AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS
Aquatic Conserv: Mar. Freshw. Ecosyst. **21**: 37–48 (2011)
Published online 7 January 2011 in Wiley Online Library
(wileyonlinelibrary.com). DOI: 10.1002/aqc.1163

Use of local ecological knowledge, scientist's observations and grey literature to assess marine species at risk in a tropical eastern Pacific estuary

GUSTAVO A. CASTELLANOS-GALINDO[a,b], JAIME R. CANTERA[c,*], SILVANA ESPINOSA[d] and LUZ MARINA MEJÍA-LADINO[d]

[a]*Grupo de Investigación en Biodiversidad Neotropical, Museo Departamental de Ciencias Naturales, INCIVA, Calle 6 No. 24–80, Cali, Colombia, South America*

[b]*Leibniz Center for Tropical Marine Ecology (ZMT), Fahrenheitstr. 6, 28359 Bremen, Germany*

[c]*Grupo de Investigación en Ecología de Estuarios y Manglares, Departmento de Biología, Universidad del Valle, A. A. 25360, Cali, Colombia, South America*

[d]*Instituto de Investigaciones Marinas y Costeras de Colombia, INVEMAR, A.A. 6713 No. 36, Cali, Colombia, South America*

ABSTRACT

1. The loss of marine biodiversity in tropical regions of the world is a major threat to human welfare. Multiple anthropogenic drivers are responsible for this situation, with complex scenarios for coastal areas in third-world countries, where economic development often competes with conservation plans.

2. The International Union for the Conservation of Nature (IUCN) Red List of Threatened Species is an influential tool for setting conservation priorities at local and regional levels. The application of IUCN criteria for assessing extinction risk, however, continues to represent a major challenge in data-poor situations present in many tropical megadiverse countries.

3. To overcome these difficulties, three different data sources on invertebrates and fishes present in an estuarine system representative of the tropical eastern Pacific (TEP) region (Bahía Málaga, Colombia) have been used to establish their relative local extinction risk and correlate this information with the existing IUCN Red List categories. Data sources included (1) IUCN global and national listings, (2) traditional ecological knowledge (TEK), and (3) grey literature, scientific and natural history observations.

4. In total, 46 threatened species were evaluated after combining the three data sources. Only 17 species were previously identified as threatened by IUCN global and national listings, whereas the remaining 29 species were classified under a threatened category after evaluating TEK, grey literature and scientific information. Some of these species are seriously threatened within the estuary because of overharvesting and habitat destruction.

5. Despite most of the species identified having large geographical ranges in the TEP, they may face the same threats throughout their ranges. The approach provides a useful tool to assess species extinction risk in tropical regions where resource exploitation and habitat degradation advance rapidly, making the setting of conservation priorities an urgent task.

Received 8 May 2010; Revised 29 October 2010; Accepted 25 November 2010

KEY WORDS: threatened species; IUCN; traditional ecological knowledge; Bahía Málaga; tropical eastern Pacific

INTRODUCTION

Species' extinction risk assessment is a current issue in conservation biology of terrestrial and marine systems. Unfortunately, there are serious difficulties in accurately determining threatened and extinct marine groups at local or global scales (Dulvy *et al*., 2003; 2004; Del Monte-Luna *et al*., 2007). These difficulties arise, in most cases, due to the paucity of information concerning the biology and ecology of marine species when compared with their terrestrial counterparts.

*Correspondence to: Jaime R. Cantera, Grupo de Investigación en Ecología de Estuarios y Manglares, Departmento de Biología, Universidad del Valle, A. A. 25360, Cali, Colombia. E-mail: jaime.cantera@correounivalle.edu.co

In the tropics, this lack of information is exacerbated by the strikingly high biodiversity and a historical scarcity of biological research effort. As habitat destruction and human population growth increase dramatically, species may tend to have higher risk of extinction in these areas (Baillie *et al*., 2004). The International Union for the Conservation of Nature (IUCN) Red List of Threatened Species provides the most comprehensive and scientifically rigorous information about the conservation status and extinction risk of species, being an important tool in conservation, with applications ranging from local to global scales (Rodríguez *et al*., 2006; Hoffmann *et al*., 2008). However, determining the extinction risk of marine species faces the enormous challenge of assessing several poorly known taxa in a changing world in order to prevent their extinction.

Few marine species were considered extinct or under certain threat until recent times. Most of the known threatened marine taxa are higher vertebrates (birds, mammals, and turtles), for which information about life cycles, geographical distribution, and exploitation trends is available (Carlton *et al*., 1999; Dulvy *et al*., 2003), with very few under certain threatened categories according to the World Conservation Red List criteria (Hilton-Taylor, 2000; IUCN, 2006). The consequences of human activity on the oceans historically have been underestimated owing to the difficulty in detecting them (destruction of habitats, overexploitation, introduction of exotic species, and pollution) compared with the more evident changes that terrestrial ecosystems have suffered (Rabb and Lacy, 1990; Wolff, 2000; Hutchings, 2001; Dulvy *et al*., 2003; Reynolds, 2003). However, it is now well known that human activities are responsible for accelerated changes in marine ecosystem function and structure (Jackson *et al*., 2001). These changes are reflected by loss of marine biodiversity and the worldwide decline in fishery catches during the last century, increasing the extinction risk of target species. Despite this, documented global extinctions of marine organisms are still low, compared with those of terrestrial organisms. Population-scale extinctions in several marine taxa have started to be identified worldwide (Dulvy *et al*., 2003). These local or regional extinctions shorten species' geographical ranges, increasing their vulnerability to extinction when stochastic events occur, and thus may be considered as the first step towards larger scale or complete extinctions.

Understanding the biology and population dynamics of vulnerable species is a useful tool in preventing extinction of species (Walters, 1991). Various methodologies have been proposed to assess the extinction risk of species: (1) approximations based on the life histories of species; (2) time series data examining changes in species' abundances; and (3) demographic approximations based on ages or state of development of vital rates (e.g. growth, survival) and reference points of fisheries (e.g. a 'desirable' fishing mortality rate; Dulvy *et al.,* 2004). These methods, however, need certain knowledge of local diversity and species' population biology. In the absence of these data it is necessary to establish precautionary management actions based on the available scientific information and local people's traditional ecological knowledge (TEK), which have proven to be extremely useful for management purposes under an ecosystem-based approach (Johannes, 1998; Johannes *et al*., 2000; Drews, 2005; Appeldoorn, 2008; Silvano and Begossi, 2010).

There is at least one categorization system of threatened species per country in the American continent (de Grammont and Cuaron, 2006), but very few are dedicated to marine species. Threatened marine species of Colombian oceans, coasts and particularly estuaries are poorly known; information has been compiled for only a very small number of fish, molluscs and crustaceans in red books for marine fauna (invertebrates and fishes) using the IUCN categorization system (Ardila *et al*., 2002; Mejía and Acero, 2002). These efforts, however, are preliminary, and a complete assessment in the Pacific and Caribbean coasts of Colombia is urgently needed.

The objective of the present study was to address marine invertebrate and fish species facing elevated risks to local extinction within an estuary of the tropical eastern Pacific (TEP) Ocean: Bahía Málaga. This bay is located in the Tumbes–Chocó–Magdalena biogeographic hotspot and is recognized for its conservation importance. In the present work we examined three issues: (1) species of marine invertebrates and fishes with high extinction risk at a local scale; (2) past and current environmental and human threats for coastal and marine biota in the estuary; and (3) the relevance of establishing extinction risk categories in areas of the world where bio-ecological information on marine species is scarce. To answer these issues, scientific information on the biological and ecological data available for marine species in the area has been compiled and supplemented with TEK.

