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Patterns of extinction risk and threat for marine vertebrates and habitat-forming species in the Tropical Eastern Pacific

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ABSTRACT: Marine conservation activities around the globe are largely undertaken in the absence of comprehensive species-specific information. To address this gap, complete regional species assemblages of major marine taxa are being progressively assessed against the Categories and Criteria of the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species. The present study is the first analysis of entire major components of the biota of a large marine biogeographic region conducted in the Tropical Eastern Pacific (TEP). It is based on recently completed IUCN Red List assessments for all known species of bony and cartilaginous shorefishes, corals, mangroves, and seagrasses in the TEP. Twelve percent of the >1600 species assessed are in threatened categories, indicative of elevated extinction risk. Spatial analysis of all assessed taxonomic groups, including previous IUCN Red List assessments for seabirds, marine mammals, and marine turtles, highlights specific geographical areas of elevated threatened-species richness. The distribution of threatened species in the TEP is primarily linked to areas with high rates of overfishing, habitat loss, and increasing El Niño-Southern Oscillation (ENSO) event impacts, as well as oceanic islands with high stochastic risk factors for endemic species. Species assigned to the highest threat categories have life history traits that likely decrease their resilience to various regional and site-specific threats. Comprehensive information in the form of IUCN Red List assessments combined with spatial analysis will greatly help to refine both site- and species-specific marine conservation priorities in the TEP.

KEY WORDS: IUCN Red List · Tropical Eastern Pacific · Marine species · Extinction risk theory · Threatened species

INTRODUCTION

Information on the geographical and habitat distributions of threatened species is often used to refine marine conservation priorities, through the designation of critical habitat or key biodiversity areas, no-take zones, and marine protected areas (MPAs); or to support policies that regulate resource use (Rodrigues et al. 2006, Edgar et al. 2008a, 2008b, Hoffmann et al. 2008). However, marine conservation priorities have often been identified and acted on in the absence of comprehensive species-level information (Margules & Pressey 2000), as such data often do not exist or are difficult to collate. Among the >50 000

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species assessed over the past decade for the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2011a), only ~3% (<1500 species) are marine. These species mainly comprise seabirds, marine mammals, marine turtles, and a few select fishes. To address this assessment gap, >20 000 marine species, including all marine fishes and primary habitat producers such as reef-building corals, seagrasses, and mangroves, are currently in the process of assessment using the IUCN (2001) Red List Categories and Criteria through the Global Marine Species Assessment (www.sci.odu.edu/gmsa/).

Recent marine species extinctions, although fewer than those documented for terrestrial species (Briggs 2011), currently include at least 20 global species (Dulvy et al. 2009) and >133 local populations (Dulvy et al. 2003). The most recent probable global extinction, where good pre- and post-extinction data exist, is considered to have occurred in the Tropical Eastern Pacific (TEP), with the disappearance during the 1982–83 El Niño-Southern Oscillation (ENSO) event of the endemic Galapagos damselfish *Azurina eupalama* (Dulvy et al. 2009, Edgar et al. 2011). Drastic recent declines have also been documented across several marine groups, including many populations of commercial marine fishes (Hutchings & Reynolds 2004, Worm et al. 2009), coral reef fishes (Wilson et al. 2006, Paddack et al. 2009), reef-building oysters (Beck et al. 2011), corals (Gardner et al. 2003, Pandolfi et al. 2003, Bruno & Selig 2007), and seagrasses (Waycott et al. 2009).

In light of these documented declines, and as more pressure is put on marine resources from overfishing, habitat loss, pollution, and invasive species (Halpern et al. 2008, Worm et al. 2009, Mora et al. 2011), an increasing need exists to identify marine species that are at highest risk of extinction (Dulvy et al. 2004, Graham et al. 2011) and how they are distributed in different regions. Additionally, understanding differential species vulnerability to major threats is needed for determining how species communities and ecosystems are likely to respond to one or more concurrent stressors (Vinebrooke et al. 2004).

Several studies have been conducted to determine the relative extinction risk for marine fishes based on combinations of life history and ecological traits, habitat specialization, or body size and age at maturation (Munday 2004, Cheung et al. 2005, Reynolds et al. 2005a, Graham et al. 2011). Relative extinction risk has also been estimated for coral species based on bleaching response and abundance (McClanahan et al. 2007). However, application of these alternative techniques to assess extinction risk across multiple taxonomic clades is problematic due to the extreme variation in physiologies and life histories, and is therefore inefficient for prioritizing multi-taxa marine conservation targets.

