

Research Article

The Occurrence of Coral Species Reported as Threatened in Federally Protected Waters of the US Pacific

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A recent study reported that seventy-five species of reef-building corals, considered to be at elevated extinction risk when assessed by the criteria of the International Union for Conservation of Nature, occur in Pacific waters under United States jurisdiction. Closer examination substantiates records of occurrence for 66 species, while records for the other 9 species were based on misinterpretations or are otherwise uncertain. Of these, at least 55 have been reported from reef habitat under federal protection within National Parks, Marine National Monuments, National Marine Sanctuaries, and National Wildlife Refuges. The highest number of species (31) is found within the Ofu Island unit of the National Park of American Samoa, followed by Kingman Reef (24) and Palmyra Atoll (21), both within the Pacific Remote Islands Marine National Monument. Federally protected areas already in place serve as important habitats for resources whose stewardship needs and priorities may vary over time.

1. Introduction

The International Union for Conservation of Nature (IUCN) Red List of Threatened Species is a tool that is widely used for focusing attention on species of potential conservation concern [1, 2]. Assessments based on the IUCN Red List Criteria allocate species to categories of extinction risk using quantitative rules based on population sizes and decline rates, and range areas and declines. Categories range from “Least Concern” with very little probability of extinction to high risk “Critically Endangered”. Three categories collectively considered “threatened” and representing increasing extinction risk (Vulnerable, Endangered, and Critically Endangered) are intended to serve as one means of setting priority measures for biodiversity conservation [3].

Corals and coral reefs in many regions of the world are reported to be in a state of decline due to numerous local and global anthropogenic stressors including coastal point source pollution, agricultural and land use practices, overutilization for commercial or recreational purposes, and climate change and ocean acidification [4–9]. In response to their declining condition, three workshops were conducted in 2006 and

2007 to apply the IUCN Red List Categories and Criteria [10] in assessing the extinction risk of all known zooxanthellate reef-building corals from the order Scleractinia plus reef-building octocorals and hydrocorals (families Helioporidae, Tubiporidae, and Milleporidae). Of the 704 species for which there were sufficient data to assign a category, 231 species (32.8%) were assigned to one of the three categories considered threatened [3]. Of these, 75 species were reported to occur in Pacific waters under US jurisdiction (Hawai‘i, American Samoa, Guam, Northern Mariana Islands, Wake Atoll, Johnston Atoll, Howland Island, Baker Island, Jarvis Island, Palmyra Atoll, and Kingman Reef).

Throughout the US Pacific, substantial areas of coral reef habitat are under federal protection within the boundaries of National Wildlife Refuges, Marine National Monuments, National Marine Sanctuaries, or National Parks (Table 1). While the establishment of protected areas may be driven by one or several key resources (e.g., the safeguarding of breeding and calving habitat for the endangered humpback whale by the Hawaiian Humpback Whale National Marine Sanctuary), their legal mandate includes the comprehensive management of the ecological, historical, and aesthetic

TABLE 1: Marine National Monuments, National Marine Sanctuaries, National Wildlife Refuges, and National Parks with coral reef habitat in the US Pacific.

| | General Location | Units |
|---|-------------------------------|---|
| Marine National Monuments | | |
| Papahānaumokuākea (PMNM) | Northwestern Hawaiian Islands | Nihoa*, Necker*, French Frigate Shoals*, Gardner*, Maro*, Laysan*, Lisianski*, Pearl and Hermes*, Midway NWR, Kure |
| Pacific Remote Islands (PRIMNM) | Central Pacific | Johnston Atoll NWR, Howland Island NWR, Baker Island NWR, Jarvis Island NWR, Palmyra Atoll NWR, Kingman Reef NWR, Wake Atoll NWR. |
| Rose Atoll (RAMNM) | American Samoa | Rose Atoll NWR |
| Marianas Trench, Islands Unit (MTMNM) | Northern Mariana Islands | Asuncion, Maug, Farallon de Pajaros |
| National Marine Sanctuaries | | |
| Hawaiian Islands Humpback Whale (HIHWNMS) | Main Hawaiian Islands | Maui, Lana‘i, Moloka‘i, O‘ahu, Kaua‘i, Hawai‘i |
| Fagatele Bay (FBNMS) | American Samoa | Tutuila |
| National Parks | | |
| NP of American Samoa (NPSA) | American Samoa | Tutuila, Ofu-Olosega, Ta‘u |
| War in the Pacific NHP (WAPA) | Southern Mariana Islands | Guam |
| American Memorial Park (AMME) | Northern Mariana Islands | Saipan |
| Kalaupapa NHP (KALA) | Main Hawaiian Islands | Moloka‘i |
| Haleakalā NP (HALE) | Main Hawaiian Islands | Maui |
| Pu‘ukoholā Heiau NHS (PUHE) | Main Hawaiian Islands | Hawai‘i |
| Kaloko-Honokōhau NHP (KAHO) | Main Hawaiian Islands | Hawai‘i |
| Pu‘uhonua o Hōnaunau NHP (PUHO) | Main Hawaiian Islands | Hawai‘i |
| Hawai‘i Volcanoes NP (HAVO) | Main Hawaiian Islands | Hawai‘i |
| Other National Wildlife Refuges | Ritidian Point | Guam |

