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Ghosts of the coast: global extinction risk and conservation of sawfishes

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ABSTRACT

1. Sawfish are arguably the world's most imperilled marine fishes. All five species are classified as highly threatened with extinction: three are Critically Endangered (smalltooth sawfish *Pristis pectinata*, largetooth sawfish *Pristis pristis,* and green sawfish *Pristis zijsron*); two are Endangered (narrow sawfish *Anoxypristis cuspidata*, and dwarf sawfish *Pristis clavata*).

2. Sawfishes are threatened primarily due to a combination of their low intrinsic rates of population increase, high catchability in fisheries, and high value. Sawfishes are among the world's largest marine fishes, and they are caught by a wide range of fishing gears owing to their tooth-studded rostra being easily entangled. Sawfish fins are some of the most valuable for shark fin soup, and their rostra have long been traded as curios. In addition, they inhabit shallow coastal waters, estuaries, and rivers of the tropics and subtropics, down to a maximum depth rarely exceeding 100 m and are associated with threatened mangrove and seagrass habitats.

3. Historically, sawfishes were distributed in the coastal waters of 90 countries and territories. Over the past century, their geographic distribution has been greatly diminished. For example, the smalltooth sawfish is now found in <20% of its former range. Globally, sawfishes are now entirely absent from 20 countries; 43 countries have lost at least one species.

4. Sawfishes are legally protected, to some degree, in 16 of the 90 range states. These safeguards encompass, on average, 81% of their Extant distribution; however, the quality and breadth of protection varies dramatically across countries and species. Smalltooth sawfish currently has the least amount of such coverage of only half (49%) of Extant distribution.

5. The global conservation strategy specifies actions to protect sawfish and their habitats. Such actions are urgently warranted to avoid global extinction and to restore robust populations for the benefit of coastal ecosystem function and biodiversity.

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KEY WORDS: estuary; functional redundancy; habitat degradation and loss; mangrove; range contraction

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INTRODUCTION

After decades of rising awareness of changing terrestrial biodiversity, only in recent years have changes to the marine environment become apparent. Emerging knowledge suggests that the timing, patterns, and processes of marine extinction are very different to that on land (Hoffmann *et al.*, 2010; Harnik *et al.*, 2012; McClenachan *et al.*, 2012; Pimm *et al.*, 2014). While large geographic ranges confer safety upon terrestrial species (Boyd *et al.*, 2008), the vast geographic ranges of many marine species presents a challenge for their assessment and conservation (Wallace *et al.*, 2011; McClenachan *et al.*, 2012).

Sawfishes (family Pristidae) are arguably the most threatened marine fishes in the world, and in many ways epitomize the challenge of assessing and conserving widely distributed large-bodied marine fishes. Their perilous status was confirmed through a global, systematic analysis of the relative risk faced by all chondrichthyan species – the sharks, rays, and chimaeras (Dulvy *et al.*, 2014), building upon more detailed studies in parts of the range of some sawfishes (Simpfendorfer, 2005; Carlson *et al.*, 2007; Fernandez-Carvalho *et al.*, 2014). In 2006, all seven then recognized species were assessed on the IUCN Red List of Threatened Species™ (the 'IUCN Red List') as Critically Endangered signifying 'an extremely high risk of extinction in the wild' (IUCN, 2012, 2013a).

Changing taxonomy and misinformation in sawfish encounter records has complicated sawfish conservation. This resulted in uncertainty in terms of distribution, life history, and population status, which in turn reduced the effectiveness of protective measures (Faria *et al.*, 2013; Melo Palmeira *et al.*, 2013; Whitty *et al.*, 2013). This taxonomic impediment was recently resolved with a global compilation of morphological and genetic data, which confirmed that the family consists of five valid species: narrow sawfish *Anoxypristis cuspidata* (Latham, 1794), dwarf sawfish *Pristis clavata* Garman, 1906, smalltooth sawfish *Pristis pectinata* Latham, 1794, largetooth sawfish *Pristis pristis* (Linnaeus, 1758), and green sawfish *Pristis zijsron* Bleeker, 1851 (Faria *et al.*, 2013). The previously recognized species, *Pristis microdon* Latham, 1794 and *Pristis perotteti* Müller and Henle, 1841 are now considered to be junior synonyms of *P. pristis* (Table 1).

Over the past decade, several nations have recognized the urgent need for conservation action for sawfishes. In particular, the USA and Australia have protected sawfish species found in their waters using national wildlife protection legislation. International commercial trade in sawfish has been banned through the listing of all species on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)[1] (Vincent *et al.*, 2013). The increasing concern for the conservation of sawfishes has prompted a surge in research activity, particularly in Florida, USA and northern Australia, owing to the need for scientific data collection and collation to help develop status assessments, management measures, and recovery plans (National Marine Fisheries Service, 2009).

The conservation of chondrichthyan species has generally been of low priority for marine fisheries bodies (Barker and Schluessel, 2005). Moreover, fisheries management capacity is lacking in much of the world, and – where it does exist – it has been focused on the most commercially valuable fish populations (Costello *et al.*, 2012). A global conservation planning perspective for sawfishes can complement and bolster existing national and international conservation efforts (Peverell, 2005; Phillips *et al.*, 2011; Norton *et al.*, 2012). The high level of threat facing all sawfishes, combined with the opportunity provided by the recent resolution of their taxonomy, motivated and enabled the development of a Global Sawfish Conservation Strategy based on revised Red List Assessments (Harrison and Dulvy, 2014). Summarized here are: (1) the conservation status of sawfishes, including their life histories, ecology, and threatening processes; (2) their historical and present day geographic distributions; and (3) their updated IUCN Red List status. Finally, the key actions of the Global Sawfish Conservation Strategy recommended to achieve a collective vision of 'all sawfishes restored to robust populations within thriving aquatic ecosystems' are specified.

[1]International commercial trade was banned through CITES Appendix I listing in 2007 for all species recognized at the time except *Pristis microdon* for which live specimen trade was allowed until 2013 when this (no longer recognized) species was transferred from Appendix II to Appendix I.

Table 1. Previous and valid sawfish species names (after Faria *et al.,* 2013), historical Extent Of Occurrence, and broad geographic distributions for valid sawfish species

Previous species name	Valid species name	Common name	Extent Of Occurrence (km^2)	Geographic distribution
Anoxypristis cuspidata	*Anoxypristis cuspidata*	narrow sawfish	5 958 957	Indo-West Pacific
Pristis clavata	*Pristis clavata*	dwarf sawfish	3 323 283	Indo-West Pacific
Pristis microdon	*Pristis pristis*	largetooth sawfish	--	--
Pristis pectinata	*Pristis pectinata*	smalltooth sawfish	2 096 097	E Atlantic; W Atlantic
Pristis perotteti	*Pristis pristis*	largetooth sawfish	--	--
Pristis pristis	*Pristis pristis*	largetooth sawfish	7 188 402	E Atlantic; W Atlantic; E Pacific; Indo-West Pacific
Pristis zijsron	*Pristis zijsron*	green sawfish	5 896 268	Indo-West Pacific

METHODS

The International Union for Conservation of Nature Species Survival Commission's (IUCN SSC) Shark Specialist Group (IUCN SSG) convened the Global Sawfish Conservation Strategy Workshop at the Zoological Society of London, UK on 21–24 May 2012 with the specific objectives to: (1) summarize the state of knowledge of sawfishes and conservation capacity worldwide; (2) map the geographic range status for each species; (3) reassess the status of sawfishes by application of the IUCN Red List of Threatened Species categories and criteria; and (4) develop a Global Sawfish Conservation Strategy.

Sawfish state of knowledge and conservation capacity

In the year leading up to this workshop, the IUCN SSG circulated a sawfish knowledge survey to the 171 IUCN SSG members (Appendix 5, Harrison and Dulvy, 2014). The survey was designed to capture informal knowledge and unpublished information on historical and recent distributions, past and present threats, fisheries patterns (e.g. bycatch or targeted), cultural values, and the existence of any management or conservation policies. This survey was also circulated through weblogs (Save Our Seas Foundation) and social media outlets (Facebook and Twitter etc.), as well as through targeted emails to fisheries agencies, scientists, non-governmental organizations (NGOs), intergovernmental organizations, and scuba diving organizations.

Geographic range mapping

Maps for each of the five sawfishes were drafted, before the workshop, based on two datasets: the International Sawfish Encounter Database (Burgess, 2013) and data from the US National Marine Fisheries Service (Carlson *et al.*, 2007; National Oceanic and Atmospheric Administration, 2013). These data comprised 8530 sawfish records of varying taxonomic resolution and credibility from 1791 to 2011, and spanning 79 countries (Appendix 4, Harrison and Dulvy, 2014). These data included 11 nominal sawfish species that, where possible, were reconciled with current taxonomic understanding (Faria *et al.*, 2013). Records that could not be reconciled or were generic (i.e. 'sawfish') were excluded. At the workshop, species distribution maps were created by combining these records with the participants' expert knowledge. For each nation and territory within a species' geographic range, current presence status was classified according to the following IUCN presence codes (IUCN, 2013b):

1. Extant – the species is known, or thought very likely to occur presently in the area;
2. Possibly Extant – the species may possibly occur, and should be searched for, but there are *no known records*. This code was applied only to the potential distribution of the dwarf sawfish in the Australian Coral Sea;
3. Possibly Extinct (PE) – the species was formerly known or thought very likely to occur in the area but it is most likely now locally extinct from the area; and,
4. Presence Uncertain (PU) – the species was formerly known or thought very likely to occur in the area but it is no longer known if it still occurs.

The historical geographic range of each species was defined as the combination of the Extant, Possibly Extinct, and Presence Uncertain range

portions. Range area calculations were based on the assumption of a 100 m depth maximum (Table 1, Figure 3). The maximum depth is less for three species: 20 m in dwarf sawfish (Stevens *et al.*, 2008), 128 m in narrow sawfish (Pogonoski *et al.*, 2002), 70 m in green sawfish (Stevens *et al.*, 2005), 122 m in smalltooth sawfish (Poulakis and Seitz, 2004; Carlson *et al.*, 2014), and 60 m in largetooth sawfish (Dineshbabu and Muniyappa, 2005). Therefore, the marine portion of the range is overestimated for some species. The freshwater range can be significant for some species, especially the largetooth sawfish, but owing to a lack of data this potentially important distribution segment could not be resolved (Fernandez-Carvalho *et al.*, 2014). The true distribution of sawfishes (out to the 100 m depth contour) is too narrow to see clearly on maps (Figure S1, Supplementary material). Therefore, in order to better visualize sawfish distributions, the mapped area was extended out to the edge of the exclusive economic zone (EEZ) of each country or territory (200 nautical miles from the coastline). Distant offshore islands where sawfishes are not thought to have previously occurred were cropped out of the mapped area, including: Fernando de Noronha off Brazil, Lord Howe Island off New South Wales in Australia, and San Antonio off Equatorial Guinea.

