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REVIEW

Are guitarfishes the next sawfishes? Extinction risk and an urgent call for conservation action

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ABSTRACT: Focusing on the most critical conservation priorities to prevent extinctions risks missing declines of lower priority taxa that may become tomorrow's emergency. Sawfishes (5 species) underwent catastrophic but largely unnoticed global declines in the latter part of the 20th century, and are now the subject of intensive research and conservation efforts. Guitarfishes (at least 55 species) share many characteristics with sawfishes: they are shark-like batoids with an often large body, prefer sedimentary habitats in warm shallow coastal waters exposed to intensive fisheries, and have high value fins and good quality meat. Guitarfishes represent a unique element of evolution and biodiversity and are vital components of complex coastal socio-ecological systems. Existing global IUCN Red List of Threatened Species assessments for nearly 60% of guitarfish species are 10 or more years old, and over 70% of species are either in threatened categories or Data Deficient. Recently described taxa not yet assessed include those likely to be at risk of extinction. Severe declines and localised extinctions have already been reported for guitarfishes. In notable contrast to sawfishes, total extinction of several guitarfish species is plausible given small distributions occurring solely in developing or least developed countries where conservation is highly challenging. Furthermore, species identification of guitarfishes is often problematic and they may lack the appeal often needed to promote conservation. To ensure that they do not follow the same trajectory as sawfishes, there is an urgent need for comprehensive and coordinated action on guitarfishes, which in many cases could integrate with sawfish conservation efforts.

KEY WORDS: Elasmobranch · Extinction · Fisheries · Conservation · Glaucostegidae · Rhinidae · Rhinobatidae · Trygonorrhinidae

INTRODUCTION

Conservationists tend to tackle the most urgent priorities to prevent extinction of the rarest (and often the most charismatic) species. Less conservation effort is directed at other taxa, but this risks missing alarming declines that may be of ecological significance. For example in Europe, the abundance of common birds such as the house sparrow *Passer domesticus* has declined dramatically, while that of rarer species such as the grey heron *Ardea cinerea* has increased (Inger et al. 2015). Furthermore, allocating the most resources to taxa with the greatest risk of extinction may not be the most efficient way to promote recovery or reduce global extinctions, as some of the most threatened species will require vast conservation effort with a small chance of success (Possingham et al. 2002). Therefore, focusing on today's critical priorities risks losing sight of those species that may well turn out to be tomorrow's emergencies.

Once collapsed, many marine fish populations do not recover rapidly, if at all, even with reduction in fishing pressure (Hutchings & Reynolds 2004). Using the precautionary principle, prevention of collapses in the first place is therefore essential. One such example of marine fish population collapse is that of the sawfishes (Pristidae, 5 species). These are large

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to massive (3.2 to 7 m maximum total length, TL) and highly recognisable shark-like batoids that were previously common to abundant in soft-bottom habitats of shallow, warm waters worldwide, often enjoying close associations with human culture through mythology and folklore (Harrison & Dulvy 2014). Despite these factors, research on sawfishes was conspicuously lacking, and one of the first focused field studies was also that which documented their disastrous fisheries-driven extinction in Lake Nicaragua (Thorson 1982). Even with this clear example of vulnerability and a significant growth in elasmobranch research in ensuing decades, catastrophic global declines went almost unnoticed, with a notable exception in the grey literature: 'The Shark Specialist Group is becoming increasingly concerned about widespread reports...of an apparent serious decline over the past few decades of formerly healthy populations of all species of sawfish' (Anonymous 1996).

Following this, conservation-driven research started in the USA and Australia, alongside efforts to list sawfishes on national and international conservation policy such as the USA Endangered Species Act and the Convention on International Trade in Endangered Species (Carlson et al. 2013). However, it was not until 2014 that a co-ordinated global conservation strategy was published, along with research from developing nations that makes up the vast majority of the range of sawfishes (Harrison & Dulvy 2014). Thus, over 3 decades had passed between explicit evidence of extinction risk and a truly global response, by which time sawfishes had all but vanished from vast areas encompassing local, regional and global scales (Moore 2015, Dulvy et al. 2016, Leeney & Downing 2016). All 5 species of sawfish are now considered Critically Endangered or Endangered on the IUCN Red List of Threatened Species (RL) (Carlson et al. 2013, D'Anastasi et al. 2013, Kyne et al. 2013a,b, Simpfendorfer 2013), and their realistic recovery in huge parts of their former range is highly unlikely.

In the wider field of conservation biology, embracing and acknowledging failure has been argued as being a fundamental requirement for success in order to improve learning, enhance innovation and promote adaptive management (Redford & Taber 2000, Knight 2009). It would be difficult to argue that the sawfish story represents anything other than a comprehensive, collective failure by scientists and managers to recognise, document and address the problem before it was too late to meaningfully intervene, for most of the world. As the current paper explains, lessons learned from the sawfish story have major relevance to another group of shark-like batoids, the guitarfishes.

The definition of guitarfish, at least for a biologist, is straightforward. As clarified in a recent major taxonomic revision (Last et al. 2016a), guitarfishes are batoid elasmobranchs comprising 4 families (Rhinidae, 10 species; Rhinobatidae, 31 species; Glaucostegidae, 6 species; and Trygonorrhinidae, 8 species; see Table 1). Together with the sawfishes, these comprise the Order Rhinopristiformes (Last et al. 2016a). For non-biologists, however, guitarfishes suffer from a confusing array of often overlapping English vernacular names. As examples, giant guitarfish is a term widely used for both *Rhynchobatus* (Rhinidae) and Glaucostegidae (also known as shovelnose rays); *Rhynchobatus* are sometimes known as wedgefish in Australia and this term is proposed for the wider family Rhinidae, even though the remainder of its genera (*Rhina* and *Rhynchorhina*) lack a wedge-shaped snout. Common names even include reference to sharks, such as the generic term guitar shark, lesser sand shark (*Acroteriobatus annulatus*) and shark ray (*Rhina ancylostoma*). This lack of nomenclatural clarity and identity may prove a barrier to public engagement, conservation policy and fisheries management, and suggests that the adoption of a standard name, the guitarfishes, is worthwhile.