A “unit” is here considered to be a geographically distinct island, atoll, or reef system. NWR: National Wildlife Refuge, *: unit within Hawaiian Islands NWR.

resources within them. As physical and biological resources continue to respond to environmental change driven by human enterprise, protected areas may provide an umbrella of shelter to habitats and communities not originally envisioned in need of refuge. However, some threats such as climate change are very widespread and challenge the ability of protected areas to limit their effects.

The purpose of this paper is to explore the currently known occurrence within federally protected waters of the 75 coral species assessed as threatened by the IUCN and reported by that body to occur within the US Pacific. The number of alleged threatened species occurring in each system of federal protection is reported and those species that are not presently known to occur within the boundaries of US federal protection are identified.

2. Materials and Methods

Assessments based on the IUCN Red List criteria were obtained from Carpenter et al. [3] Supporting Online Material. Peer-reviewed literature, published and unpublished reports, monitoring program databases, and local experts were consulted (Table 2) to corroborate the occurrence of

the 75 species stated to occur within US Pacific waters by Carpenter et al. [3] and the IUCN Red List database [43]. Occurrences within the boundaries of federally protected waters were determined from a subset of this suite of sources. No data were available for Haleakalā National Park, Hawai‘i Volcanoes National Park, or American Memorial Park (Brown, pers. comm.).

3. Results

Of the 75 coral species stated to occur in the US Pacific in Carpenter et al. [3] and the IUCN database [43], substantiated records could be identified for 66 species. Six species (*Acanthastrea regularis*, *Acropora tenella*, *Anacropora puertogalerae*, *Anacropora spinosa*, *Pectinia alcornis*, and *Physogyra lichtensteini*) are shown on distribution maps in Veron [33] as occurring in the Mariana Archipelago, which is the basis of their records in US waters in the IUCN database. However, these records were based on photos submitted to Veron by G. Paulay from Palau and elsewhere that were mistakenly attributed to Guam [31], (G. Paulay pers. comm. Veron pers. comm.), and these 6 species have not been authenticated by other reports from US waters. A seventh

TABLE 2: Data sources used to substantiate the occurrence of 75 IUCN Red List coral species in the US Pacific and in federally protected areas.

| Location | References |
|------------------------|---|
| Hawai'i | [11–25] NPS Pacific Islands Network monitoring database NOAA Pacific Islands Fisheries Science Center (PIFSC) Coral Reef Ecosystem Division (CRED) database |
| Pacific Remote Islands | [26, 27] Maragos unpubl. data 2000–2010 Kenyon and Bonito unpubl. data 2005 |
| Rose Atoll | [28] Fenner unpubl. data 2010 |
| Marianas Archipelago | [29–33] D. Burdick unpubl. data 2010 NOAA PIFSC CRED database G. Paulay, pers. comm. |
| American Samoa | [30, 34–42] Birkeland unpubl. data 1979–2007 Fenner unpubl. data 2010 |

species (*Acropora lokani*) was identified from photographs compared to Veron [33] but was reidentified as *A. caroliniana* based on the original description of *A. lokani* in Wallace [44] and the description of *A. caroliniana* in Wallace [30] (Fenner, pers. comm.). For 2 additional species (*Acropora dendrum* and *Caulastrea echinulata*), the initial tentative identifications from photographs are now uncertain (Fenner, pers. comm.).