These new range size calculations only became available after completion of the IUCN Red List Assessments, which were published in July 2013. Since the publication of these Red List Assessments, new understanding suggests sawfishes were unlikely to have been present in the Mascarene Islands (Réunion and Mauritius) and the Republic of Seychelles Islands, Western Indian Ocean. Instead, it is more likely that any records from these islands come from specimens traded from Madagascar (B. Séret, pers. comm.). The Mediterranean Sea was excluded from geographic range calculations because specific capture data are lacking and environmental conditions are outside the normal ranges used by sawfish, suggesting that reports from the Mediterranean may represent vagrants from West African populations or result from traded specimens (Ferretti, 2014).

The loss of functionally important species may result in a loss of ecosystem functionality (Rosenfeld, 2002). To document this, species richness maps were created using a hexagonal grid of cell size 23 322 km^2 covering the range of all sawfish species (mapped to the EEZ); this cell size is typically used when mapping the Extent Of Occurrence of widely distributed marine species (Hoffmann *et al.*, 2010; Dulvy *et al.*, 2014). Historical species richness was determined by the sum of species per cell, regardless of current presence code (excluding the Possibly Extant portion of the dwarf sawfish range). The loss of functional redundancy was inferred from the reduction in local species richness over time.

Red List status assessment

The IUCN Red List is widely recognized as the most comprehensive, scientifically based source of information on the global status of animal, plant, and fungi species. To date, more than 70 000 species have been assessed (IUCN, 2013a). The five valid sawfish species were assessed against the IUCN Red List Categories and Criteria Version 3.1 including the threatened categories: Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) (see IUCN, 2012 for details of these and other Red List categories). The classification of species into one of these categories requires the consideration of five quantitative criteria based on biological factors related to extinction risk; rate of population decline, population size, area of geographic distribution, degree of population and distribution fragmentation, and quantitative analysis of extinction risk in the wild (Mace *et al.*, 2008; IUCN, 2012). In addition, the species assessments contain information on taxonomy, distribution, population status and trends, habitat and ecology, threats, trade, and conservation measures in place.

The status of each sawfish species was assessed at the global scale encompassing all parts of its known geographic range. Where necessary, species were subdivided into subpopulations according to the IUCN's definition 'geographically or otherwise distinct groups in the (global) population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less)' (IUCN, 2012). Two species were inferred to comprise a series of subpopulations based on morphological and molecular dissimilarities (Faria *et al.*, 2013) and disjunct distributions. The largetooth sawfish was inferred to consist of four subpopulations:

Western Atlantic, Eastern Atlantic, Indo-West Pacific, and Eastern Pacific. The smalltooth sawfish was inferred to consist of two subpopulations: Western Atlantic and Eastern Atlantic.

Before their submission to the IUCN Red List Unit in Cambridge, UK, the sawfish Red List Assessments were peer-reviewed by two or three experts. The justification for each assessment was then circulated to all 171 members of the IUCN SSG global network for comment. These resulting assessments are the scientific consensus on the current status of each species, supported by relevant literature and other data sources, including the IUCN SSG sawfish survey. Here the status of each sawfish species based on their Red List Assessments is summarized. The full Red List assessment for each sawfish can be viewed on the IUCN Red List website (http://www.iucnredlist.org), published in July 2013.

Development of a Global Sawfish Conservation Strategy

The development of a Global Sawfish Conservation Strategy followed guidelines created by the IUCN SSC Species Conservation Planning Sub-committee (IUCN, 2008). Historically, IUCN species conservation planning has been at the regional or national level to prescribe on-the-ground actions to improve the conservation status of a local species. Given the global distribution of many marine species and the paucity of conservation capacity, a global strategic overview of sawfish conservation status in order to prioritize countries, regions, and actions was warranted.

Until recently, the conservation actions reported in IUCN Action Plans were rarely assigned to specific entities and organizations, leaving gaps in responsibilities (IUCN, 2008). To address this issue, the workshop was designed to ensure broad representation in terms of geographic region and expertise. There was a strong focus on identifying the individuals most invested in the improved status of sawfishes, including: conservationists, scientists, government officials, resource managers, and aquarium personnel, including suppliers (Harrison and Dulvy, 2014). Workshop participants were urged to review the status of sawfishes in their region or the work being carried out in their sector. Then, through a series of working subgroup discussions and plenary sessions, a vision, set of goals, and a series of objectives aimed at the improved status of sawfishes over the next 10 years were developed. Once all participants agreed on these elements, the group generated actions to support the objectives. Where possible, the group strove to develop Specific, Measurable, Achievable, Relevant/Realistic and Timed (SMART) actions. After the workshop, the objectives and actions were refined to remove duplication and align structure. Guidelines for the development of regional and national sawfish conservation strategies are provided in Appendix 1 of Harrison and Dulvy (2014).

RESULTS

Sawfish state of knowledge and conservation capacity

The IUCN SSG formed a Sawfish Network comprising 153 people representing a large proportion of the Extant geographic range of sawfishes (a comprehensive list is provided in Appendix 2; Harrison and Dulvy, 2014). The conservation strategy workshop was attended by a smaller subset of 29 experts (from eight countries) with expertise in sawfishes of 49 countries in West and East Africa, South America, the Caribbean, and the Middle East, as well as the United States, Brazil, India, Bangladesh, and Australia; Figure 1(a). Overall, Sawfish Network members with experience in 64 range states contributed information relevant to the strategy (Figure 1(b)).

Intrinsic sensitivity of, and extrinsic threats to, sawfishes

The Red List reassessments document that sawfishes are threatened due, primarily, to a combination of three major factors: low population growth rates, high catchability in fisheries, and high commercial value. Furthermore, sawfishes have strong associations with sensitive and threatened coastal and riverine habitats.

First, sawfishes, and especially the *Pristis* species, have low intrinsic rates of population increase owing to their late age at maturity and relatively small number of young (Table 2). Sawfishes are between 60 and 90 cm total length (TL) at birth with litter sizes ranging from 1 to 20 pups. The reproductive cycles need further study, but are thought to be annual in the narrow sawfish and the Indo-West Pacific

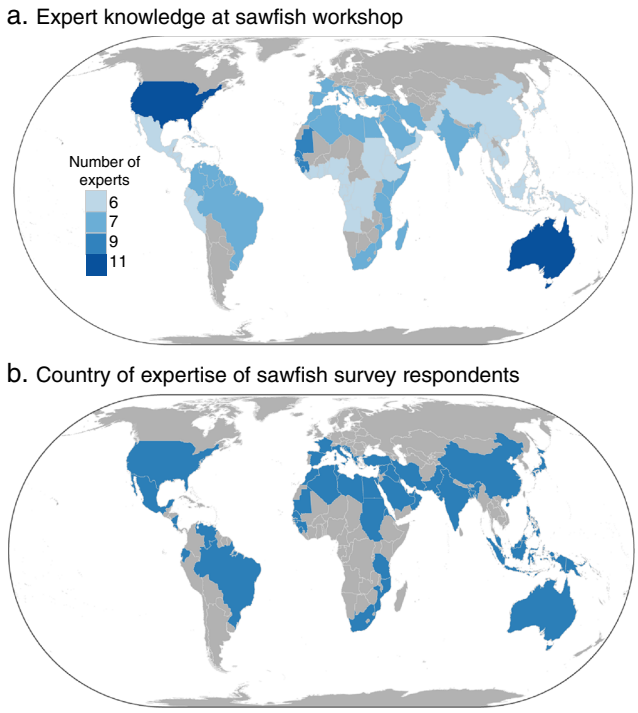

Figure 1. Expert representation at the Global Sawfish Conservation Strategy workshop and respondents to the sawfish survey. (a) The number of workshop attendees with expertise from each country is represented by degree of colour saturation. Most attendees had expertise from broad regions, such as South America (Atlantic), West Africa, East Africa, the Red Sea, and the Gulf. There were a small number of experts with global knowledge of sawfishes. (b) Geographic location of sawfish survey respondents (64 countries in total).

Table 2. Life-history parameters of sawfishes collated during reassessment of species for the IUCN Red List of Threatened Species. Data sources are provided in Carlson *et al.* (2013a), D'Anastasi *et al.* (2013), Kyne *et al.* (2013a, 2013b) and Simpfendorfer (2013). Additional references: Peverell (2005), D'Anastasi (2013), Moreno Iturria (2012), Carlson and Simpfendorfer (2014)

Life history parameter	narrow sawfish *Anoxypristis cuspidata*	dwarf sawfish *Pristis clavata*	smalltooth sawfish *Pristis pectinata*	largetooth sawfish *Pristis pristis*	green sawfish *Pristis zijsron*
Size at birth (cm TL)	70	60–81	80	72–90	76
Size at maturity (cm TL)	♀: 225 ♂: 200	♀: ? ♂: 255–260	♀: 415 ♂: 370	♀: 300 ♂: 280–300	♀:<380 ♂: ?
Maximum size (cm TL)	350	318	550[a]	656	700+
Age at maturity (years)	♀: 3 ♂: 2	♀: ? ♂: 8	♀: 7–12 ♂: 7.5	8–10	♀: 9 ♂: ?
Longevity (years)	9	34	30?[b]	44	>50
Generation length (years)	4.6	16.4	17	IWP: 14.6 WAT: 17.2	14.6
Three generation lengths (years)	13.8	49.2	51	IWP: 43.8 WAT: 51.6	43.8
Reproductive periodicity	Presumed annual	?	Presumed biennial	IWP: annual WAT: biennial	?
Litter size (mean)	5–16 (12.4)	?	15–20	1–13 (7.3)	12?[c]
Intrinsic rate of population increase, r (yr^{-1})[d]	0.27	0.10	0.07–0.14	0.12	0.02-0.1

IWP, Indo-West Pacific; TL, total length; WAT, Western Atlantic.
[a]A quantitative source for the largest reported size of 760 cm TL cannot be located.
[b]Extrapolated from a maximum measured age of 14 years (Scharer *et al.*, 2012) for an individual that was 60% maximum length (J. K. Carlson unpublished data).
[c]The origins of this often reported litter size cannot be traced to an original quantitative source and has therefore not been confirmed.
[d]All estimates from Table 4.2 of Moreno Iturria (2012), with the largetooth sawfish estimate derived from the entry for *P. microdon.*

subpopulation of largetooth sawfish. The Western Atlantic subpopulation of largetooth sawfish is known to reproduce biennially. Female size at maturity ranges from 225 cm TL in narrow sawfish to 415 cm TL in the smalltooth sawfish.

The sawfishes are among the largest chondrichthyans: maximum size ranges from 318 cm TL in the dwarf sawfish to more than 700 cm TL in the green sawfish (Table 2). The green sawfish and the largetooth sawfish are the third and fourth largest chondrichthyans, respectively, after the whale shark *Rhincodon typus* Smith, 1828 and basking shark *Cetorhinus maximus* (Gunnerus, 1765). Hence, sawfishes, along with the giant manta ray *Manta birostris* (Walbaum, 1792), are among the largest members of the rays (Superorder Batoidea).