The Categories and Criteria of the IUCN Red List (IUCN 2001) comprise the most widely accepted, standardized, quantitative system for classifying extinction risk at the species level (Butchart et al. 2005, De Grammont & Cuarón 2006, Rodrigues et al. 2006, Hoffmann et al. 2008). These criteria have been applied to an increasingly wide variety of terrestrial, freshwater, and marine species, including all the world's mammals (Schipper et al. 2008), amphibians (Stuart et al. 2004), birds (BirdLife International 2008), reef-building corals (Carpenter et al. 2008), mangroves (Polidoro et al. 2010), seagrasses (Short et al. 2011), tunas and billfishes (Collette et al. 2011), groupers (Sadovy de Mitcheson et al. in press), and a number of other vertebrate, invertebrate, and plant clades (Hilton-Taylor et al. 2009). IUCN Red List Criteria are based on extinction risk theory (Mace et al. 2008) and provide quantitative thresholds to rank a species' relative probability of extinction. In general, extinction risk increases with small population sizes or distributional ranges, high rates of decline (e.g. death rates are greater than birth rates), and large fluctuations in population size relative to growth rates (Mace et al. 2008). Some criteria are most relevant for species with small population sizes, which have inherently high extinction risk due to stochastic events and genetic effects. Others are more appropriate for species with large population sizes that are experiencing high rates of decline or large fluctuations. These require extinction risk to be defined by measures of the species' ability to recover relative to the persistence and frequency of the stressors driving the declines and fluctuations.

Critics of the IUCN Red List have questioned whether criteria that are used to assess terrestrial animals, plants, and freshwater fishes should be the same as for marine fishes (Musick 1999, Powles et al. 2000). However, a number of empirical analyses suggest that the extinction probabilities of marine fishes are unlikely to differ substantially from those of other taxa (Hutchings 2000, 2001a, 2001b, Sadovy 2001, Dulvy et al. 2003). Thus, questions related to how adequately thresholds for rates of decline used in the Red List Criteria to assign species to IUCN categories actually reflect the likelihood that a particular population or species will become extinct is better asked of all taxa rather than only of marine species (Hutchings & Reynolds 2004).

Additionally, rather than focusing simply on marine versus terrestrial, specific taxonomic analyses arguably provide more meaningful comparisons. For example, among the world's plants, approx. 16% of mangroves (Polidoro et al. 2010) and 14% of seagrasses (Short et al. 2011) are in threatened categories compared to approx. 35% of gymnosperms (Hilton-Taylor et al. 2009), the only complete clade of terrestrial plants assessed to date. Among mammals, approx. 36% of marine mammals are considered to be at elevated extinction risk compared to 25% of terrestrial mammals (Schipper et al. 2008). Of the approx. 10 000 marine and freshwater fishes assessed to date, approx. 30% of freshwater fishes and 15% of marine fishes are in threatened categories (IUCN 2011a). Among commercial fishes assessed to date, 11% of all tunas and billfishes are in threatened categories (Collette et al. 2011) as are 12% of the world's groupers (Sadovy de Mitcheson et al. in press). Successful assessment of each species group or clade through the Red List process often requires the development of unique definitions and interpretations in order to appropriately apply the IUCN Red List Criteria (Mace et al. 2008). Consequently, many of these relevant definitions and interpretations have been published for many taxa as they are globally assessed (e.g. Carpenter et al. 2008, Dulvy et al. 2008, Schipper et al. 2008, Polidoro et al. 2010, Collette et al. 2011, Short et al. 2011, Sadovy de Mitcheson et al. in press).

The present study is the first comprehensive Red List analysis conducted at the scale of a major marine biogeographic region, and it was performed with the marine fauna of the TEP. The TEP extends from southern Baja California through the Gulf of California and south to Peru, and includes 5 oceanic islands and archipelagos: the Revillagigedo Islands, Clipperton, Cocos, the Galapagos, and Malpelo islands (Robertson & Cramer 2009). The TEP is a unique and dynamic region separated from adjacent tropical marine regions by the Central American isthmus on the east, and the world's broadest deep water barrier (4000 to 5000 km wide) on the west. The region has a small continental shelf, is more strongly affected by the ENSO-driven temperature changes than any other tropical region, and has an abundance of large, seasonal coastal upwellings, a shallow thermocline (~50 m), relatively low salinity, and geographically highly variable rainfall (e.g. Glynn & Ault 2000).

In the TEP, 1342 new IUCN Red List assessments conducted between 2005 and 2009 are now available, comprising all known species of bony and cartilaginous shorefishes, reef-building corals, mangroves, and seagrasses. In addition, the 74 species of Galapagos-endemic macroalgae have also been assessed. However, those results are not extensively discussed here because assessment is still needed for ~400 remaining macroalgal species that occur more widely through the TEP. Before these new data were available, IUCN Red List assessments were only available for 226 TEP species, mainly comprising seabirds, marine mammals, and marine turtles.

MATERIALS AND METHODS

Based on IUCN Red List methodology (IUCN 2001), species assessments were conducted from extensive input and collaboration with international and regional scientific experts, including members of the IUCN Species Survival Commission's Specialist Groups (IUCN 2011b). Data compilation and assessments were conducted in 9 taxonomically themed Red List assessment workshops held between 2005 and 2008 with the participation of >200 scientific experts. These covered all species known in each taxonomic group at the time. In each workshop, experts reviewed data on each species' taxonomy, distribution, population trends, ecology, life history, past and existing threats, and conservation actions to apply the IUCN Red List Criteria and assign each species a Red List Category. All species information and results of global Red List assessments are publicly available on the IUCN Red List of Threatened Species (IUCN 2011a). However, 85 of the non-endemic (e.g. circumtropical or Indo-Pacific) shorefishes have only been assessed regionally in the TEP. Although those results are included here, these TEP non-endemic assessments will not be published on the IUCN Red List until assessments of their global populations have been completed.