Of these 66 species, records of occurrence in federally protected waters were identified for 55 species. Forty-three species were recorded within National Parks (NP), 39 species within Marine National Monuments (MNM) and National Wildlife Refuges within the MNM, and 18 within National Marine Sanctuaries (NMS) (Table 3, where data are reported as the number of discrete islands or atolls (“units”) where each species has been recorded. Additionally, a supplementary online table incorporates data presented in Tables 3, 4 and 5 in a single matrix.) The most frequently occurring species, reported at 10 or more of the 26 major units afforded federal protection from which data have been reported (excluding the Hawaiian Islands Humpback Whale NMS where reported occurrence data were not attributed to the 6 component islands), were *Montipora patula* (15), *Cyphastrea ocellina* (13), *Montipora flabellata* (13), *Psammocora stellata* (13), *Pocillopora elegans* (12), *Leptoseris incrustans* (10), *Montipora caliculata* (10), and *Pocillopora danae* (10). Twenty species were recorded from 3 to 8 reef units, and 27 species were recorded at only 1 or 2 reef units.

Eleven of the 66 species with substantiated records of occurrence in the US Pacific have not been recorded within federally protected waters (Table 3). Of these, 5 species (*Acanthastrea hemprichii*, *Acanthastrea ishigakiensis*, *Acropora jacquelineae*, *Acropora pharaonis*, and *Euphyllia paradivisa*) have been reported from single locations at

Tutuila, American Samoa, and were rare, represented by only 1 or 2 colonies (Fenner, pers. comm.). *Pachyseris rugosa* and *Turbinaria peltata* have been reported at several locations by several authors in American Samoa [36, 37, 40], (Birkeland unpubl. data, Fenner unpubl. data), indicating that they are relatively more abundant. Four species (*Alveopora fenestrata*, *Euphyllia paraancora*, *Millepora foveolata*, and *Seriatopora aculeata*) have been reported from Guam [34], (D. Burdick unpubl. data) though abundance data are not available. The occurrence of *P. rugosa* in the Mariana Archipelago as shown in Veron [33] has not been substantiated by other sources and is based on the misattribution of photographs as indicated previously for 6 other species (Veron pers. comm.).

Of the 39 species recorded within the Marine National Monuments and National Wildlife Refuges (NWR) (Table 4), the highest numbers of Red List threatened coral species have been recorded from Kingman Reef NWR (24) and Palmyra Atoll NWR (21) in the Pacific Remote Islands MNM followed by Rose Atoll NWR and MNM (17). In the Islands Unit of the Mariana Trench MNM, the highest number of Red List threatened coral species has been recorded at Asuncion Island (7). In the Papahānaumokuākea MNM covering the Northwestern Hawaiian Islands, the highest numbers of Red List threatened coral species (5) have been recorded at French Frigate Shoals, Maro Reef, Pearl and Hermes Atoll, and Midway Atoll.

Of all the federally protected locations, the highest number of Red List threatened coral species (31) has been recorded from Ofu Island in the National Park of American Samoa (Table 5). Fagatele Bay NMS and the Tutuila section of the National Park of American Samoa each host 12 Red List threatened coral species, despite the substantially smaller size of Fagatele Bay (0.65 km² and 4.9 km², resp.) [45, 46]. In Guam, War in the Pacific National Historical Park hosted

TABLE 3: IUCN Red List Categories for 66 species with substantiated records of occurrence in the US Pacific, ranked by number of units (geographically distinct islands, atolls, or reef systems) where found within federally protected waters.