The *Pristis* sawfishes are long lived, reaching between 30 and >50 years of age. By comparison the narrow sawfish is thought to live for only 9 years. The generation length varies between 14.6 and 17.2 years in the *Pristis* sawfishes, and is much shorter (4.6 years) in the narrow sawfish (Table 2). Consequently, the intrinsic rate of population increase is relatively high for narrow sawfish (0.27 yr^{-1}), compared with the other species, which range from 0.02 yr^{-1} in the green sawfish to 0.12 yr^{-1} in the largetooth sawfish (Table 2).

Second, the characteristic toothed rostrum of sawfishes in combination with their shallow-water distribution, makes them extremely susceptible to entanglement in fishing gear particularly gillnets and trawl nets (Simpfendorfer, 2000; Seitz and Poulakis, 2006).

Third, sawfishes are used for a range of products, many of which are of unusually high value even at the first point of sale by fishers. The fins from a large sawfish are highly prized for Asian shark fin soup. A set of sawfish fins can sell for several thousand dollars, making them among the most valuable marine fish products (CITES, 2007; McDavitt, 2014b). Sawfish rostra have long been traded as curios and for other purposes, including currently on internet auction sites. The individual rostral teeth, sourced from Central and South America, are the preferred material for cockfighting spurs in Peru and are valued at US$80–220 for each pair of spurs (McDavitt, 2014a). In Brazil, a captured sawfish is typically retained because the total value of rostra, teeth, and fins is upwards of US$1000 in foreign markets (National Oceanic and Atmospheric Administration, 2013). Despite a 2007 ban on international commercial trade in these products, their high value still provides considerable incentive for fishers to retain sawfishes (CITES, 2007; McDavitt, 2014b).

Sawfishes are strongly associated with threatened habitats. Juvenile sawfishes typically spend considerable time in rivers and estuaries (Poulakis *et al.*, 2013). Although adult sawfishes can be found in deeper waters down to >100 m, they typically live in extremely shallow marine and estuarine waters less than 10 m deep (Carlson *et al.*, 2014) and they are usually associated with mangroves or seagrasses (Simpfendorfer, 2007; Moore, 2014). Globally, mangrove cover has been reduced by between 20 and 35% since 1980 and seagrass cover has been reduced by 29% since the late 1800s resulting in elevated extinction risk for these critical habitats (FAO, 2007; Waycott *et al.*, 2009; Polidoro *et al.*, 2010; Short *et al.*, 2011). Furthermore, the tropical and subtropical, nearshore, estuarine and freshwater habitats of sawfishes often overlap with large megadelta cities and other areas of high human population density. Consequently, sawfishes are subject to heavy fishing pressure as well as habitat degradation.

Change in geographic distribution

Sawfishes were once found throughout the coastal and inshore regions of the tropical Atlantic, Pacific, and Indian Oceans; they were historically present in 90 countries and overseas territories (Figure 2, Table S1). Forty-three countries have at least one sawfish species that is Possibly Extinct, and sawfishes are no longer present in 20 of these countries (Figure 2, Table S1). The largetooth sawfish had the most widespread geographic distribution and was historically found in the coastal waters of 75 countries (Figures 2(e), (f) and 3). The dwarf sawfish was found in the fewest countries, albeit those with particularly large coastal zones, including: India, Indonesia, Papua New Guinea, and Australia (Figures 2(b) and 3). The dwarf sawfish was the only species for which a small portion of its range in Australia's Coral Sea is Probably Extant. The species is likely to occur there based on suitability of habitat and proximity to other nearby documented sawfish populations.

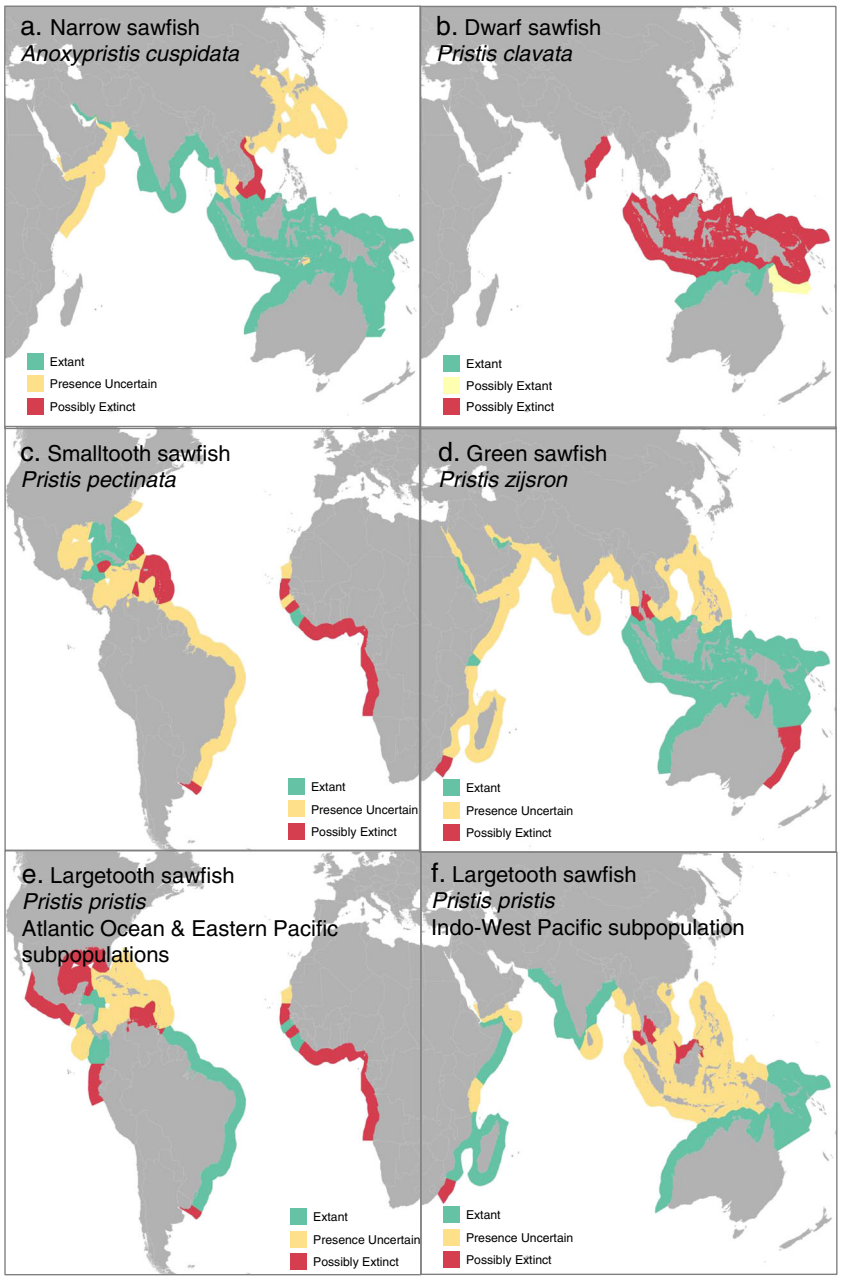

Figure 2. Sawfish species Extent Of Occurrence range maps for (a) narrow sawfish *Anoxypristis cuspidata*, (b) dwarf sawfish *Pristis clavata*, (c) smalltooth sawfish *P. pectinata*, (d) green sawfish *P. zijsron*, (e) Eastern Pacific, West Atlantic, and Eastern Atlantic subpopulations of largetooth sawfish *P. pristis,* and (f) Indo-West Pacific subpopulation of largetooth sawfish *P. pristis*. The range maps extend out to the edge of the Exclusive Economic Zone of each country for visualization purposes, true range is <100 m depth for most species.

The Extent Of Occurrence was estimated by assuming a maximum depth distribution of 100 m and therefore these calculations may be overestimates. Historically, the globally distributed largetooth sawfish had the largest geographic range, spanning 7 188 402 km^2, followed by narrow, green, dwarf and smalltooth sawfishes (Table 1, Figure 4). There is evidence for exploitation and trade of sawfishes since the late 1800s and early 1900s (Ferretti, 2014; Moore, 2014; Späet and Elhassan, 2014). Since the beginning of the 20th century, three species have undergone severe reductions in geographic range size: smalltooth sawfish (81% decline), dwarf sawfish (70% decline), and largetooth sawfish (61% decline; Figure 3). The other

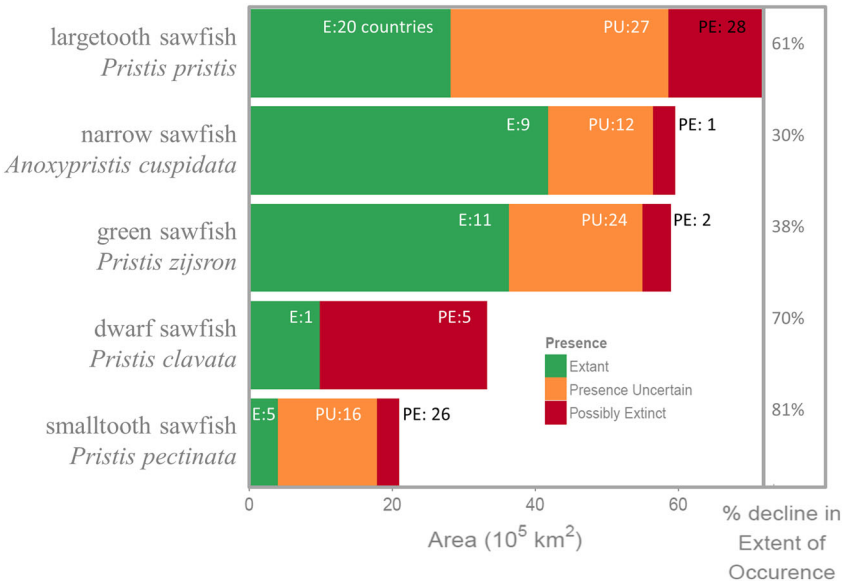

Figure 3. Historical Extent Of Occurrence and the current geographic range status categorized as: Extant (E), Presence Uncertain (PU), or Possibly Extinct (PE). Sawfish species are arranged in descending order from largest to smallest historical Extent Of Occurrence. The number of countries in each geographic range category is shown along with the percent decline in Extent Of Occurrence.

two species have undergone substantial declines: green sawfish (38% decline) and narrow sawfish (30% decline).

The smalltooth sawfish is potentially at greatest risk among sawfish species because it has the smallest and most fragmented remaining geographic range (Figure 2(c)) and has undergone the greatest range contraction (81% decline, Figure 3). This species originally had the smallest historical geographic range, and was the only species endemic to the Atlantic Ocean. The dwarf sawfish was historically found in at least five countries and is now only Extant in northern Australia. The area estimation is an overestimate as dwarf sawfish has the shallowest depth profile (<20 m). It is Possibly Extinct in India, Malaysia, Indonesia, and Papua New Guinea (Figure 2(b)).