While guitarfishes have already been identified as being amongst the most vulnerable of elasmobranch families after the sawfishes (Dulvy et al. 2014), they remain poorly known with little scientific or media attention. To relate the many similarities that sawfishes and guitarfishes share, and to identify what could be learned from the global decline of sawfishes, the purpose of the present study is 3-fold: (1) to outline why guitarfishes are important, and therefore worthy of conservation effort; (2) to review and compare broad extinction risk factors between sawfishes and guitarfishes; and (3) to provide an overview of existing global IUCN RL assessments of guitarfishes. This review concludes with an assessment of what lessons can be learned from the sawfish experience, and how these might be applied to guitarfishes.

METHODS

This paper attempts to reflect a synthesis of current knowledge (such as published literature) on guitarfishes, as well as identifying less tangible trends, gaps and opportunities observed by the author or discussed with colleagues over several years researching elasmobranch biodiversity, fisheries and conser-

Table 1. Scientific and common names of described guitarfishes, their global IUCN Red List assessment status (as of 1 March 2017) and geographical distribution as per Last et al. (2016b). CR: Critically Endangered; EN: Endangered; VU: Vulnerable; NT: Near Threatened; LC: Least Concern; DD: Data Deficient; NE: Not Evaluated. N/A: not applicable. WIO/EIO/NIO: Western/Eastern/Northern Indian Ocean; WNP/WCP/WSP: Western North/Central/South Pacific Ocean; ENP/ECP/ESP: Eastern North/Central/South Pacific Ocean; WNA/WCA/WSA: Western North/Central/South Atlantic Ocean; ENA/ECA/ESA: Eastern North/Central/South Atlantic Ocean; MED: Mediterranean

Taxon	Common English name(s)	Red List status	Year assessed	Distribution
Family Rhinidae				
Rhina ancylostoma Bloch & Schneider, 1801	Shark ray	VU	2015	WIO, EIO, NIO, WSP, WCP, WNP
Rhynchobatus australiae Whitley, 1939	Bottlenose guitarfish	VU	2003	WIO, EIO, NIO, WSP, WCP, WNP
Rhynchobatus cooki Last, Kyne & Compagno, 2016	Clown wedgefish, roughnose wedgefish	VU	2006	WCP
Rhynchobatus djiddensis (Forsskål, 1775)	Giant guitarfish; white-spotted wedgefish	VU	2006	WIO, NIO
Rhynchobatus immaculatus Last, Ho & Chen, 2013	Taiwanese wedgefish	NE	N/A	WNP
Rhynchobatus laevis (Bloch & Schneider, 1801)	Smoothnose wedgefish	VU	2015	NIO, WNP
Rhynchobatus luebberti Ehrenbaum, 1915	African wedgefish	EN	2006	ECA
Rhynchobatus palpebratus Compagno & Last, 2008	Eyebrow wedgefish	NE	N/A	EIO, WSP, WCP
Rhynchobatus springeri Compagno & Last, 2010	Broad-nosed wedgefish	VU	2006	NIO, EIO, WCP
Rhynchorhina mauritaniensis Séret & Naylor, 2016	False shark ray	NE	N/A	ECA
Family Rhinobatidae				
Acroteriobatus annulatus (Müller & Henle, 1841)	Lesser sand shark	LC	2006	WIO, ESA
Acroteriobatus blochii (Müller & Henle, 1841)	Bluntnose guitarfish	LC	2006	ESA
Acroteriobatus leucospilus (Norman, 1926)	Grayspotted guitarfish	DD	2008	WIO
Acroteriobatus ocellatus (Norman, 1926)	Speckled guitarfish	DD	2008	WIO
Acroteriobatus omanensis (Last, Henderson & Naylor 2016)	Oman guitarfish	NE	N/A	NIO
Acroteriobatus salalah (Randall & Compagno, 1995)	Salalah guitarfish	DD	2006	NIO
Acroteriobatus variegatus (Nair & Lal Mohan, 1973)	Stripenose guitarfish	DD	2008	NIO
Acroteriobatus zanzibarensis (Norman, 1926)	Zanzibar guitarfish	NT	2006	WIO
Pseudobatos glaucostigmus (Jordan & Gilbert, 1883)	Speckled guitarfish	DD	2008	ECP
Pseudobatos horkelii (Müller & Henle, 1841)	Brazilian guitarfish	CR	2007	WSA
Pseudobatos lentiginosus (Garman, 1880)	Freckled guitarfish	NT	2004	WCA, WNA
Pseudobatos leucorhynchus (Günther, 1867)	Whitesnout guitarfish	NT	2006	ECP
Pseudobatos percellens (Walbaum, 1792)	Southern guitarfish	NT	2004	WSA, WCA
Pseudobatos planiceps (Garman, 1880)	Flathead guitarfish	DD	2004	ECP, ESP
Pseudobatos prahli (Acero & Franke, 1995)	Gorgona guitarfish	DD	2007	ECP
Pseudobatos productus (Ayres, 1854)	Shovelnose guitarfish	NT	2014	ENP, ECP
Rhinobatos albomaculatus Norman, 1930	Whitespotted guitarfish	VU	2008	ECA
Rhinobatos annandalei Norman, 1926	Annandale's guitarfish	DD	2008	NIO
Rhinobatos borneensis Last, Séret & Naylor, 2016	Borneo shovelnose ray	NE	N/A	WCP
Rhinobatos holcorhynchus Norman, 1922	Slender guitarfish	DD	2008	WIO
Rhinobatos hynnicephalus Richardson, 1846	Ringstraked guitarfish	NT	2006	WCP, WNP
Rhinobatos irvinei Norman, 1931	Spineback guitarfish	VU	2008	ECA
Rhinobatos jimbaranensis Last, White & Fahmi, 2006	Jimbaran shovelnose ray	VU	2006	EIO
Rhinobatos lionotus Norman, 1926	Smoothback guitarfish	DD	2008	NIO
Rhinobatos nudidorsalis Last, Compagno & Nakaya, 2004	Bareback shovelnose ray	NT	2006	WIO
Rhinobatos penggali Last, White & Fahmi, 2006	Indonesian shovelnose ray	VU	2006	EIO
Rhinobatos punctifer Compagno & Randall, 1987	Spotted guitarfish	DD	2004	NIO
Rhinobatos rhinobatos (Linnaeus, 1758)	Common guitarfish	EN	2007	ENA, MED, ECA
Rhinobatos sainsburyi Last, 2004	Goldeneye shovelnose ray	LC	2015	EIO, WCP
Rhinobatos schlegelii Müller & Henle, 1841	Brown guitarfish	DD	2004	WNP
Rhinobatos whitei Last, Corrigan & Naylor, 2014	Philippine guitarfish	NE	N/A	WNP
Family Glaucostegidae				
Glaucostegus cemiculus (Geoffroy St. Hilaire, 1817)	Blackchin guitarfish	EN	2007	ENA, MED, ECA
Glaucostegus granulatus (Cuvier, 1829)	Granulated guitarfish	VU	2006	NIO
Glaucostegus halavi (Forsskål, 1775)	Halavi's guitarfish	DD	2008	NIO
Glaucostegus obtusus (Müller & Henle, 1841)	Widenose guitarfish	VU	2006	NIO, WCP
Glaucostegus thouin (Anonymous, 1798)	Clubnose guitarfish	VU	2006	NIO, EIO, WCP
Glaucostegus typus (Bennett, 1830)	Giant shovelnose ray	VU	2003	NIO, EIO, WSP, WCP, WNP