The IUCN Red List Categories comprise 8 levels of extinction risk: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), and Data Deficient (DD). A species qualifies for 1 of the 3 'threatened' categories (CR, EN, or VU) by meeting the threshold for that category in 1 of 5 Criteria (A to E). These criteria form the real strength of the IUCN Red List as they are based on extinction risk theory (Mace et al. 2008) and provide a standardized methodology that can be applied consistently to any species from any taxonomic group such as tunas and billfishes (Collette et al. 2011), seagrasses (Short et al. 2011), mangroves (Polidoro et al. 2010), reef-building corals (Carpenter et al. 2008), mammals (Schipper et al. 2008), or amphibians (Stuart et al. 2004).

For example, Criterion A measures extinction risk based on exceeding a threshold of population decline (30% for VU, 50% for EN, and 80% for CR) over a timeframe of 3 generations, a measure of reproductive turnover rate, in the recent past, and is generally applied to species with large or widespread populations. Criterion B measures extinction risk based on a small geographic range size (extent of occurrence $<20\,000$ km^2 or area of occupancy <2000 km^2 to meet the lowest threshold for VU) combined with continued decline and habitat fragmentation. Criterion C is applied to species with small population sizes estimated to be <10 000 mature individuals, with continued decline. Criterion D is applied to species with <1000 mature individuals, or those with an area of occupancy of <20 km^2, or those that are found in <5 locations as defined by a threat. Criterion E is applied to species with extensive population information that allows for population declines to be appropriately modeled over time. Category NT is assigned to species that come close to but do not fully meet all the thresholds or conditions required for a threatened category under any of Criteria A to E, and Category LC is assigned if a species does not meet or come close to meeting any of the thresholds required of a threatened category.

All maps and related analyses, including number of species per country and endemism, were conducted in GIS, based on compiled species range maps. Original species range maps were obtained from a number of different sources (Spalding et al. 1997, Veron 2000, Green & Short 2003, Jefferson et al. 2007, Ridgely et al. 2007, BirdLife International 2008, Robertson & Allen 2008, SWOT 2009). All maps were reviewed and updated as necessary by IUCN Specialist Groups and at IUCN Red List Workshops. All species range maps used in our analyses were created based on polygons connecting known points of occurrence, with the exception of sea turtles, where only point locations of nesting sites were used.

To improve accuracy and to standardize analyses for near-shore species with relatively small ranges, a species polygon was cut to a 100 km shoreline buffer and maximum depth of 200 m if the species was found primarily above 200 m depth. This approach helped to improve the accuracy of analyses by standardizing species ranges and by excluding large areas of open ocean, where only pelagic larval stages of shallow-water demersal species may occur. For analyses of species richness, all species polygons were analyzed using a 10 × 10 km square grid. This fine grid size was chosen to reduce over-estimation of ranges for small-range endemic species. Final maps were converted into a raster of 10 × 10 km cell size to provide visualization of geographical biodiversity patterns.

RESULTS AND DISCUSSION

Red List categorization

Of the 1642 species in the TEP that have now been assessed for the IUCN Red List (see the supplement at www.int-res.com/articles/suppl/m448p093_supp.pdf), 12% (197 species) are in threatened categories (CR, EN, or VU). Marine turtles have the highest proportion of threatened species in the TEP (Fig. 1), with all 5 species present listed in 1 of the 3 threatened categories. Many of the habitat-producing groups also have a relatively high proportion of threatened species. Of these, 40% (4 of 10 species) of mangroves, 25% (1 in 4 species) of seagrasses, and 17% (8 of 46 species) of reef-building corals are in threatened categories, as well as 20% (15 of 74 species) of Galapagos-endemic macroalgae. Approx. 15% (27 of 180 species) of cartilaginous fishes and 9% (94 of 1102 species) of the bony fishes in the TEP are now listed in a threatened category, as are approx. 15% (9 of 62 species) of marine mammals and 21% (34 of 159 species) of seabirds.