Outside of the Extant range of sawfishes, there are large areas (>25%) within which sawfish presence could not be confirmed (Presence Uncertain). There are 56 countries for which the status of at least one species of sawfish is uncertain (Figure S1). Substantial areasubstantial areas exist where extinction is likely to have occurred (Possibly Extinct), including: 70% of the historical range of dwarf sawfish; 18% for largetooth sawfish; 14% for smalltooth sawfish; 7% for green sawfish; and 5% for narrow sawfish (Figures 2 and 3).

The narrow sawfish was historically found in 22 countries, but is now Extant in nine and classified as Presence Uncertain in 12, and Possibly Extinct in one (Vietnam) (Figure 3, Table S1). Green sawfish was historically present in 37 countries, and is now classified as Extant in 11, Presence Uncertain in 24, but is now Possibly Extinct in South Africa and Thailand (Table S1). Once found in 47 countries, the smalltooth sawfish it is now considered Extant in only 5 countries, Presence Uncertain in 16, and Possibly Extinct in 26. Formerly present in 75 countries, the largetooth sawfish is now Extant in only 20 countries, Presence Uncertain in 27, and Possibly Extinct in 28.

In addition to species-specific range reductions, the functional redundancy of sawfishes has also diminished. Sawfishes are one of the largest predatory fishes in shallow coastal seas and estuaries and hence likely played a significant direct and indirect predatory role influencing tropical and subtropical fish communities. Historically, four species occupied 40% of the worldwide distribution of sawfishes (the maximum possible number is four because smalltooth sawfish is found only in the Atlantic Ocean and is the only species not found in the Indian and Pacific Oceans, Figure 4(a)). The

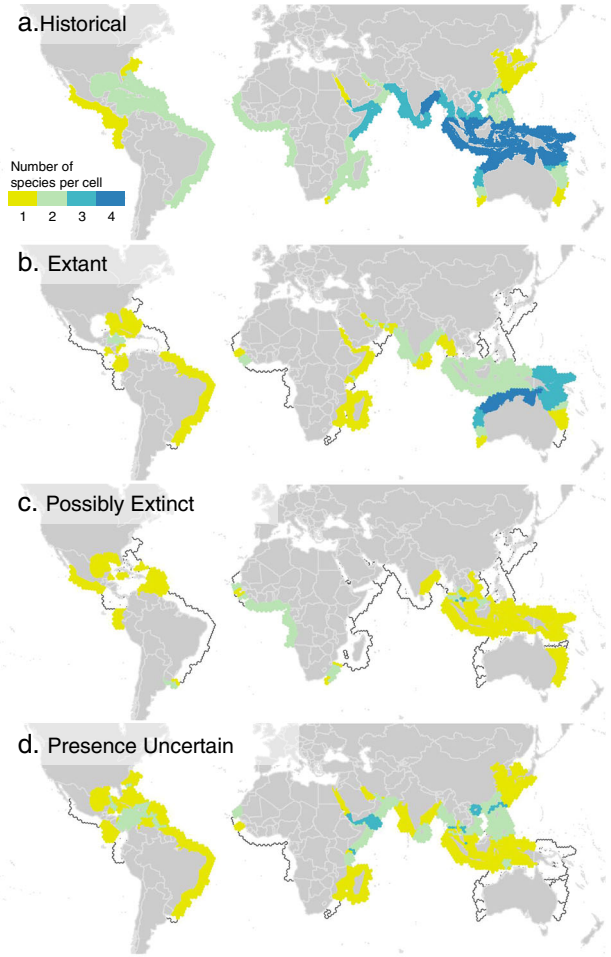

Figure 4. The historical and recent geographic distribution of sawfish diversity. (a) historical – four species were found in the Indo-West Pacific region and two in the Atlantic Ocean and (b, c, d) current geographic distribution and species richness. (b) Extant range – the only remaining area with four species is currently northern Australia (dark blue). (c) Possibly Extinct range – West Africa, South Africa, and Uruguay show areas where two species are Possibly Extinct, and (d) Presence Uncertain range – darker regions represent areas where the presence of more than one sawfish species is uncertain, most parts of the historical range have at least one species now Presence Uncertain (yellow).

area of maximum functional redundancy has declined by 70% – four species are now only Extant in 12% of the historical range of sawfishes, as shown by the contraction in the dark blue shade from historical (Figure 4(a)) to Extant (Figure 4(b)). Furthermore, the proportion of area with three species has reduced from 14 to 3%, two species from 33 to 31%. The amount of area occupied by only one sawfish species has increased (14 to 23%) as areas lose species diversity (Figure 4).

Red List status

Although the status of two species has recently been changed from Critically Endangered to Endangered, sawfishes are still among the world's most threatened marine fishes (Table 3). Three of the five sawfish species are currently assessed as Critically Endangered with an 'extremely high risk of extinction in the wild', while the remaining two are assessed as Endangered with a 'very high risk of extinction in the wild' (Table 3). This downlisting is a non-genuine change (i.e. not a genuine improvement in status) because the declines occurred before the three-generation period to which the IUCN decline criteria are applied. All five species (and their constituent subpopulations, where relevant) were considered to have undergone past population reductions based on 'a decline in Area Of Occupancy (AOO), Extent Of Occurrence (EOO) and/or habitat quality' and 'actual or potential levels of exploitation' (that is, they meet the IUCN Red List criteria A2cd) (IUCN, 2012). For the Critically Endangered species, the qualifying decline threshold is ≥80%, and for the Endangered species, ≥50%, over a period of three generation-lengths (Table 2). The justification for each Red List Assessment is summarized in Table 4.

Present conservation efforts

Sawfishes are legally protected to some degree in 16 of the 90 historical range states: Australia, Bahrain, Bangladesh, Brazil, Guinea, India, Indonesia, Malaysia, Mexico, Nicaragua, Qatar, Senegal, South Africa, Spain, U.A.E., and the USA (Figure 5). On average, these areas of protection cover 81% of the Extant distribution of all sawfish species combined; however, the breadth and effectiveness of these safeguards varies dramatically across countries and species.

The breadth of national protection potentially afforded to sawfishes can be measured as the percent of the remaining Extant range covered by countries with sawfish-specific national regulations. Overall, of the remaining range of all sawfishes combined, half the potential protection is provided by Australia, 30% from Indonesia, and most of the remaining (18%) protected Extant range of sawfishes is divided among Malaysia, Brazil, India, and the USA (Figure 5). By species, the dwarf sawfish is now Extant only in

Table 3. Global conservation status of valid sawfish species according to the IUCN Red List of Threatened Species and, where relevant, the reason for change from the original 2006 IUCN Red List status. See the text and IUCN (2013c) for explanations of the IUCN Red List Categories and Criteria

Species	2013 IUCN Red List category and criteria	2006 IUCN Red List category and criteria	Reason for change in IUCN Red List category (if applicable)
narrow sawfish *Anoxypristis cuspidata*	EN A2cd	CR A2bcd + 3cd + 4bcd	Non-genuine change[a]
dwarf sawfish *Pristis clavata*	EN A2cd	CR A2bcd + 3cd + 4bcd	Non-genuine change[a]
smalltooth sawfish *Pristis pectinata*	CR A2cd[b]	CR A2bcd + 3cd + 4bcd	No change
largetooth sawfish *Pristis pristis*	CR A2cd[c]	CR A2abcd + 3cd + 4bcd (*P. microdon*) CR A2abcd (*P. perotteti*, 2007)	No change
green sawfish *Pristis zijsron*	CR A2cd	CR A2bcd + 3cd + 4bcd	No change

[a]Initial population declines occurred outside the timescale at which the IUCN criteria are applied. Non-genuine changes do not represent an improvement in status, instead represent an improvement in knowledge of extent of decline (IUCN, 2013c).
[b]There are additional subpopulation assessments for the Eastern Atlantic and the Western Atlantic (both CR A2cd).
[c]There are additional subpopulation assessments for the Eastern Atlantic, Western Atlantic, Eastern Pacific and the Indo-West Pacific (all CR A2cd).

Australia, and hence the entirety of its geographic range is subject to some form of national regulation (Figure 5). At least half of the Extant range of the other four species is found in countries with some form of protective measures: green sawfish is potentially protected in 93% of its Extant range; narrow sawfish in 89%, largetooth sawfish in 78%; and smalltooth sawfish in 49%. Largetooth sawfish has four subpopulations with regulatory protection covering widely varying percentages ranging from 0% to 80% of the Extant range portions (Eastern Atlantic 0%; Eastern Pacific 25%; Western Atlantic 79%; and Indo-West Pacific 80%). The Eastern Atlantic subpopulation of smalltooth sawfish has no regulatory protection and the only sawfish-specific protective measures in the Western Atlantic are found in the USA.

The USA legally protects smalltooth and largetooth sawfishes under the federal Endangered Species Act (ESA), although largetooth sawfish have not been documented there since 1961 (Fernandez-Carvalho *et al.*, 2014). The ESA listing has prompted strict prohibitions on fishing, possession, and myriad forms of harm, as well as measures to mitigate bycatch mortality and conserve smalltooth sawfish critical habitat (Norton *et al.*, 2012). Australia provides similar protections under the *Environment Protection and Biodiversity Conservation Act* and state/territory legislation but has yet to extend national protection to the narrow sawfish. The protections in the 14 other range countries would also benefit from harmonization (protecting all species present), while enforcement is often inadequate.

International commercial trade is banned for the original seven previously recognized species of sawfish (Table 1) through their listing on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

In 2010, largetooth sawfish and smalltooth sawfish were added to Annex II of the Barcelona Convention Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean. States that are Party to the Convention are obligated to ensure that they provide maximum protection for, and aid the recovery of, these species. Subsequently, in 2012, the General Fisheries Commission for the Mediterranean (GFCM) adopted measures in 2012 to confer protection from fishing for these Annex II species. Evidence of implementation of these measures, however, remains sparse, and may be of little relevance to global sawfish conservation given that their occurrence in the Mediterranean is now unlikely.

Global sawfish conservation strategy

Workshop participants agreed on an overall vision for the status of sawfishes, two goals aimed at achieving this vision, and a series of nine objectives to support the goals.