Continued on next page

Table 1 (continued)

Taxon	Common English name(s)	Red List status	Year assessed	Distribution
Family Trygonorrhinidae				
Aptychotrema rostrata (Shaw, 1794)	Eastern shovelnose ray	LC	2015	WSP
Aptychotrema timorensis Last, 2004	Spotted shovelnose ray	VU	2015	WCP
Aptychotrema vincentiana (Haacke, 1885)	Western shovelnose ray	LC	2015	EIO
Trygonorrhina dumerilii (Castelnau, 1873)	Southern fiddler ray	LC	2015	EIO, WSP
Trygonorrhina fasciata Müller & Henle, 1841	Eastern fiddler ray	LC	2015	WSP
Zapteryx brevirostris (Müller & Henle, 1841)	Shortnose guitarfish	VU	2006	WSA
Zapteryx exasperata (Jordan & Gilbert, 1880)	Banded guitarfish	DD	2015	ENP, ECP
Zapteryx xyster Jordan & Evermann, 1896	Southern banded guitarfish	DD	2008	ECP

vation. Searches using taxonomic identifiers (for example 'guitarfish' and '*Rhynchobatus*') were conducted in the first half of 2016 using resources such as Web of Science, in order to identify published data on those aspects of guitarfishes relevant to their ecology and conservation (such as distribution, fisheries and trade), especially in comparison to sawfishes. Scientific names used in the current paper are consistent with the recent revisions of Last et al. (2016a,b), which changed the nomenclature of several genera. Global IUCN RL assessments for all guitarfishes were downloaded on 1 March 2017 (IUCN 2016). The year in which the assessment was performed was used for analysis, as in some cases these were not published immediately, and in some cases, a more recent publication date reflected only nomenclatural changes (as per Last et al. 2016b), and not full re-assessment. While it is acknowledged that the RL process is ongoing and dynamic, the validity of RL assessments was reviewed based on their age: those performed in 2007 or before, and therefore beyond the 5 to 10 yr aim of the IUCN for re-assessment of taxa (IUCN Species Survival Commission 2016) were considered out of date. The term 'Least Developed Countries' (LDC) is as defined by UNDESA (2016), i.e. 'low-income countries confronting severe structural impediments to sustainable development', and is taken here as being a nation severely restricted in its ability to successfully conserve threatened marine fishes, including guitarfishes. Of particular relevance to the current paper (and to coastal elasmobranch conservation in general) are 3 large tropical marine regions whose entire coastline is made up of multiple LDCs ('LDC regions' hereafter): part of West Africa (Mauritania, Senegal, Gambia, Guinea Bissau, Guinea, Sierra Leone, Liberia), Gulf of Aden/southern Red Sea (Yemen, Somalia, Djibouti, Eritrea, Sudan) and the Southwest Indian Ocean (Madagascar, Mozambique, Tanzania, Comoros).

WHY ARE GUITARFISH IMPORTANT?

