Received: 25 June 2016 | Revised: 30 October 2016 | Accepted: 8 November 2016
DOI 10.1002/aqc.2744

WILEY

RESEARCH ARTICLE

The status of marine biodiversity in the Eastern Central Atlantic (West and Central Africa)

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Abstract

1. The status of marine biodiversity in the Eastern Central Atlantic (ECA), especially of coastal and pelagic fishes, is of concern owing to a number of threats including overharvesting, habitat loss, pollution, and climate change combined with inadequate policy responses, legislation, and enforcement.
2. This study provides the first comprehensive documentation of the presence, status, and level of extinction risk, based on IUCN Red List assessment methodology, for more than 1800 marine species, including all taxonomically described marine vertebrates (marine mammals, sea turtles, seabirds, fishes); complete clades of selected marine invertebrates (sea cucumbers, cone snails, cephalopods, lobsters, reef-building corals); and marine plants (mangroves, seagrasses).
3. Approximately 8% of all marine species assessed in the ECA are in threatened categories, while 4% are listed as Near Threatened, 73% are Least Concern, and 15% are Data Deficient. Fisheries and overharvesting are the biggest threats to living marine resources in the ECA, with 87% of threatened species across all taxonomic groups affected by both large- and small-scale targeted fisheries, excessive capture as by-catch, or unsustainable harvest.
4. The results of this study will transform the current state of knowledge and increase capacity for regional stakeholders to identify and enact marine conservation and research priorities, as a number of species are identified as having high conservation and/or research priorities in the region.
5. Through the process of marine species data collection and risk assessments conducted over the past 5 years, several key conservation actions and research needs are identified to enable more effective conservation of marine biodiversity in the ECA, including increased governance, multilateral collaboration, taxonomic training, and improved reporting of fisheries catch and effort.

KEYWORDS

coastal, conservation evaluation, fish, fishing, invertebrates, mammals, ocean, pollution, Red List, urban development

1 | INTRODUCTION

The Eastern Central Atlantic (ECA), also known as the Eastern Tropical Atlantic, can be biogeographically defined as the marine zone from Mauritania to Angola, including the offshore islands of Ascension, Cape Verde and Saint Helena; and Bioko, São Tomé and Príncipe and Annobón in the Gulf of Guinea (Spalding et al., 2007). The ECA can be divided into three coastal segments: the semi-arid coast from Morocco to Senegal, which is characterized by the Canary Current; the humid tropical coast from Cape Verde to the Congo River, which is dominated by the Guinea Current; and the sub-humid coast south to Angola which is influenced by the more temperate Benguela Current and coastal upwelling (Schwartz, 2006). Although variable, the continental shelf is generally narrow, extending just 15–90 km offshore, and breaking at depths of approximately 100–120 m, making it the smallest tropical shelf area of the world's four main tropical regions (Awosika & Ibe, 1998; Briggs, 1974). The coasts of West Africa are among the world's most productive marine areas and are rich in fishery resources, oil and gas reserves, and precious minerals, and are an important global reservoir of marine biological diversity (GCLME, 2006; Ukwe, Ibe, Alo, & Yumkella, 2003).

Along the coasts of Western and Central Africa, living marine resources of the ECA form the foundation for food security and coastal livelihoods for nearly 400 million people. About 40% of the region's human populations live in coastal areas and are dependent on the lagoons, estuaries, creeks and inshore waters for their sustenance and socio-economic well-being (IGCC, 2010; UNEP, 1999). Compared with continental averages, the coastal countries in West Africa consume a high percentage of fishes, which provide more than 50% of animal protein intake in some countries such as Gambia and Sierra Leone (Agnew et al., 2010). The fishery resources support numerous local and regional artisanal fisheries, while transboundary and migratory stocks have attracted large commercial offshore foreign fishing fleets from the European Union, Eastern Europe, Korea and Japan (Atta-Mills, Alder, & Sumaila, 2004; Ukwe et al., 2003). Despite the rich endowment in natural resources, the majority of the population lives in conditions of widespread poverty because of huge imbalances in the production and distribution of goods and services and socio-political issues, among other issues (IGCC, 2010).

The status of marine biodiversity in the ECA, especially of coastal and pelagic fishes, is of concern owing to a number of known and perceived threats including: overharvesting of marine resources (unsustainable gathering, fishing and hunting); conversion of coastal lagoons and mangrove swamps (rice, shrimp, fish culture and salt production); oil exploration, drilling and production; coastal erosion and habitat degradation; urban and tourism development; pollution; sedimentation and siltation; changes to the hydrological cycle; potential impending changes owing to sea-level rise; and inadequate policy responses, legislation and enforcement (FAO, 2007; GCLME, 2006; IGCC, 2010; Scheren & Ibe, 2002; Ukwe et al., 2003; Ukwe, Isebor, & Alo, 2001). Destructive fishing practices include intensive inshore and offshore trawling with associated consequences of unwanted by-catch, the use of explosives and chemicals in inshore areas, and the use of small mesh-sized beach and purse seine nets in both nearshore and offshore regions (GCLME, 2006; Koranteng, 1998) and juvenile nursery habitats.

Marine species diversity and average body size for many important commercial fishery species have markedly declined over the past few decades, and several reviews report that many artisanal and commercial fish stocks are now considered to be overexploited (Ajayi, 1994; FAO, 2000; Mensah & Quaatey, 2002; Srinivasan, Watson, & Sumaila, 2012). These threats are compounded by the challenge of managing shared stocks across a culturally, politically and geographically diverse landscape. With the human population in this region expected to double in the next 20–25 years, the objective of this 5-year project was to provide the first comprehensive assessment of the status of marine biodiversity in this relatively data-poor region. This study provides comprehensive documentation on the presence, population status and level of IUCN Red List extinction risk for more than 1800 marine species, including all taxonomically described marine vertebrates as well as complete clades of selected marine invertebrates and marine plants. The results of this 5-year effort will transform the current state of knowledge and capacity for regional stakeholders to identify and improve marine conservation priorities.

2 | METHODS

2.1 | Taxonomic and geographic scope

The area encompassing the Eastern Central Atlantic biogeographic zone was defined as described in Spalding et al. (2007), and includes the marine areas extending from Mauritania to Angola as well as the islands of Bioko, São Tomé, Príncipe and Annobón in the Gulf of Guinea and the offshore islands of Cape Verde, Ascension and Saint Helena. Species lists for all known vertebrates (e.g. marine mammals, marine turtles, seabirds, and marine fishes) and all taxonomically valid species in certain clades of invertebrates (sea cucumbers, cone snails, cephalopods, lobsters, reef-building corals) and marine plants (mangroves and seagrasses) were compiled. With the exception of marine teleost fishes (which represent 1284 of the 1811 total species included in this study), all other species had already been globally assessed for their level of extinction risk on the IUCN Red List of Threatened Species™ (www.iucnredlist.org).

To obtain the complete list of already assessed marine species present in the ECA, the global digital distribution maps of complete taxonomic families and orders were obtained from the IUCN Red List and cut to the defined ECA biogeographic area using ArcGIS 10.1. Prior to this study, the vast majority of marine teleost fish species had not yet been assessed for risk of extinction on the IUCN Red List, and all available prior checklists of marine fishes in the ECA were considered out of date. The list of marine teleost fishes present in the ECA was compiled from distribution information for approximately 1650 marine teleost fishes listed in the newly updated *Living Marine Resources of the Eastern Central Atlantic* (Carpenter & De Angelis, 2016). However, if there were no reported or mapped occurrences within the ECA defined boundaries, which was the case for some deeper water fishes that are assumed to occur circumglobally, then that species was not included in this study. For this reason, orange roughy (*Hoplostethus atlanticus*) was not included, as its distribution is primarily anti-tropical, and no reliable catch records exist for this species in the ECA biogeographic region. In addition, species that were newly described or had reported range extensions into the ECA after 2012 were not included, such as *Malacoctenus carrowi* (Labrisomidae, newly described from Cape Verde; Wirtz (2014)) and *Liopropoma emanueli* (Serranidae, newly described from Cape Verde and Senegal; Wirtz and Schliewen (2012)). Also, subspecies were not included. In sum, the list of 1284 marine teleost fishes represents the most up-to-date, complete taxonomic list of marine bony fishes in the ECA biogeographic region.

2.2 | Species data collection

The IUCN Red List protocol for categorization of species extinction risk under the IUCN Red List Categories and Criteria (IUCN, 2001), is the most widely accepted system for classifying extinction risk at the species level (Butchart et al., 2005; de Grammont & Cuarón, 2006; Hoffmann et al., 2008; Rodrigues, Pilgrim, Lamoreux, Hoffmann, & Brooks, 2006). The IUCN Red List process consolidates the most current and highest quality data available, and ensures peer-reviewed scientific consensus on the probability of extinction for each species (Hayward, 2009; Mace et al., 2008). All marine species assessed for the IUCN Red List follow roughly the same protocol: preliminary data collection, validation and review by experts, assignment of a Red List Category, peer-review of assessments, and publication of assessments (and corresponding datasets) on the IUCN Red List of Threatened Species.