Vision *a world where sawfishes are restored – through understanding, respect and conservation – to robust populations within thriving aquatic ecosystems*

Table 4. Summaries of the IUCN Red List status justification for each of the five valid sawfish species (Red List assessment citation provided at the end of each summary)

Red List status justification summary
The narrow sawfish (*Anoxypristis cuspidata*) is an Indo-West Pacific species occurring from the northern Persian (Arabian) Gulf to Australia and north to Japan. It is the most productive sawfish species, maturing after 2 to 3 years and having intrinsic rates of population increase >0.27 yr^{-1}. However, while it has moderate resilience to fishing pressure, it has the highest post-release mortality of all sawfish species. Its remaining population stronghold appears to be northern Australia, although it is now the sawfish most likely to be recorded elsewhere in the Indo-West Pacific presumably because of its relatively fast life history. Ongoing fishing and coastal development is likely to lead to future population declines. Current information indicates that narrow sawfish across its range are considerably more rare than historically recorded. Declines of between 50 and 70% over three generation lengths are suspected and have been primarily attributed to ongoing incidental capture in commercial net and trawl fisheries, with the narrow sawfish being particularly susceptible given it has poor post-release survival (D'Anastasi *et al.*, 2013).
The dwarf sawfish (*Pristis clavata*) may now be the sawfish species with the most geographically restricted distribution. While there has been a great deal of uncertainty regarding its historical range because there are only a few verifiable records from outside of Australia, this species was thought to range from the Bay of Bengal, through parts of Southeast Asia, to northern Australia. Outside of its remaining range in Australian waters there have been no records since the 1800s hence it can now be considered Possibly Extinct outside of Australia. It is a shallow water coastal and estuarine sawfish occurring on sand and mud flats, with a close association to those adjacent to mangroves. Although it penetrates upstream into rivers it does not regularly occur in freshwater reaches. While management measures are now in place in Australia, declines of 50–80% are inferred from capture in continuing commercial fisheries, with dwarf sawfish particularly susceptible given its restricted inshore occurrence and relatively limited global range. Areas of northern Australia with little commercial fishing activities may provide localized refugia for dwarf sawfish, but until such time that viable populations can be verified, it is assumed that the species is continuing to decline, given that threats are ongoing (Kyne *et al.*, 2013a).
The smalltooth sawfish (*P. pectinata*) has been wholly or nearly eliminated from large parts of its former range in both subpopulations in the tropical Western and Eastern Atlantic. The distribution of this species is possibly the best understood and there have been sufficient absences recorded from directed scientific surveys, anecdotal fisher observations, and fish landings data over its historical range to infer a population reduction of ≥95% over a period of three generations. The remaining populations are now small, and fragmented. The species can only be reliably encountered in the USA (south Florida) and to a lesser degree in suitable habitat in the Bahamas. It is very rare but has been recently present in Honduras, Belize, Cuba, Sierra Leone, and possibly Guinea-Bissau and Mauritania. Threats to smalltooth sawfish still exist today in areas where sawfishes are unprotected and habitat modification (mangrove removal) and inshore netting still occur (Carlson *et al.*, 2013a).
The largetooth sawfish (*P. pristis*) formerly had a widespread tropical distribution, consisting of four subpopulations (Eastern Atlantic, Western Atlantic, Eastern Pacific and Indo-West Pacific). It is a very large-bodied euryhaline species, with juveniles occurring in freshwater systems and adults in marine and estuarine environments. In Lake Nicaragua, even adults spent much, if not all, of their lives in freshwater and largetooth sawfish can be found up to 1000 km inland in the Amazon basin. All subpopulations have undergone significant population declines and the species is now apparently extinct in many former range states with few records elsewhere. For example, despite targeted searches there have only been between two and four records in the Eastern Atlantic in the last decade. In the Western Atlantic, current records indicate that it can only be regularly encountered today in the Amazon River basin, the Rio Colorado-Rio San Juan area in Nicaragua, and possibly some remote areas of French Guiana, Suriname, and Guyana. In the Indo-West Pacific, northern Australia represents a globally important remaining population centre. Overall, a population reduction based on a reduction in Extent Of Occurrence is inferred with ongoing threats restricting the possibility of global or regional recovery. Very little is known of the status of the Eastern Pacific subpopulation (Kyne *et al.*, 2013b).
The green sawfish (*P. zijsron*) historically occurred throughout the Indo-West Pacific in coastal nearshore waters and offshore habitats (as adults). While the current population size and historical abundance is unknown, it is suspected to have declined in all of its range states. In Australian waters, its range has contracted significantly, although Australia has some of the last remaining viable populations of green sawfish in the world (albeit at significantly reduced levels). Historically, the species has been negatively affected by commercial net and trawl fisheries that operate in inshore areas throughout most of its range, the cumulative impacts of which have led to population declines. Subsequently, the species is considerably rarer than historically across its entire range. Declines in the population are suspected to exceed 80% over three generation lengths, and it is possible that there has been localized extinction in a number of range states due to intensive fishing, reducing its Extent Of Occurrence (Simpfendorfer, 2013).

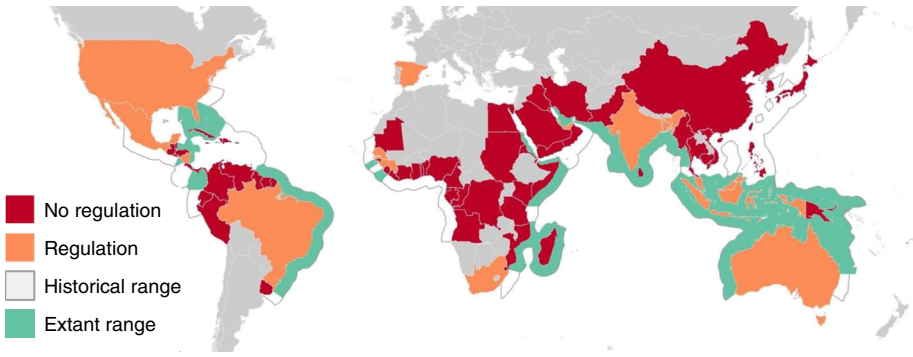

Figure 5. Global historical and current Extant distribution of all sawfishes combined, and legislated protection status of sawfishes by country. Key: countries that have no sawfish regulations in place to our knowledge (dark red), countries with finalized sawfish regulations either for all, or some of the species found in their waters (orange).

The nine objectives were divided between two goals. The details of the actions under each goal and objective are shown in Table S2.

Goal A. *Robust sawfish populations where threats are minimized through improved fisheries management, strategic research, species and habitat protection, and trade limitation.*

Objectives:

1. Fisheries Management: ensure interactions are minimized between fisheries and sawfishes, while maximizing associated sawfish survival, catch reporting, and analysis of interactions (10 actions).
2. Species Protection: ensure that sawfish range states have applied their strictest national wildlife protection legislation to all sawfish species, including a prohibition on targeted take, retention*, and sale (*temporary non-lethal retention as part of a well controlled, peer-reviewed research programme may be excepted) (five actions).
3. Habitat Conservation: ensure development by range states of regional plans/agreements to harmonize and strengthen national efforts to identify, restore, and protect critical sawfish habitats (four actions).
4. Trade Limitation: ensure awareness of and compliance with CITES Appendix I obligations and domestic trade regulations (three actions).
5. Strategic Research: ensure knowledge guides and underpins the development of operational fisheries management, species protection, and habitat conservation (10 actions).

This operational goal can only be achieved through the following 'enabling' goal:

Goal B. *Effective sawfish conservation and management enabled through capacity building, outreach and fundraising.*

Objectives:

6. Education and Communication: increase societal awareness of, and interest in, sawfishes (nine actions).
7. Responsible Husbandry: ensure that captive sawfishes are handled, studied, displayed, and (where legal) transported according to the highest standards with a view to contributing to their recovery (three actions).
8. Sawfish Network: grow and mobilize a coordinated global group of engaged scientists, conservationists, fishers, aquarists, educators, government officials, and experts to play leadership roles in implementation of the Global Sawfish Conservation Strategy (three actions).
9. Fundraising: Ensure a continued stream of financial resources to ensure timely implementation of the actions included in the Global Sawfish Conservation Strategy (three actions).

DISCUSSION

The perilous status of sawfishes warns of an emerging coastal megafauna crisis. While the declines of coastal marine mammals and turtles have long been well documented (Lotze *et al.*, 2006; McClenachan and Cooper, 2008; Lotze and Worm, 2009), the true extent of depletion for large marine fishes has only recently come to light (Sadovy and Cheung, 2003; Sadovy de Mitcheson *et al.*, 2013; Adams *et al.*, 2014). All five sawfishes face a very high risk of global extinction based on steep declines in their numbers and spatial extent over the past century. These striking patterns were previously masked by the large geographic distribution of sawfishes and limited scientific capacity with which to assemble fragmentary records. The scale of the declining spatial extent of sawfishes was documented through the development of databases of historical records, supplemented by the deliberations of the global expert workshop (Burgess, 2013; Davidson, 2014; Fernandez-Carvalho *et al.*, 2014). Some sawfishes are likely to be locally extinct in Mexico, Ecuador, Peru, and South Africa, as well as parts of West Africa, Asia, and eastern Australia. Most notably, the smalltooth sawfish was formerly found in the waters of 47 Atlantic nations, and is Possibly Extinct in 26 countries. Similarly, the largetooth sawfish is Possibly Extinct in 28 countries.

While species-specific identification is often challenging, members of this culturally iconic and highly recognizable family are unlikely to be mistaken for either sawsharks (order Pristiophoriformes), which are mostly temperate and/or deepwater chondrichthyan species, or swordfish (*Xiphias gladius*), an oceanic teleost species (Harrison and Dulvy, 2014). The key conservation challenge is to develop and implement effective actions at local and regional scales, particularly in countries where there is high

incentive to retain sawfishes for their parts and little capacity to enforce regulations.

There are five key questions. (1) Can sawfishes be recovered? (2) Is a two-tiered conservation planning approach required for wide-ranging marine species? (3) What sawfish conservation progress has been made since planning began? (4) Why has the Red List status of two species changed? (5) How can uncertainty in the current geographic distribution be reduced?

1. Can sawfishes be recovered?

All analysis points to significant extinction risk for wild sawfishes, particularly in the absence of improved and expanded conservation measures. There are, however, two regions that potentially represent 'lifeboat' areas for sawfish species and therefore hope: Florida, USA, and northern Australia. Both areas have imposed national and local sawfish protections, and have reproducing populations (Peverell, 2005; National Marine Fisheries Service, 2009; Norton *et al.*, 2012). Given the pressures that sawfishes face outside of these critical areas, United States and Australian regulatory protections may be a key factor preventing the extinction of entire sawfish species. The USA smalltooth sawfish population size is relatively small (Chapman *et al.*, 2011), but there are strong signs that their decline has been halted, the extent of occurrence in their historical core range is expanding (Carlson *et al.*, 2007; Carlson and Osborne, 2012), and their genetic diversity has not been adversely affected (Chapman *et al.*, 2011). Moreover, population viability analysis suggests the USA population is more productive than previously estimated and has the capacity to recover (Carlson and Simpfendorfer, 2014).