| | IUCN Red List Category | National Parks | Marine National Monuments | National Marine Sanctuaries | Total units |
|------------------------------|------------------------|----------------|---------------------------|-----------------------------|-------------|
| <i>Montipora patula</i> | VU | 2 | 13 | 1 | 15 |
| <i>Cyphastrea ocellina</i> | VU | 2 | 11 | 1 | 13 |
| <i>Montipora flabellata</i> | VU | 1 | 12 | 1 | 13 |
| <i>Psammocora stellata</i> | VU | 0 | 13 | 1 | 13 |
| <i>Pocillopora elegans</i> | VU | 1 | 11 | 1 | 12 |
| <i>Montipora calciculata</i> | VU | 2 | 7 | 1 | 10 |
| <i>Pocillopora danae</i> | VU | 2 | 8 | 0 | 10 |
| <i>Leptoseris incrustans</i> | VU | 2 | 7 | 1 | 10 |
| <i>Acropora verweyi</i> | VU | 2 | 6 | 0 | 8 |
| <i>Acropora acuminata</i> | VU | 1 | 5 | 1 | 7 |
| <i>Acropora paniculata</i> | VU | 1 | 5 | 0 | 6 |
| <i>Turbinaria reniformis</i> | VU | 1 | 4 | 1 | 6 |
| <i>Acropora aspera</i> | VU | 2 | 3 | 0 | 5 |
| <i>Acropora retusa</i> | VU | 1 | 4 | 0 | 5 |
| <i>Acropora vaughani</i> | VU | 1 | 4 | 0 | 5 |
| <i>Pavona venosa</i> | VU | 3 | 2 | 1 | 5 |
| <i>Turbinaria stellulata</i> | VU | 1 | 4 | 0 | 5 |
| <i>Acropora aculeus</i> | VU | 1 | 3 | 0 | 4 |
| <i>Acropora globiceps</i> | VU | 1 | 3 | 0 | 4 |
| <i>Acropora microclados</i> | VU | 1 | 3 | 0 | 4 |
| <i>Acropora polystoma</i> | VU | 1 | 3 | 0 | 4 |
| <i>Cyphastrea agassizi</i> | VU | 2 | 2 | 1 | 4 |
| <i>Heliopora coerulea</i> | VU | 2 | 2 | 0 | 4 |
| <i>Acropora palmerae</i> | VU | 1 | 1 | 1 | 3 |
| <i>Alveopora verrilliana</i> | VU | 0 | 3 | 0 | 3 |
| <i>Isopora cuneata</i> | VU | 1 | 2 | 0 | 3 |
| <i>Montipora dilatata</i> | EN | 0 | 3 | 0 | 3 |
| <i>Montipora lobulata</i> | VU | 0 | 2 | 1 | 3 |
| <i>Acropora striata</i> | VU | 1 | 1 | 0 | 2 |
| <i>Astreopora cucullata</i> | VU | 1 | 1 | 0 | 2 |
| <i>Isopora crateriformis</i> | VU | 2 | 0 | 1 | 2 |
| <i>Leptoseris yabei</i> | VU | 1 | 1 | 0 | 2 |
| <i>Millepora tuberosa</i> | EN | 2 | 0 | 1 | 2 |
| <i>Montipora calcarea</i> | VU | 1 | 1 | 1 | 2 |
| <i>Pavona cactus</i> | VU | 1 | 1 | 0 | 2 |
| <i>Pavona decussata</i> | VU | 2 | 0 | 0 | 2 |
| <i>Acanthastrea brevis</i> | VU | 0 | 1 | 0 | 1 |
| <i>Acropora donei</i> | VU | 1 | 0 | 0 | 1 |
| <i>Acropora horrida</i> | VU | 1 | 0 | 0 | 1 |
| <i>Acropora listeri</i> | VU | 1 | 0 | 0 | 1 |
| <i>Acropora rudis</i> | EN | 0 | 0 | 1 | 1 |
| <i>Acropora speciosa</i> | VU | 0 | 1 | 0 | 1 |
| <i>Alveopora allingi</i> | VU | 1 | 0 | 0 | 1 |
| <i>Barabattoia laddi</i> | VU | 0 | 1 | 0 | 1 |
| <i>Euphyllia cristata</i> | VU | 1 | 0 | 0 | 1 |
| <i>Galaxea astreata</i> | VU | 1 | 0 | 0 | 1 |
| <i>Montipora angulata</i> | VU | 0 | 1 | 0 | 1 |

TABLE 3: Continued.

| | IUCN Red List Category | National Parks | Marine National Monuments | National Marine Sanctuaries | Total units |
|-----------------------------------|------------------------|----------------|---------------------------|-----------------------------|-------------|
| <i>Montipora australiensis</i> | VU | 1 | 0 | 0 | 1 |
| <i>Pavona bipartita</i> | VU | 0 | 1 | 0 | 1 |
| <i>Pavona diffluens</i> | VU | 1 | 0 | 0 | 1 |
| <i>Porites horizontalata</i> | VU | 1 | 0 | 0 | 1 |
| <i>Porites napopora</i> | VU | 0 | 0 | 1 | 1 |
| <i>Porites nigrescens</i> | VU | 1 | 0 | 0 | 1 |
| <i>Porites pukoensis</i> | CR | 0 | 1 | 0 | 1 |
| <i>Turbinaria mesenterina</i> | VU | 1 | 0 | 0 | 1 |
| <i>Acanthastrea hemprichii</i> | VU | 0 | 0 | 0 | 0 |
| <i>Acanthastrea ishigakiensis</i> | VU | 0 | 0 | 0 | 0 |
| <i>Acropora jacquelineae</i> | VU | 0 | 0 | 0 | 0 |
| <i>Acropora pharaonis</i> | VU | 0 | 0 | 0 | 0 |
| <i>Alveopora fenestrata</i> | VU | 0 | 0 | 0 | 0 |
| <i>Euphyllia paraancora</i> | VU | 0 | 0 | 0 | 0 |
| <i>Euphyllia paradivisa</i> | VU | 0 | 0 | 0 | 0 |
| <i>Millepora foveolata</i> | VU | 0 | 0 | 0 | 0 |
| <i>Pachyseris rugosa</i> | VU | 0 | 0 | 0 | 0 |
| <i>Seriatopora aculeata</i> | VU | 0 | 0 | 0 | 0 |
| <i>Turbinaria peltata</i> | VU | 0 | 0 | 0 | 0 |