MATERIALS AND METHODS

The study area

Bahía Málaga is a tectonic estuarine system located in the central region of the Colombian Pacific coast (3°56′–4°05′N and 77°19′–77°21′W) within the TEP region (Figure 1). The bay is surrounded by low cliffs (200–300 m high), oriented 35° N–NE, with an area of *c*. 130 km^2 and average depth 15 m. The coast is bordered by rocky cliffs constituted by tertiary sediments of mudstones and shales and is strongly modified by erosion, with groups of islands distributed within the whole area and well-developed fringe-mangroves and mudflats along riverbanks. The external border has extended sandy beaches with high hydrodynamism (Cantera, 1991). The bay is located in an area with one of the highest precipitation rates in the lowlands of the world (6000 mm $year^{-1}$; Eslava, 1992). The forest area bordering the bay is still pristine, with great extensions of tropical rain forests characterized by high biodiversity (Faber-Langendoen and Gentry, 1991). Few human settlements are found in the area. Nevertheless, Bahía Málaga has faced over the last 25 years accelerated changes as a consequence of the construction of a naval base in the mid-1980s and increasing tourism activity nearby. Mangrove loss in the whole Colombian Pacific coast was calculated as 13.712 ha over the period 1969 to 1996 (Zambrano-Escamilla and Rubiano-Rubiano, 1996). However, no specific estimates of mangrove loss are available for Bahía Málaga. Development plans by central and local governments to construct a deep-water commercial harbour threaten the marine biodiversity of the area; nevertheless, two areas within the bay (La Plata and La Sierpe representing 6791 ha and 25178 ha, respectively) have recently been declared protected areas by local environmental agencies (Figure 1).

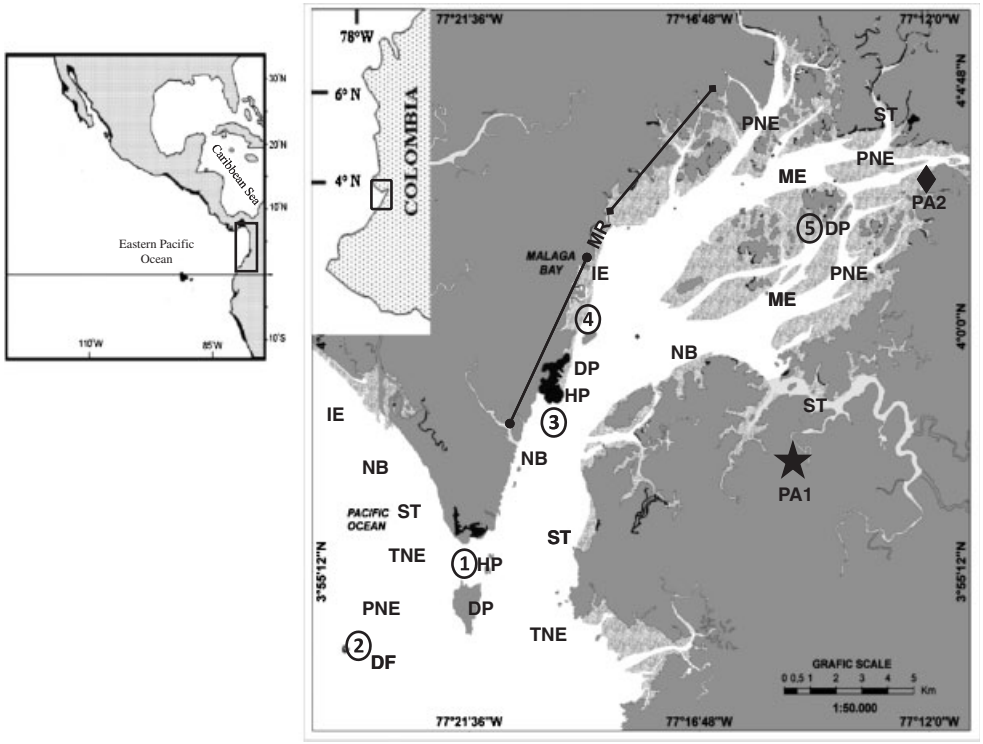

Figure 1. Localities and main human and environmental threats in marine zones of Malaga Bay: 1. Juanchaco; 2. Los Negritos, 3. Naval Base, 4. Curichiche Island, 5. La Plata Village; ME = manual mollusks exploitation, TNE = trawling net exploitation (Changa), PNE = pelagic net exploitation, DF = Diving fisheries exploitation, ST = seasonal tourism, IE = induced by man coastal erosion, NB = natural bioerosion, HP = hydrocarbon pollution, DP = domestic pollution, MR = Military reserve. Newly declared protected areas: PA1: La Sierpe and PA2: La Plata.

Methodological approach

IUCN global and local lists and scientific literature

To make a first approximation of the species that could be threatened within the estuarine area, we consulted the on-line IUCN Red List of Threatened Species (IUCN, 2006), restricting the search to all the assessments made since 1996 of marine species under any category of Colombian waters of the eastern Pacific. In the same way, the national marine red lists (Ardila *et al.* 2002; Mejía and Acero, 2002) were consulted, selecting the species cited for the Pacific coast of the country. From these two sources marine invertebrates and fishes were chosen, whose presence was confirmed according to marine species lists for Bahía Málaga (see Escallón and Cantera, 1989; Cantera, 1991; Cantera and Neira, 1998; Castellanos-Galindo *et al.*, 2006).

Traditional ecological knowledge–TEK

To gather information from local communities, two different approaches were used. (1) Anecdotal information from local inhabitants was gathered by one of the authors during 25 years of field trips to the two largest villages within the area (Juanchaco and La Plata) (Figure 1). In addition, during 2004–2006, semi-structured interviews took place at the same villages where this kind of anecdotal information was collected. (2) During 2004–2009, 16 sites within the bay were visited, accompanied by two inhabitants of the nearest villages involved in fishing activities. At each site informal interviews (non-structured) took place. Both types of approaches focused on four specific topics: common fishing practices at the site; main species exploited; observed decline in the capture of certain species; and the main causes of these declines (see Supplementary Material (Table S1) for a full list of topics).

With the information gathered, a qualitative assessment of the main species exploited was carried out, taking into account the fishing methods employed, the frequency of exploitation of resources, and the observed decline of the resource by the fishermen. The exploitation frequency of each species was divided into three main categories: 'regularly', if the resource was exploited on a year-round basis; 'seasonally' if the resource was exploited every year according to a known peak in abundance or to a special tourism demand; and 'occasionally', if the resource was exploited only in atypical situations where other resources were not available. Comments on the state of the resource were classified as 'highly declined', if the respondents agreed that the species' population had suffered a considerable reduction over the years; 'declined', if there was an observable reduction; 'reduced mean size', if the species is still being harvested but the average sizes have declined; and 'no observed trend' if the respondents could not answer if the population has declined or remained the same. This information was further used in discussions among the authors trying to correlate the species' threatened status given by people with that of the IUCN categories.

Grey literature, natural history and scientific observations

A series of observations was made during 2005–2009 in the bay to identify species that were not recognized as principal targets by local fishermen (minor commercial value), but were thought to be vulnerable according to the principal threats to biodiversity

identified in Salafsky *et al.* (2008). The observations were focused on surveys of intertidal and subtidal hard bottoms where previous human perturbations had taken place (near the naval base) and analysis of the by-catch composition of an artisanal trawling fishing method used in the outer zones of the bay. These observations were compared with descriptive reports available (CENIPACIFICO, 1986 and 363 grey literature and published references, see INVEMAR *et al.*, 2006) and with previous observations by one of the authors concerning the past state of specific populations. Additionally, based on grey literature and reports, species whose geographic range was considered reduced (rare species confined to the area) were used to elaborate this third list of species at risk. After a preliminary list of species was compiled, discussions were held with experts within each taxonomic group to determine its status.

With these three data sources, an agreement on which populations would be assessed or reassessed (in the case of IUCN existing national and global lists) at the regional level was reached using the IUCN guidelines. The second step consisted of applying the IUCN Red List criteria to the selected regional populations, generating a preliminary estimation of extinction risk. As a final step, the IUCN regional guidelines were applied to these populations to obtain a regional estimation of extinction risk (Gärdenfors *et al.*, 1999; 2001; IUCN, 2003). In all cases, discussions were held with experts in each taxonomic group and the data on each species evaluated in order to make a definitive assessment of its threatened status and extinction risk. Greater relevance was given to the exploitation trend within the area, the habitat occupied, and its degradation trend, when available or suspected. A final assessment considered also life history characteristics of each species based on the available information in similar areas of the TEP. Species that were common between this list and the IUCN national and global lists were reassessed in a threatened category according to the local situation. At the end, a consolidated list of threatened species for Bahía Málaga was constructed following the IUCN nomenclature.