While greatly encouraging, the protections afforded in the USA and Australia are not sufficient for the conservation of all sawfish species present or their constituent subpopulations. In particular, Australian protections for narrow sawfish are much weaker than for *Pristis* species, with only fisheries regulations in some parts of the region (Department of the Environment, 2014). Furthermore, there is a risk that hard-won riverine protections could be revoked under pressure from mining and development interests (Chin *et al.*, 2012). There is also a need to connect riverine protections and extend them out to the marine habitats of the adult segment of sawfish populations. For example, while juvenile sawfishes are protected in World Heritage listed Kakadu National Park, there are no spatial protections in place for the adjacent coastal marine range of adult sawfishes. It is imperative that 'lifeboat' locations not be an excuse to forego conservation and recovery efforts in other parts of species' ranges. Instead, additional lifeboat areas should be created to protect subpopulations.

2. Is a two-tiered conservation planning approach required for wide-ranging marine species?

Until recently, IUCN Species Action Plans, Conservation Strategies and systematic conservation planning have been applied mainly to terrestrial species with both narrow geographic ranges and for which there is substantial understanding of both biology and potential conservation activities (Pressey *et al.*, 2007; IUCN, 2008). In marine ecosystems, the scale of the challenge is vastly greater due to the breadth of ranges and paucity of knowledge across such large expanses. Many threatened species are widely distributed from freshwaters to estuaries, across coastal seas and ocean basins. In addition, however, marine species are incredibly data-poor, with only tiny islands of data in an ocean of knowledge gaps. In stark contrast to much of terrestrial conservation, no single country or organization can save wide-ranging marine species. Hence, a two-stage approach to marine conservation planning is recommended, modelled on the tiered hierarchical approach to ecological risk assessment in fisheries (Simpfendorfer *et al.*, 2008; Hobday *et al.*, 2011). A strategic overview of status, actions, and scientific and conservation capacity is necessary before regional and local prioritization of more focused, concrete conservation action. It is essential to first develop a global overview of species conservation status and actions needed as has been done here, and for similarly distributed marine turtles (Wallace *et al.*, 2010, 2011). A key function

of this two-tier process is to begin to identify scientific and conservation capacity, and to raise awareness and momentum (Redford *et al.*, 2013), which then provides the foundation and motivation for regional and local conservation strategies.

3. What sawfish conservation progress has been made since planning began?

The sawfish network and workshop participants have been involved in a series of activities that have improved our understanding of their status and measurably improved their conservation. Many of these actions are continuing and are being taken forward by members of the sawfish network and a much wider group of individuals, agencies and non-governmental organizations. Here, we highlight some of the most significant.

Awareness of the plight of sawfishes has been communicated to fisheries and conservation audiences Global Sawfish Conservation Strategy (Actions 1.1 and 2.1). The International Union for Conservation of Nature Shark Specialist Group (IUCN SSG), and the United States government hosted the 'Securing a Safe Future for Sawfishes' Side Event on 10 July 2012 at the United Nations Food and Agriculture Organization Committee on Fisheries (FAO) (International Institute for Sustainable Development, 2012). Participants from FAO, the Convention on International Trade of Endangered Species in Wild Fauna and Flora (CITES), the Convention on the Conservation of Migratory Species of Wild Animals (CMS), several sawfish range countries, artisanal fishermen, and conservation NGOs attended. The IUCN SSG hosted a Species Pavilion Event, in partnership with the IUCN Species Conservation Planning Sub-Committee, at the World Conservation Congress, Jeju, Korea to raise awareness of the status of and threats to sawfishes and the conservation challenges marine species face. The event helped connect the IUCN SSG to conservationists from Bangladesh, India, Pakistan, Columbia, Peru, and Australia.

Significant steps have been made toward securing the addition of sawfishes as species protected under the Convention on Migratory Species (CMS) Appendices, Memorandum of Understanding for Migratory Sharks, and associated conservation plan (Action 2.2). At the time of writing, all five sawfish species are proposed for listing on both Appendix I and II (CMS, 2014). The fate of this proposal will be decided at the 11th Meeting of the CMS Conference of the Parties (COP11), 4–9 November 2014, Quito, Ecuador.

There has been significant progress in controlling international trade in sawfish products (Action 4.1). Efforts to list sawfishes on CITES began in 1997 with an unsuccessful proposal from the USA (the history of this listing is summarized in Vincent *et al.* (2013)). Six of the seven then recognized species were eventually listed on CITES Appendix I 10 years later, with the remaining species (*P. microdon*) listed in Appendix II solely for the 'exclusive purpose of allowing international trade in live animals to appropriate and acceptable aquaria for primarily conservation purposes' based on a request from Australia. At the time the Australian government believed that *P. microdon* population were robust enough to sustain low levels of removal for the aquarium trade. In 2012, after being unable to demonstrate that such trade would not be detrimental to the sawfish population Australia proposed this species for CITES Appendix I listing. IUCN, TRAFFIC, and the ad hoc Expert panel convened by the FAO reviewed the proposal and concluded that the species met the Appendix I criteria (FAO, 2013; IUCN/TRAFFIC, 2013). In March 2013, the CITES Parties adopted the proposal to uplist *P. microdon* to Appendix I by consensus.

Surveys and documentation of fisher knowledge of sawfish distribution and recent catches have been undertaken in Africa and Asia (Actions 5.1.2, 5.2 and 5.4), including: Guinea-Bissau (Leeney and Poncelet, 2013), Gambia, Mozambique (Ruth Leeney, pers. comm.), Guinea Conakry, Sierra Leone (Armelle Jung, pers. comm.), and Bangladesh (Hossain *et al.*, 2014). The West African AfricaSaw project has also developed a cellphone reporting system for sawfishes in Guinea-Bissau and Sierra Leone (Action 5.2; http://saveourseas.com/projects/africasaw).

There have been several targeted searches for smalltooth sawfish off Andros Island in the

Bahamas, the most recent of which (in 2014) led to five sightings within 4 days (John K. Carlson, pers. comm.). In addition, a new approach to surveying for sawfish using environmental DNA (eDNA) in water samples has been trialled in aquaria and will be field-tested in northern Australia during 2014 (Action 5.6; Colin Simpfendorfer pers. comm.).

Early in 2012, the IUCN Red List of Threatened Species™ website was launched featuring a new 'Amazing Species' every week (www.iucnredlist.org/amazing-species). By the end of 2012, the green sawfish was the fourth most viewed Amazing Species account (http://www.iucnredlist.org/news/pangolin-takes-top-spot). The largetooth sawfish is included in a joint IUCN/Zoological Society of London publication featuring the world's 100 most threatened species. The revised IUCN Red List Assessments of each of the five sawfishes were published in 2013 (D'Anastasi *et al.*, 2013; Kyne *et al.*, 2013a, b; Simpfendorfer, 2013; Carlson *et al.*, 2014).

The Changing Seas environmental education series of the Public Broadcasting Service Florida WPBT2 recently aired (26/5/2014) a 26-minute documentary entitled 'Saving Sawfish' on the science of sawfish conservation in Florida (Objective 6; http://changingseas.tv/episode604.html)

4. Why has the Red List status of two sawfishes changed?

While most chondrichthyans have now been assessed for the Red List, few have been reassessed. It is important to note that the change in status of narrow and dwarf sawfishes from Critically Endangered to Endangered does not reflect an improvement in their populations. Instead these 'non-genuine changes' are the result of new information on distribution, life histories, and population dynamics (IUCN, 2013c; 11–12). First, the previous assessors did not have access to historical data on spatial distributions and the change in EOO presented here (Figures 3 and 4). We caution that the 2013 Red List Assessments were made without the benefit of quantitative estimates of percentage change, nevertheless, the assessors were aware of the qualitative patterns of change over time. Second, new knowledge suggests the narrow sawfish is the most resilient of the sawfishes because it matures relatively early (2–3 years) and, hence, has a considerably shorter generation time (4.7 years) and a moderately fast population growth rate (0.27 yr^{-1}) (Moreno Iturria, 2012). This new information on life history, combined with the historical pattern of decline and the recent improvements in fisheries management in Australian waters, the assessors judged it more likely that the most dramatic declines in EOO occurred prior to the most recent three-generation period of ~18 years for the narrow sawfish (D'Anastasi *et al.*, 2013) and ~49 years for the dwarf sawfish (Kyne *et al.*, 2013a). We caution that the population trends of both these species, and all other sawfishes, were inferred to be decreasing, and that further action is still required to halt declines and recover populations.

5. How can the uncertainty in geographic status be reduced?

There are large proportions of sawfish ranges for which status is uncertain, where there have been no confirmed sightings or captures in the past decade, and few areas have been subject to targeted surveys (Figures 2 and 3). In these locations, the geographic status has been assigned mainly as Presence Uncertain or Possibly Extinct. The difference in the application of these classifications is based on expert opinion, relying on the inferred pattern of fisheries exploitation and scientific capacity – a proxy for the likelihood that scientists would have documented any sawfish sightings or catches. For example, in coastal Brazil the geographic status of one species (smalltooth sawfish) was classified as Presence Uncertain, while in West and Central Africa, both largetooth and smalltooth sawfishes were classified as Possibly Extinct. The only difference for these purposes is that there is greater scientific capacity in Brazil, especially for sawfishes research (Charvet-Almeida, 2002; McDavitt and Charvet-Almeida, 2004; Charvet-Almeida *et al.*, 2007; Faria *et al.*, 2013; Fernandez-Carvalho *et al.*, 2014). In contrast, the conservation planning team was not aware of any local scientists with sawfish expertise in Central Africa.

However, there has been groundbreaking work conducted in West Africa to build capacity and undertake sawfish surveys, which provides a template for other sawfish range states (Diop and Dossa, 2011; Leeney and Poncelet, 2013; Tamburello *et al.*, 2014). Hence, it would be unwise to overlook Possibly Extinct areas when prioritizing scientific and conservation action. Instead scientists, non-governmental entities and governments are urged to conduct surveys of traditional ecological knowledge (TEK) and catch records to provide a better understanding of the status of sawfishes in Presence Uncertain and Possibly Extinct regions.

These data- and knowledge-based mappings reported on here should be considered as a hypothesis rather than the final word on the geographic status of sawfishes. Local sawfish status surveys have recently begun in Africa and Asia. The Bijagos Archipelago in Guinea-Bissau was thought to be a refuge for sawfishes in West Africa (Robillard and Séret, 2006), but recent surveys of TEK of local fishers suggests there have been very few captures in the past decade (Leeney and Poncelet, 2013). More promising, recent surveys of fisher landings sites in Bangladesh – home to the largest continuous block of mangrove wetlands in the world (the Sundarbans) – suggest that sawfishes were very frequently encountered historically and are still captured in modest numbers today (Hossain *et al.*, 2014). Further west, sawfishes were historically present in the Middle East Arabian/Persian Gulf region up to the 1960s, but have rarely been encountered since the 1980s (Moore, 2014). These and all areas classified as Presence Uncertain or Possibly Extinct should be prioritized for sawfish surveys.