“Total units” is not strictly additive, as Tutuila hosts both a National Park and a National Marine Sanctuary.

6 Red List threatened coral species. In Hawai‘i, the highest number of Red List threatened coral species (5) was recorded in the Hawaiian Islands Humpback Whale NMS.

4. Discussion

This paper summarizes information drawn from publications, reports, museum voucher specimens, monitoring program databases, and coral expert records to the extent that species occurrence could be assigned to benthic habitat within the boundaries of federally protected waters of the US Pacific. However, not all sources provide detailed geographic information; see for example, [32], and not all benthic habitat within the boundaries of federal protection has been surveyed and assessed. Consequently, the extent to which IUCN Red List threatened coral species appear to occur within Marine National Monuments, National Wildlife Refuges, National Parks, and National Marine Sanctuaries of the US Pacific is likely underestimated.

Occurrence records are also likely confounded by problems inherent to current methods of species identification and to classifying corals solely on the basis of morphological criteria. Only relatively recently has coral taxonomy reached a sufficiently comprehensive stage to enable identification of many species over wide areas; see for example, [31, 33, 47]. Corals are highly variable at all scales, and many taxonomic

problems remain. A generally accepted hierarchy of data quality, from highest to lowest, is species identification based on examination of voucher specimens, primarily skeletal remains; examination of photographs of both skeletons and living corals; visual field inspection. Even identification of voucher specimens requires resources that are often not available, such as the original description and the type specimen. Nevertheless, many publications and reports are based on visual field identification which for some taxa can be challenging even for veteran experts. In this study, though *Pocillopora elegans* and *P. danae* are considered valid species [33], they can be difficult to distinguish from *P. meandrina* and *P. verrucosa*, respectively, in the field where they co-occur, and consequently their representation within federally protected waters in the current analysis may be over- or underestimated. Similarly, *Porites pukoensis*, described from Vaughan [48] and said to be restricted to a single small site off the coast of Moloka‘i Island in Hawai‘i [3, 49], has been reported from Kingman Reef NWR in the Pacific Remote Islands Marine National Monument (Table 4) based on visual identification by a coral taxonomist (Maragos, unpubl. data 2010). *Porites pukoensis* has also been reported from American Samoa [34, 35], Indonesia [50], Tabuaeran Atoll in the Line Islands and Kanton Atoll in the Phoenix Islands [51, 52], Madagascar [53, 54], Mauritius [54], and Reunion [53, 54], demonstrating the difficulty of validating

TABLE 4: Occurrence of 39 IUCN Red Listed Coral Species in US Pacific Marine National Monuments, ranked by frequency of occurrence at reef units. "1" indicates presence; empty cell indicates no record of occurrence.

