Translating Globally Threatened Marine Species Information into Regional Guidance for the Gulf of Mexico

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Original Research Article

Translating globally threatened marine species information into regional guidance for the Gulf of Mexico

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A B S T R A C T

A comprehensive understanding of the status of marine organisms in the Gulf of Mexico is critical to the conservation and improved management of marine biodiversity in the region. Threats and extinction risk, based on application of the IUCN Red List Categories and Criteria at the global level, were analyzed for 1,300 Gulf of Mexico marine species. These species include all known marine mammals, sea birds, marine reptiles, cartilaginous fishes, bony shorefishes, corals, mangroves, seagrasses and complete clades of select invertebrates. Analyses showed that 6% of these species are threatened, 2% Near Threatened, 9% Data Deficient, and 83% Least Concern. However, the majority of these species are not endemic to the Gulf, and therefore are globally impacted by threats that may or may not be particularly intense within the Gulf. For example, many of these species are impacted by fisheries in much of their global range; however, the intensity of fishing pressure varies across their ranges, and some of these exploited species are well managed in the Gulf of Mexico. Other anthropogenic impacts, including industrial development, pollution, and habitat loss also vary in intensity across species' global ranges. Here we provide recommendations for interpreting the application of global IUCN Red List Categories at the sub-global/regional scale, while highlighting conservation measures needed for marine species specific to the Gulf region.

1. Introduction

The ongoing loss of marine biodiversity due to threats such as overfishing, coastal development, pollution and climate change, is negatively affecting ecosystem function and associated ecosystem services across the globe (Balvanera et al., 2006; Gamfeldt et al., 2008; Halpern et al., 2008; Hooper et al., 2012). As such, it has become increasingly important to monitor the impact of anthropogenic stressors on marine biodiversity and ecosystems, including improved tracking of fisheries catch statistics (Coleman and Williams, 2002; Bache, 2003; Shirley et al., 2010; Barron, 2012; Pauly and Zeller, 2016). Species-specific extinction risk assessments are one method to monitor the impacts of change, by providing detailed information on the status of species' global and regional populations over time (Carpenter et al., 2008; Polidoro et al. 2010, 2012, 2017; Collette et al., 2011; Short et al., 2011; Linardich et al., 2018; Buchanan et al., 2019). The application of the IUCN Red List of

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Threatened Species methodology to create species-specific extinction risk assessments is a globally accepted, standardized tool for identifying the impacts of threats to species and populations (de Grammont et al., 2006; Hoffmann et al., 2008; IUCN, 2012a; IUCN, 2012b). These assessments not only identify those species most at risk of extinction, but also help define pathways toward sustainable management, reducing biodiversity loss and preserving ecosystem function (Klein et al., 2008).

The spatial distribution and intensity of threats can vary widely across a species range, especially for marine species with widespread distributions extending over many governmental jurisdictions, which often differ in preferences, practices, capacity, and cultural norms (Bolten et al., 2011; Senko et al., 2011; Lascelles et al., 2014). As conservation actions are typically implemented at the local or regional scale, the utilization of global level threat and risk information to inform conservation and management practices often needs further resolution to capture local or regional differences in the severity and impact of threats (Broennimann et al., 2006; Mace et al., 2008; Bolten et al., 2011). Therefore, in order to support more effective regional conservation planning and identification of research priorities, additional species-specific information on extinction risk, population trends, and the impact of regional threats are needed (Polidoro et al. 2012, 2017).

The Gulf of Mexico (hereafter referred to as "the Gulf") is a primarily subtropical, large marine ecosystem bordered by the United States, Mexico, and Cuba in which marine species are facing threats such as overfishing, habitat loss, and pollution (Adams et al., 2004). The global conservation status of more than 2000 marine species that occur in the Gulf are now publically available through the IUCN Red List of Threatened Species. These include all known marine vertebrates, as well as species in selected, complete clades of marine invertebrates and marine plants. This study aims to translate about 1300 of these global level extinction risk assessments into recommendations for regional conservation action by analyzing the severity of global vs. regional threats. Quantifying and comparing the severity of global and regional threats on marine populations in the Gulf of Mexico will allow for better informed decision making when implementing regional conservation strategies, as well as identifying critical research needs.

2. Methods

2.1. Definition of geographic range

The Gulf of Mexico is defined according to boundaries described by Felder et al. (2009), which extend from the southern tip of Florida to northwest Cuba and the northern tip of the Yucatan Peninsula, encompassing an area of about 1,554,000 km^2. The Gulf is the ninth largest body of water in the world and is a semi-enclosed basin or marginal sea consisting mainly of subtropical habitats bordered on all sides by primarily continental land masses, except in the south where it is connected to the Caribbean Sea and flows outwards towards the Bahamas through the Florida Strait in the north (GNIS, 2000).

2.2. Taxonomic inclusion

A comprehensive species list for the Gulf was compiled for marine vertebrates (e.g. marine bony fishes, sharks and rays, marine mammals, marine reptiles), some groups of marine invertebrates in complete taxonomic clades (e.g. cone snails, cephalopods, sea cucumbers, and lobsters), and habitat-building species (e.g. mangroves, reef-building corals and seagrasses) that are both present in the Gulf of Mexico and have been globally assessed for the IUCN Red List of Threatened Species. Species lists were derived by querying the IUCN Red List website (www.iucnredlist.org) for all assessed marine species in the above taxonomic groups having an occurrence in the United States, Mexico, or Cuba and then culling species that do not occur within the Gulf of Mexico. Assessments for the deep sea bony fishes, comprised of about 500 species occurring primarily off the continental shelf and below 200 m, were not available at the time of the initiation of this study, and were therefore not included.