Guitarfishes are important components of coastal socio-ecological systems. They have provided a source of marine protein to coastal human communities since at least the Bronze Age (Uerpmann & Uerpmann 2005), and continue to do so: Senegal, an LDC, reported to the FAO annual guitarfish landings averaging 1148 t yr^{-1} in the period 2004 to 2014 (FAO 2016). Other nations currently specifically reporting guitarfish landings include Pakistan, Indonesia, Libya, Benin and Palestine (FAO 2016). Guitarfishes can contribute to local economies through dive ecotourism (African Dive Adventures 2014) and recreational angling (Dunlop et al. 2013), and to education as exhibits in public aquaria (Georgia Aquarium 2016). As relatively large and sometimes abundant benthic mesopredators, guitarfish have an important role in the trophic functioning of soft-sediment ecosystems (Kyne & Bennett 2002). As many guitarfish are found associated with seagrasses (Vaudo & Heithaus 2011), their presence presumably contributes to the healthy functioning of this habitat that is of very high ecosystem service value to humans (Campagne et al. 2015). Guitarfishes are important prey items to non-human apex predators vital to ecosystem functioning, such as to bull (*Carcharhinus leucas*), sevengill (*Notorynchus cepedianus*), and great hammerhead (*Sphyrna mokarran*) sharks off southern Africa (Cliff & Dudley 1991, Ebert 1991, Cliff 1995). This ecosystem importance also extends downward, with guitarfish being shown to consume up to 77% of the annual benthic invertebrate production of a lagoon in South Africa (Harris et al. 1988). Some species appear to have a specialised diet, such as the banded guitarfish *Zapteryx exasperata* in the Gulf of California, which consumes mainly benthic fish (Blanco-Parra et al. 2012). Preliminary stable isotope studies have also hinted at a more pelagic role in the ecosystem for some guitarfish (i.e. bowmouth guitarfish *Rhina ancylostoma*) despite their dorso-ventrally flattened morphology (Borrell et al. 2011).

Guitarfishes also have high intrinsic value as a unique example of biodiversity, adaptation and vast evolutionary lineage. Rhinobatids appeared in the early Jurassic, and the extant sawfishes arose from them (Wueringer et al. 2009). Guitarfishes provide habitat to a large suite of unique fauna in the form of highly host-specific parasites (e.g. Bullard & Dippenaar 2003). Hydrodynamic studies of guitarfish nostrils have shown an arrangement of vertical structures similar to those on aircraft wings that may enhance olfaction and reduce the energetic costs of swimming (Agbesi et al. 2016), and the giant guitarfish *Rhynchobatus djiddensis* has the ability to protect its eye by a degree of retraction that is probably one of the largest among all vertebrates (Tomita et al. 2016).

EXTINCTION RISK FACTORS: COMPARISON OF SAWFISHES AND GUITARFISHES

Economic value

A key extinction risk factor to fish species is economic and food value to humans: those that are highly prized by humans, especially those that are large (e.g. sturgeons *Acipenser* spp. and bluefin tuna *Thunnus maccoyii*), are often most at risk. For both sawfishes and guitarfishes their high economic and food value likely presents a similar factor in extinction risk in terms of having targeted fisheries and retention of any bycatch. The fins of both guitarfishes and sawfishes have long been known to be of exceptionally high value in the shark fin trade. In the second half of the 20th century, bowmouth guitarfish *Rhina ancylostoma* fins were 'the choicest and most expensive' in the Philippines (Herre 1954, p. 386), and *Rhynchobatus* fins were considered high value in India and Indonesia (James 1973, Keong 1996). Trade in high grade 'tongari' fins from *Rhynchobatus* spp. was thought to be the main factor responsible for the doubling of the value of Indonesian fin exports to Hong Kong twice in the 1980s (1983 to 1984 and 1986 to 1987; Suzuki 2002). Keong (1996) reported that a set of fins from a single individual of *Rhynchobatus* spp. could attain around US\$396 kg^{-1}. More recently, the fins of guitarfishes including *Rhynchobatus* and *Rhina* are considered by East Asian shark fin traders as being the sources of the best quality fin needles for consumption (Clarke et al. 2007). Targeting of *Rhynchobatus* for their fins occurs widely, such as in the Southwest Indian Ocean LDC region off northern Madagascar (Hopkins 2011), Mozambique (Pierce et al. 2008) and off Zanzibar, Tanzania, where this activity was believed by some fishers to have been driving declines (Schaeffer 2004). The extremely high value of *Rhynchobatus* fins in Indonesia has driven intensive targeted fisheries since the 1970s, with apparent localised depletions around Java, Sumatra, Kalimantan and Sulawesi (White & Sommerville 2010). In Madagascar in 2014, guitarfish fins were around US\$70 kg^{-1}, around twice as valuable as shark fins (Cripps et al. 2015). Blackchin guitarfish *Glaucostegus cemiculus* landed on the beach in The Gambia in 2014 always had their dorsal and caudal fins removed (Fig. 1); in 2007 their fins were reported as fetching around €100 kg^{-1} in the region (Notarbartolo di Sciara 2016).

In addition to fins, guitarfish meat is of good quality (White & McAuley 2003) and a highly conservative estimate of at least 5000 t was landed in 2014, as reported by a handful of nations (FAO 2016). Meat is widely utilised both fresh (e.g. *Rhynchobatus* species

Fig. 1. Individuals of the Endangered blackchin guitarfish *Glaucostegus cemiculus* landed for salting and drying of meat, Ghana Town, The Gambia, March 2014. Dorsal and caudal fins have already been removed for separate onward sale. Daisy whipray *Fontitrygon margarita* also in foreground

in fish markets of Kuwait in 2011, Fig. 2) and dried and salted, sometimes for export (*G. cemiculus* in The Gambia, author's pers. obs.). Furthermore, there is an as yet unquantified level of trade in other guitarfish products in Southeast Asia, including novel dishes made of head cartilage, and jewellery made from the dorsal thorns of *Rhina ancylostoma* (M. McDavitt pers. comm.).

The economic value of guitarfishes sustains illegal fishing activity, such as the retention of the prohibited and Critically Endangered Brazilian guitarfish *Pseudobatos horkelii* off Brazil (Alexandre de-Franco et al. 2012), and the retention of fins of several species in illegal fishing activity off northern Australia (Holmes et al. 2009).