In the initial data collection phase, all available species data are obtained in collaboration with regional and international scientists, including extensive literature reviews, published reports, fishery databases, and other sources. All relevant species data are entered into the IUCN Species Information Service (SIS), and draft digital range maps are created in ArcGIS for each species. Data collected include information on each species' taxonomy, distribution, population status and trends, habitat, ecology, use and trade, major threats and current conservation measures. Sources of regional biodiversity and population trend data in the ECA included species catch data from fisheries-independent scientific surveys, national fisheries stock assessments and reported landings, and independent academic surveys. Species presence and historical abundance was examined in historical datasets. These include the Danish Atlantide expedition (1945–1946), which took 170 samples along the West African coast from the Canary Islands south to Angola (Bruun, 1950); the Guinean Trawling Survey (1963–1964), conducted in two phases with paired French trawlers, which surveyed along eight transects off the West African coast at depths ranging from about 15–20 m to 400–600 m (Williams, 1968); and more recently, coastal surveys conducted by the RV *Fridtjof Nansen*, in collaboration with the FAO and the Norwegian Agency for Development Cooperation.

2.3 | Extinction risk assessments

For this ECA assessment, all species extinction risk assessments were based on assessing their entire global population and range, using the IUCN Red List Categories and Criteria (IUCN, 2001), for application at global levels. It is important to note that some other IUCN Red List regional assessment initiatives (Abdul Malak et al., 2011; Nieto et al., 2015) assess only the status of the species in a given region, using the IUCN Red List Regional Guidelines (IUCN, 2012). Of the 1811 marine species included in this study, species-specific data and global extinction risk assessments for 778 species were obtained directly from the IUCN Red List of Threatened Species, as these species were already globally assessed. These included all marine mammals (37 species), sea turtles (five species), seabirds (66 species), sharks and rays (137 species), hagfish (one species), cephalopods (114 species), lobsters (26 species), sea cucumbers (22 species), cone snails (97 species), mangroves (seven species), seagrasses (four species), corals (11 species), and 251 teleost fishes. Groups of teleost fishes that had already been globally assessed included the tunas and billfishes (Collette et al., 2011), bonefishes (Adams et al., 2014), surgeonfishes (Comeros-Raynal et al., 2012), groupers (Sadovy de Mitcheson et al., 2013) and wrasses, blennioids (Polidoro, Williams, Smith-Vaniz, & Carpenter, 2014), Tetraodontidae and Sparidae (Comeros-Raynal et al., 2016), among others. The remaining 1033 marine teleost fishes present in the ECA were assessed during three Red List assessment workshops held in Dakar, Senegal (9–13 July 2012), in Accra, Ghana (5–9 May 2013) and in Libreville, Gabon (7–11 July 2014). These IUCN Red List assessment workshops were facilitated by IUCN Marine Biodiversity Unit staff in collaboration with representatives from a number of local organizations and regional IUCN programme staff. The workshops involved more than 65 leading scientific experts, including fisheries biologists, marine ecologists, taxonomists, government officials, and conservation practitioners from 14 countries, including Australia, Benin, Cape Verde, Denmark, France, Gambia, Gabon, Guinea, Ghana, Mauritania, Nigeria, Senegal, South Africa and the United States.

During the Red List assessment workshops, data for each species were reviewed and updated, and used to assign each species to one of the eight IUCN Red List categories based on quantitative criteria (IUCN, 2001). Following each workshop, additional scientific consultations continued via e-mail to finalize each species' assessment and distribution map. Each species assessment was then peer-reviewed by outside reviewers, and an internal consistency check for application of the Red List criteria, along with coding (e.g. for countries of occurrence, operating threats, habitat types, etc.), was conducted prior to publication on the IUCN Red List of Threatened Species in November 2015.

The IUCN Red List Categories comprise eight different 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 one of the three threatened categories (CR, EN, or VU) by meeting the threshold for that category in one of the five different available criteria (A–E). These different criteria are based on extinction risk theory (Mace et al., 2008) and form the real strength of the IUCN Red List as they provide a standardized methodology that is applied consistently to any species from any taxonomic group (Carpenter et al., 2008; Polidoro et al., 2010; Schipper et al., 2008; Stuart et al., 2004).

The majority of marine species in the ECA that qualified for a threatened category were assessed under Criterion A, which measures the rate of decline over three generation lengths or 10 years, whichever is longer. Generation length, defined as the average age of the current cohort of reproducing individuals, can be calculated in several different ways, depending on the data available (IUCN, 2016). For fishes with stock assessments, estimates of numbers of individuals and mortality rates in each age class, when available, were used to determine generation length. For fishes without age class data, the average age of reproducing adults was calculated as the median age between age of first reproduction and its historical maximum longevity. In some cases, calculation of generation length using both methods can yield different values for the same species, resulting in an overestimation or underestimation depending on the method chosen. In these cases, decline was calculated over the range of generation lengths values, with the final Red List Category classification based on supporting data and information.

Species with small range sizes can qualify for a threatened category under Criterion B, which measures extinction risk based on a small extent of occurrence (< 20 000 km^2) or area of occupancy (< 2000 km^2), combined with having a small number of locations, and/or continued decline and habitat fragmentation. The majority of teleost fishes assessed under Criterion B, for example, were island endemics with an area of occupancy estimated to be less than 2000 km^2 owing to very specific habitat requirements. Criterion C is applied to species with small population sizes estimated to be less than 10 000 mature individuals, Criterion D is applied to species with less than 1000 mature individuals or those with an area of occupancy less than 20 km^2 and affected by a plausible future threat, and Criterion E is applied to species with extensive population information that allows for population declines to be appropriately modelled over time. A category of NT was assigned to species that came close to, but did not fully meet, all the thresholds or conditions required for a threatened category.

Following IUCN convention, the proportion of threatened species is calculated as the total number of species in threatened categories (CR, EN, or VU) divided by the total number of species not assessed as DD or EX. This method accounts for the uncertainty that a DD species may be threatened, especially if threats have been identified (Butchart & Bird, 2010).

2.4 | Spatial analyses

Based on IUCN Marine Biodiversity Unit protocol, maps for species inhabiting depths of less than 200 m were clipped to a 100 km shoreline buffer or a maximum depth of 200 m, whichever was further from the coastline. Pelagic and deepsea species were digitized by hand based on point data from museum databases for poorly-known deepsea species, and from known and inferred occurrences for well-known pelagic species. Maps for teleost fishes known only from very few localities (typically less than 10) were created by adding a 50 m buffer to each verified point of occurrence. For all richness analyses, all species maps were clipped to the ECA biogeographic region and converted to 10 km by 10 km square grid raster. The number of species in each grid cell was calculated by adding the rasters together. This was completed for all species as well as for specific subsets of species, including threatened species and DD species.

3 | RESULTS

3.1 | Marine species extinction risk in the ECA

Of the 1811 marine species (Table S1, Supporting material) in the ECA, approximately 8% (125 species) are in threatened categories (CR, EN or VU). Only 4% (64 species) are listed as NT, while 73% (1322 species) are LC and 15% (279 species) are DD (Table 1). In the ECA, sea turtles constitute the most threatened taxonomic group, with all five species in globally threatened categories (Figure 1). Approximately 56% of sharks, 49% of batoids, 41% of cone snails, and 33% of chimaeras that occur in the ECA are globally listed in threatened or NT categories. Less than 5% of bony fishes, lobsters and cephalopods are threatened or NT. Although significant habitat loss has occurred throughout the region (GCLME, 2006; FAO, 2007; IGCC, 2010), none of the habitat-producing species (mangroves, seagrasses, reef-building corals) are in globally threatened categories, probably because their widespread distributions extend outside of the ECA. Approximately 58% (748 of 1284 species) of marine teleost fishes in the ECA can be found in or over (in the case of pelagics) waters deeper than 300 m. Of these, more than 87% (648 of 748 species) are listed as LC compared with 78% (174 of 220 species) of marine teleost fishes that are restricted to

TABLE 1 Numbers of species in each Red List category for all 1811 species assessed. *18 cephalopods and 1 sea cucumber are awaiting final assessments and do not currently have Red List categories, and are therefore listed as not evaluated (NE)

	EX	CR	EN	VU	NT	LC	DD	NE*	Total Species
Seagrasses						4			4
Mangroves						7			7
Reef-building corals						8	3		11
Cone snails		3	11	10	16	54	3		97
Cephalopods				2		58	36	18	114
Lobsters					1	15	10		26
Sea cucumbers						11	10	1	22
Hagfish						1			1
Chimaeras					1	1	1		3
Batoids (rays, skates)		3	8	7	10	9	20		57
Selachii (sharks)		3	2	20	18	18	16		77
Teleost fishes		1	10	25	13	1072	163		1284
Sea turtles		1	1	3					5
Seabirds	2	1	4	3	5	51			66
Marine mammals			4	3		13	17		37
Total in Red List category	2	12	40	73	64	1322	279	19	1811

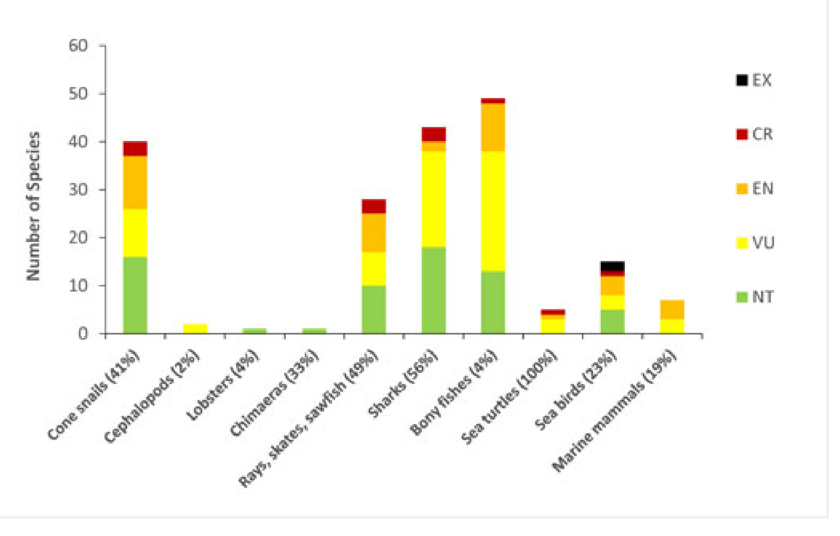

FIGURE 1 Number of Near Threatened, threatened (CR, EN, VU) and Extinct (EX) species by taxonomic group. Proportion of total species in Near Threatened and threatened categories in parentheses

shallow waters less than 50 m deep. Deeper water fishes also represent 50% of all of the DD marine teleosts (88 of 163 species). Many of these deeper water marine fishes are only known from a few specimens or the holotype, and little is known of their distribution, population, habitat, life history or the impact of potential threats. Mapping all known point localities of these deep water fishes (Figure 2), illustrates the narrow continental shelf in the ECA region as well as the lack of sampling effort in deeper offshore waters, particularly in the southeastern Atlantic.