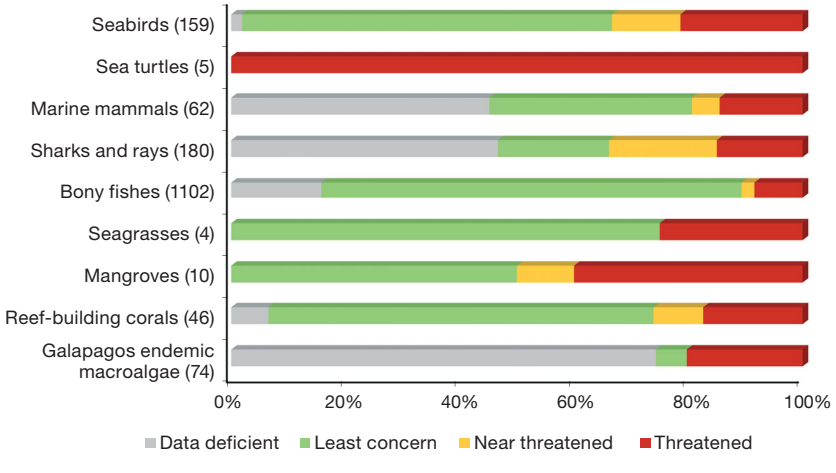

Fig. 1. Proportion of Tropical Eastern Pacific (TEP) species in IUCN Red List Categories for global assessments of major species groups. Numbers in parentheses refers to total number of species present in the TEP

Endemism

The TEP has one of the highest rates of regional endemism of near-shore fishes of any tropical area of the world: almost 90% of bony fishes and 33% of cartilaginous fishes are endemic to the TEP (Robertson & Cramer 2009). Further, 30% of mangrove species and 17% of reef-building coral species are endemic to the region (Glynn & Ault 2000). With only approx. 25 km^2 of structural coral reef in the TEP, mangroves — which are a major habitat feature on approx. one-third of the TEP coastline (Robertson & Allen 2008) — are by far the most dominant marine habitat-forming taxon.

Seabirds (20%), marine mammals (11%), and marine turtles (0%) have relatively low regional endemism in the TEP. As the majority of species in these groups are widespread, pelagic, and/or highly migratory, areas of high threatened-species richness based on overlaps in the distributions of seabirds, marine mammals, and marine turtles primarily occur in the high seas and open ocean (Fig. 2A). The majority of globally threatened marine mammal species, for example, that occur in the TEP are found in temperate areas outside of the region (Schipper et al. 2008). Marine mammal and marine turtle populations are affected by a number of different historical and current threats throughout their global oceanic range, including fishery by-catch, entanglement in fishing gear, boat strikes, noise pollution from military and seismic sonar, loss of prey or other food sources due to poor fisheries management, and historical or current effects of hunting (Reynolds et al. 2005b, Schipper et al. 2008, Polidoro et al. 2009, Wallace et al. 2010a). As these larger-scale threats may not all occur in the TEP region or may be difficult to mitigate on a local scale, mitigation of threats at the site or regional level for the majority of seabirds, marine mammals, and marine turtles may be limited to protection of known breeding or nesting sites (Wallace et al. 2010b).

Spatial analyses

Excluding Galapagos-endemic macroalgae, spatial analyses of the threatened marine species now known in the TEP (e.g. all marine mammals, marine turtles, seabirds, fishes, corals, mangroves, and seagrasses) highlight specific near-shore areas of high threatened-species richness (Fig. 2B) which are