| TAXON | Pacific Remote Islands | | | | | Rose | | | | | Marianas | | | | | Papahānaumokuākea | | | | | No. units | | |
|------------------------------|------------------------|---------|-------|--------|---------|---------|------|------|------|------|----------|-----|-------|--------|-----|-------------------|------|--------|----------|-----|-----------|--------|------|
| | Johnston | Howland | Baker | Jarvis | Palmyra | Kingman | Wake | Rose | Rose | Maug | Asuncion | FDP | Nihoa | Necker | FFS | Gardner | Maro | Laysan | Lisinski | P&H | | Midway | Kure |
| <i>Montipora patula</i> | 1 | | | | 1 | 1 | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 13 |
| <i>Psammocora stellata</i> | 1 | 1 | | | 1 | 1 | | | | | | | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 13 |
| <i>Montipora flabellata</i> | 1 | | | | 1 | 1 | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 12 |
| <i>Pocillopora elegans</i> | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | 11 |
| <i>Cyphastrea ocellina</i> | 1 | | | | 1 | 1 | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 11 |
| <i>Pocillopora danae</i> | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | | | | | | | | | | | 8 |
| <i>Leptoseris incrustans</i> | 1 | | | 1 | | | | 1 | | | | | | | 1 | | | | | | | | 7 |
| <i>Montipora caliculata</i> | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | | | | | | | | | | | | | 7 |
| <i>Acropora verweyi</i> | | 1 | 1 | 1 | 1 | 1 | | | 1 | | | | | | | | | | | | | | 5 |
| <i>Acropora acuminata</i> | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | | 5 |
| <i>Acropora paniculata</i> | 1 | | | | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | 5 |
| <i>Acropora retusa</i> | 1 | | | | | 1 | | 1 | | | | | | | | | | | | | | | 4 |
| <i>Acropora vaughani</i> | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | | | 4 |
| <i>Turbinaria reniformis</i> | | 1 | | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | 4 |
| <i>Turbinaria stellulata</i> | | | | | 1 | 1 | 1 | 1 | 1 | | | 1 | | | | | | | | | | | 4 |
| <i>Acropora aculeus</i> | | | | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | 3 |
| <i>Acropora aspera</i> | | | | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | 3 |
| <i>Acropora globiceps</i> | | | | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | 3 |
| <i>Acropora microclados</i> | | | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | | | 3 |
| <i>Acropora polystoma</i> | 1 | 1 | | | 1 | 1 | | | | | | | | | | | | | | | | | 3 |
| <i>Alveopora verrilliana</i> | | | | | 1 | 1 | | 1 | | | | | | | | | | | | | | | 3 |
| <i>Montipora dilatata</i> | | | | | 1 | 1 | | | | | | | | | | 1 | | | | | | | 3 |

TABLE 4: Continued.

| TAXON | Pacific Remote Islands | | | Marianas | | | Papahānaumokuākea | | | | | | | | | | | | | | | | |
|-----------------------------|------------------------|---------|-------|----------|---------|---------|-------------------|------|------|------|----------|-----|-------|--------|-----|---------|------|--------|----------|-----|--------|------|-----------|
| | Johnston | Howland | Baker | Jarvis | Palmyra | Kingman | Wake | Rose | Rose | Maug | Asuncion | FDP | Nihoa | Necker | FFS | Gardner | Maro | Laysan | Lisinski | P&H | Midway | Kure | No. units |
| <i>Cyphastrea ogassizi</i> | | | | | 1 | | | | | | 1 | | | | | | | | | | | | 2 |
| <i>Heliopora coerulea</i> | | | | | | | | | 1 | | 1 | | | | | | | | | | | | 2 |
| <i>Isopora cuneata</i> | | | | | 1 | | | | | | | | | | | | | | | | | | 2 |
| <i>Montipora lobulata</i> | | | | | | | 1 | 1 | | | | | | | | | | | | | | | 2 |
| <i>Pavona venosa</i> | | | | | | 1 | | 1 | | | | | | | | | | | | | | | 2 |
| <i>Acanthastrea brevis</i> | | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| <i>Acropora palmerae</i> | | | | | | | 1 | | | | | | | | | | | | | | | | 1 |
| <i>Acropora speciosa</i> | | | | | | 1 | | | | | | | | | | | | | | | | | 1 |
| <i>Acropora striata</i> | | | | | | 1 | | | | | | | | | | | | | | | | | 1 |
| <i>Astreopora cucullata</i> | | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| <i>Barabattoia laddi</i> | | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| <i>Leptoseris yabei</i> | | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| <i>Montipora angulata</i> | | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| <i>Montipora calcarea</i> | | | | | | | | 1 | | | | | | | | | | | | | | | 1 |
| <i>Pavona bipartita</i> | | | | | | | | | | | 1 | | | | | | | | | | | | 1 |
| <i>Pavona cactus</i> | | | | | | | 1 | | | | | | | | | | | | | | | | 1 |
| <i>Porites pukoensis</i> | | | | | | | | | | | | | | | | | | | | | | | 1 |
| # Red List species | 8 | 9 | 9 | 6 | 21 | 24 | 5 | 17 | 6 | 7 | 2 | 3 | 3 | 3 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 5 | 4 |

FDP: Farallon de Pajaros; FFS: French Frigate Shoals; P&H: Pearl and Hermes.