3.2 | Marine species endemism in the ECA

Many species present in the ECA have geographic ranges that extend across to the Western Atlantic (Floeter et al., 2008; Joyeux, Floeter, Ferreira, & Gasparini, 2001), or spill northward into Moroccan waters and into the Mediterranean Sea, or extend southward into waters of northern Namibia. In addition, a large proportion of the deeper water and pelagic species have circumglobal ranges. For these reasons, endemism in ECA marine species is relatively low, with less than 20% of all marine species assessed (356 of 1811) considered endemic to the ECA biogeographic region. The taxonomic group with the highest endemism is the cone snails, with approximately 96% (93 of 97 species). Many of the cone snails in the ECA are only known from a very limited distribution, such as from single localities off the coast of Angola, Senegal or Cape Verde, for example. On a global scale, the eastern Atlantic has been shown to have a higher number of restricted range cone snail species than other regions (Peters, O'Leary, Hawkins, Carpenter, & Roberts, 2013; Peters, O'Leary, Hawkins, & Roberts, 2015). As restricted range species often face an elevated risk for extinction, it is important to identify areas where these species are concentrated (Harnik et al., 2012; Hawkins, Roberts, & Clark, 2000).

Among the other taxonomic groups, 21% of batoids (12 of 57 species), 18% of teleost fishes (230 of 1284) and 18% of reef-building corals (2 of 11 species) are endemic to the ECA. Of the teleost fishes, higher rates of endemism occur in those species restricted to shallower

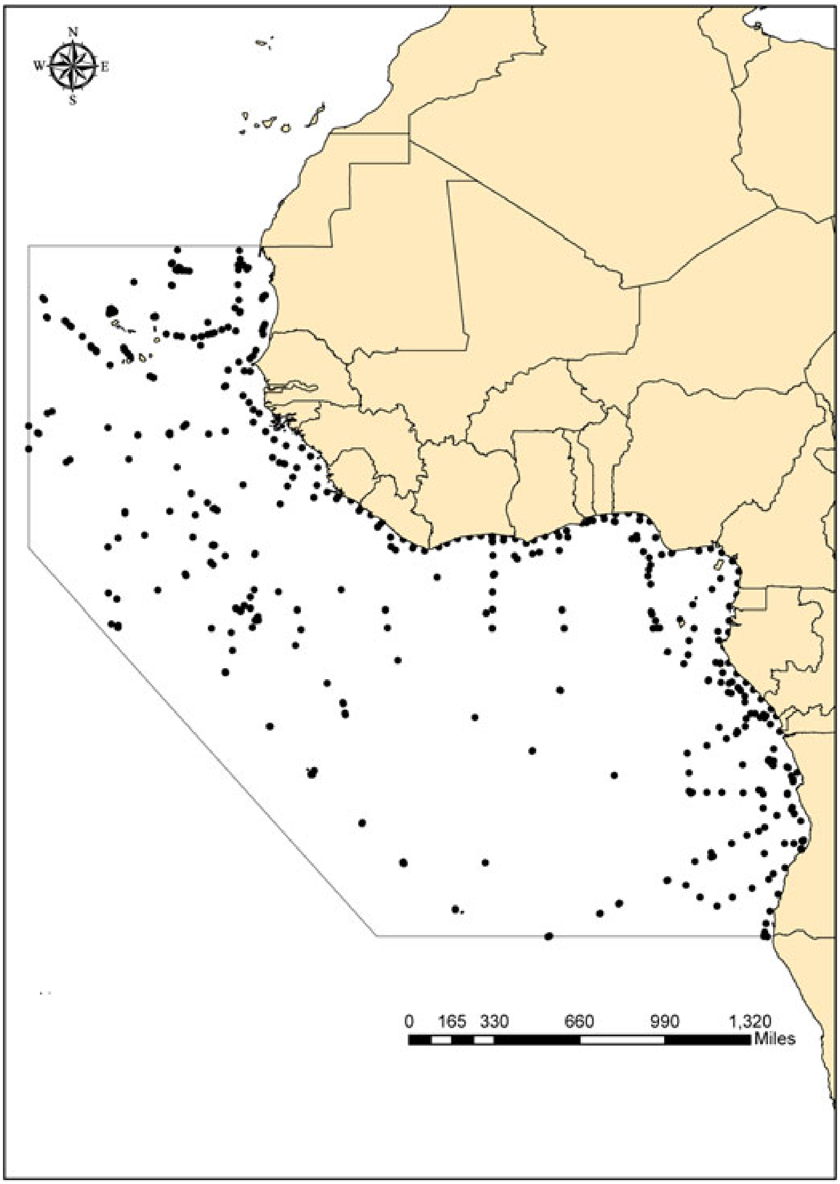

FIGURE 2 Deep sea teleost fishes point localities in the ECA

habitats. Approximately 45% (99 of 220 species) of marine teleosts found only in shallow waters (<50 m) are endemic to the ECA, compared with 24% (76 of 309 species) of species found over the entire continental shelf (0–300 m), and only 6% (47 of 748 species) of deeper water species. Two marine mammals are endemic to the ECA (*Sousa teuszii* and *Trichechus senegalensis*), and the only two seabirds considered endemic to the ECA, *Pterodroma rupinarum* and *Bulweria bifax* are now Extinct. Both seabird species were considered endemic to St. Helena island, but were hunted to extinction shortly after the island's discovery in 1502 (Olson, 1975). No sharks, chimaeras, sea turtles, mangroves or seagrasses are endemic to the ECA. The single hagfish, *Myxine ios*, is potentially endemic to the ECA, as it is only known from off the coast of southern Western Sahara and Angola. However, there are records off the coast of Ireland that may be this same species (Fernholm, 1981), and records in the North Atlantic may have confused *M. ios* and *M. jespersenae* (Møller, Feld, Poulsen, Thomsen, & Thormar, 2005).

3.3 | Patterns of species richness in the ECA

Overall marine species biodiversity (1811 species), is highest in the Gulf of Guinea, around the Cape Verde islands (Wirtz et al., 2013), and off the coast of Senegal (Figure 3(a)). As teleost fishes comprise more than 70% of all species assessed, this pattern is primarily driven by marine bony fish diversity. The highest number of threatened species occurs off of Senegal and Mauritania, as well as in the area of the Niger Delta, around Bioko Island, and the Nigeria/Cameroon border (Figure 3(b)). Several threatened species occur in this area, including four species of sea turtles, the Atlantic humpback dolphin (*Sousa teuszii*), and several bony fishes. Among the threatened bony fishes are *Epinephelus itajara* (CR) which occurs to just south of the Mauritania/Senegal border, *Pseudotolithus senegalensis* (EN) which occurs from Namibia to Western Sahara, and *Merluccius senegalensis* (EN) which occurs south to Guinea-Bissau.

There are several areas along the coasts of West and Central Africa with relatively high numbers of DD species (Figure 3(c)). Many of the deeper water and pelagic DD species, including several shark species, lack data on their life history, habitat requirements, and impact of known or potential threats. Similarly, many deeper water teleosts are only known from a single or few specimens, with few or no data on their distribution, habitat requirements, or threats. Some relatively well-known commercial species, such as *Lutjanus goreensis*, *Lutjanus agennes*, and *Lutjanus dentatus*, are listed as DD as they are heavily exploited but lack adequate species-specific landings or effort data in order to quantify decline.