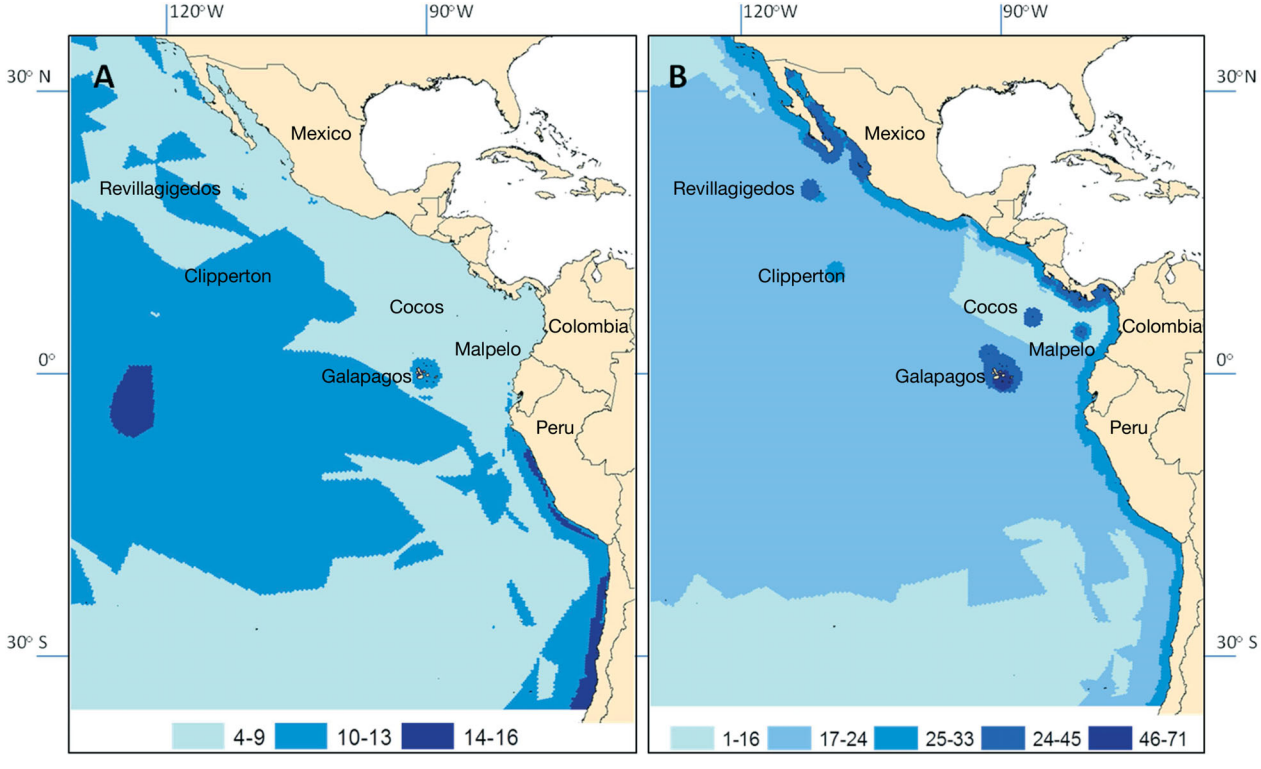

Fig. 2. Number of threatened species known in the Tropical Eastern Pacific (A) prior to 2008 (e.g. based on IUCN Red List Assessments for all seabirds, marine mammals, and marine turtles), and (B) as of 2010 (e.g. based on IUCN Red List Assessments for all seabirds, marine mammals, marine turtles, marine fishes, corals, mangroves, and seagrasses)

related to different types of threats to species populations. High numbers of threatened species in the lower Gulf of California and along the Pacific coast of southern Baja, Mexico, are driven by species population declines due to overfishing and destructive fishing techniques, and the loss of critical habitat due to expansion of shrimp fisheries, coastal development, and diversion of virtually all the flow of the Colorado River for agriculture in the USA (Páez-Osuna et al. 1998, Lluch-Cota et al. 2007). Mexico hosts the highest number of marine species assessed (1081) and the highest number of threatened species (82) in the TEP (Fig. 3).

Spatial analyses show overlaps among threatened shore fishes and primary habitat-producer species, such as in the mangrove ecosystems along the coast of Costa Rica and Panama. Four of the 10 mangrove species present in the TEP are threatened, primarily due to intensive coastal development and extraction (Jiménez 1994, Polidoro et al. 2010). The Costa Rican and Panamanian coasts show high threatened-species richness (Fig. 2B), likely because this area has the highest abundance of species in the TEP (Robertson & Cramer 2009). Among the 800 bony fishes that occur along this coastline, >100 are associated with mangrove habitat for at least a portion of their life stage (Robertson & Allen 2008). Four mangrove-associated bony fishes are in threatened categories. Two gobioids (*Gobulus birdsongi*, *Gobiosoma homochroma*) and one clingfish (*Tomicodon abuelorum*) are only known from a few mangrove areas, and are threatened by continued coastal development, pollution, and removal of mangrove habitat. The sea catfish *Notarius cookei*, listed as Category VU, is known from <5 estuarine and mangrove areas in Panama and is exposed to severe threats from river and coastal pollution as well as indiscriminate gillnetting in rivers.

The offshore islands of Revillagigedo, Clipperton, Cocos, Malpelo, and the Galapagos have high numbers of threatened species as a result of their numerous island-endemic species with very restricted ranges (Robertson & Cramer 2009) that are affected by a combination of both anthropogenic and climate-induced threats. Approx. 14% of species assessed from Clipperton (33 of 239 species), the Revillagigedos (51 of 377 species), and the Galapagos archipelago (71 of 527 species) are in threatened categories (Fig. 3), as are approx. 12% from Malpelo (41 of 341 species), and 11% from Cocos (46 of 405 species).

Clipperton is the only coral atoll in the TEP, contains the largest coral reef in the region, and is the only TEP location where all shallow habitat is produced by corals. The high proportion of threatened species, a very small area of shallow shoreline habitat (~4 km^2), and current lack of MPAs make the marine fauna of this tiny island uniquely vulnerable. This atoll is administered by the French Polynesian government in Tahiti, which only supports occasional, brief visits by its personnel, effectively eliminating any management or protection capacity. In contrast, all the other offshore islands in the TEP are entirely within MPAs. The Galapagos archipelago, which is surrounded by an MPA for a distance of 40 nautical miles offshore, has the second highest number of threatened species in the TEP after Mexico, and provides 95% of the insular shelf habitat in the TEP. Of the 71 threatened species that occur in the Galapagos, approx. half (34 species) are bony fishes with small geographic ranges that are threatened by overfishing or major oceanographic environmental changes arising from the increasing frequency, intensity, and duration of El Niño events (Grove 1985, Glynn 2000, Glynn & Ault 2000, Chen et al. 2004, Edgar et al. 2010). The proportional abundance of threatened species off the coast of the 10 countries with continental shoreline are lower than those surrounding the oceanic islands of the TEP, ranging from 4 to 8%. These differences illustrate the vulnerability of island marine faunas. Studies are currently underway to identify fine-scale sites of global biodiversity conservation significance in the Galapagos and TEP (Edgar et al. 2008a,b).