TABLE 5: Occurrence of 46 IUCN Red Listed Coral Species in US Pacific National Parks and National Marine Sanctuaries, ranked by total frequency of occurrence at reef units. See Table 1 for name codes.

| TAXON | National Parks | | | | | | | | | | Marine Sanctuaries | | |
|-------------------------------|----------------|------|------|------|------|--------------|----------|------------------|-------|---------|--------------------|---|--|
| | WAPA | KAHO | PUHE | PUHO | KALA | NPSA Tutuila | NPSA Ofu | Total park units | FBNMS | HIHWNMS | Total sanctuaries | | |
| <i>Leptoseris incrustans</i> | | | | 1 | 1 | | | 1 | | | 1 | 1 | |
| <i>Pavona venosa</i> | 1 | | | | | 1 | | 3 | 1 | | | 1 | |
| <i>Cyphastrea ocellina</i> | | 1 | 1 | | 1 | | | 2 | | 1 | | 1 | |
| <i>Cyphastrea agassizi</i> | | 1 | | | 1 | | | 2 | | 1 | | 1 | |
| <i>Isopora crateriformis</i> | | | | | | 1 | | 2 | 1 | | | 1 | |
| <i>Millepora tuberosa</i> | | | | | | 1 | | 2 | 1 | | | 1 | |
| <i>Montipora patula</i> | | 1 | 1 | 1 | 1 | | | 2 | | 1 | | 1 | |
| <i>Montipora calciculata</i> | | | | | | 1 | | 2 | 1 | | | 1 | |
| <i>Turbinaria reniformis</i> | | | | | | | | 1 | 1 | | | 1 | |
| <i>Pocillopora elegans</i> | | | | | | 1 | | 1 | 1 | | | 1 | |
| <i>Pocillopora danae</i> | 1 | | | | | | | 2 | | | | 0 | |
| <i>Pavona decussata</i> | 1 | | | | | | | 2 | | | | 0 | |
| <i>Montipora flabellata</i> | | | | | 1 | | | 1 | | 1 | | 1 | |
| <i>Montipora calcarea</i> | | | | | | 1 | | 1 | 1 | | | 1 | |
| <i>Helopora coerulea</i> | 1 | | | | | | | 2 | | | | 0 | |
| <i>Acropora verweyi</i> | | | | | | 1 | | 2 | | | | 0 | |
| <i>Acropora palmerae</i> | | | | | | | | 1 | 1 | | | 1 | |
| <i>Acropora aspera</i> | 1 | | | | | | | 2 | | | | 0 | |
| <i>Acropora acuminata</i> | | | | | | | | 1 | 1 | | | 1 | |
| <i>Turbinaria stellulata</i> | | | | | | | | 1 | | | | 0 | |
| <i>Turbinaria mesenterina</i> | | | | | | | | 1 | | | | 0 | |
| <i>Porites nigrescens</i> | | | | | | | | 1 | | | | 0 | |
| <i>Porites napopora</i> | | | | | | | | 1 | 1 | | | 1 | |
| <i>Porites horizontalata</i> | | | | | | 1 | | 1 | | | | 0 | |
| <i>Pavona diffluens</i> | | | | | | 1 | | 1 | | | | 0 | |

TABLE 5: Continued.

| TAXON | National Parks | | | | | | | Marine Sanctuaries | | | |
|--------------------------------|----------------|------|------|------|------|--------------|----------|--------------------|-------|---------|-------------------|
| | WAPA | KAHO | PUHE | PUHO | KALA | NPSA Tutuila | NPSA Ofu | Total park units | FBNMS | HIHWNMS | Total sanctuaries |
| <i>Pavona cactus</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Montipora lobulata</i> | | | | | | | | 0 | 1 | | 1 |
| <i>Montipora australiensis</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Leptoseris yabei</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Isopora cuneata</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Galaxea astreata</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Euphyllia cristata</i> | 1 | | | | | | | 1 | | | 0 |
| <i>Astreopora cucullata</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Alveopora allingi</i> | | | | | | 1 | | 1 | | | 0 |
| <i>Acropora vaughani</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Acropora striata</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Acropora rudis</i> | | | | | | | | 0 | 1 | | 1 |
| <i>Acropora retusa</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Acropora polystoma</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Acropora paniculata</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Acropora microclados</i> | | | | | | 1 | | 1 | | | 0 |
| <i>Acropora listeri</i> | | | | | | 1 | | 1 | | | 0 |
| <i>Acropora horrida</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Acropora globiceps</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Acropora donei</i> | | | | | | | 1 | 1 | | | 0 |
| <i>Acropora aculeus</i> | | | | | | | 1 | 1 | | | 0 |
| # Red List species | 6 | 3 | 2 | 2 | 5 | 12 | 31 | 12 | 12 | 5 | 5 |