3.4 | Threats to marine species in the ECA

Fisheries and overharvesting is the biggest threat to living marine resources present in the ECA, with 87% (109 of 125 species) of threatened species across all taxonomic groups affected by both large- and small-scale targeted fisheries, excessive capture as by-catch, or unsustainable harvest (Figure 4). All threatened marine mammals (seven species), sea turtles (five species), batoids (18 species), sharks (25 species), and cephalopods (two species) are adversely affected by fishery activities in the ECA and across their global ranges. In addition, 87% of threatened seabirds (seven of eight species) and cone snails (21 of 24 species), as well as 70% of threatened teleost fishes (25 of 36 species), are in decline owing to direct or indirect impacts of fisheries. Following fisheries, habitat loss and coastal development is the second biggest threat, affecting 55% of threatened species (69 of 125) across their ranges. In the ECA, coastal development impacts include adverse effects from urbanization, oil and gas drilling, mining, dams, aquaculture, agriculture, tourism and other ecosystem modifications (GCLME, 2006; IGCC, 2010). Approximately 33% (42 of 125 species) of threatened species are affected by pollution. In the ECA, primary sources of pollution include runoff from urban development, sewage and agriculture, as well as from oil exploration and extraction activities, including dredging of channels, digging new canals, clearance for platforms, pipelines and seismic surveys (Spalding, Kainuma, & Collins, 2010). All of the threatened seabirds (eight species) are affected by introduced or invasive species, including widespread disturbance and

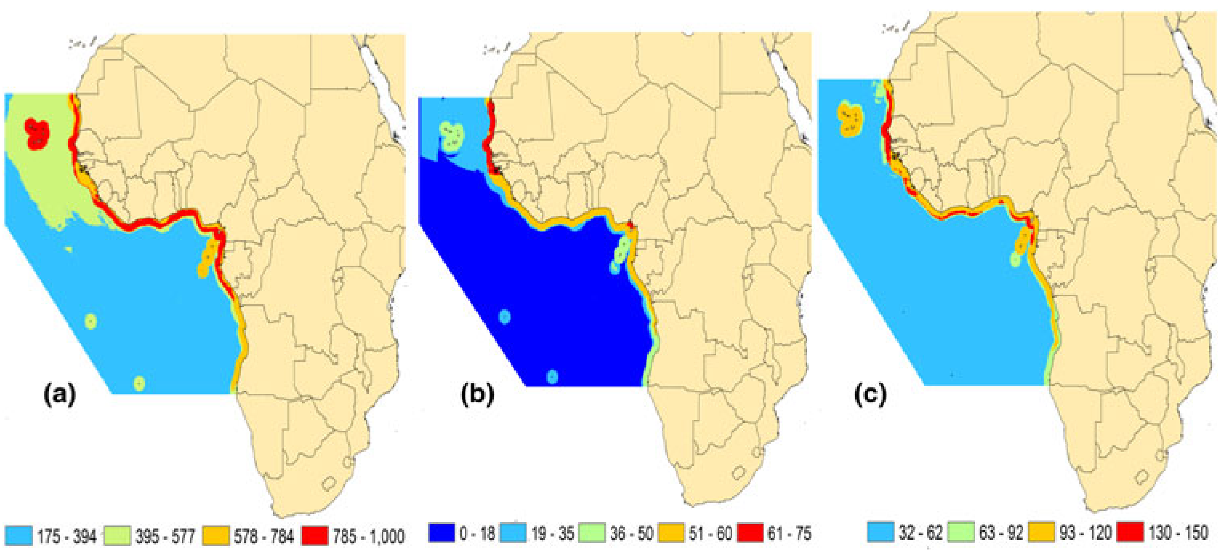

FIGURE 3 (a) Total species richness; (b) threatened species richness; and (c) DD species richness

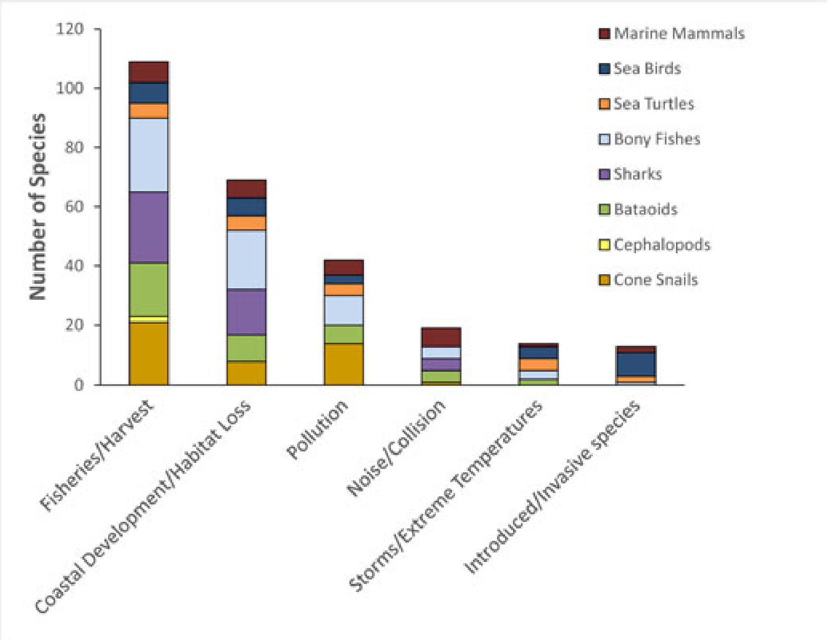

FIGURE 4 Threat distributions by taxonomic group for threatened species

predation of seabirds by the introduced black rat (*Rattus rattus*), feral cats, pigs, and other livestock.

4 | DISCUSSION

4.1 | Comparison of ECA with other regions

The only other study based on global-level IUCN Red List assessments conducted across different marine taxonomic groups is in the Eastern Tropical Pacific (ETP), where approximately 12% (197 of 1642) of marine species were in threatened categories (Polidoro et al., 2012) compared with 9% in the ECA (125 of 1811). The ETP study included all known marine mammals, seabirds, sea turtles, sharks and rays, bony shorefishes, mangroves, seagrasses, and reef-building corals, but excluded deepsea teleosts. The slightly lower proportion of threatened species in the ECA compared with the ETP is probably due to the inclusion of additional invertebrate groups as well as the deepsea teleosts in the ECA. Deeper water species, although generally less well-known, are often perceived to have less exposure to threats compared with shallow, near shore species which are closer to anthropogenic activity, and are generally better studied. However, in contrast to the ECA, the ETP has one of the highest rates of marine species endemism in the world, with more than 90% of marine bony shorefishes, 33% of cartilaginous fishes, and approximately 25% of habitat-producing species (mangroves, seagrasses and reef-building corals) considered endemic (Polidoro et al., 2012).

Several other Red List initiatives for marine teleost fishes have recently been completed in other regions around the world (Table 2). Comparison across all regions shows about 2–9% of marine teleost fishes in threatened categories. However, it is important to note that some assessments were conducted at the global scale (e.g. all species present in a given region are assessed based on their global populations) vs. a regional scale (e.g. all species present in a given region are assessed based on their regional populations). Therefore, species assessed in the Eastern Central Atlantic initiative, as well as in the Eastern Tropical Pacific or Caribbean initiatives, may have populations in the region that are of higher or lower risk, compared with the species' global classification. Across the various regional assessments, approximately 8–29% of marine teleost fishes were classified as DD. Marine fishes are generally classified as DD if they are only known from a few specimens, however, relatively well-known species can be

TABLE 2 Summary of results from other global or regional marine teleost Red List assessment initiatives

Region	Year completed	Global or regional RL	Marine teleosts scope	Number of species assessed	Number of threatened species (%)	Number of DD species (%)	Reference
Eastern Central Atlantic	2015	Global	All	1284	36 (3%)	163 (13%)	This study
Eastern Tropical Pacific	2012	Global	Shorefishes only	1102	94 (9%)	176 (16%)	Polidoro et al., 2012
Greater Caribbean	2015	Global	Shorefishes only	1360	65 (5%)	114 (8%)	Linardich, 2016
Persian Gulf	2015	Regional	All	457	13 (3%)	89 (19%)	Buchanan, 2016
European Union	2015	Regional	All	854	13 (2%)	179 (21%)	Nieto et al., 2015
Mediterranean Sea	2007	Regional	All	442	9 (3%)	128 (29%)	Abdul Malak et al., 2011

classified as DD if there is a known significant threat, but the impacts of the threats on the species population cannot be adequately quantified (IUCN, 2016). In the Mediterranean Sea, as in other regions, a high proportion of commercial species are classified as DD owing to the lack of a unified fisheries dataset in the region combined with mostly aggregate landings and relatively few stock assessments (Abdul Malak et al., 2011). The Mediterranean also has relatively low marine fish endemism similar to the ECA, with approximately 14% of fishes considered endemic (Abdul Malak et al., 2011).

4.2 | Priority ECA species for marine conservation

In general, IUCN recommends conservation prioritization of both threatened species and of DD species (Hoffmann et al., 2008). Often, in the latter classification, the impacts of known threats cannot be quantified because of significant gaps in research (e.g. distribution, population trends, life history, impacts of known threats, etc.), and as such, DD species should be prioritized for research. Aside from DD species, several threatened species standout across the different taxonomic groups assessed in the ECA. With a total population of just 14 000 individuals, the Damara tern (*Sterna balaenarum*), is probably the region's most at-risk seabird (du Toit et al., 2002; Simmons, Cordes, & Braby, 1998). It disperses north after the breeding season in Namibia, and is a regular resident of the coastal waters of Cameroon, Nigeria, Benin, Togo, Ghana and Côte d'Ivoire (Urban, Fry, & Keith, 1986). The main threats to both resident and migrant birds in this region include habitat loss owing to urbanization, agricultural activities, and pollution from activities connected with the oil industry (IGCC, 2010).

Among marine mammals, the Atlantic humpback dolphin (*Sousa teuszii*) and the African manatee (*Trichechus senegalensis*) are the most threatened in the region. Both species are endemic to the ECA, and are limited to shallow coastal, estuarine and riverine habitats (Reynolds & Odell, 1991; Ross, 2002; Van Waerebeek et al., 2004). Populations of both species are considered to be highly fragmented, and in low numbers. Both the African manatee and the Atlantic humpback dolphin have high incidental mortality in fishing nets, and are also taken directly for food. Habitat destruction from mangrove harvesting, siltation, dams, coastal development and drought, as well as boat strikes and water pollution are additional potential threats to these species, causing near extirpation in some areas.