The list of sea birds was initially created using the GulfBase database (http://biogomx.org/). This initial list was revised by following the definition of a sea bird according to Birdlife International (Croxall et al., 2012). To be considered for inclusion, a large portion of the bird's population must utilize the marine environment for resources or have a large role in the marine ecosystem food web for at least part of the year to be considered a true sea bird. This reduced the sea bird list to a total of 45 species, including species such as pelicans, while excluding species such as the Trumpeter Swan.

2.3. IUCN species assessment process

Data collection for Red List assessments of marine fishes of the Gulf of Mexico was overseen and conducted by the Marine Biodiversity Unit at Old Dominion University between 2012 and 2015. Data and assessments for all other groups were overseen by a variety of IUCN Species Survival Commission Species Specialists Groups (https://www.iucn.org/ssc-groups). The application of the IUCN Red List Categories and Criteria (IUCN, 2012a) to complete all species' assessments is described in additional detail in the Supplemental Online Material. The process begins with the collation of scientific articles, gray literature, and direct input from species' experts, on life history, habitats and ecology, distribution, population trends, threats, and conservation measures for each species. A digital range map is also produced as part of the assessment process. These data are then reviewed by species experts and assigned an IUCN Red List category based on application of the standardized criteria. A species is listed in a threatened category, as Vulnerable, Endangered, or Critically Endangered, only if certain quantitative thresholds and conditions are met. If these criteria are not met, a species can be listed as either Least Concern or

Table 1
Definitions of threat categories.

Threat Category	Definition
Aquarium Trade	Includes those species thought to be impacted by the aquarium trade.
Bycatch	Includes species regularly caught as bycatch in commercial industries as well as entanglement in ghost nets or pots.
Disease	Includes species known to be significantly impacted by diseases.
Directed Fishing	Includes those species which are the focus of targeted fishing efforts.
Habitat Loss	Includes those species whose ranges are declining due to declining habitat availability.
Hunting and Predation	Limited to marine turtles and birds which are impacted by hunting efforts for their shells and eggs, and predation of seabird populations by rats.
Industrial Development	Includes species thought to be impacted by tourism, dredging, shipping, and drilling.
Invasives	Includes species thought to be impacted by invasive species.
Pollution	Includes species impacted by runoff, eutrophication, chemical/oil spills, and noise pollution.
Storms	Limited to species whose habitats and/or migration routes can be impacted by tropical storms
Warming	Includes species significantly impacted byocean warming, bleaching events, and/or changes in migratory movements or habitats due to changing water temperatures.

Data Deficient depending on the amount of data currently available. Any species that nearly meets the quantitative threshold and conditions for inclusion in a threatened category is listed as Near Threatened. A species may also be listed as Extinct in the Wild or Extinct if extensive surveys indicate that no extant individuals remain in wild populations or if surveys fail to record any remaining individuals in the wild or in captivity. Once the peer review process is completed, the final assessments are made publicly available on the IUCN Red List of Threatened Species website (www.iucnredlist.org).

2.4. Threat analyses

Species-specific data were compiled from the IUCN Red List assessments, including taxonomy, habitat, life history, threats, and distribution. Only the 79 species listed in a threatened category (Table 2) were analyzed for threat impacts, as details on threats are not required for species listed as Data Deficient (DD) or Least Concern (LC) (IUCN, 2013). In Red List assessments, threat categories follow the classification scheme developed by Salafsky et al. (2008). The threat categories extracted from the 79 threatened species assessments were simplified to Aquarium Trade, Bycatch, Disease, Directed Fishing, Habitat Loss, Hunting and Predation, Industrial Development, Invasives, Pollution, Storms, and Warming (Table 1).

The threats impacting species assessed as Vulnerable, Endangered or Critically Endangered were then compared at a regional vs. global scale. The overall impacts of threats on each species was designated as either the 'same', 'more', or 'less' in the Gulf as compared to outside the Gulf according to text within the Red List assessment. If the listed threats were equally impacting areas both outside and inside the Gulf, threat impacts were coded as 'same' across the species' range. If the majority of listed threats were considered stronger in the Gulf, then the overall severity of threats was coded as 'more' severe in the Gulf. If the listed threats occurred only or to a greater extent in areas outside the Gulf region, threats were considered stronger outside the Gulf than inside, and consequently coded as 'less' severe in the Gulf. Current species listings from the IUCN Red List, the US Endangered Species Act, and the Mexico NORMA 59 were also compared to show differences in currently recognized threats at both the regional and global levels, and to compare species protections which may exist both inside and outside the Gulf.

2.5. Statistical and spatial analyses

Species distribution maps were created in ArcGIS using protocols created by the IUCN Marine Biodiversity Unit or the respective protocols of individual IUCN Species Specialist Groups such as those for birds or marine mammals. Species

Table 2
Red List status by taxonomic group.

	LC	DD	NT	VU	EN	CR	Total Species
Mangroves & Seagrasses	12	1	1	1			15
Reef-Building Corals	42	8	1	5	2	2	60
Gastropods	27	1		2			31
Lobsters, Horseshoe Crabs	19	2		1			22
Cephalopods	30	13					43
Sea Cucumbers	20	6					26
Sharks	14	11	10	7	2		44
Rays, Skates, Sawfishes	7	23	2	2		2	36
Chimaeras	1	1	1				3
Bony Fishes	856	35	11	29	9	1	941
Reptiles	2			4	1	2	9
Seabirds	42		1	1	1		45
Marine Mammals	10	12		2	3		27
Grand Total	**1082 (83%)**	**113 (9%)**	**27 (2%)**	**54 (4%)**	**18 (1.5%)**	**7 (0.5%)**	**1301**

inhabiting coastal areas/continental shelf were clipped to a shoreline buffer of 100 km or a depth of 200 m, whichever was further from the coast. Ranges for pelagic species and species with poorly described ranges were drawn based on points from museum collections, as well as known and inferred occurrences. All maps were then clipped to the Gulf of Mexico region and converted to 5 km by 5 km raster grids which were then overlaid and added together to calculate species richness. This process was done for all species, and separately for threatened species and for DD species.