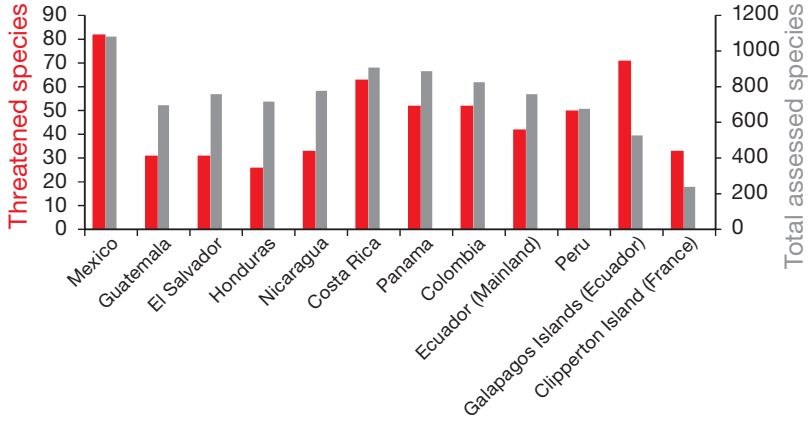

Fig. 3. Number of threatened species (red bar) and total number of species assessed (gray bar) within each country's Exclusive Economic Zone in the Tropical Eastern Pacific

Critically Endangered species

Species assigned to the highest threat categories have particular biological or ecological traits that provide poor adaptation to regional or site-specific threats. Four seabirds endemic to the TEP are listed as CR, the IUCN's highest threat category, 3 of which were assessed under either Criterion B or D due to their very restricted breeding areas and associated population declines caused by predation of nests or by incidental capture in fisheries (IUCN 2011a): Guadalupe storm-petrel *Oceanodroma macrodactyla* (possibly already extinct), waved albatross *Phoebastria irrorata*, and Townsend's shearwater *Puffinus auricularis*. Galapagos petrel *Pterodroma phaeopygia*, assessed as Category CR under Criterion A, has undergone extreme declines over the past 60 yr primarily due to heavy predation of nests by introduced cats, dogs, and pigs (IUCN 2011a). The vaquita dolphin *Phocoena sinus* is the only Category CR marine mammal in the TEP. Assessed under both Criteria A and C, this species has a total global population estimated to be <250 mature individuals, with catastrophic population decline primarily attributed to excessive incidental capture in gillnets in the northern Gulf of California (Rojas-Bracho et al. 2006).

Two marine turtles present in the TEP, the leatherback *Dermochelys coriacea* and the hawksbill *Eretmochelys imbricata*, have been globally assessed under Criterion A as Category CR. These long-lived species have experienced significant population declines in the past due to multiple threats to all stages of their life cycles, including loss of critical coastal nesting habitat, egg predation, targeted capture in small-scale subsistence fisheries, and by-catch (largely by long line and trawling activities). Both of these species have several significant sites for nesting along the mainland coast of the TEP.

Six endemic bony fishes in the TEP are listed as Category CR. Four of these species were assessed under Criterion B, as they have very small distributions and are declining due to extensive habitat loss from coastal development and pollution (*Paraclinus walkeri* in Mexico, *Gobulus birdsongi* in Panama, *Sciaena callaensis* in Peru), or due to oceanographic environmental changes associated with increased ENSO cycle activity (*Azurina eupalama* in the Galapagos, listed as Category CR but quite possibly Category EX). Two other Category-CR endemic bony fishes found primarily in Mexico were assessed under Criterion A: *Totoaba macdonaldi*, which is endemic to the Gulf of California, and *Stereolepis gigas*, which also occurs in California. Both species have limited ability to cope with severe overfishing because they are large desirable food fishes, are relatively long-lived, and have spawning aggregations that are targeted by fishers (Barrera Guevara 1990). The *T. macdonaldi* population has also apparently been catastrophically affected by loss of spawning grounds dependent on flow from the Colorado River (Rowell et al. 2008). Rapid declines of the 2 Category-CR coral species (*Millepora boschmai* and *Siderastrea glynni*) in the TEP assessed under Criterion B have been linked to low resilience to ENSO-induced bleaching and disease following extensive coastal development, coral extraction, and pollution within their restricted ranges in Panama (Glynn & De Weerdt 1991, Fenner 2001, Maté 2003).

Data Deficient species

Species assigned to the DD category may also be of conservation concern, and should be a priority for further research. A species is listed as DD if there are insufficient data to apply the Red List Criteria. This can apply to species that need taxonomic clarification, or that are only known from a few specimens. In some cases, relatively well-known species are listed as DD when significant threats are known but cannot be adequately quantified. Almost 75% of Galapagos-endemic macroalgae are listed as DD, primarily because many species have not been well studied and are only known from a few sites or are difficult to identify. As a result, little is known on their population size or trends, or on the impact of potential threats such as habitat warming from increased ENSO events. Approx. 45% of marine mammals and cartilaginous fishes in the TEP have been categorized as DD, primarily due to a lack of life history or population information needed to quantify the impact of known threats to these species. Many of those species spend long periods of time offshore and/or are highly migratory, which makes it difficult to conduct studies on population status or reproductive biology. Almost half of the 16% of bony fishes that are categorized as DD are heavily fished but lack reliable catch statistics and demographic information. Some of these commercial fishes likely will qualify in the future for a threatened category as better data on species biology, the history of fisheries landings or stock biomass, and catch per unit effort (CPUE) become available.