Four of the five species of marine turtles in the ECA have important nesting beaches in the Gulf of Guinea region: green turtle (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*) and leatherback (*Dermochelys coriacea*). All four of these species nest on Bioko's southern beaches along a restricted 20 km coastline, which is considered the most important nesting site in the region in terms of number of sea turtle species and nesting individuals (Castroviejo, Juste, Del Val Pérez, Castelo, & Gil, 1994). Several other nesting beaches have been reported throughout the region, including sites in Guinea Bissau, Sierra Leone, Liberia, Cote d'Ivoire, Ghana, Cameroon, Sao Tome and Principe (Catry et al., 2002; Fretey, 1999, 2001; Peñate, Karamoko, Bamba, & Djadji, 2007), but estimates of population sizes and comprehensive inventories have not been conducted in all of the sites. Some estuarine and lagoon areas have also been identified as essential habitat for juveniles, including the Cameroon Estuary (Fretey, 2001). In general, sea turtle nesting populations are being severely depleted throughout the ECA, especially on the Gulf of Guinea islands. Where sea turtles are abundant, they are considered significant sources of food and income, and they are harvested for meat and eggs (Castroviejo et al., 1994). In areas with large turtle aggregations (such as green turtle feeding or nesting grounds in Equatorial Guinea, Sao Tome and Principe), organized market systems have developed (Formia, Tiwari, Fretey, & Billes, 2003). Although often illegal, sea turtles are systematically killed both on land and at sea, their nests are looted, and a significant trade for their carapaces exists. They are also affected as by-catch in commercial fisheries, by marine pollution, and by habitat loss from coastal erosion and garbage litter along developed beaches (Formia et al., 2003).

Of special concern among the sharks and rays, are several species of sawfishes (*Pristis* spp.) and guitarfishes (*Rhinobatos* spp.) Historical records indicate that sawfishes (*Pristis pristis* and *Pristis pectinata*) were once common in the estuaries of western Africa (Burgess, Carvalho, & Imhoff, 2009; Faria et al., 2013). However, there have been only a few recent confirmed records in Sierra Leone and only historical records from the other countries (Burgess et al., 2009), suggesting that they may be near extinction in the region. Several threatened species of guitarfishes (*Rhinobatos albomaculatus*, *Rhinobatos irvinei*, *Rhinobatos rhinobatos* and *Rhyncobatus leubberti*) inhabit shallow inland coastal waters in the region and are heavily targeted for their fins. Shark fishing has increased significantly in the past several decades and has decimated many species in the region (Diop & Dossa, 2011). Several rays, including a poorly known electric ray (*Torpedo bauchotae*) and the smalltoothed stingray (*Dasyatis rudis*), may be endemic to the shallow, near-shore waters in the area, however very little is known of their populations, ecology or impact of threats in the ECA.

The most threatened teleost marine fishes are those with global populations that are declining faster than they are able to recover, owing to unsustainable and overfishing, including several species of grouper (*Epinephelus itajara*, *Epinephelus marginatus*, *Mycteroperca fusca*), the Senegalese hake (*Merluccius senegalensis*), several species of croaker (*Pseudotolithus senegalensis*, *Pseudotolithus senegallus*), and the Atlantic horse mackerel (*Trachurus trachurus*). For many of these species, stock assessments and independent fisheries surveys in the ECA region are severely lacking or inadequate, even as reported regional catch landings continue to decline (FAO, 2013) and effort increases. Several small-ranging endemics including gobioids (*Bathygobius burtoni*, *Priolepis ascensionis*), blennioids (*Scartella* spp.), and the West African seahorse (*Hippocampus algiricus*) are in decline owing to extensive habitat loss and pollution, as well as collection for the aquarium trade, or potentially Asian markets. Of special concern are a number of heavily targeted commercial and artisanal fishes that are listed as DD, as there are anecdotal or empirical signs of decline (e.g. declining body sizes, increasing market value, lower reported landings) but stock assessments or disaggregated species landings data do not readily exist. These priority species include four snappers (*Lutjanus* spp.), the rubberlip grunt (*Plectorhinchus mediterraneus*), several groupers (*Epinephelus* spp.), several soles (*Microchirus* spp.), and several mullets (*Liza* spp.). Further research and better coordination and identification of landings, along with estimated effort, for these species is urgently needed to determine the status of their populations and the impact of fisheries.

Perhaps the most overlooked species group in the region, with relatively high numbers of threatened species, is the cone snails with 25% (24 of 97 species) in threatened categories. All of the threatened cone snails have distributions of 20 000 km^2 or less, and are often restricted to a single bay. The main threats to these species are extensive habitat and population decline from pollution, shipping, urbanization and coastal development. Many species, such as *Conus mordeirae* and *Conus lugubris*, may also be affected by current or historical collection. Cone snails and other narrow ranging invertebrates are often overlooked in terms of conservation measures, and even if found within marine protected areas, are not always protected from collection or other threats.

4.3 | Fisheries

As in many other regions of the world (Abdul Malak et al., 2011; Pinsky, Jensen, Ricard, & Palumbi, 2011; Polidoro et al., 2012; Nieto et al., 2015), fisheries and overharvesting are the biggest threats to marine biodiversity in the ECA. Independent trawl surveys have shown significant decreases in overall fish biomass over the past 10–15 years, which has been attributed to the increase in fishing activity of trawlers in inshore areas (GCLME, 2006), as well as globalization of the fishing industry (Atta-Mills et al., 2004). Trawl surveys carried out across the Gulf of Guinea from 1977–2000 have shown an approximate 50% decline in fish biomass (Brashares et al., 2004). Large-scale industrial and artisanal fisheries operate throughout the region, and can be categorized into two main groups: (1) the small and large pelagics which make up about 70% of the total reported catch; and (2) the demersal fish resources. Small and large pelagics that are important fishery species include the sardinellas, Bonga, carangids, anchovy, scombrids, and tunas. Important demersal fish species, many of which occur in shallow, near-shore waters, include the sciaenids (croakers), lutjanids (snappers), haemulids (grunts), and sparids (seabreams). Demersal fisheries also target many invertebrates, including shrimp, octopus, univalves, bivalves, and cephalopods.

Across western and central Africa, the artisanal sector dominates fishing employment and the fishing industry, with 70% of the total fishery production estimated to come from small-scale artisanal fisheries (GCLME, 2006). Typically, artisanal fishermen use traditional wooden boats, sometimes motorized, with a variety of gear types, including nets, lines and seines. However, a huge array of distant water fleets from Europe and East Asia also exploit the depleted West African fisheries resources through annual ‘access agreements’ (Palomares & Pauly, 2004; Pauly & Zeller, 2016). There have been numerous cases of illegal fishing by a variety of countries, and it is estimated that illegal catches exceed more than 40% of the reported legal catch (Pauly & Zeller, 2016). In some countries, relatively few local fishing companies are in operation, whereas a large number of local agents are engaged in joint ventures with foreign fleets, which results in few fish actually landed locally. This reliance on non-African trawlers and fleets results in limited economic and employment benefit to West African countries, and further encourages high levels of illegal and unreported fishing. As a result, fisheries in the ECA are providing little benefit to national economies, and are underperforming and overexploited because of poor governance and unregulated, open-access.

At a regional scale, fishery management in the ECA is overseen by the FAO Fishery Commission for the Eastern Central Atlantic (CECAF). Composed of members from each of the nations in the region, this regional fishery body is responsible for all living marine resources within the area (which is defined by the FAO as extending from approximately the Straits of Gibraltar and northern Morocco to northern Angola). The CECAF committee produces reports on the status of exploited fish stocks in the region, including small pelagic and demersal fishes. The CECAF commission includes three sub-regional fisheries commissions, the Sub-Regional Fisheries Commission (SRFC) that covers Mauritania to Sierra Leone, including Cape Verde; the Fishery Committee of the West Central Gulf of Guinea (FCWC), which extends from Liberia to Nigeria; and the Regional Fisheries Committee for the Gulf of Guinea (COREP), which covers the area from Cameroon to northern Angola, including the island nation of São Tomé and Príncipe. International Commission for the Conservation of Atlantic Tunas (ICCAT), a regional fisheries organization, manages all species of Atlantic tunas and their relatives, as well as billfishes and some sharks. Most, but not all, of the countries in the ECA as defined herein are contracting parties to ICCAT. However, annual catch and effort data are not widely available for most fishery resources in the region, and only a few species are regularly evaluated by CECAF.

A large number of marine species and their near-shore habitats are affected by extensive, industrial near-shore trawling. However, very little information exists on the quantities and species caught as by-catch. It is estimated that the by-catch from the industrial shrimp trawling fleets is approximately 70% of the total catch, and essentially comprises juvenile finfish (GCLME, 2006). In addition, given that the Ghanaian driftnet fishery has been introduced into other Gulf of Guinea countries (Segniagbeto & Van Waerebeek, 2010), it is reasonable to assume, though currently undocumented, that cetacean and sea turtle by-catch is also associated with this fishery.

4.4 | Habitat loss and pollution

Coastal habitats in the ECA are threatened by degradation and destruction through urban and coastal development, pollution (residential, agricultural, hydrocarbon and heavy metals) and mangrove deforestation (GCLME, 2006). In the ECA, the dominant coastal features are primarily mangroves, coastal lagoons and large estuarine areas from the drainage of major rivers, including the Niger, Volta, Gambia and Congo, all of which serve as important reservoirs for biological diversity (Ajao et al., 2009). There are essentially no coral reefs along the West African coastline, owing to upwellings and cooler waters, in combination with heavy rainfall and high volumes of fresh water entering from rivers, which create an unfavourable environment for coral reef development. Only the coasts of Sierra Leone, Liberia, and São Tomé harbour some relatively small coral communities (Spalding, Ravilious, & Green, 2001). Similarly, seagrass beds in general are not very well developed in the region, and tend to form isolated patches in some estuaries and delta mouths.