Habitat

Habitat likely plays a key role in extinction vulnerability of elasmobranchs as it modifies exposure to fishing pressure. Soft-bottom habitats (such as sand, mud, seagrass and mangrove) are generally much easier for humans to fish with a range of demersal gears such as trawls and gillnets compared to rocky or reef habitats, where gear loss or damage is a constraint. Habitat preference may at least partly explain why 2 morphologically similar, ambush-predator benthic sharks have such vastly different conservation status: over half of angel shark (Squatinidae) species, which favour soft-bottom habitats, are in RL threatened categories, while most species of wobbegong (Orectolobidae), which favour rocky and reef habitat, are 'Least Concern' (IUCN 2016). Some highly threatened elasmobranch species that were formerly common in a range of habitat types now only persist in habitat that provides refuge. An example is remnant populations of the skate species complex *Dipturus* spp. around the western British Isles, which appear to be afforded protection by seabed that is difficult to trawl (Shephard et al. 2012, Neat et al. 2015).

Fig. 2. Meat of large wedgefish *Rhynchobatus* spp. on sale in Sharq market, Kuwait, April 2011

Sawfishes and most guitarfishes are likely to face broadly similar exposure to habitat-related extinction risk factors. Some species of sawfishes such as the largetooth sawfish *Pristis pristis* are reliant on freshwater habitat for at least some of their life cycle (Kyne et al. 2013a), and therefore significant habitat modification such as damming (in addition to fisheries) may present an extinction risk factor that guitarfishes, restricted to marine and estuarine habitat, are not exposed to. However, all species of sawfishes, and the vast majority of guitarfish species, are strongly associated with soft-bottom habitats in shallow (<50 m, but usually considerably less) warm-temperate to tropical coastal waters, which are exposed to intensive and expanding fisheries (Harrison & Dulvy 2014, White & Sommerville 2010), as well as widespread loss of mangrove and seagrass habitat (Valiela et al. 2001, Duke et al. 2007, Waycott et al. 2009). It is possible that not all guitarfish are limited to inshore soft-sediment habitat: for example, the southern banded guitarfish *Zapteryx xyster* may be reef-associated (Casper et al. 2009) and the bareback shovelnose ray *Rhinobatos nudidorsalis* is known only from deeper water (125 m) on a mid-ocean ridge (Compagno & Marshall 2006a).

Distribution

The geographic distribution of marine species is thought to affect extinction risk. Some authors have proposed that a large range decreases vulnerability (Roberts & Hawkins 1999), while others have more recently supported an alternative view of large range across multiple jurisdictions failing to mitigate risk, because of the need for effective international management (Dulvy et al. 2014, McClenachan et al. 2016).

While the majority of the range of sawfish distribution is in developing countries, all 5 sawfish species have at least part of their range in developed countries that currently afford a safe haven of effective protection: the USA (for smalltooth sawfish *P. pectinata*, Carlson et al. 2013) and Australia (for dwarf sawfish *P. clavata*, *P. pristis*, green sawfish *P. zijsron* and narrow sawfish *Anoxypristis cuspidata*; D'Anastasi et al. 2013, Kyne et al. 2013a,b, Simpfendorfer 2013). As such, none of the 5 sawfish species are currently likely to undergo total, global extinction. Most sawfish species also have vast historic ranges: for example *P. zijsron* has been recorded across the Indo-West Pacific from South Africa to Taiwan (Simpfendorfer 2013). This large distribution may provide an additional buffer against extinction, increasing the probability of individuals or as yet unknown remnant populations in remote or refuge areas.

In stark contrast, the known geographical distribution of many guitarfish species may increase global extinction risk. Several species are endemic (or only known from highly restricted distributions), or only a handful of specimens have been found (see 'IUCN Red List assessments; Data Deficient' below). Additionally, most guitarfish species are known only from developing or LDC nations where issues such as intensive fisheries and lack of fisheries management make any attempts at conservation highly challenging. Some guitarfish are affected by both of these risk factors: the recently described false shark ray *Rhynchorhina mauritaniensis* is known only from a handful of specimens from a restricted area in Mauritania (Séret & Naylor 2016). There are warnings from similarly afflicted elasmobranch species: the stingaree *Urolophus javanicus*, known only from Java, has not been recorded for over 150 yr and may be extinct (Last & Marshall 2006).

Size and morphology

Extinction threat in extant marine systems is strongly associated with large body size (Payne et al. 2016), and numerous Critically Endangered marine fishes have a maximum reported TL of 2 m or more, such as sturgeons, southern bluefin tuna and giant sea bass *Stereolepis gigas* (IUCN 2016). While guitarfishes do not attain the size of the largest sawfish species (up to 7 m TL), a number of species exceed 2.5 to 3 m TL (e.g. *Rhynchorhina mauritaniensis*, *Rhina anclyostoma*, white-spotted guitarfish *Rhynchobatus australiae*, *Rhynchobatus djiddensis*, clubnose guitarfish *G. thouin* and giant shovelnose ray *G. typus*; Last et al. 2016b), presenting significant extinction risk when combined with overfishing. While sawfishes and guitarfishes both share the same dorso-ventrally flattened body shape that makes them vulnerable to fisheries capture, guitarfishes lack the long tooth-studded rostrum that greatly increases the entanglement risk of sawfishes in net fisheries. This may partly explain the persistence of *Rhynchobatus* spp. catches in areas where sawfishes have all but disappeared, such as in eastern Indonesia (White & Dharmadi 2007).