3. Results

3.1. Species extinction risk in the Gulf of Mexico

Of the 1301 species (Table S1, Supplemental Online Material), 6% (79 species) are listed in one of the three threatened categories (VU, EN, or CR). More than 75% (7 of 9 species) of marine reptiles are listed in a threatened category, which represented the largest threatened percentage out of all the clades analyzed. Almost 20% (5 of 27 species) of marine mammals are listed in a threatened category. Of the 941 marine bony fishes, 39 species, or 4%, are listed in a threatened category. Of the 45 seabirds, two, or 4%, are listed in a threatened category. Thirteen of the 83 chondrichthyan species, 16%, are listed in a threatened category. Three of the 122 non-coral invertebrates, or 2%, are listed in a threatened category, including two cone snails and one horseshoe crab. Lastly, 10 of the 75 habitat-building species (e.g. corals, mangroves and seagrasses), 13%, are listed in a threatened category (Table 2).

Factors such as taxonomic confusion and lack of population data led to 9% (113) of species being listed as Data Deficient. Species were generally listed as Data Deficient due to taxonomic confusion, lack of key life history information that can inform the impact of known threats, or lack of population data to adequately quantify the impact of known threats. This lack of data can be due to collection difficulty, low sampling effort and/or insufficient data on habitat decline or fisheries catch and effort. For example, several Data Deficient species are only known from the holotype.

3.2. Threats to marine species in the Gulf of Mexico

The five most common threats to species in the Gulf are Directed Fishing, Habitat Loss, Industrial Development, Pollution and Bycatch (Fig. 1). Almost half (37 of 79) of all threatened species in the Gulf are impacted by directed fishing, including 20 of the 39 threatened bony fishes and all of the threatened sharks and rays. Approximately half of all threatened bony fishes are also impacted by habitat loss, primarily those that are dependent upon seagrass, coral or estuarine habitats for some or all of their life stages. Additionally, approximately one-quarter of threatened bony fishes are also impacted by the invasive lionfish, *Pterois volitans/miles* complex.

All five of the sea turtle species present in the Gulf are impacted by habitat loss, industrial development, incidental capture as bycatch, and hunting. Similarly, all nine threatened coral species are impacted by increased sea surface temperatures (warming), and other oceanographic changes which can cause an increased incidence of disease (Brodnicke et al., 2019). The five threatened marine mammals present in the Gulf are globally impacted by bycatch, industrial development and pollution. These results are consistent with those of Linardich et al. (2018) who found that smaller bodied bony shorefishes were more likely to be impacted by habitat loss while larger bodied species were more likely to be impacted by exploitation. Additional information on examples of threatened species in the Gulf within each taxonomic group, along with their global Red List Categories, can be found in the Supplemental Online Material.

3.3. Comparison of global and regional threats

In general, more than one-third (26 of 79 species) of IUCN listed threatened species were less impacted by threats in the Gulf when compared to threats outside the Gulf, while only 10% (9 of 79 species) were more impacted by threats occurring within the Gulf (Table 3). The threat levels for 44 species were found to be the same as elsewhere across their global range. In order to determine which globally threatened species have also been recognized as regionally threatened under national regulations, the 79 IUCN threatened species were compared with those species protected regionally by either the US Endangered Species Act (ESA) (1973) and/or the Mexico NORMA 59. Although the lack of consistency across protections is likely due to large differences in assessment processes, more than 70% (57 of 79 species) of species listed in an IUCN threatened category were not designated as threatened, and therefore not protected, under either the ESA or NORMA 59 (including 2 species Under Review). Within these, none of the 14 Gulf endemic IUCN threatened species is protected by either the US ESA or NORMA 59, although 1 endemic species is currently under review (*Fundulus jenkinsi*). A comparison of the severity of regional vs. global threats to species listed on either or both the ESA and NORMA 59, shows that 9 of these 22 species are facing the same level of threat across the entirety of the species range both inside and outside the Gulf. The level of threat within the Gulf was less for 12 species when compared to the level of threat faced outside the Gulf. Only one species, the Nassau Grouper (*Ephinephelus striatus*), had experienced higher levels of threat (e.g. due to fishing) within the Gulf, due to historical exploitation of spawning aggregations that have not recovered (Ault et al., 2013; Aguilar-Perera and Tuz-Sulub, 2012).