The mangrove regions of the ECA provide critical breeding grounds for many fish and shrimp species, and critical habitat for a variety of other coastal species, including mammals, reptiles and birds (FAO, 2007; Polidoro et al., 2010; Ukwe et al., 2001). Collectively, Nigeria, Cameroon and Sierra Leone host approximately 80% of all mangrove forests by area (FAO, 2007), with the best-structured sites being the Niger Delta communities in Nigeria and those in Yawri Bay in Sierra Leone. However, overall mangrove forest area has declined by about 15% in the ECA over the past 25 years, with the highest losses in Côte d'Ivoire (67%), Liberia (65%), Sierra Leone (40%), and Ghana (30%) (FAO, 2007). Mangroves are harvested for fuelwood, timber, boat construction and charcoal; and are removed for conversion to other land uses, including the production of rice and salt, aquaculture, and for the development of urban and industrial areas, road construction, plantations, ports, airports, and tourist resorts. Other threats include pollution from sewage effluents, solid wastes, siltation, oil, and agricultural and urban runoff (FAO, 2007). Declines in the production of demersal fish species across the ECA have been linked to pollution and the loss of mangroves (Shumway, 1999).

Oil exploration and exploitation processes, including gas flaring and oil spills, are significant disturbances to mangroves and other coastal ecosystems across western and central Africa. In the Niger Delta, direct pollution incidents from oil spills are a regular occurrence, with more than 2000 incidents recorded from 1997–2001 (Nwilo & Badejo, 2006). Oil pollution in the region results in ecological and public health problems, to which women and children are particularly susceptible. However, the impacts of both acute and chronic hydrocarbon pollution on near-shore marine organisms are largely unknown. Oil exploration and extraction activities, including dredging of channels, digging new canals, clearance for platforms, pipelines and seismic surveys have also severely changed water flows, salinities, and siltation rates (Spalding et al., 2010).

Although the petroleum industry has been singled out as a major polluter, improper domestic and industrial waste disposal are also significant threats. As wastewater treatment systems are either absent or inadequate, pollution from residential and industrial sources is often directly discharged into fresh water and near-shore marine waters in the Gulf of Guinea resulting in habitat degradation, loss of biological diversity and productivity, and degenerating human health (Ukwe et al., 2003). An estimated 3.8 million metric tonnes per year of solid waste is produced in the Gulf of Guinea coastal zone (Scheren & Ibe, 2002). Much of this ends up in the ocean, and solid waste on Gulf of Guinea beaches predominantly comprises plastics (Scheren & Ibe, 2002). Solid waste or debris sometimes constituted 69% of coastal trawl catches in Nigeria (Solarin et al., 2010). Cetaceans, sea turtles and marine fishes in particular are at risk of physical entanglement with certain kinds of debris, including plastics and discarded fishing nets.

5 | CONCLUSIONS AND RECOMMENDATIONS

Across the ECA, better reporting of landings and estimation of fishing effort is needed throughout the region, in addition to development and enforcement of catch quotas and appropriate fishing techniques and gears in order to reduce the impact of fisheries on marine biodiversity. However, marine resource management in the ECA is complicated due to the number of governments and ministries involved. The jurisdictional landscape differs by country, and coordinating management goals and policies is immensely challenging. In many countries, limited surveillance and enforcement capacity leads to illegal fishing and overfishing, which compromises regional management efforts. National management capacities are also constrained by their inability to limit entry of national and international fleets into fisheries, and to control the type of fishing gear used. Overall, great needs exist for strengthening governance and increasing capacity, for training and resources for improved management and for the reduction of illegal and unregulated fishing activities. To increase regional coordination, at least one regional fisheries management programme, the Programme Régional de Conservation de la Zone Côtière et Marine en Afrique de l'Ouest (PRCM) has been formed in partnership with SRFC and covers the seven countries from Mauritania to Sierra Leone. The goals of the PRCM are to coordinate the efforts of institutions and individuals to strengthen the conservation of the littoral zone in the coastal SRFC countries.

There is little capacity in the ECA to conduct stock assessments or report on species population trends. As such, there is a need to better quantify the impacts of local, national and regional fishery efforts on targeted and non-targeted species, including the identification of important spawning aggregations and spawning grounds, through enhanced outreach with fishers (Heyman & Kjerfve, 2008; Lindeman, Pugliese, Waugh, & Ault, 2000). Specific challenges in West Africa that could benefit from research to implement affordable, culturally-appropriate and sustainable solutions include the lack of access to credit and financing, poor cold storage infrastructure, poor transportation infrastructure, inefficient and outdated equipment, lack of knowledge about export standards, and weak industrial organization. Of particular importance is the need to train more scientists and practitioners in taxonomic identification techniques. In many cases, fishes being recorded in landings, fish markets, academic surveys and other instances are incorrectly identified, compounding the difficulties of understanding species distributions and population trends. Similarly, the vast majority of fishery landings are reported by family or genus, which does not easily allow for adequately quantifying the impacts of threats on individual species.

In addition to fisheries, many species are threatened by habitat loss from coastal development and pollution from a variety of sectors (e.g. oil and gas activities, shipping, agriculture, solid waste disposal, etc.). As most of the industries operating in the ECA are located in or around the coastal areas and discharge untreated effluents directly into sewers, canals, streams and rivers (GCLME, 2006), there is a great need to fund and establish better infrastructure and policies for pollution and waste monitoring, management, treatment and disposal throughout the region. In already degraded environments, habitat restoration programmes are needed. Equally as important, is the need to protect human health and increase public awareness of pollution and solid waste issues, including the promotion of guidelines or policies to reduce, recycle and reuse waste items.

A number of marine and coastal protected areas have been established in the ECA to limit harvesting of coastal resources and ensure their sustainable utilization. However, many of these protected areas lack capacity, funding, infrastructure and governance for effective enforcement and conservation. Several Ramsar and World Heritage Sites have also been designated or proposed in the ECA for protection of these resources, yet many areas are still lacking in marine or coastal protected areas. For example, 71 priority biodiversity sites have been identified in the ECA, but many of these have not been formally designated (Armah, 2006). Equally as important as strengthening local and national efforts to improve marine protected area designation and management, is the need for improved transboundary collaboration on shared fish stocks, regional data management and the creation of marine protected area networks. Lastly, as more invertebrate groups are assessed, conservation actions to protect small-ranging, threatened invertebrate species, such as cone snails, should not be overlooked.

ACKNOWLEDGEMENTS

The vast majority of non-fish species assessments were completed by IUCN Species Survival Commission Specialist Groups, under the guidance of the IUCN Marine Biodiversity Unit and funding by the New Hampshire Charitable Trust and others. We thank Roger McManus for his continued advice and support of marine Red List Assessments. For the marine fish assessments, we thank Thierry Renaud and the MAVA Foundation for their financial support. Thanks also to Arizona State University's Center for Biodiversity Outcomes for supporting the finalization of many of the marine fish assessments. A special thanks to Titus Ayo Adeofe, Paul Bannerman, Jean Noel Bibang Bi Nguema, Youssouf Hawa Camara, Kadiatou Cissoko, Roger Djiman, Ebou Mass Mbye, Jean Egard Mikolo, Jean Bernard Mougoussi, Jean Herve Mve Beh, Richmond Quartey, and Alphonse Sagna for their assistance in conducting the marine fish assessments. We thank the following organizations for logistical support for the marine fish workshops in West Africa: IUCN Regional Marine and Coastal Programme for Central and West Africa (IUCN MACO), IUCN Senegal Programme Office, the Centre de Recherches Océanographiques Dakar (CRODT), IUCN Programme for West and Central Africa (IUCN PACO), IUCN Ghana Project Office, the Department of Marine & Fisheries Sciences of the University of Ghana, the Ghana Marine Fisheries Research Division of the Fisheries Commission, Agence Nationale du Parcs Nationaux (ANPN), Gabon Bleu and the Direction Générale de la Pêche et d' l'Agriculture (DGPA). We also thank the following individuals for their support during these workshops: Alain Nkoghe Nze (ANPN), Mathieu Ducrocq (Gabon Bleu), Madeleine Diouf (IUCN Senegal), Andrew Rodrigues (IUCN), Massal Fall (CRODT), Michael Vakily (Sub-Regional Fisheries Commission), Pablo Chavance (IUCN), Philippe Tous (Sub-Regional Fisheries Commission), and Craig Hilton-Taylor (IUCN Red List Unit). This project could not have been completed without the more than 400 scientific experts who contributed to all of these species assessments over the past 8 years. We also thank the many individuals involved in the data collection, initial map generation and post-workshop clean-up for the marine bony fishes, including A. Bubnash, B. Corley, A. Goodpaster, C. Gorman, A. Hines, N. Muniz, B. Pogue, C. Radtke, A. Santa Cruz, D. Slater, S. Smith, S. Soto, C. Twiford and S. Weller.

REFERENCE LIST

Abdul Malak, D., Livingstone, S. R., Pollard, D., Polidoro, B. A., Cuttelod, A., Bariche, M., … Tunesi, L. (2011). *Overview of the Conservation Status of the Marine Fishes of the Mediterranean Sea*. IUCN: Gland, Switzerland and Malaga, Spain.

Adams, A. J., Horodysky, A. Z., McBride, R. S., Guindon, K., Shenker, J., MacDonald, T. C., … Carpenter, K. (2014). Global conservation status and research needs for tarpons (Megalopidae), ladyfishes (Elopidae) and bonefishes (Albulidae). *Fish and Fisheries*, *15*, 280–311.

Agnew, D. J., Walmsley, S. F., Leotte, F., Barnes, C. , White, C., & Good, S. (2010). MRAG: Estimation of the cost of illegal fishing in West Africa. World Bank West Africa Regional Fisheries Project ZO0906 – IUU West Africa.

