) Species richness of bony coral reef fish species assessed in Oceania, (b) species richness of bony shore fish species assessed in threatened categories (Critically Endangered, Endangered, or Vulnerable), (c) proportion of all bony coral reef fish species assessed in threatened categories, and (d) proportion of all bony coral reef fish assessed as Data Deficient.

related to the protection of threatened species include Fiji, the Marshall Islands, the Federated States of Micronesia, Palau, Tonga, and Vanuatu [69]. Amongst the various national laws, the designated species to be protected range from a few species of sea turtles to any species declared by the state to be endangered or threatened [70]. The Secretariat of the South Pacific Environmental Programme (SPREP) plays an important role in unifying regional conservation efforts, and a number of regional conventions have been developed (e.g., Apia Convention 1976, Noumea Convention 1986, and Waigani Convention 1995) but none to date are specifically designed for the protection of threatened or endangered species. Similarly, some but not all countries are signatories to international treaties and conventions which include protection for some species of threatened coral, shark, or whale species, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean, and the International Convention for the Regulation of Whaling. Finally, it is important to note that the degree of enforcement of national laws and regional or international conventions among countries and territories in the Oceania region is likely to be highly variable.

Of the 43 million km^2 of ocean in the Oceania region, approximately 2% (865,000 km^2) is found within designated marine protected areas (MPAs), although the degree of protection for species and enforcement of MPA regulations is also highly variable in the region. Nearly all of the 1190 species assessed in Oceania have a distribution that overlaps with at least one MPA area within its range. Only 5 of the 196 threatened species in Oceania do not have ranges that overlap with a MPA in Oceania. These are an Acroporid coral (*Acropora willisae,* VU), a Faviid coral (*Leptastrea aequalis* VU), Cooke's Petrel (*Pterodroma cookie* VU), the Fairy Tern (*Sterna nereis*, VU), and the Doubleheader Wrasse (*Coris bulbifrons* VU). These species are therefore of high concern, as there is currently no protection for these species in Oceania.

The majority of threatened species identified in this study receive poor MPA protection. Of the 196 threatened species in Oceania, 93% (182 species) have less than 10% of their range within an MPA. Threatened species with the best MPA coverage include three Acroporid corals (*Montipora patula, Montipora flabellata,* and *Monitpora dilatata*) and the Hawaiian monk seal (*Monachus schauinslandi*) which are all endemic to the Hawaiian islands and have between 50%–75% of their range within the Northwestern Hawaiian Islands Marine National Monument. The only record of the widespread Oil Shark (*Galeorhinus galeus*) in Oceania is also in the northwestern Hawaiian Islands, and therefore a high percentage (80%) of this species known range is within an MPA. The percent of MPA protection that a species receives relative to its distribution is not in itself a measure of effective protection, but must be accompanied by enforcement of MPA regulations and continued monitoring of population trends.

There is extensive debate on the size and design of MPAs and MPA networks for species conservation [71] due to the large variation in marine species life history strategies, connectivity, and asymmetry in their distribution. A comprehensive dataset of threatened marine species in Oceania can support the management of current MPAs by providing information on threats to individual species, and the gaps to mitigating these threats. This information can also be used to prioritize areas for the designation of new MPAs. For example, many of the currently identified threatened species in Oceania are pelagic and wide-ranging. Protection of these species through pelagic MPAs may be easier to enforce than catch or gear restrictions for fisheries, particularly in international waters and in countries with limited regulatory capacity, though there are challenges for the effective implementation of such areas [72]. Although MPAs are insufficient to address certain threatening processes, such pollution or climate change that may occur outside of MPA boundaries, Red List data can help to identify the protection measures needed to ensure viable populations of threatened species in Oceania.

3.7. Benefits and Limitations of Marine Species Assessments in Oceania. Around the world, the presence of threatened species is often used to refine marine conservation priorities, such as the designation of critical habitat or key biodiversity areas, no-take zones, and marine protected areas, or to support policies that regulate resource use [18, 19, 73]. Protection of IUCN Red List threatened species in Oceania is currently very limited, mainly because before now IUCN Red List assessments were only available for a few dozen megafauna species, such as the marine mammals, some sharks, and the sea turtles. As the majority of threats to these highly migratory or wide-ranging species occur globally, it is difficult to identify priority sites for conservation action for these species in Oceania, with the exception of mitigating local threats at breeding, foraging, or nesting sites. Similarly, the protection afforded by high seas legislation for these species has been very limited to date.