RESULTS

Identification of species with local extinction risk

Forty-six species of invertebrates and fishes were evaluated (one sponge, five cnidarians, 10 molluscs, 10 crustaceans and 20 fish species) according to IUCN extinction risk criteria. When considering species already listed in IUCN categories (globally and locally), only 17 species were found. Four species are shared among global and national listings (blacktip shark – *Carcharhinus limbatus*, Pacific goliath grouper – *Epinephelus quinquefasciatus*, Pacific seahorse – *Hippocampus ingens*, and largetooth sawfish – *Pristis pristis*). Nine of them were previously reported in Colombian IUCN red books, corresponding mostly to commercially important species in the Colombian Pacific (shrimps and cockles; Table 1). Nine species correspond to Global IUCN recently assessed cartilaginous fish. Fish form the most abundant group among this list, representing 76% of the total species, with molluscs and crustaceans representing the remaining 24%.

Interviews were conducted with around 40 fishermen, 10 mangrove cockle collectors and 22 key informants from the main coastal settlements in Bahía Málaga. The interviews

Table 1. Marine fishes and invertebrates of Bahía Málaga (tropical eastern Pacific) under IUCN Global and/or National Red List classifications

Taxa	Species	Common name	IUCN global category	IUCN national category	Year of assessment	Reference
Molluscs	*Grandiarca grandis*	Grand ark, mangrove cockle	–	VU A2d	2002	MacKenzie, 2001; Ardila *et al.*, 2002
	Anadara tuberculosa	Pustulose ark, mangrove cockle	–	VU A2d	2002	MacKenzie 2001; Ardila *et al.*, 2002
Crustaceans	*Litopenaeus occidentalis*	Western white shrimp	–	VU A4cde	2002	Ardila *et al.*, 2002
	Litopenaeus vannamei	Whiteleg shrimp	–	VU A4cde	2002	Ardila *et al.*, 2002
Fish	*Carcharhinus limbatus*	Blacktip shark	NT	LC	2002	Burgess and Branstetter, 2005; Mejía and Acero, 2002
	Carcharhinus porosus	Smalltail shark	DD	–	2005	Lessa *et al.*, 2005
	Galeocerdo cuvier	Tiger shark	NT			Simpfendorfer, 2005
	*Pristis pristis**	Guacapá	CR A2abc+ 3cd	CR A2a	2000	Cook and Compagno, 2005; Mejía and Acero, 2002
	Aetobatus narinari	White-spotted eagle ray	NT	–	2005	Kyne *et al.*, 2005
	Dasyatis longa	Longtail stingray	DD	–	2005	Smith, 2005
	Rhinobatos leucorhynchus	Whitesnout guitarfish	NT	–	2005	Bizzarro, 2005
	Urotrygon rogersi	Roger's Round Ray	DD		2008	Valenti, 2008
	Manta birostris	Manta ray	NT	–	2006	Marshall *et al.*, 2006
	Sphyrna lewini	Scalloped hammerhead	EN A4bd	–	2000	Baum *et al.*, 2007
	Cetengraulis mysticetus	Pacific anchoveta		VU	2002	Mejía and Acero, 2002
	Hippocampus ingens	Pacific seahorse	VU A4cd	VU A2ad	2003	Project Seahorse, 2003; Mejía and Acero, 2002
	*Epinephelus itajara***	Goliath grouper	CR A2d	CR A2a	2006, 2002	Mejía and Acero, 2002; Chan Tak-Chuen and Padovani Ferrera, 2006

*Eastern Pacific and Caribbean *Pristis pristis* populations are thought to be different species based on genetic evidence, thus eastern Pacific populations may be considered to be *Pristis zephyreus* (Colin Simpfendorfer and Vicente Faria pers. comm. 2008, Robertson and Allen, 2008).
***Epinephelus itajara* has recently been considered to be a species restricted to the Atlantic Ocean and the eastern Pacific populations considered to be a sister species *Epinephelus quinquefasciatus* (Craig *et al.*, 2009).

indicated that at least 18 species are exploited regularly (nine molluscs, five crustaceans and four fishes; Table 2). Three species of mangrove cockles (*Anadara tuberculosa*, *A. similis* and *Grandiarca grandis*) are the most intensively exploited resources. They are collected year-round despite recent efforts to establish a ban in two months of the year. Mainly women and children undertake collection. Catches have severely declined in the last 15 years. The people interviewed agreed that there has been a decline in the total community catch (*c*. 30 collectors) from 1200–1800 to 120–360 individuals per day. *G. grandis* was often regarded by respondents as an abundant species that has seriously declined in numbers over the years. The decline in this species, however, was difficult to quantify for interviewees. Respondents identified six other mollusc species as commonly harvested. These are exploited before a religious celebration each year (April). There is little information about exploitation pressure on *Iliochione subrugosa*, but our interviews revealed that this species as well as other molluscs (*Donax* spp. and littorinids) are regularly collected for local consumption and occasionally on a commercial basis in the local touristic village (Juanchaco) outside the bay (Figure 1).

Based on grey literature and specialist observations, 39 species at risk of extinction in the area were identified (10 molluscs, seven crustaceans, 16 fishes, one sponge and five cnidarians). Apart from commercially important species that were identified in the previous analysis, other species were identified. Most of these species were captured accidentally in artisanal shrimp fisheries. Three mollusc species are caught accidentally (*Northia pristis*, *Conus patricius* and *Terebra robusta*). The majority of the fish were sharks and rays (i.e. *Carcharhinus* spp., *Dasyatis longa*, *Rhinobatos leucorhynchus* and *Sphyrna lewini*); however, bony fishes belonging to Sciaenidae were also identified within by-catch species at risk. Five crustaceans (Alpheidae) and one mollusc (*Phenacovolva brevirostris)* considered rare in the bay were identified. Some of these species have been collected only once and have restricted geographical ranges in the TEP (Table 3). At least five species of Cnidaria are threatened by sedimentation and destructive fishing practices (shrimp trawling). Finally, one species of Porifera has been identified as threatened due to disease that produces tissue loss and white discoloration. This was observed regularly during the surveys. A similar disease has been reported in the Caribbean (Wulff, 2007), but further investigation is needed to confirm the nature of this disease in the Colombian Pacific.

Threats

Residential and commercial development and transportation and service corridors

As the result of military and tourism development, key habitats have been lost. These habitats include rocky shores and subtidal rocky reefs adjacent to the tourism areas and the naval base (Figure 1). Moreover, since the mid-1980s when major developments (i.e. naval port construction) occurred in the bay, the adjacent intertidal and shallow-water areas have been affected by severe sedimentation, drastically affecting benthic populations, principally cnidarians (octocorals) and sponges (Cantera, 1991).

Logging and wood harvesting

Timber extraction from the mangrove forests and adjacent forest in the inner zones of the bay has taken place over the last 50 years. This activity is probably responsible for the reduction of mangrove forest complexity and abundances of certain species. However, estimated mangrove loss in the Colombian Pacific is relatively low, compared with the global trends (Zambrano-Escamilla and Rubiano-Rubiano, 1996).