Ajao, E., Awosika, L., Diop, S., Koranteng, K., Soumare, A., & Snoussi, M. (2009). AoA Region: Western African Seas. In *UNEP/Dewa Regional Reports* (pp. 217–230). UNEP.

Ajayi, T. (1994). The status of marine fisheries resources of the Gulf of Guinea. In *Proceedings of the 10th Session FAO CECAF*. (pp. 10–13). Rome: FAO.

Armah, A. K. (2006). *Biodiversity status of the Guinea Current Large Marine Ecosystem*. Legon, Ghana: University of Ghana.

Atta-Mills, J., Alder, J., & Sumaila, U. R. (2004). The decline of a regional fishing nation: The case of Ghana and West Africa. *Natural Resources Forum*, *28*, 13–21.

Awosika, L. F., & Ibe, A. C. (1998). Geomorphic features of the Gulf of Guinea shelf and littoral drift dynamics. In A. C. Ibe, L. F. Awosika, & K. Aka (Eds.), *Nearshore dynamics and sedimentology of the Gulf of Guinea*. (pp. 21–27). Cotonou, Benin: IOC/UNIDO. CEDA Press.

Brashares, J. S., Arcese, P., Sam, M. K., Coppolillo, P. B., Sinclair, A. R., & Balmford, A. (2004). Bushmeat hunting, wildlife declines, and fish supply in West Africa. *Science*, *306*, 1180–1183.

Briggs, J. C. (1974). *Marine zoogeography*. New York: McGraw-Hill.

Bruun, A. F. (1950). *Scientific results of the Danish expedition to the coasts of Tropical West Africa 1945–46. Atlantide-Report. University of Copenhagen and the British Museum (Natural History), London*. Ltd, Copenhagen: Danish Science Press.

Buchanan, J. R. (2016). Regional extinction risk and conservation priorities for Persian Gulf marine bony fishes. Master's thesis, Department of Biological Sciences, Old Dominion University, Norfolk, VA.

Burgess, G. H., Carvalho, J., & Imhoff, J. L. (2009). An evaluation of the status of the largetooth sawfish, *Pristis perotteti*, based on historic and recent distribution and qualitative observations of abundance. Internal report to NOAA.

Butchart, S. H. M., & Bird, J. P. (2010). Data Deficient birds on the IUCN Red List: What don't we know and why does it matter? *Biological Conservation*, *143*, 239–247.

Butchart, S. H. M., Stattersfield, A. J., Baillie, J., Bennun, L. A., Stuart, S. N., Akçakaya, H. R., … Mace, G. M. (2005). Using Red List Indices to measure progress towards the 2010 target and beyond. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *360*, 255–268.

Carpenter, K., & De Angelis, N. (2016). *The living marine resources of the Eastern Central Atlantic (Vol 2-4). FAO Species Identification Guide for Fishery Purposes*. Rome: FAO.

Carpenter, K. E., Muhammad, A., Aeby, G., Aronson, R. B., Banks, S., Bruckner, A., … Wood, E. (2008). One third of reef building corals face extinction from climate change and local impacts. *Science*, *321*, 560–563.

Castroviejo, J., Juste, B. J., Del Val Pérez, J., Castelo, R., & Gil, R. (1994). Diversity and status of sea turtle species in the Gulf of Guinea islands. *Biodiversity and Conservation*, *3*, 828–836.

Catry, P., Barbosa, C., Indjai, B., Almeida, A., Godley, B. J., & Vie, J. C. (2002). First census of the green turtle at Poilão, Bijagós Archipelago, Guinea-Bissau: The most important nesting colony on the Atlantic coast of Africa. *Oryx*, *36*, 400–403.

Collette, B. B., Carpenter, K. E., Polidoro, B. A., Juan-Jorda, M. J., Boustany, A., Die, D. J., … Yañez, E. (2011). High value and long life—double jeopardy for tunas and billfishes. *Science*, *333*, 291–192.

Comeros-Raynal, M. T., Choat, J. H., Polidoro, B. A., Clements, K. D., Abesamis, R., Craig, M. T., … Carpenter, K. E. (2012). The likelihood of extinction of iconic and dominant components of coral reefs: The parrotfishes and surgeonfishes. *PLoS ONE*, *7*, e39825. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0039825

Comeros-Raynal, M., Polidoro, B., Broatch, J., Mann, B., Gorman, C., Buxton, C., … Carpenter, K. E. (2016). Predictors, patterns and processes of extinction risk in porgies. *Biological Conservation*, *202*, 88–98.

de Grammont, P. C., & Cuarón, A. D. (2006). An evaluation of threatened species categorization systems used on the American continent. *Conservation Biology*, *20*, 14–27.

Diop, M., & Dossa, J. (2011). *Thirty years of shark* fishing in West Africa. European Union: Fondation Internationale du Banc d'Arguin.

Du Toit, M., Boere, G. C., Cooper, J., de Villiers, M. S., Kemper, J., Lenton, B., … Byers, O. P. (2002). *Conservation assessment and management plan for southern African seabirds*. Cape Town, South Africa: Workshop Report.

FAO. (2000). *State of the World's fisheries and aquaculture*. Rome: FAO.

FAO. (2007). *The World's mangroves 1980-2005, FAO Forestry Paper 153*. Rome: FAO Forest Resources Division.

FAO. (2013). *Fisheries and aquaculture software. FishStat Plus - universal software for fishery statistical time series*. Rome: FAO Fisheries and Aquaculture Department (online).

Faria, V. V., McDavitt, M. T., Charvet, P., Wiley, T. R., Simpfendorfer, C. A., & Naylor, G. J. P. (2013). Species delineation and global population structure of Critically Endangered sawfishes (Pristidae). *Zoological Journal of the Linnean Society*, *167*, 136–164.

Fernholm, B. (1981). A new species of hagfish of the genus *Myxine*, with notes on other eastern Atlantic myxinids. *Journal of Fish Biology*, *19*, 73–82.

Floeter, S. R., Rocha, L. A., Robertson, D. R., Joyeux, J. C., Smith-Vaniz, W. F., Wirtz, P., … Brito, A. (2008). Atlantic reef fish biogeography and evolution. *Journal of Biogeography*, *35*, 22–47.

Formia, A., Tiwari, M., Fretey, J., & Billes, A. (2003). Sea turtle conservation along the coast of Africa. *Marine Turtle Newsletter*, *100*, 33–37.

Fretey, J. (1999). La tortue olivâtre: Une espèce très menacée au Cameroun. *Canopée*, *14*, iii–iiv.

Fretey, J. (2001). *Biogeography and conservation of marine turtles of the Atlantic coast of Africa/Biogéographie et conservation des tortues marines de la cote Atlantique de l'Afrique. CMS Technical Series Publication 6*. Bonn, Germany: UNEP/CMS Secretariat.

GCLME. (2006). *Transboundary diagnostic analysis: Guinea Current large marine ecosystem programme*. Accra, Ghana: GCLME Regional Coordinating Unit.

Harnik, P. G., Lotze, H. K., Anderson, S. C., Finkel, Z. V., Finnegan, S., Lindberg, D. R., … O'Dea, A. (2012). Extinctions in ancient and modern seas. *Trends in Ecology & Evolution*, *27*, 608–617.

Hawkins, J. P., Roberts, C. M., & Clark, V. (2000). The threatened status of restricted-range coral reef fish species. *Animal Conservation*, *3*, 81–88.

Hayward, M. W. (2009). The need to rationalize and prioritize threatening processes used to determine threat status in the IUCN Red List. *Conservation Biology*, *23*, 1568–1576.

Heyman, W. D., & Kjerfve, B. (2008). Characterization of transient multi-species reef fish spawning aggregations at Gladden Spit, Belize. *Bulletin of Marine Science*, *83*, 531–551.

Hoffmann, M., Brooks, T. M., da Fonseca, G. A., Gascon, C., Hawkins, A. F. A., James, R. E., … Silva, J. M. C. (2008). Conservation planning and the IUCN Red List. *Endangered Species Research*, *6*, 113–125.

IGCC. (2010). *State of the coastal and marine ecosystems in the Guinea Current large marine ecosystem region* GP/RAF/04/004/1191. Interim Guinea Current Commission.

IUCN. (2001). *IUCN Red List categories and criteria, version 3.1*. Gland, Switzerland: IUCN Species Survival Commission.

IUCN. (2012). *Guidelines for application of IUCN Red List criteria at regional and national levels: Version 4.0*. Gland, Switzerland: IUCN Species Survival Commission.

IUCN. (2016). *Guidelines for using the IUCN Red List categories and criteria*. Gland, Switzerland: IUCN Species Survival Commission.

Joyeux, J.-C., Floeter, S. R., Ferreira, C. E. L., & Gasparini, J. L. (2001). Biogeography of tropical reef fishes: The South Atlantic puzzle. *Journal of Biogeography*, *28*, 831–841.

Koranteng, K. A. (1998). The impacts of environmental forcing on the dynamics of demersal fishery resources of Ghana. PhD thesis, University of Warwick, UK.

Linardich, C. (2016). Hotspots, extinction risk and conservation priorities of greater Caribbean and Gulf of Mexico marine bony shorefishes. Master's thesis, Department of Biological Sciences, Old Dominion University, Norfolk, USA.

Lindeman, K. C., Pugliese, R., Waugh, G. T., & Ault, J. S. (2000). Developmental patterns within a multispecies reef fishery: Management applications for essential fish habitats and protected areas. *Bulletin of Marine Science*, *66*, 929–956.