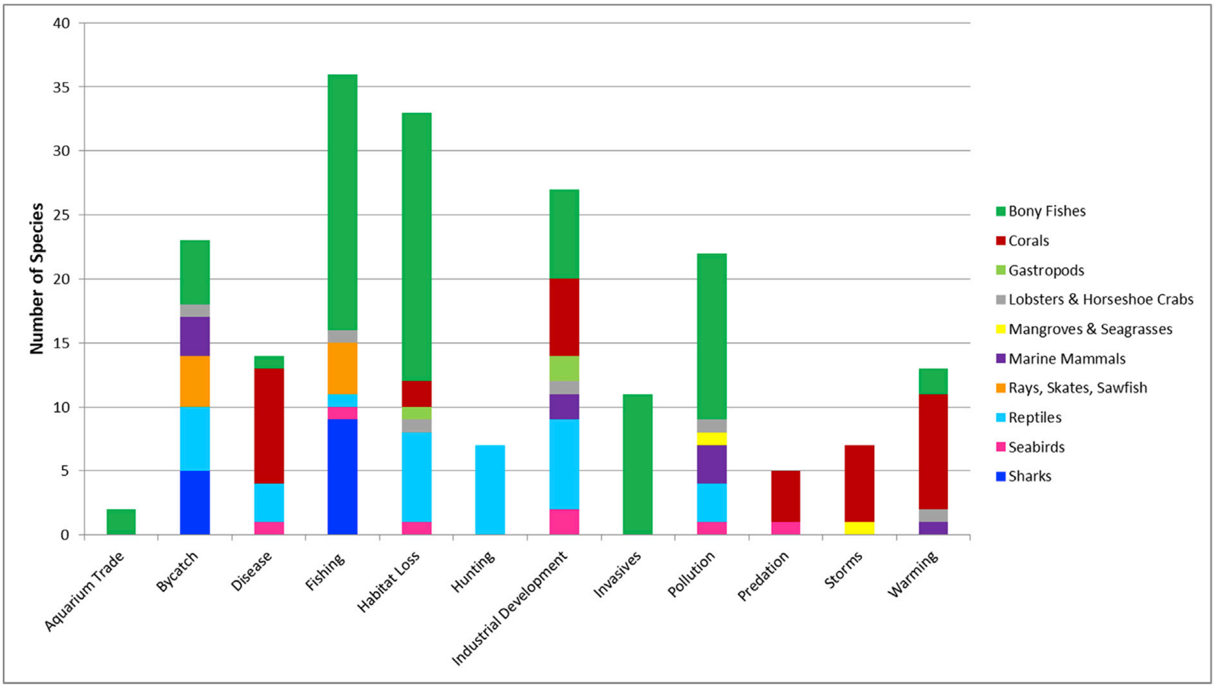

Fig. 1. Threats affecting species in threatened categories according to IUCN Categories and Criteria.

3.4. Spatial analyses

The Florida Keys have the highest species richness within the Gulf of Mexico (Fig. 2a). Both threatened and Data Deficient species richness is also concentrated around the Florida Keys, the northern and western side of the Yucatan Peninsula, and the eastern coast of Mexico (Fig. 2b and c). Many of the Data Deficient species occur in the southern and eastern Gulf, mainly Cuba and Mexico, where more sampling effort and fisheries information is needed.

4. Discussion

4.1. Threatened species

This is the first study to examine the conservation status and associated threats of all Red List comprehensively assessed clades of marine species across the Gulf of Mexico. Other regional, comprehensive studies of marine biodiversity extinction risk and patterns of threat have been conducted in the Persian Gulf (Buchanan et al., 2019), the Eastern Central Atlantic (Polidoro et al., 2017) and the Eastern Tropical Pacific (Polidoro et al., 2012). Although comprehensive species groups included in each study varied, with only 6% (79 of 1301 total species) of species being listed in a threatened category in the Gulf of Mexico, this percentage is less than that in the Eastern Tropical Pacific (12%) and the Eastern Central Atlantic (9%). A recent study of the greater Caribbean (Linardich et al., 2018) found that 65 of the 1360 bony shorefishes (5%) there were listed in a threatened category, and 34 of the 940 bony shorefishes (4%) that occur in the Gulf of Mexico were listed in a threatened category at the Gulf regional-level.

4.2. Data Deficient species

There are a variety of factors that can lead a species to be listed as Data Deficient, including taxonomic confusion, the lack of species-specific data in aggregate population trend information, and the lack of information on the impact of known threats. Twelve of the 27 marine mammals present in the Gulf of Mexico were listed as Data Deficient. Species such as *Balaenoptera edeni*, the Bryde's Whale, and *Orcinus orca*, the Killer Whale, have taxonomic confusion and possible subspecies groups, making it difficult to assess the impact of threats and the current population status of distinct species due to conflicting data. Thirty-five bony fishes, 35 chondrichthyans, and 22 marine invertebrates were also listed as Data Deficient due to taxonomic confusion and/or lack of information to adequately quantify the impact of known threats. The Southern Eagle Ray, *Myliobatis goodei*, is listed as Data Deficient because it is commonly caught as bycatch, but the impacts on its population are unknown. Nine of the 22 marine invertebrates listed as Data Deficient, such as *Helicocranchia papillata (*Siphonate cranch

Table 3
Comparison of species status on IUCN Red List, US ESA, and Mexico NORMA 59. Abbreviations are as follows: (CR) - Critically Endangered, (EN) or (E) - Endangered, (VU) - Vulnerable, (T) - Threatened, (SP) - sujeta a proteccion especial (special protection), (PE) - peligro de extincion (in danger of extinction), (UR) - Under Review. * Endemic Gulf species.