Table 2. Invertebrate and fish species identified by local inhabitants and/or fisherman as currently suffering exploitation pressure. The main habitats occupied by the species, the harvesting method and comments on local people's perceived population trend are shown. A correlate with IUCN categories is derived from local perceptions

Group	Species	Collection method	Frequency of capture	Abundance and population trends	IUCN proposed category
Molluscs	*Grandiarca grandis*	Manual	Regularly	Declined	Vulnerable (VU)
	Anadara tuberculosa	Manual	Regularly	Declined	Vulnerable (VU)
	Anadara similis	Manual	Regularly	Declined	Vulnerable (VU)
	Iliochione subrugosa	Manual	Seasonally	Declined	Vulnerable (VU)
	Melongena patula	Manual, Artisanal Bottom trawling	Occasionally	No observed trend	Data deficient (DD)
	Pinctada mazatlanica	Underwater manual collection	Occasionally	No observed trend	Data deficient (DD)
	Strombus galeatus	Underwater manual collection	Occasionally	No observed trend	Data deficient (DD)
	Donax spp.	Manual	Seasonally	No observed trend	Data deficient (DD)
	Littoraria spp.	Manual	Occasionally	No observed trend	Data deficient (DD)
Crustaceans	*Litopenaeus occidentalis*	Gillnets and artisanal bottom trawling	Regularly	Highly declined	Vulnerable (VU)
	Litopenaeus vannamei	Gillnets and artisanal bottom trawling	Regularly	Highly declined	Vulnerable (VU)
	Cardisoma crassum	Manual	Occasionally	No observed trend	Least concern (LC)
	Callinectes spp.	Pelagic gillnets, artisanal bottom trawling	Regularly	No observed trend	Least concern (LC)
	Panulirus gracilis	Harpoons, spearguns	Occasionally	Declined	Data deficient (DD)
Fish	*Mugil* spp.	Gillnets	Regularly	Reduced mean size	Data deficient (DD)
	Lutjanus spp.	Gillnets, spearguns, harpoons	Regularly	No observed trend	Data deficient (DD)
	Centropomus nigrescens	Gillnets	Regularly	Reduced mean size	Data deficient (DD)
	Ephinephelus quinquefasciatus	Spearguns, harpoons	Seasonally	No observed trend	Critically endangered (CR)

Table 3. Threatened invertebrates and fish of Bahía Málaga based on grey literature and specialist observations. Threats are classified according to Salafsky *et al.* (2008)

Group	Species	IUCN category	Threat
Sponges	*Aplysina cauliformis*	DD	Invasive and other problematic species and genes (disease), climate change and severe weather
Cnidarians	*Leptogorgia alba*	VU	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors
	Pacifigorgia eximia	VU	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors
	Pacifigorgia agassizii	VU	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors
	Muricea spp.	VU	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors
	Pocillopora damicornis	VU	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors
Molluscs	*Grandiarca grandis*	VU A2d	Fishing and harvesting aquatic resources
	Anadara tuberculosa	VU A2d	Fishing and harvesting aquatic resources
	Anadara similis	VU A2d	Fishing and harvesting aquatic resources
	Iliochione subrugosa	DD	Fishing and harvesting aquatic resources
	Pinctada mazatlanica	DD	Fishing and harvesting aquatic resources
	Strombus galeatus	DD	Fishing and harvesting aquatic resources
	Northia pristis	DD	Fishing and harvesting aquatic resources (bycatch)
	Conus patricius	DD	Fishing and harvesting aquatic resources (bycatch)
	Terebra robusta	DD	Fishing and harvesting aquatic resources (bycatch)
	Phenacovolva brevirostris	DD	Residential and commercial development (military bases), transportation and service corridors
Crustaceans	*Litopenaeus occidentalis*	VU A4cde	Fishing and harvesting aquatic resources
	Litopenaeus vannamei	VU A4cde	Fishing and harvesting aquatic resources
	*Pilumnus nobili**	DD	Restricted geographic range (Prahl, 1982)
	*Pinnotheres malaguena***	DD	Restricted geographic range (Garth, 1948)
	*Alpheus colombiensis***	DD	Restricted geographic range (Wicksten, 1988)
	*Alpheus wickstenae***	DD	Restricted geographic range (Christoffersen and Ramos, 1987)
	*Synalpheus arostris***	DD	Restricted geographic range (Wicksten, 1989)
Fish	*Carcharhinus limbatus*	NT	Fishing and harvesting aquatic resources
	Carcharhinus porosus	DD	Fishing and harvesting aquatic resources
	Galeocerdo cuvier	NT	Fishing and harvesting aquatic resources
	Pristis pristis	CR A2a	Fishing and harvesting aquatic resources
	Aetobatus narinari	NT	Fishing and harvesting aquatic resources
	Dasyatis longa	DD	Fishing and harvesting aquatic resources
	Rhinobatos leucorhynchus	NT	Fishing and harvesting aquatic resources (bycatch)
	Manta birostris	NT	Fishing and harvesting aquatic resources
	Sphyrna lewini	EN A4bd	Fishing and harvesting aquatic resources
	Hippocampus ingens	VU A2ad	Fishing and harvesting aquatic resources, residential and commercial development (military bases), transportation and service corridors
	Epinephelus quinquefasciatus	VU A2a	Fishing and harvesting aquatic resources
	Larimus spp.	DD	Fishing and harvesting aquatic resources (bycatch)
	Ophioscion spp.	DD	Fishing and harvesting aquatic resources (bycatch)
	Paralonchurus spp.	DD	Fishing and harvesting aquatic resources (bycatch)
	Stellifer spp.	DD	Fishing and harvesting aquatic resources (bycatch)
	Urotrygon rogersi	DD	Fishing and harvesting aquatic resources (bycatch)

* This species is only known from a few localities in the tropical eastern Pacific.
**These species are considered to be endemics of Bahía Málaga.

Climate change and severe weather

Specific coastal zones of the bay experience continuous terrigenous sediment deposition, transported by freshwater run-off or by currents originating in the northern part of the bay (San Juan Delta; Restrepo and Kjerfve, 2002). Sediments are deposited or removed by spring tides and are also transported when heavy rains occur (annual rainfall can reach up to 8 m). In some areas, the amount of sediments deposited has increased in recent years as a consequence of deforestation in river basins.

Fishing and harvesting aquatic resources

Four major fisheries occur in the area. Manual collection of molluscs from mudflats, sandy beaches, and mangroves, with four main species being exploited (*Anadara tuberculosa, A. similis, Grandiarca grandis* and *Iliochione subrugosa*). These activities take place mainly in the inner bay, where mangrove forests are widely distributed.

The second major fishery is based on shrimp species (*Farfantepenaeus brevirostris, Litopenaeus occidentalis, L. vannamei, Rimapenaeus byrdi* and *Xiphopenaeus kroyeri*). The gear used in this fishery is a 'mini-trawling shi-device' called 'changa' comprising a small boat with two nets *c.* 2 m long on each side of the boat. This gear is extremely invasive, disturbing the substrate and capturing a variety of non-target species (by-catch) ranging from epifaunal, benthic and pelagic invertebrates to small fishes. These species are usually not retained for consumption and discarded in poor condition or dead to the sea. By-catch marine invertebrates include sea stars (*Luidia* spp. and *Astropecten* spp.), molluscs

(*Melongena patula*, *Northia pristis, Conus patricius* and *Terebra robusta*), crustaceans (*Hepatus kossmanni, Callinectes* spp. and *Squilla* spp.), and cnidarians.

By-catch fish are dominated by drums or croakers (Sciaenidae). Other families commonly captured are Ariidae (*Notarius planiceps, N. troschelli* and *Arius* spp.), Batrachoididae (*Batrachoides pacifici* and *Porichthys* spp.), and Engraulidae (*Anchovia macrolepidota* and *Anchoa* spp.). Cartilaginous fishes are also captured and are represented by different species of sharks and rays. Tongue fishes (Cynoglossidae), large-tooth flounders (Paralichthydae), and American soles (Achiridae) are also important by-catch components in this fishery. In most cases, all these species are caught before they have reached maturity.

A third fishery uses monofilament nylon nets often with mesh size <2 inches. To-date the effect that these artisanal fisheries have on local resources is unknown. Fishermen's perceptions revealed a decline in the capture-per-unit-effort (CPUE), and some species have not been captured in the zone for the past 20 years (i.e. sawfish *Pristis pristis*). Fishermen agreed that catches of previously important and abundant species are now less abundant (i.e. snappers – Lutjanidae, snooks –Centropomidae, and catfish – Ariidae). A common view of fishermen is that the fishery is today principally based on mullet (Mugilidae). Interviews indicate that previously other species were frequently captured along with mullet. It is not known if this current tendency reveals a possible change in composition of the fish community, or if it is simply the result of the selectivity of the fishing gear.