Mace, G. M., Collar, N. J., Gaston, K. J., Hilton-Taylor, C., Akçakaya, H. R., Leader-Williams, N., … Stuart, S. N. (2008). Quantification of extinction risk: IUCN's system for classifying threatened species. *Conservation Biology*, *22*, 1424–1442.

Mensah, M. A., & Quaatey, S. N. K. (2002). An overview of the fishery resources and fishery research in the Gulf of Guinea. *Large Marine Ecosystems*, *11*, 227–230.

Møller, P. R., Feld, T. K., Poulsen, I. H., Thomsen, P. F., & Thormar, J. G. (2005). *Myxine jespersenae*, a new species of hagfish (Myxiniformes: Myxinidae) from the North Atlantic Ocean. *Copeia*, *2*, 374–385.

Nieto, A., Ralph, G. M., Comeros-Raynal, M. T., Kemp, J., García Criado, M., Allen, D. J., … Williams, J. T. (2015). *European Red List of marine fishes*. Gland, Switzerland and Brussels, Belgium: IUCN and European Commission.

Nwilo, P. C., & Badejo, O. T. (2006). Impacts and management of oil spill pollution along the Nigerian coastal areas. FIG Publication 26: *Administrating Marine Spaces: International Issues*, Copenhagen, Denmark: International Federation of Surveyors (FIG). https://www.fig.net/resources/publications/figpub/pub36/pub36.pdf

Olson, S. L. (1975). Paleornithology of St Helena Island, South Atlantic Ocean. *Smithsonian Contributions to Paleobiology*, *23*, 1–49.

Palomares, M. L. D., & Pauly, D. (2004). *West African marine ecosystems: Models and fisheries impacts*. Vancouver: University of British Columbia.

Pauly, D., & Zeller, D. (2016). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications*, *7*, 10244.

Peñate, J. G., Karamoko, M., Bamba, S., & Djadji, G. (2007). An update on marine turtles in Côte d'Ivoire, West Africa. *Marine Turtle Newsletter*, *116*, 7–8.

Peters, H., O'Leary, B. C., Hawkins, J. P., Carpenter, K. E., & Roberts, C. M. (2013). Conus: First comprehensive conservation Red List assessment of a marine gastropod mollusc genus. *PloS ONE*, *8*, e83353. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0083353

Peters, H., O'Leary, B. C., Hawkins, J. P., & Roberts, C. M. (2015). Identifying species at extinction risk using global models of anthropogenic impact. *Global Change Biology*, *21*, 618–628.

Pinsky, M. L., Jensen, O. P., Ricard, D., & Palumbi, S. R. (2011). Unexpected patterns of fisheries collapse in the world's oceans. *Proceedings of the National Academy of Sciences of the United States of America*, *108*, 8317–8322.

Polidoro, B. A., Brooks, T., Carpenter, K. E., Edgar, G. J., Henderson, S., Sanciangco, J., & Robertson, D. R. (2012). Patterns of extinction risk and threat for marine vertebrates and habitat species in the Tropical Eastern Pacific. *Marine Ecology Progress Series*, *448*, 93–104.

Polidoro, B. A., Carpenter, K. E., Collins, L., Duke, N. C., Ellison, A. M., Ellison, J. C., … Hong Yong, J. W. (2010). The loss of species: Mangrove extinction risk and geographic areas of global concern. *PloS ONE*, *5*, e10095. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0010095

Polidoro, B. A., Williams, J., Smith-Vaniz, W., & Carpenter, K. E. (2014). *Potential impact of climate change on the World's blennioids*. Poster Presentation: International Marine Conservation Congress, 14-18 August 2014. Glasgow, Scotland. http://birenheide.com/IMCC2014/program/singlesession.php3?sessid=P

Reynolds, J. E., & Odell, D. K. (1991). *Manatees and dugongs*. New York: Facts on File Inc.

Rodrigues, A. S., Pilgrim, J. D., Lamoreux, J. F., Hoffmann, M., & Brooks, T. M. (2006). The value of the IUCN Red List for conservation. *Trends in Ecology & Evolution*, *21*, 71–76.

Ross, G. J. B. (2002). Humpback dolphins *Sousa chinensis*, *S. plumbea*, and *S. teuszii*. In W. F. Perrin, B. Wursig, & J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals*. (pp. 585–589). New York: Academic Press.

Sadovy de Mitcheson, Y., Craig, M. T., Bertoncini, A. A., Carpenter, K. E., Cheung, W. W., Choat, J. H., … Sanciangco, J. (2013). Fishing groupers towards extinction: A global assessment of threats and extinction risks in a billion-dollar fishery. *Fish and Fisheries*, *14*, 119–136.

Scheren, P. A. G. M., & Ibe, A. C. (2002). Environment pollution in the Gulf of Guinea: A regional approach. In J. M. McGlade, P. Cury, K. A. Koranteng, & N. J. Hardman-Mountford (Eds.), *Gulf of Guinea large marine ecosystem*). Amsterdam: Elsevier Science B.V.

Schipper, J., Chanson, J. S., Chiozza, F., Cox, N. A., Hoffmann, M., Katariya, V., … Young, B. E. (2008). The status of the world's land and marine mammals: Diversity, threat, and knowledge. *Science*, *322*, 225–230.

Schwartz, M. T. (2006). *Encyclopedia of coastal science*. Dordrecht, Netherlands: Springer.

Segniagbeto, G., & Van Waerebeek, K. (2010). A note on the occurrence and status of cetaceans in Togo. Paper SC/62/SM11 presented to IWC Scientific Committee, June 2010, Agadir, Morocco.

Shumway, C. A. (1999). *Forgotten waters: Freshwater and marine ecosystems in Africa. Strategies for biodiversity conservation and sustainable development*. Boston MA: Boston University.

Simmons, R. E., Cordes, I., & Braby, R. (1998). Latitudinal trends, population size and habitat preferences of the Damara Tern *Sterna balaenarum* on Namibia's desert coast. *Ibis*, *140*, 439–445.

Solarin, B. B., Williams, A. B., Hamzat, M. B., Rabiu, A., Oguntade, O. R., Bolaji, D. A., & Oramadike, M. (2010). Report on survey of fish and other living resources of the Nigerian coastal waters conducted between 14th April and 6th June 2009. NIOMR, Lagos.

Spalding, M., Kainuma, M., & Collins, L. (2010). *World atlas of mangroves*. London: Earthscan.

Spalding, M., Ravilious, C., & Green, E. P. (2001). *World atlas of coral reefs*. Berkeley, CA: University of California Press.

Spalding, M. D., Fox, H. E., Allen, G. R., Davidson, N., Ferdaña, Z. A., Finlayson, M., … Martin, K. D. (2007). Marine ecoregions of the world: A bioregionalization of coastal and shelf areas. *BioScience*, *57*, 573–583.

Srinivasan, U. T., Watson, R., & Sumaila, U. R. (2012). Global fisheries losses at the exclusive economic zone level, 1950 to present. *Marine Policy*, *36*, 544–549.

Stuart, S. N., Chanson, J. S., Cox, N. A., Young, B. E., Rodrigues, A. S. L., Fischman, D. L., & Waller, R. W. (2004). Status and trends of amphibian declines and extinctions worldwide. *Science*, *306*, 1783–1786.

Ukwe, C. N., Ibe, C. A., Alo, B. I., & Yumkella, K. K. (2003). Achieving a paradigm shift in environmental and living resources management in the Gulf of Guinea: The large marine ecosystem approach. *Marine Pollution Bulletin*, *47*, 219–225.

Ukwe, C. N., Isebor, C. E., & Alo, B. I. (2001). *Implementing the quality of coastal waters in the Gulf of Guinea large marine ecosystem through mangrove restoration*. Proceedings of the 12th Biennial Coastal Zone Conference. Cleveland, Ohio, July 15-19, 2001. NOAA/CSC/20120-CD.

UNEP. (1999). Overview of land-based sources of and activities affecting the marine, coastal and associated freshwater environment in the West and Central African Region. UNEP Regional Seas Reports and Studies no. 171, UNEP, Nairobi.

Urban, E. K., Fry, C. H., & Keith, S. (1986). *The birds of Africa, Volume II*. London: Academic Press.

Van Waerebeek, K., Barnett, L., Camara, A., Cham, A., Diallo, M., Djiba, A., … Bamy, I. L. (2004). Distribution, status, and biology of the Atlantic humpback dolphin, *Sousa teuszii* (Kukenthal, 1892). *Aquatic Mammals*, *30*, 56–83.

Williams, F. (1968). *Report on the Guinean trawling survey, Lagos. Vol. 1-3*. Lagos: Organization of African Unity STRC.

Wirtz, P. (2014). A new species of Malacoctenus from the Cape Verde Islands, eastern Atlantic (Pisces Teleostei, Labrisomidae). Arquipélago. *Life and Marine Science*, *31*, 15–20.

Wirtz, P., & Schliewen, U. K. (2012). A new species of Liopropoma Gill, 1862 from the Cape Verde Islands, Eastern Atlantic. *Spixiana*, *35*, 149–154.

Wirtz, P., Brito, A., Falcon, J. M., Freitas, R., Fricke, R., Monteiro, V., … Tariche, O. (2013). The coastal fishes of the Cape Verde Islands – new records and an annotated check-list. *Spixiana*, *36*, 113–142.

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

How to cite this article: Polidoro BA, Ralph GM, Strongin K, et al. The status of marine biodiversity in the Eastern Central Atlantic (West and Central Africa). Aquatic Conserv: Mar Freshw Ecosyst. 2017;00:1–14. https://doi.org/10.1002/aqc.2744