Identification

Correct identification of species is fundamental to effective management as biological parameters, and therefore vulnerabilities, can vary widely, even between closely related taxa that are similar in appearance. In most of their current global range, identification of sawfishes is relatively straightforward, given clear morphological differences between species (Last et al. 2016b). Conversely, the effective management of guitarfish fisheries is constrained by numerous difficulties in identification. In Brazil, processed landings of the protected and Critically Endangered *Pseudobatos horkelii* are difficult for enforcement agencies to distinguish from similar species (Alexandre de-Franco et al. 2012). There is wide inter- and intra-specific variation in morphology and colouration, particularly amongst *Rhynchobatus*. Examples from developing world fisheries include the presence of cryptic, sympatric species (e.g. Henderson et al. 2016) and considerable within-species variability in dorsal colouration and morphology (Giles et al. 2016). Even apparently well-managed fisheries in the developed world may pose risks to sustainability due to the presence of undistinguishable sympatric taxa. Prior to recent taxonomic clarification, a species complex considered at the time to comprise at least 3 species of *Rhynchobatus* that could not be reliably separated in the field were managed as a single group in Queensland, Australia, despite there being a difference of 2 m between the maximum known TL of the smallest and largest species (White et al. 2014a). Significant variation in colouration in guitarfishes has also led to erroneous designation of species, with the magpie fiddler ray *Trygonorrhina melaleuca* in South Australia, previously thought to be rare and Endangered, recently demonstrated as being a rare colour variant of the common and widespread *T. dumerilii* (Donnellan et al. 2015). These authors also provided evidence of hybridisation, rarely reported in chondrichthyans, adding further complexity to identification in the field.

While the highly distinctive rostrum and sometimes huge size of sawfishes may be a disadvantage in terms of entanglement risk, it may actually benefit sawfishes in some ways. Amidst a plethora of organisms in need of saving from extinction, the rostrum provides an unmistakeable 'personality', a unique selling point to the public and potential funders of research and conservation. The memorable nature of sawfish, and the fact their rostra are retained as tangible evidence of their existence, has also been shown as being valuable in identifying former abundance, distribution and potentially important locations in which to target conservation efforts (Leeney & Poncelet 2015, Moore 2015). The lack of a unique feature in guitarfishes is therefore unlikely to assist in conservation efforts.

IUCN RED LIST ASSESSMENTS

A total of 55 species of guitarfish are currently recognised (Table 1), although up to 3 further new species are awaiting description (W. White pers. comm.). At the time of writing (1 March 2017), 49 species have publically available RL assessments (Table 1). The age, and therefore the validity, of global RL assessments varies widely, with assessments performed from 2003 until 2015. Nearly 60% (28 species) of assessments are out of date (2007 or before). At a family level (excluding species that are Not Evaluated or Data Deficient) the Rhinidae and Glaucostegidae are both notable in that 100% of species are in threatened categories, compared to only 19% of the Rhinobatidae and 33% of the Trygonorrhinidae. Of the 49 species that have been assessed, 20 species (41%) are in threatened categories, comprising 1 (2%) Critically Endangered species, 3 (6%) Endangered species and 16 (33%) Vulnerable species. A further 7 species (14%) are Near Threatened, while 15 species (31%) are currently assessed as Data Deficient. Only a relatively small proportion of guitarfishes are currently assessed as Least Concern (7 species, 14%). In addition, 6 recently described taxa have not yet been subject to RL assessments and are Not Evaluated, although these are currently being progressed (P. Kyne, IUCN Shark Specialist Group Red List Authority, pers. comm.). Examples of each of the categories are discussed below.

Critically Endangered. The Brazilian guitarfish *Pseudobatos horkelii* is currently the only guitarfish classed as Critically Endangered, based on an assessment in 2007 (Lessa & Vooren 2016). This medium-sized species (maximum recorded TL 1.42 m) has a centre of distribution in southern Brazil and was abundant in the 1980s, but suffered severe declines in abundance due to intensive fisheries, particularly due to trawling in areas important for reproduction (Lessa & Vooren 2016). Although protected, this species continues to be illegally landed by fishers (Alexandre de-Franco et al. 2012).

It is highly likely that updating assessments will identify other guitarfishes as Critically Endangered. This is particularly the case for species that represent the 'perfect storm' of extinction risk of being large, having very high value fins and occurring largely or solely in LDCs with high levels of unregulated or unsustainable fisheries activity (e.g. African wedgefish *Rhynchobatus luebberti*; see 'Endangered' below), especially when they have extremely restricted known distributions (e.g. *Rhynchorhina mauriteniensis*).

Endangered. Global assessments for all 3 Endangered species (*G. cemiculus*, common guitarfish *Rhinobatos rhinobatos*, *Rhynchobatus luebberti*) were made in 2006 or 2007 and are out of date. All 3 species have significant parts of their distribution along the coastlines of the West Africa LDC region. Both *G. cemiculus* and *R. rhinobatos* appear to have disappeared from the northern Mediterranean, and *G. cemiculus* has undergone declines in abundance and size reductions in West Africa (Notarbartolo di Sciara et al. 2007, 2016). In The Gambia, *G. cemiculus* continues to be targeted for fins and meat for salting and drying, and *R. rhinobatos* is also landed as bycatch (author's unpubl. data). Deserving of special mention is *R. luebberti*: the only member of its genus to occur in the Atlantic, this large species (3 m TL) has a reported range from Mauritania to Angola (Compagno & Marshall 2006b). Along with sawfishes, *R. luebberti* has been reported as having disappeared from a vast West African region encompassing the coasts of Mauritania to Sierra Leone (Diop & Dossa 2011), and an authority on the regional elasmobranch fauna does not know of any recent records (B. Séret pers. comm. September 2016). Annual surveys of fish landing and processing sites in The Gambia from 2010 to 2016 have not recorded this species, despite other guitarfish species (*G. cemiculus* and *R. rhinobatos*) and other batoids being commonly recorded (author's unpubl. data). A relatively recent record is of a 1.6 m TL specimen (Fig. 3) caught by recreational angling in Rubane Island, Bijagos archipelago, Guinea Bissau, in 2006. The captor, an angling guide, reported the capture as 'very, very rare', and also that this species was not caught in Gabon where he had spent time (O. Charpentier pers. comm. July 2016). As such, and especially given that the last RL assessment was in 2006, *R. luebberti* is likely to be a strong candidate for re-assessment as Critically Endangered.