With the release of the 2010 IUCN Red List of Threatened Species, 1190 Red List Assessments for a wide range of marine species in the region are now available, including many endemic species, in addition to wide-ranging species with low abundance and/or high specialization of habitat. The availability of data on threatened species across multiple taxonomic and trophic levels allows for the development of more effective conservation priorities at the national and regional level, in particular by identifying areas with high concentrations of threatened species. Research priorities can also be focused on regions where many Data Deficient species are found. In addition, species-specific conservation targets can be developed that prioritize threatened endemic species as well as widespread species in the highest threat categories that have high specialization or are undergoing rapid decline in Oceania.

However, compared to terrestrial species, marine species assessments in Oceania especially for bony fish, are still severely lacking [12]. It is estimated that there are over 2,000 bony shore fish species present in Oceania, of which only around one-fifth have been fully assessed through the IUCN Red List process. Without completion of all marine bony fishes, conservation priorities based on knowledge of threatened species will be biased toward mega charismatic and/or widespread species (such as marine mammals, sharks and rays, sea turtles, and sea birds), or primary habitat producers (corals, mangroves and seagrasses). It will also be difficult to identify comprehensive species- and site-specific conservation priorities especially as (1) bony fishes form the foundation for regional economies and human livelihoods throughout Oceania, (2) more than 20% of the remaining 1,600 species of bony fish lacking IUCN Red List assessments are considered endemic to the region, and (3) the vast majority of the species assessed to date are impacted by threatening processes across their global range, which does not necessarily translate to the development of effective mitigation at the regional level.

Of particular concern are key coral reef associated endemic species, such as damselfishes. As many of the coral species in Oceania are threatened, the deterioration of reef structure and ability of these ecosystems to sustain other organisms, including reef-dependent shore fishes may be compromised [74]. Assessments are also urgently needed for species of importance in artisanal and industrial fisheries, such as tunas (Scombridae), emperor fishes (Lethrinidae), snappers (Lutjanidae), mulletfish (Mugilidae), and jacks and pompano (Carangidae) [75]. It is estimated that more than 200 species of marine shore fishes are consumed in artisanal and subsistence fisheries in the Oceania region [76]. Additionally, there are over 200 vessels of various nationalities including the US, Japanese, Korean, and Taiwan China operating purse seining vessels in the Pacific Islands region, representing about 40% of all the large tuna seiners in the world [76].

In addition to shore fishes, other noticeable gaps include seaweeds and marine invertebrates such as sea cucumbers, echinoderms, and worms. Additional comprehensive information on the distribution and conservation status of marine fishes and other key marine groups in Oceania will only continue to provide meaningful analysis and improve the ability to implement effective conservation planning and resource management at the national or regional level [77, 78].

4. Conclusion

Marine resources form the foundation for the livelihoods and economies of Pacific islanders and nations in the Oceania region. As of 2010, 1190 species present in Oceania have been assessed by the IUCN Red List of Threatened Species to determine their population status and probability of extinction, widely expanding the taxonomic breadth and knowledge of threatened species in the region. Almost one-fifth of the marine species assessed in Oceania are in threatened categories due to population decline from a myriad of threats including habitat degradation, overfishing, invasive species introductions, and oceanic environmental changes associated with climate change. High dependency on marine resources and a growing population size in Oceania indicate that pressure on marine resources is only expected to increase.

Urgent action is required to address some of the immediate conservation issues identified by already completed species Red List assessments in Oceania. These include the protection of breeding grounds of highly threatened endemic seabirds that are affected by invasive predators, the monitoring and mitigation of threats to the Critically Endangered Hawaiian monk seal, the implementation of national and high seas policies to reduce the overexploitation of many shark species in targeted fisheries and by-catch, and the halting of destructive fishing practices and the negative impacts of coastal development on coral reefs.

Although Oceania is one of the first regions of the world to be included in a comprehensive analysis of IUCN Red List assessments for marine species, the status of the vast majority of the 2,000 marine shore fish species present in Oceania is still largely unknown. IUCN Red List assessments for these species, especially for important species in artisanal or industrial fisheries and for those found in coral reefs, are urgently needed. Current protection of threatened species in Oceania is very limited and primarily focused on widespread megafauna. Data currently available on the IUCN Red List in addition to subsequent assessments for all remaining marine fish will form the foundation for more effective identification of both site and species-specific conservation and research priorities. In addition to increased species data availability, effective conservation of threatened species in Oceania will also require additional mechanisms to disseminate species data and knowledge, to expand national and regional laws for protected species, and to improve marine protected area management and enforcement.

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