Finally, one of the greatest uncertainties with respect to sawfishes involves their existence in the Mediterranean Sea. Previous IUCN Red List Assessments classified sawfishes as Presence Uncertain in this region (Ferretti, 2014). A recent survey of the literature shows that the largetooth and smalltooth sawfishes have been included in faunal lists of the region based on 83 documented records and museum specimens (Ferretti, 2014). These records have come from the western Mediterranean, particularly French and Italian waters, though there are two 20th century records from the eastern Mediterranean Sea. Sawfishes were almost certainly vagrant in the Mediterranean Sea. While more permanent populations are suggested by a number of juvenile records, the seasonal temperature minimum is cooler than current sawfish distributions suggest that they can tolerate (Ferretti, 2014). Whether or not sawfishes were previously Extant in the Mediterranean Sea has little bearing on current conservation priorities as any activities benefitting West African sawfishes can only restore migration and improve the likelihood of vagrancy to the Mediterranean Sea once again.

CONCLUSION

Owing to a combination of complicating factors, the sawfishes are at greater risk of extinction than all other rays and sharks. Although the threat is exceptionally high and global, encouraging trends in the USA and Australia demonstrate that recovery from the brink is possible for sawfishes, if the species are strictly protected and their critical habitats are conserved, with the help of focused, regional research and recovery programmes. Recovery is most likely to occur under a coordinated conservation-planning regime that shares the lessons learned, particularly from regions where declines have been stemmed to areas of priority need. It is hoped that the IUCN Global Sawfish Conservation Strategy will swiftly spark effective recovery initiatives throughout the range of these remarkable and imperilled marine species.

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REFERENCES

Adams AJ, Horodysky AZ, McBride RS, Guindon K, Shenker J, MacDonald TC, Harwell HD, Ward R, Carpenter K. 2014. Global conservation status and research needs for tarpons (Megalopidae), ladyfishes (Elopidae) and bonefishes (Albulidae). *Fish and Fisheries* **15**: 280–311.

Barker MJ, Schluessel V. 2005. Managing global shark fisheries: suggestions for prioritizing management strategies. *Aquatic Conservation: Marine and Freshwater Ecosystems* **15**: 325–347.

Boyd C, Brooks TM, Butchart SHM, Edgar GJ, da Fonseca GAB, Hawkins F, Hoffmann M, Sechrest W, Stuart SN, van Dijk PP. 2008. Spatial scale and the conservation of threatened species. *Conservation Letters* **1**: 37–43.

Burgess GH. 2013. International Sawfish Encounter Database. http://www.flmnh.ufl.edu/fish/sharks/sawfish/sawfishdatabase.html.

Carlson JK, Osborne J. 2012. Relative abundance of smalltooth sawfish (*Pristis pectinata*) based on the Everglades National Park Creel Survey. National Marine Fisheries Service, Southeast Fisheries Science Centre, 12.

Carlson JK, Simpfendorfer CA. 2014. Recovery potential of smalltooth sawfish, *Pristis pectinata*, in the United States determined using population viability models. *Aquatic Conservation: Marine and Freshwater Ecosystems* DOI: 10.1002/aqc.2434.

Carlson JK, Osborne J, Schmidt TW. 2007. Monitoring the recovery of smalltooth sawfish, *Pristis pectinata*, using standardized relative indices of abundance. *Biological Conservation* **136**: 195–202.

IUCN 2013. Carlson JK, Wiley T, Smith K. 2013. In: *The IUCN Red List of Threatened Species*. Version 2013.2. *Pristis pectinata* (Smalltooth Sawfish). http://www.iucnredlist.org/details/18175/0.

Carlson JK, Gulak SJB, Simpfendorfer CA, Grubbs RD, Romine JG, Burgess GH. 2014. Movement patterns and habitat use of smalltooth sawfish, *Pristis pectinata*, determined using pop-up satellite archival tags. *Aquatic Conservation: Marine and Freshwater Ecosystems* **24**: 104–117.

Chapman DD, Simpfendorfer CA, Wiley TR, Poulakis GR, Curtis C, Tringali M, Carlson JK, Feldheim KA. 2011. Genetic diversity despite population collapse in a Critically Endangered marine fish: the Smalltooth Sawfish (*Pristis pectinata*). *Journal of Heredity* **102**: 643–652.

Charvet-Almeida P. 2002. Sawfish trade in the north of Brazil. *Shark News: Newsletter of the IUCN Shark Specialist Group* **14**: 9.

Charvet-Almeida P, Faria V, Furtado M, Cook SF, Compagno L.J.V., Oetinger MI. 2007. *Pristis perotteti*. http://www.iucnredlist.org.

Chin A, White J, Dulvy NK. 2012. Environment in Queensland at risk. *Nature* **490**: 176.

CITES. 2007. Consideration of proposals for Amendment of Appendices I and II; CoP14. Convention on the International Trade in Endangered Species, The Hague, Netherlands.

CMS. 2014. Proposal for the Inclusion of all Species of Sawfish (Family Pristidae) on CMS Appendix I and Appendix II. United Nations Environment Programme, Convention on Migratory Species, Bonn, Germany.

Costello C, Ovando D, Hilborn R, Gaines SD, Deschenes O, Lester SE. 2012. Status and solutions for the world's unassessed fisheries. *Science* **338**: 517–520.

IUCN 2013. D'Anastasi B, Simpfendorfer CA, van Herwerden L. 2013. In: *The IUCN Red List of Threatened Species*. Version 2013.2. Anoxypristis cuspidata (Narrow Sawfish). http://www.iucnredlist.org/details/39389/0.

D'Anastasi BR. 2013. Conservation genetics of the critically endangered narrow sawfish (*Anoxypristis cuspidata*) in northern Australia. BSc. Honours Thesis, James Cook University.

Davidson LNK. 2014. Species mapping. In *Sawfish: A Global Strategy for Conservation*, Harrison LH, Dulvy NK (eds). IUCN Shark Specialist Group: Vancouver, Canada; 41.

Department of the Environment. 2014. Draft Recovery Plan for Sawfish and River Sharks: (*Pristis pristis, Pristis zijsron, Pristis clavata, Glyphis glyphis* and *Glyphis garricki*). Department of the Environment, Australian Government, Canberra.

Dineshbabu AP, Muniyappa Y. 2005. On the landing of largetooth sawfish, *Pristis microdon* at Mangalore. *Marine Fisheries Information Service Technical and Extension Series* **184**: 20.

Diop M, Dossa J. 2011. *30 years of Shark Fishing in West Africa*. Fondation Internationale du Banc d'Arguin: Senegal; 92.

Dulvy NK, Fowler SL, Musick JA, Cavanagh RD, Kyne PM, Harrison LR, Carlson JK, Davidson LNK, Fordham S, Francis MP, *et al*. 2014. Extinction risk and conservation of the world's sharks and rays. *eLIFE* **3**: e00590.

FAO. 2007. The world's mangroves 1980–2005. Food and Agriculture Organization of the United Nations, Rome. 153, 75.

FAO. 2013. Fourth FAO Expert Advisory Panel for the Assessment of Proposals to Amend Appendices I and II of CITES Concerning Commercially-exploited Aquatic Species. Food and Agriculture Organization of the United Nations, Rome, Italy.

Faria VV, McDavitt MT, Charvet P, Wiley TR, Simpfendorfer CA, Naylor GJP. 2013. Species delineation and global population structure of Critically Endangered sawfishes (Pristidae). *Zoological Journal of the Linnean Society* **167**: 136–164.

Fernandez-Carvalho J, Imhoff JL, Faria VV, Carlson JK, Burgess GH. 2014. Status and the potential for extinction of the largetooth sawfish *Pristis pristis* in the Atlantic Ocean. *Aquatic Conservation: Marine and Freshwater Ecosystems* **24**: 478–497.

Ferretti F. 2014. Geographical distribution and status. 7.2.1 Mediterranean Sea. In *Sawfish: A Global Strategy for Conservation*, Harrison LH, Dulvy NK (eds). IUCN Shark Specialist Group: Vancouver, Canada; 50–51.

Harnik PG, Lotze HK, Anderson SC, Finkel ZV, Finnegan S, Lindberg DR, Liow LH, Lockwood R, McClain CR, McGuire JL*, et al*. 2012. Extinctions in ancient and modern seas. *Trends in Ecology and Evolution* **27**: 608–617.

Harrison LR, Dulvy NK. 2014. *Sawfish: A Global Strategy for Conservation*. International Union for the Conservation of Nature Species Survival Commission's Shark Specialist Group, Vancouver, Canada.

Hobday AJ, Smith ADM, Stobutzki IC, Bulman C, Daley R, Dambacher JM, Deng RA, Dowdney J, Fuller M, Furlani D*, et al*. 2011. Ecological risk assessment for the effects of fishing. *Fisheries Research* **108**: 372–384.

Hoffmann M, Hilton-Taylor C, Angulo A, Bohm M, Brooks TM, Butchart SHM, Carpenter KE, Chanson J, Collen B, Cox NA*, et al*. 2010. The impact of conservation on the status of the world's vertebrates. *Science* **330**: 1503–1509.

Hossain MA, Thompson BS, Chowdury GW, Mohsanin S, Fahad ZH, Koldewey HJ, Islam MA. 2014. Sawfish exploitation and status in Bangladesh. *Aquatic Conservation: Marine and Freshwater Ecosystems* DOI: 10.1002/aqc.2466.

International Institute for Sustainable Development. 2012. Earth Negotiations Bulletin, COFI 30 Highlights: Tuesday 10 July 2012. http://www.iisd.ca/download/pdf/enb2908e.pdf.

IUCN. 2008. Strategic Planning for Species Conservation: A Handbook. International Union for the Conservation of Nature Species Survival Commission, Gland, Switzerland.

IUCN. 2012. IUCN Red List Categories and Criteria: version 3.1, second edition. IUCN Species Survival Commission, Gland Switzerland and Cambridge, UK.

IUCN. 2013a. The IUCN Red List of Threatened species. http://www.iucnredlist.org/.

IUCN. 2013b. METADATA: Digital Distribution Maps of The IUCN Red List of Threatened Species™. Version 3. http://www.iucnredlist.org/technical-documents/spatial-data.

IUCN. 2013c. Guidelines for using the IUCN Red List Categories and Criteria. IUCN Species Survival Commission, Gland, Switzerland.

IUCN/TRAFFIC. 2013. IUCN/TRAFFIC Analyses of the Proposals for CITES CoP15. http://www.traffic.org/cop16-table/.

IUCN 2013. Kyne PM, Rigby C, Simpfendorfer CA. 2013a. In: *The IUCN Red List of Threatened Species*. Version 2013.2. *Pristis clavata* (Dwarf Sawfish). http://www.iucnredlist.org/details/39390/0.

IUCN 2013. Kyne PM, Carlson JK, Smith K. 2013b. In: *The IUCN Red List of Threatened Species*. Version 2013.2. *Pristis pristis* (Largetooth Sawfish). http://www.iucnredlist.org/details/39389/0.