Of particular concern among the bony fishes is the Pacific goliath grouper *Epinephelus quinquefasciatus.* This TEP-endemic species was recently con-

firmed as being distinct from its trans-Atlantic sibling species *E. itajara* (Craig et al. 2009). *E. itajara* has been listed as Category CR since 1996 due to overfishing. Although west Atlantic populations are showing some signs of recovery, notably in the southern USA due to a moratorium on fishing proposed in 1990, a listing of CR has been maintained until this species can be reassessed (likely in the next 5 yr). As catch landings data across the TEP for groupers are often lumped into a single category, there are very few species-specific data on population trends for *E. quinquefasciatus*. However, severe population reductions are suspected due to intensive fishing over the past 3 decades. Sala et al. (2004) found an increase in catch and CPUE for this species in the Gulf of California between 1960 and 1980, followed by a rapid decline, with both landings and CPUE close to zero since the 1990s. There is no reason to suspect that the situation is different anywhere else in the TEP, as *E. quinquefasciata* is a large, commercially valuable food-fish that likely matures at a large size (*E. itajara* matures at 1 m length). A near absence of recent records indicates that the situation for the Pacific goliath grouper is probably considerably worse than for its sister species in the Caribbean, which has been provided relief through a long-standing fishing moratorium in a significant proportion of its range. At present *E. quinquefasciata* is listed as DD, and better information on its population status, including landings, catch effort data, and biomass across its range in the TEP, are urgently needed.

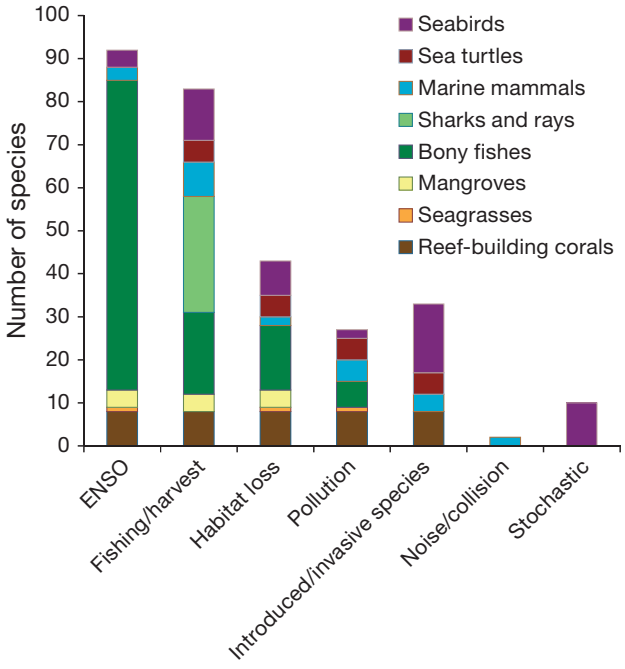

Fig. 4. Major threats impacting species listed in threatened categories in the Tropical Eastern Pacific. ENSO: El Niño-Southern Oscillation

Major threats to species in threatened categories

Oceanographic environmental changes, such as increased water temperatures and decreased productivity that are associated with an increasing duration and frequency of ENSO events in the TEP (Boer et al. 2004), is the major identified threat affecting the highest number of species listed in threatened categories across all taxonomic groups (Fig. 4). Almost 80% (72 of 91 species) of bony fishes listed in threatened categories were considered to be negatively impacted by increasing ENSO events. All of these fishes are very small-ranging, primarily island endemics that are found in relatively shallow waters or within a narrow depth zone. Several marine mammals are also threatened by ENSO events, including Galapagos fur seals *Arctocephalus galapagoensis* (listed as Category EN), which have experienced declines from El Niño-caused ocean warming and up to 80% associated reduced marine productivity (Trillmich & Dellinger 1991, Alava & Salazar 2006). For similar reasons, the 1982–83 ENSO reduced the population of the Galapagos penguin *Spheniscus mendiculus* (also listed as Category EN) by 77%, and the 1997–98 ENSO induced a further decline of 66% (Vargas et al. 2006). Increased coral bleaching and disease is also associated with ENSO events in the region (Glynn 2000), as is increased seagrass mortality (Orth et al. 2006) and loss of specific environmental conditions required for mangrove species (Ellison 2005).

In the TEP, large coastal populations and small-scale fisheries are dependent on marine species for food and income. Harvest or fishing, including capture as by-catch, is the second biggest threat in the TEP to the region's threatened species, although adequate data to quantify these effects on species' populations is largely absent. For example, capture as by-catch and targeted fishing for fins is the main threat to the region's threatened sharks and rays, yet almost half of all sharks and rays in the TEP are listed as DD because no information exists on the impact of direct or indirect fishing on these species.