Genus species	Common Name	Global RL	ESA	NORMA 59	Aquarium Trade	Bycatch	Disease	Fishing	Habitat Loss	Hunting	Industrial Development	Invasives	Pollution	Predation	Storms	Warming	Strength of Threats in Gulf Compared to Globally
Acropora cervicornis	Staghorn Coral	CR	T	SP			x							x	x	x	Same
Acropora palmata	Elkhorn Coral	CR	T	SP			x							x	x	x	Same
Agaricia lamarcki	Lamarck's Sheet Coral	VU	–	–			x				x					x	Same
Alopias superciliosus	Bigeye Thresher Shark	VU	–	–		x		x									More
Alopias vulpinus	Common Thresher Shark	VU	–	–		x		x									Same
Balaenoptera borealis	Sei Whale	EN	E	SP		x											Less
Balaenoptera musculus	Blue Whale	EN	E	SP									x			x	Less
Balistes capriscus	Gray Triggerfish	VU	–	–				x									More
Carcharhinus longimanus	Oceanic Whitetip Shark	VU	–	–				x									More
Carcharhinus obscurus	Dusky Shark	VU	–	–		x		x									More
Carcharhinus plumbeus	Sandbar Shark	VU	–	–				x									More
Carcharias taurus	Sand Tiger Shark	VU	–	–		x		x									Same
Caretta caretta	Loggerhead Sea Turtle	VU	T	PE		x	x		x	x	x		x				Less
Chelonia mydas	Green Sea Turtle	EN	T	PE		x		x	x	x	x						Less
Conus anabathrum*	Florida Cone	VU	–	–							x						Same
Conus stearnsii*	Cone Snail sp.	VU	–	–					x		x						Same
Coryphopterus eidolon	Pallid Goby	VU	–	–								x					Same
Coryphopterus hyalinus	Glass Goby	VU	–	–	x							x					Same
Coryphopterus lipernes	Peppermint Goby	VU	–	–					x			x					Same
Coryphopterus personatus	Masked Goby	VU	–	–					x			x					Same
Coryphopterus thrix	Bartail Goby	VU	–	–					x			x					Same
Coryphopterus tortugae	Patch Reef Goby	VU	–	–					x			x					Same
Crocodylus acutus	American Crocodile	VU	T	SP					x	x	x						Less
Ctenogobius claytonia*	Mexican Goby	VU	–	–					x				x				Same
Dermochelys coriacea	Leatherback Sea Turtle	VU	E	PE		x	x		x	x	x		x				Less
Dichocoenia stokesii	Elliptical Star Cone	VU	–	–			x				x				x	x	Same
Elacatinus jarocho*	Jarocho Goby	EN	–	–					x		x						Same
Elacatinus prochilos	Broadstripe Goby	VU	–	–					x				x				More
Epinephelus itajara	Atlantic Goliath Grouper	VU	–	–				x					x				Less
Epinephelus morio	Red Grouper	VU	–	–				x					x				More
Epinephelus striatus	Nassau Grouper	CR	T	–				x	x		x	x					More
Eretmochelys imbricata	Hawksbill Sea Turtle	CR	E	PE		x			x	x	x						Less
Eubalaena glacialis	North Atlantic Right Whale	EN	E	PE		x					x		x				Less
Fundulus grandissimus*	Giant Killifish	VU	–	–					x				x				Same
Fundulus jenkinsi*	Saltmarsh Topminnow	VU	UR	–					x								Same
Fundulus persimilis*	Yucatan Killifish	EN	–	–					x				x				Same
Halichoeres burekae*	Mardi Gras Wrasse	EN	–	–							x	x	x				Same
Halophila baillonii	Clover Grass	VU	–	–									x		x		Less
Hippocampus erectus	Lined Seahorse	VU	–	SP	x	x		x	x				x				Same

Hypoplectrus castroaguirrei*	Veracruz White Hamlet	EN	–	–				x		x	x	x				Same
Hyporthodus flavolimbatus	Yellowedge Grouper	VU	–	–			x									Less
Hyporthodus niveatus	Snowy Grouper	VU	–	–			x									Less
Isurus oxyrinchus	Shortfin Mako	VU	–	–			x									Same
Kajikia albida	White Marlin	VU	–	–			x									Same
Lachnolaimus maximus	Hogfish	VU	–	–			x	x		x						Same
Lepidochelys kempii	Kemp's Ridley Sea Turtle	CR	E	PE	x	x		x	x	x		x				Same
Limulus polyphemus	American Horseshoe Crab	VU	–	PE	x		x	x		x		x			x	Less
Lopholatilus chamaeleonticeps	Golden Tilefish	EN	–	–			x									Same
Lutjanus campechanus	Red Snapper	VU	–	–	x		x									Same
Lutjanus cyanopterus	Cubera Snapper	VU	–	–			x	x								Same
Makaira nigricans	Blue Marlin	VU	–	–	x		x									More
Malaclemys terrapin	Diamondback Terrapin	VU	–	–				x	x	x						Same
Manta birostris	Giant Manta Ray	VU	–	–	x		x									Less
Megalops atlanticus	Tarpon	VU	–	–			x	x		x		x				Same
Menidia colei*	Golden Silverside	EN	–	–				x				x				Same
Menidia conchorum*	Key Silverside	EN	–	–				x							x	Same
Mola mola	Ocean Sunfish	VU	–	–	x		x									Less
Montastraea annularis	Boulder Star Coral	EN	–	–		x									x	Less
Montastraea faveolata	Mountainous Star Coral	EN	–	–		x		x		x			x	x	x	Less
Montastraea franksi	Star Coral	VU	–	–		x		x		x			x	x	x	Same
Mycetophyllia ferox	Rough Cactus Coral	VU	T	–		x				x					x	Same
Mycteroperca interstitialis	Yellowmouth Grouper	VU	–	–			x									Same
Narcine bancroftii	Caribbean Electric Ray	CR	–	–	x		x									Same
Neoopisthopterus cubanus*	Cuban Longfin Herring	VU	–	–				x								Same
Oculina varicosa	Large Ivory Coral	VU	–	–						x						Less
Odontaspis ferox	Smalltooth Sand Tiger	VU	–	–			x									Less
Physeter macrocephalus	Sperm Whale	VU	E	SP	x							x				Less
Podiceps auritus	Horned Grebe	VU	–	–		x	x			x		x				Less
Pomatomus saltatrix	Bluefish	VU	–	–			x									Less
Pristis pectinata	Smalltooth Sawfish	CR	E	T	x		x									Less
Pterodroma hasitata	Black-capped Petrel	EN	UR	–				x		x			x			Same
Rhincodon typus	Whale Shark	EN	–	T	x		x									Less
Rhomboplites aurorubens	Vermilion Snapper	VU	–	–	x		x				x					Less
Sanopus reticulatus*	Reticulated Toadfish	EN	–	–				x		x		x				Same
Sphyrna lewini	Scalloped Hammerhead	EN	T	–	x		x									Same
Thunnus obesus	Bigeye Tuna	VU	–	–			x									Less
Thunnus thynnus	Atlantic Bluefin Tuna	EN	–	–			x					x			x	Same
Tigrigobius redimiculus*	Cinta Goby	VU	–	–		x		x			x					Same
Trichechus manatus	West Indian Manatee	VU	T	PE						x						Same