Vulnerable. Most Vulnerable guitarfish assessments are out of date, from 2007 or before (Table 1), and it is unlikely that the situation has improved for many species, as most have all or most of their range in developing countries or LDCs. The majority of Glaucostegidae and Rhinidae are classed as Vulnerable, including *Rhina ancylostoma.* This distinctive species is distributed across the Indo-West Pacific, where it occurs in fisheries (e.g. White & Dharmadi 2007, Moore et al. 2012), is popular as a marine aquaria exhibit (Georgia Aquarium 2016), has very high value fins and is the subject of trade in jewellery made from its thorns (M. McDavitt pers. comm.). Yet a search on ISI Web of Science shows the existence of more peer-reviewed research on the parasite fauna of *R. ancylostoma* (e.g. Bullard & Dippenaar 2003) than the single ecological study relevant to its conservation, of which it was not even the main focus (White et al. 2013a). The clown wedgefish *Rhynchobatus cooki*, assessed as Vulnerable in 2006 before its very recent description, is only known from a handful of specimens collected in Southeast Asia, and has not been recorded since 1996 (Last et al. 2016c).

Fig. 3. African wedgefish *Rhynchobatus luebberti* caught by recreational angling in Bijagos archipelago, Guinea Bissau, in 2006. This species is currently considered Endangered and has been reported as having disappeared from a vast area of West Africa

Near Threatened. Notably, all but one of the Near Threatened assessments are out of date, from 2007 or before, and include species known from only a few specimens. The Zanzibar guitarfish *Acroteriobatus zanzibarensis* is a large (≥2.05 m TL) species known only from the type specimens and apparently endemic to Zanzibar, which lies within the SW Indian Ocean LDC region (Burgess & Marshall 2016). Similarly, the bareback shovelnose ray *Rhinobatos nudidorsalis* is known only from the holotype, collected from a seamount in the Western Indian Ocean (Compagno & Marshall 2006a).

Least Concern. Just 14 % of assessed guitarfish species are considered as Least Concern, and it is notable that 5 of the 7 species (goldeneye shovelnose ray *Rhinobatos sainsburyi*, southern fiddler ray *Trygonorrhina dumerilii*, eastern fiddler ray *T. fasciata*, eastern shovelnose ray *Aptychotrema rostrata*, western shovelnose ray *Aptychotrema vincentiana*) are endemic to Australian waters, where fisheries are generally well-regulated with high enforcement capacity (White & Kyne 2010). The 2 remaining species (lesser sand shark *Acroteriobatus annulatus* and bluntnose guitarfish *Acroteriobatus blochii*) occur in southern Africa, and are old assessments that require updating.

Data Deficient. All but one Data Deficient species occur in the Northern and Western Indian Ocean or the Eastern Pacific, making these areas a clear priority for research. Data Deficient species include those that occur regularly in intensively fished areas: since assessment in 2008 (Barnett et al. 2016), the large (≥1.87 m TL) Halavi's guitarfish *Glaucostegus halavi* has been recorded in landings in the Persian Gulf, Red Sea and Gulf of Aden (Moore et al. 2012, Moore & Peirce 2013, Spaet & Berumen 2015, author's unpubl. data) (Fig. 4). Conversely, some species remain very poorly known. The Gorgona guitarfish *Pseudobatos prahli* from the Eastern Pacific was only known from 3 specimens upon RL assessment in 2007 (Kyne 2016), and only a handful have been reported since (Payan et al. 2010, Carrera-Fernandez et al. 2012).

Not Evaluated. A total of 6 recently described species have not yet been subject to assessments against the IUCN RL categories and criteria. Most notable is *Rhynchorhina mauritaniensis*, a large (at least 2.75 m TL) species from an entirely new genus known only from Mauritania where targeted fisheries and processing of guitarfishes takes place (Diop & Dossa 2011, Séret & Naylor 2016). The Oman guitarfish

Fig. 4. Large Halavi's guitarfish *Glaucostegus halavi*, a Data Deficient species, in Manama fish market, Bahrain, April 2012

Acroteriobatus omanensis is known only from a handful of specimens from the Gulf of Oman (Last et al. 2016d), and the Philippine guitarfish *Rhinobatos whitei* and Borneo shovelnose ray *Rhinobatos borneensis* are from intensively fished areas (Last et al. 2014, 2016a). The IUCN Shark Specialist Group is currently in the process of assessing these species (P. Kyne pers. comm.). In addition to these newly described guitarfish species, there may be at least 3 more awaiting description (W. White pers. comm.), which will also require RL assessments in the future.

DISCUSSION

This review has demonstrated that both sawfishes and guitarfishes are exposed to similar vulnerabilities of shallow, soft-sediment coastal habitat accessible to intensive fisheries, often large size and high economic value. While sawfishes are exposed to extinction risk factors that guitarfishes are not (valuable rostra highly prone to entanglement, huge size and reliance on freshwater habitat of some species), the distribution of some species of guitarfishes may render them much more susceptible to total global extinction than any of the sawfish species. Furthermore, many guitarfish species are hindered by problematic identification, and, as indicated by often outdated RL assessments, the vast majority of guitarfishes are threatened, poorly known or both.