A recreational speargun fishery was identified in the outer zones of the bay (Los Negritos, Figure 1) and in certain rocky areas where it is possible to use scuba or snorkeling gears. During surveys in the last 4 years, an increasing group of local fishermen were observed to exploit these resources. Target species include the Pacific goliath grouper, *Epinephelus quinquefasciatus,* which is considered to be critically endangered by the IUCN. There is also strong pressure on large snappers. Besides fish, in these areas there are populations of the Cortez conch (*Strombus galeatus*) and the pearl oyster (*Pinctada mazatlanica*), which are also collected by divers.

Blast fishing in the area has been practised for at least 30 years (J.R.C.K, personal observation). This illegal activity takes place near rock banks inside and outside the bay. Despite it being considered rare in recent times, the use of dynamite by fishermen in a rocky bank in the inner part of the bay occurred during one field trip in 2009.

DISCUSSION

The IUCN Red Lists are one of the most reliable and useful tools in the study of endangered species and conservation planning (Hoffmann *et al*., 2008). However, additional rapid methods to identify threatened species need to be developed. It is also imperative that IUCN Red Lists and other methods incorporate non-charismatic organisms, increasing the taxonomic coverage of such classifications. A major constraint of regional and local listings was that the original target of the IUCN Red List system was an assessment at the global level of entire species, subspecies, or other taxonomic units below the level of species (Mace *et al*., 2008). To overcome this problem, a series of discussions led to new guidelines aimed at synchronizing regional and global assessments (Gärdenfors *et al*., 1999; Gärdenfors, 2001; Miller *et al*., 2006, 2007). This process presents a major challenge, in which IUCN global assessors must assist the increasing number of people at the national level willing to use IUCN criteria. Only in this manner will it be possible to integrate and synchronize both assessment processes (Rodríguez, 2008).

In the TEP few studies have tried to identify threatened marine species. The few known threatened species correspond to widely distributed and charismatic species (i.e. mammals, turtles, and birds). The tectonic estuary of Bahía Málaga harbours a number of representative marine habitats and species within the Colombian Pacific and the whole TEP region. Mangrove habitats within the region have recently been identified as of particular concern due to the high proportion of threatened mangrove species (Polidoro *et al*., 2010). If habitat degradation continues, many of the mangrove-associated species will face the same threat of extinction. Most of the endangered species identified in the present study are distributed throughout the whole region, with very few endemic species (see Table 4). This may be considered as a signal of low risk at the global level. However, there is evidence that the same species are experiencing the same threats and reductions at different localities within the region (Sáenz-Arroyo *et al*., 2005a; Cipriani *et al*., 2008). Ultimately, global extinctions may result from the accumulation of local extinctions within the geographical range of a species. This picture may be similar to other areas of the world where little is known about local resource exploitation and habitat degradation.

Strombus galeatus and *Pinctada mazatlanica* populations have suffered dramatic depletions over the past centuries in Mexico, Costa Rica and Panama (Arroyo-Mora and Mena, 1998; Sáenz-Arroyo *et al*., 2005a; Cipriani *et al*., 2008), with their current populations facing a serious risk of extinction. Both species are exploited in Mexico by divers in shallow water areas in the same way that they are harvested in Bahía Málaga. Similarly, *Anadara* spp. populations have been seriously over-harvested in various areas from Mexico to Peru (MacKenzie, 2001). Some reports draw attention to the drastic reduction of *Anadara tuberculosa* and *Anadara similis* populations on the Pacific coast of Colombia. For example, near the border with Ecuador, populations of *A. tuberculosa* have been seriously affected by overexploitation (Borda and Cruz, 2004). Few reports in the past have expressed concern for *Grandiarca grandis* populations. Observations in Bahía Málaga suggest that this species has been subjected to strong exploitation pressure in the past with several sites identified where there were considerable accumulations of empty shells that had built up over time. Both *G. grandis* and *Anadara* spp. typically have low growth rates (Rodriguez, 1985). The demand for these resources in Ecuador has dramatically increased the pressure on them in the southern part of Colombia. Other species, not included in the national Red Lists that are an important part of the local economies and are exploited for human consumption with no regulations in the area were identified. These species include the molluscs *A. similis*, *Illiochione subrugosa*, *Melongena patula*, *Pinctada mazatlanica* and *Strombus galeatus*, and the crustaceans *Callinectes* spp., *Cardisoma crassum* and *Panulirus gracilis*.

The driving forces that could increase fishing pressure and the use of damaging fishing gears in Bahía Málaga are associated with the increase of human population and tourism activities. This may cause a higher pressure to supply the local

Table 4. Consolidated list of threatened fish and invertebrates in Bahía Málaga, Colombia, tropical eastern Pacific

Group	Species	IUCN established or proposed category	Habitat	Threat	Determination criteria
Sponges	*Aplysina cauliformis*	DD	Subtidal hard bottoms	Invasive and other problematic species and genes (disease), climate change and severe weather	Specialists observations
Cnidarians	*Leptogorgia alba*	VU (A4ac)	Subtidal hard bottoms	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors	Specialist observations
	Pacifigorgia eximia	VU (A4ac)	Subtidal hard bottoms	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors	Specialist observations
	Pacifigorgia agassizii	VU (A4ac)	Hard subtidal bottoms	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors	Specialist observations
	Muricea spp.	VU (A4ac)	Hard subtidal bottoms	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors	Specialist observations
	Pocillopora damicornis	VU (D2)	Hard subtidal bottoms	Residential and commercial development (military bases), climate change and severe weather, transportation and service corridors	Specialist observations
Molluscs	*Grandiarca grandis*	VU (A2d)	Mudflats	Fishing and harvesting aquatic resources	IUCN lists, TEK, literature and specialist observations
	Anadara tuberculosa	VU (A2d)	Mangroves	Fishing and harvesting aquatic resources	IUCN lists, TEK, literature and specialist observations
	Anadara similis	VU (A2d)	Mangroves	Fishing and harvesting aquatic resources	TEK, literature and specialist observations
	Pinctada mazatlanica	VU	Hard subtidal bottoms	Fishing and harvesting aquatic resources	TEK, literature and specialist observations
	Strombus galeatus	VU	Intertidal and subtidal soft bottoms	Fishing and harvesting aquatic resources	TEK, literature and specialist observations
	Iliochione subrugosa	DD	Mudflats	Fishing and harvesting aquatic resources	TEK, literature and specialist observations
	Northia pristis	DD	Soft-bottoms	Fishing and harvesting aquatic resources (bycatch)	Specialist observations
	Conus patricius	DD	Soft-bottoms	Fishing and harvesting aquatic resources (bycatch)	Specialist observations
	Terebra robusta	DD	Soft-bottoms	Fishing and harvesting aquatic resources (bycatch)	Specialist observations
	Phenacovolva brevirostris	DD	Octocorals	Habitat destruction	Specialist observations
Crustaceans	*Alpheus colombiensis*	DD	Rocky-bottoms octocorals	Restricted geographic range	Grey literature, specialist observations
	Alpheus wickstenae	DD	Rocky-bottoms octocorals	Restricted geographic range	Grey literature, specialist observations
	Callinectes spp.	LC	Estuary, mangrove creeks	Fishing and harvesting aquatic resources (bycatch)	TEK, specialist observations
	Cardisoma crassum	VU (A4d)	Mangroves, mudflats	Fishing and harvesting aquatic resources	TEK, specialist observations
	Litopenaeus occidentalis	VU (A4cde)	Sand-bottoms	Fishing and harvesting aquatic resources	IUCN list, TEK
	Litopenaeus vannamei	VU (A4cde)	Sand-bottoms	Fishing and harvesting aquatic resources	IUCN list, TEK
	Panulirus gracilis	DD	Rocky reefs, crevices	Fishing and harvesting aquatic resources	TEK, specialist observations
	Pilumnus nobili	DD	Rocky-bottoms octocorals	Restricted geographic range	Grey literature, specialist observations
	Pinnotheres malaguena	DD	Rocky-bottoms octocorals	Restricted geographic range	Grey literature, specialist observations
	Synalpheus arostris	DD	Rocky-bottoms octocorals	Restricted geographic range	Grey literature, specialist observations
Fish	*Aetobatus narinari*	NT	Pelagic	Fishing and harvesting aquatic resources	IUCN red list
	Carcharhinus limbatus	NT	Pelagic	Fishing and harvesting aquatic resources	IUCN list, specialist observations
	Carcharhinus porosus	DD	Pelagic	Fishing and harvesting aquatic resources	IUCN list, specialist observations
	Centropomus nigrescens	DD	Estuary, mangrove creeks	Fishing and harvesting aquatic resources	TEK