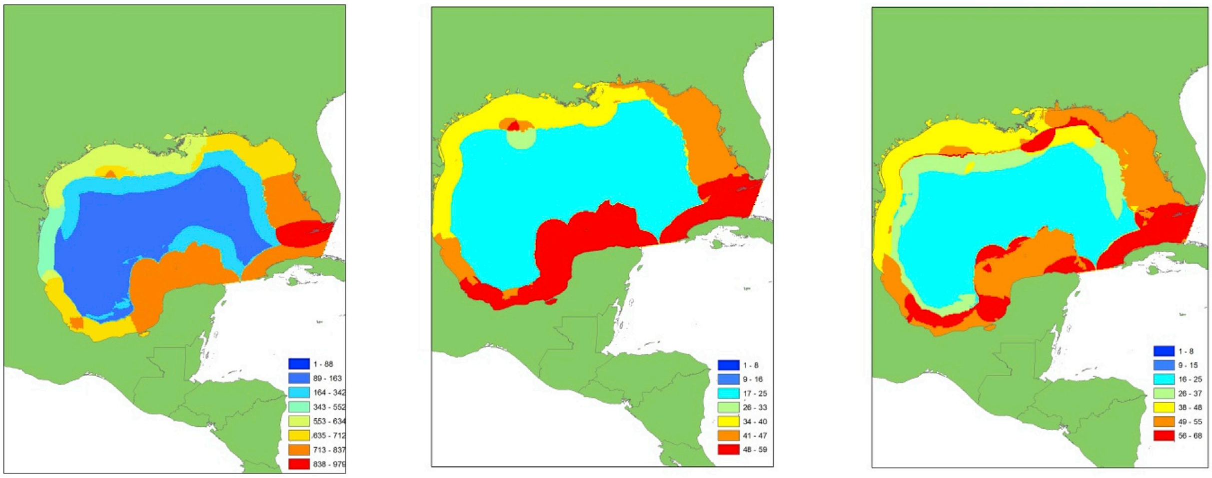

Fig. 2. Spatial analysis of (a) total species richness; (b) threatened species richness including CR, EN, and VU species; (c) Data Deficient species richness.

squid), *Sandalops melancholicus* (Sandal-eye squid), and *Holothuria arenicola* (Sand sea cucumber) are also lacking population data due to taxonomic confusion. These species highlight the importance of continued research on taxonomy, population, and the impact of known threats on many marine species. In addition, efforts are needed to educate resource users, managers, field data collection staff, and the public on proper identification of important species in the region (Chizinski et al., 2014).

4.3. Translating global extinction risk categories into regional conservation priorities

Translating the Red List assessment of a species, that is not endemic to a certain management locality, such as a national jurisdiction or a marine protected area, can be problematic. For example, a widespread species can still be listed as threatened based on population decline data that has been averaged across its global range, even if some regional or local populations may be stable or increasing. In contrast, a species can be globally listed as Least Concern, but have populations in smaller portions of its range that are in decline or even extirpated. For these reasons, prioritization of conservation actions at the regional scale for globally threatened species must consider: 1) the efficacy of any regional or local protections for species that may provide for improved population stability, 2) the severity of major threats to the species within the region of interest, compared to those threats operating elsewhere, and 3) the connectivity of populations within and outside the area of interest, in order to account for any rescue or sink effects.

Threats such as hunting, collection for the aquarium trade, and predation are likely of lower intensity within the Gulf, compared to outside regions, primarily due to improved regulations. Species such as the Sei Whale, Blue Whale, Right Whale, and the Loggerhead, Green, Kemp's Ridley, and Leatherback Sea Turtles, have faced high levels of global exploitation in the past century, but their protected status under ESA or NORMA 59 most likely allows these species to have a higher opportunity for recovery at least in U.S. and/or Mexican waters. Unfortunately, details of biological connectivity between populations inside and outside the Gulf are generally not known for the vast majority of marine species. Of the 79 threatened species, 20 are currently recognized on either the ESA or NORMA 59 as needing some level of protection; 2 additional species are currently under review. For example, sea turtles are mainly impacted by illegal hunting and poaching outside of the Gulf region (Campbell, 2003; Garcia-Martinez and Nichols, 2000; Senko et al., 2011), and sea birds are primarily impacted by rat predation (Jones et al., 2008), which is a threat to nesting populations on islands outside the Gulf region. For the other 57 IUCN Red List threatened species, a closer look at the severity of threats affecting their Gulf populations (Table 3) may help prioritize species and geographic areas for conservation and further research, and may identify threat mitigation strategies.