species distributions even from peer-reviewed publications as the data quality underlying the classification is frequently not stated, and samples that can be used for later verification are rarely collected. Moreover, this species is similar to another species reported from Australia (*Porites stephensoni*), and molecular analysis may be needed to determine whether these are the same or different species. *Montipora dilatata* is considered a valid species based on morphological criteria [14, 33, 48, 55] and is thought to have a restricted and disjunct distribution in the Hawaiian Archipelago [3, 13, 14, 33, 56]; however, it has also been reported from Palmyra Atoll NWR [26] and Kingman Reef NWR (Maragos unpubl. data). Moreover, examination of a suite of molecular markers (mitochondrial and nuclear) in addition to a suite of measurements on skeletal microstructure suggest that *Montipora dilatata*, *M. flabellata*, and *M. cf. turgescens* reported from Hawai'i may be morphological variants of the same biological species [57]. However, *Montipora turgescens* at its type locality in Australia may not be the same as those identified from Hawai'i by Veron [33], which are separated by a distance of more than 5000 km, and as a result, the latter may still be a valid species. Occurrence records in this study are based on peer-reviewed literature and the reported observations of scientists widely considered as experts in their field, and therefore, they represent the most current reliable application of coral species identification.

Of the 75 petitioned Pacific species, all but four (*Montipora dilatata*, *M. flabellata*, *M. patula*, and *Porites pukoensis*) were evaluated under IUCN Red List subcriterion A4, an observed, estimated, inferred, projected, or suspected population size reduction of $\geq 50\%$ (for Endangered, EN) or 30% (for Vulnerable, VU) over two generations in the past and one into the future, where the generation length for all but 2 species was considered as 10 years [3]. Species-specific population trend data were not available for the Pacific coral species across their global distributional range, so loss of coral cover within a species distribution in combination with life history traits were used as a surrogate for population reduction. For each species, a quantitative estimate of population reduction was calculated using the coral reef area within its distributional range in conjunction with an estimate of the percent of total coral cover loss or the combined percent of total coral cover loss and critically declining reef [3]. "Total coral cover loss" was operationally defined as the percentage of reef with $>90\%$ coral cover loss over at least the past 15 to 20 years, and "critically declining reef" was operationally defined as the percentage of reefs with 50%–90% coral cover loss and likely to join the total coral cover loss category within 10 to 20 years [6]. Three species (*Montipora flabellata*, *M. patula*, and *Porites pukoensis*) were evaluated under IUCN Red List Criterion D, which can be applied to very small populations, where "population" is defined as the total number of individuals of the taxon [10]. *Porites pukoensis* was listed as Critically Endangered as the population size was estimated to number fewer than 50 mature individuals. *Montipora flabellata* and *M. patula* were listed as Vulnerable because they are endemic to Hawai'i and the number of locations for these species was less than five, where "location" is defined as "a geographically

or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present". *Montipora dilatata* was evaluated under IUCN Red List Criterion B, which can be applied to very geographically restricted populations, and was listed as Endangered as its area of occupancy was less than 500 km² and it existed in less than 5 locations.

While widely viewed as a useful index in estimating extinction risk, the IUCN Red List of Threatened Species carries no weight of law. In October 2009 the nongovernmental organization Center for Biological Diversity petitioned the NOAA to list 83 species of corals under the US Endangered Species Act, including the 75 Pacific species addressed in this study. The Endangered Species Act does have the weight of law. As of this publication, the NMFS is currently leading the process to independently evaluate the extinction risk of these species, and if listed as endangered species, these corals would receive legal protection. Coral reef habitat presently under federal protection harbors at least 55 of the 66 species with validated occurrence records in the US, with three reef units—Palmyra Atoll NWR, Kingman Reef NWR, and the Ofu unit of the National Park of American Samoa—each hosting more than 20 Red List threatened coral species. Protected areas already in place serve as important habitats and may be models for other areas deserving protection because they harbor species at elevated risk.

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