Cetengraulis mysticetus	LC	Pelagic	Fishing and harvesting aquatic resources	IUCN list, specialist observations
Dasyatis longa	DD	Benthic	Fishing and harvesting aquatic resources	IUCN red list
Epinephelus quinquefasciatus	VU (A2a)	Benthic	Fishing and harvesting aquatic resources (spear gun fishing)	IUCN lists, specialist observations
Galeocerdo cuvier	NT	Pelagic	Fishing and harvesting aquatic resources	IUCN list
Hippocampus ingens	VU (A2ad)	Benthic	Fishing and harvesting aquatic resources, residential and commercial development (military bases), transportation and service corridors	IUCN lists
Larimus spp.	DD	Benthic, soft bottoms	Fishing and harvesting aquatic resources (bycatch)	Specialists observations
Lutjanus spp.	DD	Rocky reefs, estuary	Fishing and harvesting aquatic resources (blast fishing)	TEK, specialist observations
Mugil spp.	LC	Pelagic	Fishing and harvesting aquatic resources	TEK, specialist observations
Manta birostris	NT	Pelagic	Fishing and harvesting aquatic resources	IUCN red list
Ophioscion spp.	DD	Benthic, soft bottoms	Fishing and harvesting aquatic resources (bycatch)	Specialist observations
Paralonchurus spp.	DD	Benthic, soft bottoms	Fishing and harvesting aquatic resources (bycatch)	Specialist observations
Pristis pristis	CR (A2abc+3cd)	Benthic	Fishing and harvesting aquatic resources	IUCN list, TEK, specialist observations
Rhinobatos leucorhynchus	NT	Benthic	Fishing and harvesting aquatic resources (bycatch)	IUCN red list
Sphyrna lewini	EN A4bd	Pelagic	Fishing and harvesting aquatic resources	IUCN red list
Stellifer spp.	DD	Benthic, soft bottoms	Fishing and harvesting aquatic resources (bycatch)	Specialist observations
Urotrygon rogersi	DD	Benthic, soft bottoms	Fishing and harvesting aquatic resources (bycatch)	IUCN red list, specialist observations

markets and the demand for animal protein locally. Fish catches in Bahía Málaga are mainly marketed locally with part of the catches being sent to the main port on the Colombian Pacific (Buenaventura). No international markets exist for fishing products harvested in the area yet. However, some products, such as mangrove cockles, can be marketed in Ecuador, as they command substantially higher prices there.

The most common genera of croakers and drums caught as by-catch in Bahía Málaga are *Larimus*, *Paralonchurus*, *Ophioscion* and *Stellifer*. Although these species do not reach large sizes (<45 cm; Fischer *et al*., 1995), they are important protein sources for local communities in the Colombian Pacific and they are commonly found in local markets. The massive discard of juveniles by the commercial and artisanal trawling fisheries can lead to population depletions of these species, which are mostly endemic to the eastern Pacific region. Unfortunately, no data on population trends and/or biology exist for these species. Therefore, we have categorized this group of species as data deficient in Bahía Málaga and recommend further monitoring in order to assess the state of these populations.

Probability of local extinction tends to be higher in species with restricted geographical ranges, yet the simple measure of a species' geographical range may not be sufficient to determine its vulnerability to extinction. A group of endemic species have been reported for Bahía Málaga (see Table 3). These species, although rare, may have wider geographic ranges if appropriate sampling effort is put into adjacent areas of the region, and may be threatened by habitat destruction, caused by sedimentation and pollution. Rarity is a possible criterion to establish the vulnerability of some species, mainly in areas such as Bahía Málaga, which has variable climatic cycles and strong sedimentation processes. Very small populations may be susceptible to demographic stochasticity.

Three species may have disappeared from Bahía Málaga in recent years: the sawfish *Pristis pristis* and the corals *Pocillopora damicornis* and *Pocillopora capitata*. *Pristis pristis* is extremely vulnerable to by-catch in virtually all fisheries throughout its Atlantic and Eastern Pacific range. The remaining populations are critically endangered in the whole region. In Bahía Málaga it has not been caught in the last 20 years. Pieces of *Pocillopora* spp. accumulated as debris are found around rocky areas in the inner part of the bay; this may be indicative of an ancient presence of this species in the area. A single report of live colonies of one of these species was made in the 1990s in the outer part of the bay (Escobar and Neira, 1992). Small colonies have been found in several rocky areas outside the bay, but not in the inner part. Increasing sedimentation from the adjacent San Juan Delta and from the dredging activities associated with the port at Buenaventura are the most important threats for *Pocillopora* species in Bahía Málaga. Other threats known to affect coral reefs along the Pacific coast of Colombia such as ENSO, and periodic exposure to air during extreme low tides, do not affect corals in Bahía Málaga. Human threats, such as tourism and domestic pollution, although present, do not affect the areas were coral colonies are found.

Despite the limited biological information about most marine populations in the area, it is necessary to design strategies that allow species extinction risk assessments. Together with other biological and socio-economic considerations, these assessments are the best way to assign conservation priorities to species

(Miller *et al*., 2006; 2007). In this context, the present effort is one of many useful approaches to be implemented in areas where habitat destruction and marine resource exploitation are increasing rapidly and conservation resources need to be efficiently targeted. The use of TEK plays a fundamental role in assessing the extinction vulnerability of species in these areas. This knowledge is also extremely useful to detect 'shifting baselines' syndromes (Sáenz-Arroyo *et al*., 2005b), which may prevent accurate species extinction risk assessments. Nevertheless, the interpretation of TEK must be accompanied, when possible, by biological studies (Silvano and Begossi, 2010), or by verification of specialists in the field (Huntington, 2000). The present analysis sets a baseline for further biological studies with more quantitative approaches that could reinforce the findings for the species identified as threatened within this estuary. The increase of human activities in the area in the future is likely to affect environment conditions and will probably accelerate habitat loss, pollution, and increase the pressure on the marine species currently exploited. The creation of this regional red list may stimulate more biological data collection in Bahía Málaga to fully understand the population trends of the species identified as threatened and will further encourage the generation of new regional red lists elsewhere in the tropical eastern Pacific region.

ACKNOWLEDGEMENTS

This work is a result of the research projects 'Biodiversidad de Estadíos de Vida Vulnerable de organismos marinos de Bahía Málaga (Pacífico colombiano) como criterio de conservación: Evaluación de la heterogeneidad de ambientes en la reproducción y reclutamiento (No. 1106-405-20155)' and 'Valoración de la biodiversidad marina y costera de Bahía Málaga (Valle del Cauca, Pacífico colombiano): uno de los insumos para respaldar su declaratoria como área protegida' (No. 210509-16821), funded by Colciencias, and conducted in cooperation with Invemar, Universidad del Valle and Inciva. The Rufford Small Grants Foundation and the Conservation Leadership Programme (CLP) have supported GA Castellanos-Galindo's work in Bahía Málaga. The authors give special thanks to J. Lazarus, L.Á. López de Mesa, R. Neira and G. Bolívar for help in the identification of organisms and suggestions for processing the data, as well as, the BIOMÁLAGA team for their support during sampling activities. The authors would also like to thank P.A. Silverstone-Sopkin for English proof-reading. Comments by Nick Dulvy, John Baxter and two anonymous reviewers on early versions of the manuscript are strongly appreciated.