Globally pervasive threats such as disease, invasive species, storms and increased ocean warming are growing in severity in many parts of the world. For example, increased storm activity, ocean warming, and ocean acidification are linked to global climate change (Leiserowitz et al., 2013). The projected increased intensity and frequency of storms is estimated to have a negative impact on coral species almost everywhere (Pandolfi et al., 2011; De'ath et al., 2012). Globally, coral communities are also experiencing an increased threat from marine diseases (Harvell et al., 1999; Weil et al., 2006). Although little may be known about the causes or mode of their transmission (Richardson, 1998), human related threats, such as pollution and habitat degradation, in combination with changes in oceanographic conditions related to climate change, are thought to increase the incidence of these diseases (Ruiz-Morenol et al., 2012; Osterhaus et al., 1995). Similarly, the invasive lionfish, which can drive biomass declines in small-bodied reef fishes, is rapidly expanding its range throughout the Gulf of Mexico, the Caribbean and Western Atlantic (Johnston and Purkis, 2015; Côté and Smith, 2018).

Further discussion is warranted for the top five threats to marine species in the Gulf of Mexico (Directed Fishing, Habitat Loss, Industrial Development, Pollution and Bycatch), particularly as there are likely certain cases where these threats may be more severe in the Gulf compared to other adjacent regions in the Caribbean and Western Atlantic. Therefore, improved management and mitigation of these threats should be a priority for the conservation of threatened marine species in the Gulf of Mexico.

4.3.1. Threats from fisheries

Fisheries in the Gulf currently target high-value species such as groupers, snappers, and tunas, which are also of interest to artisanal and recreational fisheries. In U.S. waters, management of these fisheries is prescribed in the Magnuson-Stevens Act (MSA). Since the implementation of the MSA, the status of fisheries stocks in U.S. waters has improved, with nearly 90% of all U.S. managed fisheries maintained at sustainable levels. Although the Mexican National Fisheries Institute has recommended management to prevent collapse of fisheries (Castillo-Geniz et al., 1999), including increasing mariculture to supplement supply in the face of decreasing fish stocks, many concerns remain, including barriers to full reporting, mostly open access fisheries, poor administrative practices, and corruption (Cisneros-Montemayor et al., 2015). In addition, industrialization has created well-equipped fleets that are continually subsidized, further endangering stocks in the region. Similarly, in Cuba, management plans and incentives exist to limit harvests, particularly for shark fisheries, but the efficacy of these actions is not known (NPOA-Sharks, 2015).

Since 1983, the United States-Mexico Fisheries Cooperation Program has encouraged bilateral communication and cooperation on the protection of endangered species and the management and enforcement of some recreational and commercial fisheries. However, it does not address issues where conflicts of interest between the two countries may exist (NOAA, 2017), which can facilitate the continued decline in stocks and loss of biodiversity. Although these programs are important steps forward, overfishing and illegal fishing is still occurring, including in marine protected areas (Mangin et al., 2018; Pala et al., 2018). Estimates show that the Gulf is severely overfished due to illegal and unreported catches, so increased regulation will be necessary to improve the health of Mexico's fish stocks (Cisneros-Montemayor et al., 2013; Espinoza-Tenorio et al., 2015). The need for better management plans in Cuba is supported by catches which have been declining for the last 30 years, with more than 18% of catches from 1950 to 2009 going unreported. In addition, changing political environments and associated policies have also led to most Cuban fish stocks being considered fully- or over-exploited (Au et al., 2014).

4.3.2. Threats from habitat degradation

Habitat degradation continues to be an issue impacting many species globally (Hoekstra et al., 2005). Although there are 295 marine protected areas in the Gulf of Mexico, comprising 112,600 km^2 (UNEP-WCMC and IUCN, 2018), or about 7% of total marine waters in the Gulf, extensive coastal development and shoreline modification continue to impact species dependent on sensitive, near-shore environments, such as seagrass and estuarine habitats. These species may be experiencing more severe impacts from habitat loss and degradation compared to outside of the Gulf, especially in the northern Gulf of Mexico (Short and Wyllie-Echeverria, 1996; Waycott et al., 2009; Archambault et al., 2018). Between 1930 and 1990, more than 3900 km^2 of coastal habitat has been lost in the Mississippi River Delta alone (Boesch et al., 1994), due in part to the construction and maintenance of levees and dams for flood control and maintenance channels for boat traffic (Dahl and Stedman, 2013). With more than 50 million people living along the Gulf of Mexico coastline, near-shore habitats are often the most severely degraded (Halpern et al., 2008). Current recommendations for preventing and mitigating further habitat loss in these areas include ecosystem restoration, sediment management, and re-vegetation (Barry et al., 2015).

4.3.3. Threats from industrial development

Activities such as industrial drilling and dredging can permanently change habitats, often resulting in the most severe forms of modification and destruction (Jetz et al., 2007). Petrochemical drilling has the potential to release trapped chemicals and gasses into the environment, while dredging can significantly change topography in ways that eliminate prior habitats and ecosystems. Compared to the Caribbean, industrial development in the Gulf of Mexico is estimated to be more severe, especially in the northern Gulf where the oil and gas industry has had a major influence on ecosystem modifications (Turner and Rabalais, 2019).

However, impacts to species threatened by tourism within the Gulf of Mexico are likely to be less than other areas outside the Gulf, such as in the Caribbean. Historically, tourism in the region has been driven by the development of resort areas (Mendoza-Gonzalez et al., 2012), which has been closely linked to habitat loss (Sevilla et al., 2019) and has been established on a much larger scale in the Caribbean as compared to the Gulf.