Leeney RH, Poncelet P. 2013. Using fishers' ecological knowledge to assess the status and cultural importance of sawfish in Guinea-Bissau. *Aquatic Conservation: Marine and Freshwater Ecosystems* DOI: 10.1002/aqc.2419.

Lotze HK, Worm B. 2009. Historical baselines for large marine animals. *Trends In Ecology and Evolution* **24**: 254–262.

Lotze HK, Lenihan HS, Bourque BJ, Bradbury RH, Cooke RG, Kay MC, Kidwell SM, Kirby MX, Peterson CH, Jackson JBC. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science* **312**: 1806–1809.

Mace GM, Collar NJ, Gaston KJ, Hilton-Taylor C, Akcakaya HR, Leader-Williams N, Milner-Gulland EJ, Stuart SN. 2008. Quantification of extinction risk: IUCN's system for classifying threatened species. *Conservation Biology* **22**: 1424–1442.

McClenachan L, Cooper AB. 2008. Extinction rate, historical population structure and ecological role of the Caribbean monk seal. *Proceedings of the Royal Society B: Biological Sciences* **275**: 1351–1358.

McClenachan L, Cooper AB, Carpenter KE, Dulvy NK. 2012. Extinction risk and bottlenecks in the conservation of charismatic marine species. *Conservation Letters* **5**: 73–80.

McDavitt MT. 2014a. The cultural value of sawfishes. In *Sawfish: A Global Strategy for Conservation*, Harrison LH, Dulvy NK (eds). IUCN Shark Specialist Group: Vancouver, Canada; 30–31.

McDavitt MT. 2014b. Sawfish products and trade. In *Sawfish: A Global Strategy for Conservation*, Harrison LH, Dulvy NK (eds). IUCN Shark Specialist Group: Vancouver, Canada; 72–75.

McDavitt MT, Charvet-Almeida P. 2004. Quantifying trade in sawfish rostra: two examples. *Shark News: Newsletter of the IUCN Shark Specialist Group* **16**: 10–11.

Melo Palmeira CA, da Silva Rodrigues-Filho LF, de Luna Sales JB, Vallinoto M, Schneider H, Sampaio I. 2013. Commercialization of a Critically Endangered species (Largetooth sawfish, *Pristis perotteti*) in fish markets of northern Brazil: authenticity by DNA analysis. *Food Control* **34**: 249–252.

Moore ABM. 2014. Sawfishes (*Pristidae*) in the Arabian region: history, diversity, distribution, and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* DOI: 10.1002/aqc.2441.

Moreno Iturria DA. 2012. Demographic analysis of the family *Pristidae* to aid in conservation and management. BSc Honours thesis, James Cook University.

National Marine Fisheries Service. 2009. Recovery Plan for Smalltooth Sawfish (*Pristis pectinata*). Smalltooth Sawfish Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland.

National Oceanic and Atmospheric Administration. 2013. Endangered and Threatened Wildlife and Plants; 12-Month Finding and Proposed Endangered Listing of Five Species of Sawfish Under the Endangered Species Act, June 4 2013. In *50 CFR Part 224, Docket No. 101004485–3501–02*, Department of Commerce DoNOaAA (ed). Department of Commerce, Department of National Oceanic and Atmospheric Administration, National Marine Fisheries Service: USA.

Norton SL, Wiley TR, Carlson JK, Frick AL, Poulakis GR, Simpfendorfer CA. 2012. Designating critical habitat for juvenile endangered Smalltooth Sawfish in the United States. *Marine and Coastal Fisheries* **4**: 473–480.

Peverell SC. 2005. Distribution of sawfishes (*Pristidae*) in the Queensland Gulf of Carpentaria, Australia, with notes on sawfish ecology. *Environmental Biology of Fishes* **73**: 391–402.

Phillips NM, Chaplin JA, Morgan DL, Peverell SC. 2011. Population genetic structure and genetic diversity of three

critically endangered *Pristis* sawfishes in Australian waters. *Marine Biology* **158**: 903–915.
Pimm SL, Jenkins CN, Abell R, Brooks TM, Gittleman JL, Joppa LN, Raven PH, Roberts CM, Sexton JO. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. *Science* **344**: 1246752. DOI:10.1126/science.1246752.
Pogonoski JJ, Pollard DA, Paxton JR. 2002. Conservation overview and action plan for Australian threatened and potentially threatened marine and estuarine fishes. Environment Australia: Canberra.
Polidoro BA, Carpenter KE, Collins L, Duke NC, Ellison AM, Ellison JC, Farnsworth EJ, Fernando ES, Kathiresan K, Koedam NE*, et al.* 2010. The loss of species: mangrove extinction risk and geographic areas of global concern. *PLoS One* **5**: e10095.
Poulakis GR, Seitz JC. 2004. Recent occurrence of the smalltooth sawfish, *Pristis pectinata* (Elasmobranchiomorphi: Pristidae), in Florida Bay and the Florida Keys, with comments on sawfish ecology. *Florida Scientist* **67**: 27–35.
Poulakis GR, Stevens PW, Timmers AA, Stafford CJ, Simpfendorfer CA. 2013. Movements of juvenile endangered smalltooth sawfish, *Pristis pectinata*, in an estuarine river system: use of non-main-stem river habitats and lagged responses to freshwater inflow-related changes. *Environmental Biology of Fishes* **96**: 763–778.
Pressey RL, Cabeza M, Watts ME, Cowling RM, Wilson KA. 2007. Conservation planning in a changing world. *Trends in Ecology and Evolution* **22**: 583–592.
Redford KH, Padoch C, Sunderland T. 2013. Fads, funding, and forgetting in three decades of conservation. *Conservation Biology* **27**: 437–438.
Robillard M, Séret B. 2006. Cultural importance and decline of sawfish (*Pristidae*) populations in West Africa. *Cybium* **30**: 23–30.
Rosenfeld JS. 2002. Functional redundancy in ecology and conservation. *Oikos* **98**: 156–162.
Sadovy de Mitcheson Y, Craig MT, Bertoncini AA, Carpenter KE, Cheung WWL, Choat JH, Cornish AS, Fennessy ST, Ferreira BP, Heemstra PC*, et al.* 2013. Fishing groupers towards extinction: a global assessment of threats and extinction risks in a billion dollar fishery. *Fish and Fisheries* **14**: 119–136.
Sadovy Y, Cheung WL. 2003. Near extinction of a highly fecund fish: the one that nearly got away. *Fish and Fisheries* **4**: 86–99.
Scharer RM, Patterson WF, Carlson JK, Poulakis GR. 2012. Age and growth of endangered smalltooth sawfish (*Pristis pectinata*) verified with LA-ICP-MS analysis of vertebrae. *PLoS One* **7**: e47850.
Seitz JC, Poulakis GR. 2006. Anthropogenic effects on the smalltooth sawfish (*Pristis pectinata*) in the United States. *Marine Pollution Bulletin* **52**: 1533–1540.
Short FT, Polidoro B, Livingstone SR, Carpenter KE, Bandeira S, Bujang JS, Calumpong HP, Carruthers TJB, Coles RG, Dennison WC*, et al.* 2011. Extinction risk assessment of the world's seagrass species. *Biological Conservation* **144**: 1961–1971.
Simpfendorfer CA. 2000. Predicting population recovery rates for endangered western Atlantic sawfishes using demographic analyses. *Environmental Biology of Fishes* **58**: 371–377.
Simpfendorfer CA. 2005. Threatened fishes of the world: *Pristis pectinata* Latham, 1794 (Pristidae). *Environmental Biology of Fishes* **73**: 20.
Simpfendorfer CA. 2007. The importance of mangroves as nursery habitat for smalltooth sawfish (*Pristis pectinata*) in South Florida. *Bulletin of Marine Science* **80**: 933–934.
Simpfendorfer CA. 2013. *Pristis zijsron* (Green Sawfish). In: *The IUCN Red List of Threatened Species*. Version 2013.2. http://www.iucnredlist.org/details/39393/0.
Simpfendorfer CA, Cortés E, Heupel MR, Brookes E, Babcock EA, Baum JK, McAuley R, Dudley SFJ, Stevens JD, Fordham S*, et al.* 2008. An integrated approach to determining the risk of over-exploitation for data-poor pelagic Atlantic sharks. International Commission for the Conservation of Atlantic Tunas, Madrid. 2008/138/140, 1–14.
Späet JLY, Elhassan IS. 2014. Geographical distribution and status. 7.3.2 Red Sea. In *Sawfish: A Global Strategy for Conservation*, Harrison LH, Dulvy NK (eds). IUCN Shark Specialist Group: Vancouver, Canada; 58–59.
Stevens JD, Pillans RD, Salini J. 2005. Conservation assessment of *Glyphis* sp. A (speartooth shark), *Glyphis* sp. C (northern river shark), *Pristis microdon* (freshwater sawfish) and *Pristis zijsron* (green sawfish). CSIRO Marine Research, Hobart, Australia.
Stevens JD, McAuley RB, Simpfendorfer CA, Pillans RD. 2008. Spatial distribution and habitat utilisation of sawfish (*Pristis* spp.) in relation to fishing in northern Australia. A report to Department of the Environment, Water, Heritage and the Arts. 31.
Tamburello N, Diop M, Dossa J. 2014. Geographical distribution and status. 7.2.2 Eastern Central and Southeast Atlantic Ocean. In *Sawfish: A Global Strategy for Conservation*, Harrison LH, Dulvy NK (eds). IUCN Shark Specialist Group: Vancouver, Canada; 52–54.
Vincent ACJ, Sadovy de Mitcheson YJ, Fowler SL, Lieberman S. 2013. The role of CITES in the conservation of marine fishes subject to international trade. *Fish and Fisheries* DOI: 10.1111/faf.12035.
Wallace BP, DiMatteo AD, Hurley BJ, Finkbeiner EM, Bolten AB, Chaloupka MY, Hutchinson BJ, Abreu-Grobois FA, Amorocho D, Bjorndal KA*, et al.* 2010. Regional management units for marine turtles: a novel framework for prioritizing conservation and research across multiple scales. *PLoS One* **5**: e15465.
Wallace BP, DiMatteo AD, Bolten AB, Chaloupka MY, Hutchinson BJ, Abreu-Grobois FA, Mortimer JA, Seminoff JA, Amorocho D, Bjorndal KA*, et al.* 2011. Global conservation priorities for marine turtles. *PLoS One* **6**: e24510.
Waycott M, Duarte CM, Carruthers TJB, Orth RJ, Dennison WC, Olyarnik S, Calladine A, Fourqurean JW, Heck KL, Hughes AR*, et al.* 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences of the United States of America* **106**: 12377–12381.
Whitty JM, Phillips NM, Thorburn DC, Simpfendorfer CA, Field I, Peverell SC, Morgan DL. 2013. Utility of rostra in the identification of Australian sawfishes (Chondrichthyes: Pristidae). *Aquatic Conservation: Marine and Freshwater Ecosystems* DOI: 10.1002/aqc.2398.

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