REFERENCES

Appeldoorn RS. 2008. Transforming reef fisheries management: application of an ecosystem-based approach in the USA Caribbean. *Environmental Conservation* **35**: 232–241.

Ardila N, Navas G, Reyes J. 2002. *Libro rojo de invertebrados marinos de Colombia. INVEMAR. Ministerio de Medio Ambiente*. La serie de Libros Rojos de Especies Amenazadas de Colombia. Bogotá, Colombia.

Arroyo-Mora D, Mena L. 1998. Estructura de la población del cambute *Strombus galeatus* (Gastropoda: Strombidae) en Cabo Blanco, Costa Rica. *Revista de Biología Tropical* **46**: 37–46.

Baillie JEM, Hilton-Taylor C, Stuart SN. 2004. *A Global Species Assessment*. IUCN: Gland, Switzerland and Cambridge, UK.

Baum J, Clarke S, Domingo A, Ducrocq M, Lamónaca AF, Gaibor N, Graham R, Jorgensen S, Kotas JE, Medina E, *et al*. 2007. *Sphyrna lewini* (Eastern Central and Southeast Pacific subpopulation). In *IUCN Red List of Threatened Species*. Version 2009.2. Available from http://www.iucnredlist.org (accessed November 2009).

Bizzarro JJ. 2005. *Rhinobatos leucorhynchus*. In *2006 IUCN Red List of Threatened Species*. Available from http://www.iucnredlist.org (accessed February 2007).

Borda C, Cruz R. 2004. Reproducción y reclutamiento del molusco *Anadara tuberculosa* (SOWERBY, 1833) en el Pacífico colombiano. *Revista de Investigaciones Marinas* **25**: 185–195.

Burgess HG, Branstetter S. 2005. *Carcharhinus limbatus*. In *IUCN Red List of Threatened Species*. Version 2009.2. Available from http://www.iucnredlist.org (accessed November 2009).

Cantera JR. 1991. Etude structurale des mangroves et des peuplements littoraux des deux baies du pacifique colombien (Málaga et Buenaventura). Rapport avec les conditions du milieu et les perturbations anthropiques. These d'Etat Sciences. Université d'Aix-Marseille II. Marseille France.

Cantera J, Neira R. 1998. Notas ecológicas y taxonómicas de los equinodermos de Bahía Málaga, costa pacífica colombiana. Memorias VI Seminario Nacional de Ciencias del Mar; 121–129.

Carlton J, Geller G, Reaka-Kudla M, Norse E. 1999. Historical extinctions in the sea. *Annual Review of Ecology and Systematics* **30**: 525–538.

Castellanos-Galindo GA, Caicedo-Pantoja JA, Mejía-Ladino LM, Rubio E. 2006. Peces marinos y estuarinos de Bahía Málaga, Valle del Cauca, Pacífico colombiano. *Biota Colombiana* **7**: 263–268.

Cenipacifico. 1986. Impacto Ecológico en Bahía Málaga a raíz de los desarrollos de la Base Naval del Pacífico y carretera de acceso. Technical report, 7 Volumes, Cali, Colombia.

Chan Tak-Chuen T, Padovani Ferrera B. 2006. *Epinephelus itajara*. In *2006 IUCN Red List of Threatened Species*. Available from http://www.iucnredlist.org (accessed February 2007).

Christoffersen M, Ramos M. 1987. A new snapping shrimp (Caridea: Alpheidae) from the Pacific coast of Colombia. *Revista de Biología Tropical* **35**: 333–338.

Cipriani R, Guzman HM, Vega AJ, Lopez M. 2008. Population assessment of the conch *Strombus galeatus* (Gastropoda, Strombidae) in Pacific Panama. *Journal of Shellfish Research* **27**: 889–896.

Cook SF, Compagno LJV. 2005. *Pristis pristis*. In *IUCN Red List of Threatened Species*. Version 2009.2. Available from http://www.iucnredlist.org (accessed November 2009).

Craig MT, Graham RT, Torres RA, Hyde JR, Freitas MO, Ferreira BP, Hostim-Silva M, Gerhardinger LC, Bertoncini AA, Robertson DR. 2009. How many species of goliath grouper are there? Cryptic genetic divergence in a threatened marine fish and the resurrection of a geopolitical species. *Endangered Species Research* **7**: 167–174.

de Grammont PC, Cuaron AD. 2006. An evaluation of threatened species categorization systems used on the American continent. *Conservation Biology* **20**: 14–27.

Del Monte-Luna P, Lluch-Belda D, Serviere-Zaragoza E, Carmona R, Reyes-Bonilla H, Aurioles-Gamboa D, Castro-Aguirre JL, Guzmán del Próo SA, Trujillo-Millán O, Brook BW. 2007. Marine extinctions revisited. *Fish and Fisheries* **8**: 107–122.