4.3.4. Threats from pollution

Pollution within the Gulf of Mexico is comparable to levels in the Greater Caribbean and Western Atlantic (Hyland et al., 2003; Jambeck et al., 2015). Although natural petrochemical seeps are present within the Gulf of Mexico, hundreds of minor and major petrochemical accidents and spills have occurred over the past several decades (Turner and Rabalais, 2019). The two largest spills, the 2010 Deepwater Horizon and the 1979 Ixtoc I oil spills, impacted coastlines from Mexico to Texas to Florida, including many populations of marine mammals, sea birds, fishes, invertebrates, and habitat building species (Biello, 2010; DeLeo et al., 2015).

The outflow of nutrients and agrochemicals from the Mississippi River is another major source of pollution in the Gulf, and leads to frequent, large-scale eutrophication events and anoxic zones in the northern Gulf (Mitsch et al., 2001). Although the effects of these hypoxic events on marine communities are not well-known, documented decreases in net surface productivity and deficiencies in benthic oxygen levels can significantly alter species composition and ecosystem function (Atwood et al., 1994; Diaz and Solow, 1999; Davis, 2017).

4.3.5. Threats from bycatch

Bycatch rates within the Gulf of Mexico are similar to those outside the Gulf (Davies et al., 2009). Various regulations have been put into place in recent years to decrease the impact that bycatch is having on non-targeted populations. In U.S. waters, policies are in place to reduce the impact of bycatch; however these policies have not fully addressed this bycatch issue. For example, shrimp trawling activities catch juvenile reef fish in their operations, especially red snapper and gray triggerfish, killing many newly recruited animals (Diamond, 2004). Sharks and turtles are also still regularly caught as bycatch. Atlantic Bluefin Tuna, which are already at very low population levels, get caught in pelagic longline gear. Since Bluefin are entering the Gulf to spawn, any significant rates of bycatch can be disruptive to spawning activities (Beerkircher et al., 2009). Longline fishing is also one of the leaders in bycatch of sea birds and sharks. In 2008, the United States became a member of the Agreement on the Conservation of Albatrosses and Petrels. This international agreement between 13 other member nations which has yet to be signed by the United States, requires seabird mitigation devices on all longlines (Audubon, 2017).

4.4. Comparing regional vs. global listings

The threats mentioned in the previous sections are those most likely to impact a broad range of species groups in the Gulf. However, given that there are at least 57 species, including *Alopias superciliosus* (Bigeye Thresher Shark), *Balistes capriscus* (Gray Triggerfish), and *Epinephelus morio* (Red Grouper) which are listed in an IUCN threatened category and are not protected or under consideration by either the ESA or NORMA 59, it is important to understand differences in criteria and the listing process for IUCN vs. ESA and NORMA 59. The IUCN Red Listing process aims to systematically assess the status of all valid species in a given taxonomic group against the same set of criteria, by meeting or exceeding established quantitative thresholds of decline in population or range size. By contrast, the ESA listing process is based on petitioning for species of special interest to be listed, through the presentation of scientific information as it relates to five factors that have unspecified quantitative thresholds.

The current management and commercial importance of species is also taken into consideration by the ESA; species that are considered to have insufficient regulatory mechanisms can be considered for listing (Sullins, 2001). This differs from the IUCN listing process, which is only concerned with quantifying past, present or future decline under a known threat, regardless of current management and/or commercial importance. For example, biomass for the Gray Triggerfish (*Balistes capriscus*), which is currently managed as a single stock in the northern Gulf, has declined from 63 to 68% over the past 3 generations or 12–14 years (Liu et al., 2015), is listed as VU under IUCN Criterion A2bd, but may not be petitioned for listing under the US ESA since current management strategies could be seen as sufficient. These differences in listing processes and criteria also mean that the impacts of regional and global threats may be quantified differently. For consistency, the IUCN also supports regional applications of the IUCN Red List methodology (IUCN, 2012b), which essentially follows the same global listing process, but takes into account the connectivity of regional populations with non-regional populations for the purposes of accounting for source or sink population dynamics.

5. Conclusion

The most significant threats to marine species in the Gulf are directed fishing, habitat loss, industrial development, pollution and bycatch. Several species groups are also impacted by threats that are pervasive across the globe, including increased sea surface warming, storms, invasive species and increased incidence of disease. Regardless, global level extinction risk assessments need to be used in combination with regional knowledge of already existing protections and information on the severity of known threats operating within the area of management interest. This is especially important when the connectivity between regional populations and those outside the region is not known. By integrating information on regional protections and the severity of regional threats, global-level extinction risk assessments can be used to inform local or regional scale conservation initiatives. Specifically, they can identify species or geographic areas where further research is needed on globally threatened species populations and/or on the severity of threats.

Conservation of priority species, such as those listed under the U.S. Endangered Species Act and the Mexico NORMA 59, highlight those species at greatest risk in the Gulf. However, as this study has shown, many species that are listed in a threatened category at the global scale are not recognized by regional conservation efforts, even when threats within the Gulf are the same as across their global range or even increased in severity within the Gulf. This is of most concern for 13 of the 14 Gulf endemic IUCN threatened species that are not protected by either the ESA or NORMA 59. This study should inform current and future conservation measures in the Gulf, as it provides a comprehensive summary of those species currently in need of additional regional protections. By also addressing threats that are currently having a greater impact in the Gulf region, management strategies can provide a better framework for rebuilding impacted populations. In sum, differences in regional and global conservation assessment processes and threatened species status should not be ignored, but rather embraced, as they can identify critical needs for further research and action to conserve regional populations of globally threatened species.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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