Among the bony fishes, fishing and by-catch represents the largest threat in this region, with 19% (207 of 1102 species) considered to be negatively impacted by targeted or incidental catch, even though related population declines were not always high

enough to reach the threshold for a threatened category. In general, large-bodied marine fishes, such as the larger tunas and billfishes (Collette et al. 2011), attract high market prices and therefore tend to be under greater threat of global extinction due to commercial fishing (Olden et al. 2007). In addition to localized and regional depletion of some fishery species, there is regional evidence that overfishing of selected species has also led to harmful artificial imbalances in other fish and invertebrate communities (Edgar et al. 2011). Only 36% of bony fishes were considered to have no significant threats, and threats are suspected but undefined for 16% of bony fishes. Thus, estimates of the level of threat affecting regional shore fish fauna may well be underestimated.

Habitat loss, pollution, and predation or competition with introduced or invasive species are also significant threats to threatened species in the TEP. All species groups, with the exception of sharks and rays, are impacted by habitat loss in the region. Coastal development and near-shore alteration are the main factors contributing to habitat decline for many species in the TEP, including all of the region's threatened mangroves, seagrasses, and corals. Almost 10% of the region's bony fishes are impacted by habitat loss, primarily due to the removal or degradation of mangrove and estuarine habitats.

Ten species of threatened seabirds in the region have breeding populations so small that they are considered to be inherently threatened by probable stochastic events and human impacts, such as coastal development, habitat loss, predation, invasive species, tourism, or major storms. For example, the pink-footed shearwater *Puffinus creatopus* (listed as Category VU) is found throughout the TEP, but only breeds on Robinson Crusoe Island and Santa Clara Island in the Juan Fernández Islands, and on Isla Mocha off the coast of Chile. It is estimated that there are <20 000 breeding pairs of pink-footed shearwater (IUCN 2011a).

Conservation and management

Identification of threatened species and patterns of threat in the TEP can help guide local and regional marine conservation priorities for biodiversity conservation, as well as serve to inform policy. The presence of threatened species is used to identify marine key biodiversity areas and marine biodiversity hotspots, which target conservation action to areas where it is most needed and can have the most benefits in terms of species recovery (Roberts et al. 2002, Edgar et al. 2008a). In the case of the TEP, important areas with high species richness and threatened-species richness include the Gulf of California, the coasts of Panama and Costa Rica, and the 5 offshore oceanic islands and archipelagos.

IUCN Red List species assessments can also be used to inform reserve system design and to constrain development and exploitation (Possingham et al. 2002). Tiny Clipperton Island has one of the highest proportions of threatened species in the TEP and a regionally unique habitat and faunal assemblage. The creation of a Clipperton MPA should be a high regional priority. Further, legislation to limit mangrove removal from important fishery nursing grounds along the coasts of Costa Rica and Panama is needed. For the few fishery species that are threatened based on the availability of adequate data, better management is needed on both local and regional scales. More importantly, however, increased reporting and better monitoring of by-catch are needed for the majority of species considered to be threatened by overexploitation in the TEP.

CONCLUSIONS

The availability of more comprehensive threatened species information is important for guiding marine conservation priorities, such as the improved management of MPAs, the development of more effective species conservation policies, or the identification of key biodiversity areas. Increased understanding of the factors that contribute to a species' threatened status is essential for developing the most effective measures to protect threatened species and to mitigate threats. Conservation action for threatened species will therefore be more effective in mitigating both species-specific and ecosystem wide threats if they are based on an understanding of the Red List Category, Criterion, and the specific threat or suite of threats under which a threatened species has been assessed.

Previously available Red List assessments of widespread and/or highly migratory species such as the majority of seabirds, marine mammals, and marine turtles could not be readily used to identify species or area-specific conservation priorities in the TEP, given that most threats to those species are global or historic (the exception being breeding sites; Bass et al. 2011). Analyses of the more comprehensive and recent species Red List assessments that include all marine fishes and primary habitat producers in the region, combined with an understanding of the crite-

ria and data used to assess each species' probability of extinction, will more effectively identify areas of high threatened-species richness and patterns of threat for site- and species-specific marine conservation priorities. In terms of proportional abundance of threatened species, the highest threat levels exist for the ocean-island faunas. On the continental shore, the greatest abundances of threatened species occur around the mouth of the Gulf of California and the coastlines of Panama and Costa Rica. Those insular and continental areas represent priority conservation areas in the TEP. Regional scale conservation efforts exist, such as the Eastern Tropical Pacific Seascape Initiative (Shillinger 2005), that are making progress in addressing the range of threats to marine species. In several nations, including Mexico, Costa Rica, and Honduras, there are now total or seasonal closures for shark finning, although the level of enforcement is speculative. Regardless, better fisheries information and monitoring of by-catch should be an urgent priority for the improvement of marine conservation efforts throughout the region.

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