Drews JA. 2005. Use of traditional ecological knowledge in marine conservation. *Conservation Biology* **19**: 1286–1293.
Dulvy N, Sadovy Y, Reynolds J. 2003. Extinction vulnerability in marine populations. *Fish and Fisheries* **4**: 25–64.
Dulvy N, Ellis J, Goodwin N, Grant A, Reynolds J, Jennings S. 2004. Methods of assessing extinction risk in marine fishes. *Fish and Fisheries* **5**: 255–276.
Escallón S, Cantera J. 1989. Moluscos marinos de Bahía Málaga, costa Pacífica colombiana. I. Pelecypoda. *Boletín Científico de la Universidad de la Salle* **3**: 159–178.
Escobar JE, Neira R. 1992. Primer registro de un coral hermatípico (*Pocillopora capitata* Verrill, 1864) y su fauna asociada en el área de Bahía Málaga, Pacífico colombiano. Memorias Congreso Centroamericano y del Caribe de Ciencias del Mar y VIII Seminario Nacional de Ciencias y Tecnologías del Mar; 370–376.
Eslava J. 1992. La precipitación en la región del Pacífico colombiano (Lloró el sitio más lluvioso del mundo). *Revista Zenit* **3**: 47–71.
Faber-Langendoen D, Gentry A. 1991. The structure and diversity of rain forests at Bajo Calima, Chocó region, western Colombia. *Biotropica* **23**: 2–11.
Fischer W, Krupp F, Schneider W, Sommer C, Carpenter KE, Niem VH. 1995. Guía FAO para la identificación de especies para los fines de la pesca. Pacífico centro-oriental. Volumen II. Vertebrado. FAO, Rome.
Garth J. 1948. The Brachyura of the Askoy Expedition with remarks on carcinological collecting in the Panama Bight. *Bulletin of the American Museum of Natural History* **92**: 1–66.
Gärdenfors U. 2001. Classifying threatened species at national versus global levels. *Trends in Ecology and Evolution* **16**: 511–516.
Gärdenfors U, Rodríguez JP, Hilton-Taylor C, Hyslop C, Mace GM, Molur S, Poss S. 1999. Draft guidelines for the application of IUCN Red List criteria at regional and national levels. *Species* **31/32**: 58–70.
Gärdenfors U, Hilton-Taylor C, Mace GM, Rodríguez JP. 2001. The application of IUCN Red List criteria at regional levels. *Conservation Biology* **15**: 1206–1212.
Hilton-Taylor C. 2000. *IUCN Red List of Threatened Species*. International Union for the Conservation of Nature: Gland, Switzerland.
Hoffmann M, Brooks TM, da Fonseca GAB, Gascon C, Hawkins AFA, James RE, Langhammer P, Mittermeier RA, Pilgrim JD, Rodrigues ASL, Silva JMC. 2008. Conservation planning and the IUCN Red List. *Endangered Species Research* **6**: 113–125.
Huntington HP. 2000. Using traditional ecological knowledge in science: methods and applications. *Ecological Applications* **10**: 1270–1274.
Hutchings JA. 2001. Conservation biology of marine fishes: perceptions and caveats regarding assignment of extinction risk. *Canadian Journal of Fisheries and Aquatic Science* **58**: 108–121.
INVEMAR, UNIVALLE, INCIVA. 2006. BIOMÁLAGA: Valoración de la biodiversidad marina y costera de Bahía Málaga (Valle del Cauca), como uno de los instrumentos necesarios para que sea considerada un área protegida. Cali, Colombia. Technical report. INVEMAR-UNIVALLE-INCIVA, Cali, Colombia.
IUCN. 2003. *Guidelines for Application of IUCN Red List Criteria at Regional Levels*: *Version 3.0*. IUCN, Gland, Switzerland, and Cambridge, UK.
IUCN. 2006. *Red List of Threatened Species*. Available from www.iucnredlist.org (accessed May 2006).
Jackson JBC, Kirby MX, Berger WH, Bjorndal KA, Botsford LW, Bourque BJ, Bradbury RH, Cooke R, Erlandson J, Estes JA, *et al*. 2001. Historical overfishing and the recent collapse of coastal ecosystems. *Science* **293**: 629–638.
Johannes R. 1998. The case for data-less marine resource management: examples from tropical nearshore finfisheries. *Trends in Ecology and Evolution* **13**: 243–246.
Johannes RE, Freeman MMR, Hamilton RJ. 2000. Ignore fisher's knowledge and miss the boat. *Fish and Fisheries* **1**: 257–271.
Kyne PM, Ishihara H, Dudley SFJ, White WT. 2005. *Aetobatus narinari*. In *2006 IUCN Red List of Threatened Species*. Available from http://www.iucnredlist.org (accessed February 2007).
Lessa R, Almeida Z, Santana FM, Siu S, Perez M. 2005. *Carcharhinus porosus*. In *2006 IUCN Red List of Threatened Species*. Available from http://www.iucnredlist.org (accessed February 2007).
Mace GM, Collar NJ, Gaston KJ, Hilton-Taylor C, Akçakaya HR, Leader-Williams N, Milner-Gulland EJ, Stuart SN. 2008. Quantification of extinction risk: IUCN's system for classifying threatened species. *Conservation Biology* **22**: 1424–1442.
MacKenzie C. 2001. The fisheries for mangrove cockles, *Anadara* spp., from Mexico to Peru, with descriptions of their habitats and biology. The Fishermen's lives and the effects of shrimp farming. *Marine Fisheries Review* **63**: 1–40.
Marshall A, Ishihara H, Dudley SFJ, Clark TB, Jorgensen S, Smith WD, Bizzarro JJ. 2006. *Manta birostris*. In *2006 IUCN Red List of Threatened Species*. Available from http://www.iucnredlist.org (accessed February 2007).
Mejía L, Acero A. 2002. Libro rojo de peces marinos de Colombia. INVEMAR. Instituto de Ciencias Naturales-Universidad Nacional de Colombia and Ministerio del Medio Ambiente. La serie Libros Rojos de Especies Amenazadas de Colombia. Bogotá, Colombia.
Miller RM, Rodríguez JP, Aniskowicz-Fowler T, Bambaradeniya C, Boles R, Eaton MA, Gärdenfors U, Keller V, Molur S, Walker S, Pollock C. 2006. Extinction risk and conservation priorities. *Science* **313**: 441.
Miller RM, Rodríguez JP, Aniskowicz-Fowler T, Bambaradeniya C, Boles R, Eaton MA, Gärdenfors U, Keller V, Molur S, Walker S, Pollock C. 2007. National threatened species listing based on IUCN criteria and regional guidelines: current status and future perspectives. *Conservation Biology* **21**: 684–696.
Polidoro BA, Carpenter KE, Collins L, Duke NC, Ellison AM, Farnsworth EJ, Fernando ES, Kalthiresan K, Koedam NE, Livingstone SR, *et al*. 2010. The loss of species: mangrove extinction risk and geographic areas of global concern. *PLoS ONE* **5**: e10095. doi:10.1371/journal.pone.0010095.
Prahl H. von. 1982. Cangrejos xántidos asociados a formaciones rocosas en la zona sur el Pacífico colombiano. *Cespedesia* **11**(41–42): 69–82.
Project Seahorse. 2003. *Hippocampus ingens*. In *2006 IUCN Red List of Threatened Species*. Available from http://www.iucnredlist.org (accessed February 2007).
Rabb G, Lacy R. 1990. Endangered species biology. *Science* **249**: 612.
Restrepo J, Kjerfve B. 2002. The San Juan Delta, Colombia: tides, circulation, and salt dispersion. *Continental Shelf Research* **22**: 1249–1267.
Reynolds JD. 2003. Life histories and extinction risk. In *Macroecology*, Gaston KJ, Blackburn TJ (eds). Blackwell Publishing: Oxford; 195–217.
Rodríguez A, Pilgrim J, Lamoreux J, Hoffmann M, Brooks T. 2006. The value of the IUCN red list for conservation. *Trends in Ecology and Evolution* **21**: 71–76.

Rodriguez F. 1985. Taxonomía, crecimiento y mercadeo de la piangua *Anadara tuberculosa* y *A. similis* en el Pacífico colombiano. Informe Final de Investigación, Proyecto Maricultura Colombia, C.I.I.D.

Rodríguez JP. 2008. National Red Lists: the largest global market for IUCN Red List categories and criteria. *Endangered Species Research* **6**: 193–198.

Sáenz-Arroyo A, Roberts C, Torre J, Cariño-Olvera M. 2005a. Using fishers' anecdotes, naturalists' observations and grey literature to reassess marine species at risk: the case of the Gulf grouper in the Gulf of California, Mexico. *Fish and Fisheries* **6**: 121–133.

Sáenz-Arroyo A, Roberts CM, Torre J, Carino-Olvera M, Enriquez-Andrade RR. 2005b. Rapidly shifting environmental baselines among fishers of the Gulf of California. *Proceedings of the Royal Society of London B* **272**: 1957–1962.

Salafsky N, Salzer D, Stattersfield AJ, Hilton-Taylor C, Neugarten R, Butchart SHM, Collen B, Cox N, Master LL, O'Connor S, Wilkie D. 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. *Conservation Biology* **22**: 897–911.

Silvano RAM, Begossi A. 2010. What can be learned from fishers? An integrated survey of fishers' local ecological knowledge and bluefish (*Pomatomus saltatrix*) biology on the Brazilian coast. *Hydrobiologia* **637**: 3–18.

Simpfendorfer C. 2005. *Galeocerdo cuvier*. In *IUCN Red List of Threatened Species*. Version 2009.2. Available from http://www.iucnredlist.org (accessed November 2009).

Smith WD. 2005. *Dasyatis longa*. In *2006 IUCN Red List of Threatened Species*. Available from http://www.iucnredlist.org (accessed February 2007).

Valenti SV. 2008. *Urotrygon rogersi*. In *IUCN Red List of Threatened Species*. Version 2009.2. Available from http://www.iucnredlist.org (accessed November 2009).

Walters J. 1991. Application of ecological principles to the management of endangered species: the case of the red-cockaded Woodpecker. *Annual Review of Ecology and Systematics* **22**: 505–523.

Wicksten M. 1988. A new species of snapping shrimp from the Pacific coast of Colombia (Decapoda: Caridea: Alpheidae). *Crustaceana* **54**: 1–4.

Wicksten M. 1989. *Synalpheus arostris* and *Philocheras lapillus*, two new species of caridean shrimp (Crustacea) from the Tropical Eastern Pacific. *Proceedings of the Biological Society of Washington* **102**: 78–83.

Wolff D. 2000. Causes of extirpations in the Wadden Sea, an Estuarine Area in the Netherlands. *Conservation Biology* **14**: 876–885.

Wulff JL. 2007. Disease prevalence and population density over time in three common Caribbean coral reef sponge species. *Journal of the Marine Biological Association of the United Kingdom* **87**: 1715–1720.

Zambrano-Escamilla CH, Rubiano-Rubiano DJ. 1996. Mapas del bosque de manglar de la costa pacífica colombiana años 1969, 1996 y multitemporal. Ministerio del Medio Ambiente, Bogotá, Colombia.