It would be comforting to think that directing conservation effort towards guitarfishes now could prevent any of the severe declines and localised extinctions seen for sawfishes, but declines have already occurred in numerous locations. As noted, 2 formerly abundant species (*Rhinobatos rhinobatos*, *Glaucostegus cemiculus*) in the northern Mediterranean have now disappeared (Notarbartolo di Sciara et al. 2007, 2016), as has *Rhynchobatus luebberti* in much of West Africa (Compagno & Marshall 2006b, Diop & Dossa 2011). There was evidence of the near complete disappearance of formerly abundant shovelnose guitarfish *Pseudobatos productus* in Elkhorn Slough, California, USA, by the 1970s, the reasons for which remain unclear (Carlisle et al. 2007). More anecdotal sources suggest that declines of guitarfishes are common, such as of *Rhynchobatus djiddensis* off Madagascar (Hopkins 2011), and of *R. djiddensis* and *Rhina ancyclostoma* off Mozambique, where these were reportedly abundant prior to fisheries commencing in the early 2000s (Pierce et al. 2008). In 2014, an elderly fisherman in the Dhofar region of southern Oman lamented the disappearance of large *Rhynchobatus* to the author.

As noted above, acknowledgement of past failure is important in advancing future conservation efforts. So what could have been done better for sawfishes, and how can this be applied to guitarfishes? Firstly, severe sawfish declines may have been at least partially ameliorated with a comprehensive and prompt response to known vulnerability and rumoured extinctions, yet it took 3 decades for a coordinated response. The vulnerability of guitarfishes has previously been identified (White et al. 2013b, Dulvy et al. 2014, Lessa & Vooren 2016), and there is already some evidence of severe declines and localised extinctions: comprehensive and coordinated action is therefore needed urgently.

Secondly, an almost total lack of accessible sawfish distribution and relative abundance data in most of their range prevented identification or monitoring of declines. It is therefore essential that scientists and managers review both existing historic fishery-dependent and fishery-independent datasets specifically for guitarfishes, and ensure robust species-specific data are collected in new or ongoing programs, particularly for threatened, Data Deficient and Not Evaluated species.

Thirdly, while recent focused first-hand field studies of sawfishes in the USA and Australia have advanced our understanding of spatial ecology (e.g. through tagging) and sensitivities (e.g. nursery areas) that are critical to conservation efforts (e.g. Simpfendorfer et al. 2010, Morgan et al. 2015), this information is still largely lacking for vast areas of the developing world. Very little is known about the spatial ecology of guitarfishes to inform conservation, and what is known is largely limited to the developed world (Farrugia et al. 2011, White et al. 2014b). In addition to the potential to provide significant economic benefits to local communities in LDCs (Potts et al. 2009), recreational fisheries may offer opportunities for gaining crucial knowledge of guitarfish spatial ecology, particularly for larger species that may be both the most threatened and the most attractive to anglers. Over 6000 *Acroteriobatus annulatus* were tagged in South African sport fisheries between 1984 and 2011, revealing important information such as a maximum distance travelled of 726 km. Yet the tagging of this species was discouraged from 1998 onwards due to it being considered a low research priority (Dunlop et al. 2013).

Finally, it will be important to address taxonomic bias by elasmobranch researchers, funding bodies and conference organisers. The historic and current lack of research on sawfishes and guitarfishes, respectively, may at least partly be due to a bias in elasmobranch research that favours a tiny minority of fearsome and handsome shark species over batoids (Huveneers et al. 2015). Encouragingly, this has been partly redressed with recent coordinated conservation focuses on sawfishes (Harrison & Dulvy 2014) and devil rays (Lawson et al. 2016), although it is worth noting that both of these groups are perhaps the most highly charismatic of all batoids, being highly recognisable, often large and with strong cultural associations. Engaging researchers and the public alike in less charismatic taxa like guitarfishes will require innovative and collaborative approaches. For example, students of global communications were recently involved in an international competition to develop a winning public relations strategy for dugong and seagrass conservation (Emirates News Agency 2016).

It is not the intention of this paper to list a multitude of research and conservation recommendations, but to highlight the very clear imperative for an urgent, coordinated and comprehensive response for guitarfishes. Based on their large size, high value fins and existing threatened status, the Rhinidae and Glaucostegidae should be among the key priorities. The imperative for action is doubly pressing given the precedent of a collective failure to address catastrophic sawfish declines in most of their global range. Given shared habitat and vulnerabilities, there may be significant opportunities for cost-effective conservation of both sawfishes and guitarfishes, with efforts for the latter offering benefits to the often much rarer former that might otherwise preclude focused conservation attention and funding. However, the inefficiencies of conservation devoted to single taxa such as guitarfish (or elasmobranchs more widely) should be better acknowledged and addressed, when conservation resources are limited and inshore fisheries threaten a myriad of other threatened vertebrates such as teleosts, turtles, dugongs and cetaceans. Updating of RL assessments (and performing them for Not Evaluated species) is an ongoing process that will be essential as a first step for coordinated guitarfish conservation. Research on biological and ecological aspects such as life history and spatial ecology will play a role in our understanding of some guitarfish species, as will use of state-of-the-art techniques such as environmental DNA to locate rare species (Simpfendorfer et al. 2016). Research should acknowledge the hotspots for Data Deficient guitarfish species identified in this study (i.e. North and Western Indian Ocean, Eastern Pacific). However, it is important to acknowledge the significant limitations of research in itself for conservation purposes, particularly in the socio-political realities of very poor coastal human communities facing food security issues that exist alongside some of the most threatened guitarfishes. As noted, total extinction of some guitarfish species is plausible, especially where endemism overlaps with LDC regions, and these should be a key priority for action. Innovative approaches to guitarfish — and wider elasmobranch — conservation in inshore areas of the developing world will be required. While a solid foundation of biological knowledge of elasmobranchs in these areas has been gained in recent decades, human and economic aspects of their fisheries remain disproportionately poorly understood, yet will need to be at the core of any conservation efforts. In this sense, the young movement of elasmobranch conservation may have much to learn from the decades of successes and failures of terrestrial conservation.

Note added in proof. A new species of guitarfish has just been described (Ebert & Gon 2017).

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