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Status and the potential for extinction of the largetooth sawfish Pristis pristis *in the Atlantic Ocean*

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ABSTRACT

1. Sawfishes currently are among the most threatened elasmobranchs in the world. Only two species inhabit Atlantic waters: the largetooth sawfish (*Pristis pristis*) and the smalltooth sawfish (*Pristis pectinata*), both having suffered dramatic declines in their ranges.

2. The goal of this study was to evaluate the status of *P. pristis* in the Atlantic, and estimate local extinction risk based on historical and recent occurrence records. In order to accomplish these goals, a thorough search for historical and recent records of *P. pristis* in the Atlantic was conducted, by reviewing scientific and popular literature, museum specimens, and contacting regional scientists from the species' historical range.

3. In total, 801 *P. pristis* records (1830–2009) document its occurrence in four major regions in the Atlantic: USA (n = 41), Mexico and Central America (n = 535), South America (n = 162), and West Africa (n = 48). Locality data were not available for 15 records.

4. Historical abundance centres were the Colorado-San Juan River system in Nicaragua and Costa Rica (and secondarily Lake Izabal of Guatemala), the Amazon estuary, and coastal Guinea-Bissau.

5. Currently, the species faces drastic depletion throughout its entire former range and centres of abundance. It appears to have been extirpated from several areas. The probability of extinction was highest in the USA, northern South America (Colombia to Guyane), and southern West Africa (Cameroon to Namibia).

6. Currently, the Amazon estuary appears to have the highest remaining abundance of *P. pristis* in the Atlantic, followed by the Colorado–San Juan River system in Nicaragua and Costa Rica and the Bissagos Archipelago in Guinea Bissau. Therefore the protection of these populations is crucial for the preservation and recovery of the species.

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INTRODUCTION

Over the last century, significant exploitation and habitat destruction has led to concerns that populations of marine fish may be at risk of extinction (Dulvy *et al*., 2003; Monte-Luna *et al*., 2007). Detecting and determining local extinctions is important to prevent further loss of the species in other areas and to establish factors related to the cause of the extinction. Dulvy *et al*. (2003) identified 133 local, regional and global extinctions of marine populations and determined that exploitation caused most extinctions followed by habitat loss, invasive species, climate change, pollution and disease.

The most common approach to inferring the extinction of a particular species is based on the record of its sightings (Solow and Roberts, 2003). For marine species, information about past occurrences has been compiled from historical sightings and museum records. Records are then analysed in a probabilistic framework to generate confidence intervals on the potential time of extinction given the sighting records (Solow, 1993a, 2005; Burgman *et al*., 1995; Roberts, 2006). For example, among elasmobranchs, Luiz and Edwards (2011) concluded that the Galapagos shark, *Carcharhinus galapagensis* has been locally extinct since 1998 at St. Paul's Rocks in the Atlantic Ocean. Smalltooth sawfish, *Pristis pectinata*, were determined to be extirpated in US waters from Virginia to New York state from between 1929 and 1956 (Monte-Luna *et al*., 2009; NMFS (National Marine Fisheries Service), 2009b). Reliably estimating the spatial patterns and/or the timing of extinction remains a major challenge for scientists, as the danger of extinction can be overestimated because of incorrect assumptions on population size.

The largetooth sawfish (*Pristis pristis*, Linnaeus, 1758) is one of the two species of the family Pristidae occurring in the Atlantic Ocean. It is found in tropical and subtropical waters in both the western and eastern Atlantic, with northern and southern range extremes largely dictated by seasonal water temperature regimes. The western North Atlantic distributional termini of both species occur in the USA whereas those found in the eastern Atlantic ranged as far north as Mauritania in the north and Namibia in the south (Bigelow and Schroeder, 1953; Faria *et al*., 2013).

Like all species of sawfish, *P. pristis* has significantly declined owing to overfishing, chiefly as bycatch, and habitat loss (Fowler *et al*., 2005). As a result *P. pristis* is listed as Critically Endangered on the International Union for Conservation of Nature Red List (Fowler *et al*., 2005; Kyne *et al*., 2013) and as Endangered Globally on the US Endangered Species Act (76 FR 40822). Despite being listed as Critically Endangered and Endangered, respectively, the status of largetooth sawfish was determined based on anecdotal information. Thus there is a need both to qualify and quantify historical records of *P. pristis* in the Atlantic Ocean to provide a better determination of its current status. Here, we report on the results of an extensive search of historical and recent records of *P. pristis* in the Atlantic Ocean and provide a region by region analysis of its current status and risk of extinction.

MATERIAL AND METHODS

Data collection

Sawfish records were collected between July and September 2009, and records were individually screened for accuracy. Species identification was based on taxonomic characters described in Bigelow and Schroeder (1953) for *Pristis perotteti* (e.g. the number of rostral teeth). Following Faria *et al*. (2013) all records of *Pristis perotteti* and *Pristis microdon* from the Atlantic were considered largetooth sawfish and as such are referred to as *Pristis pristis*.

Records of *P. pristis* were gathered by consulting primary literature, media, museums and local expert scientists. Primary literature records and *P. pristis* distribution information were obtained by searching card catalogues from the libraries of the key regional universities (University of Florida, University of Texas, Texas A&M University, University of South Alabama) within the species' historical US range. Library databases and online search engines were used for finding photographs and fishing and historical blogs pertaining to *P. pristis* records. In addition, two online historical newspaper databases (Proquest Historical Newspapers database and

www.NewspaperArcive.com) were used to find sawfish articles in local and regional newspapers. Positive identifications from historical newspapers were only possible when photographs were available or rostral tooth counts were provided in the story.

Twenty-seven museums were contacted to obtain records of archived *P. pristis* specimens. Additional specimen records from museums and private collections were obtained from the International Sawfish Encounter Database (ISED) housed at Florida Museum of Natural History and from Faria V. (unpublished data). Owing to the lack of recent studies addressing the status of *P. pristis* in the majority of its range, scientists and fisheries managers were queried directly about any sawfish records and asked to provide their personal evaluations of the regional status of the species (only regarding Atlantic range) using a standardized set of questions. The inquiry included questions about their knowledge of the species, the existence of any records (museum, literature, research, fisheries data, evaluation of the species, etc.) in their region, their personal evaluation and possible colleagues in the region that should be contacted because of their expertise. Hundreds of researchers in the Gulf of Mexico and Caribbean regions were contacted via the list server of the Gulf and Caribbean Fisheries Institute (GCFI) in English, Spanish, Portuguese and French. Furthermore, 43 scientists (representing 13 countries: Aruba, Belize, Brazil, Colombia, Cuba, Curaçao, Guinea-Bissau, Honduras, Mexico, Nicaragua, Panama, Puerto Rico, Venezuela) were contacted directly after being identified as knowledgeable experts in their locale by colleagues, though not all replied.

All the scientists who contributed sawfish information are credited in the acknowledgement section with their affiliation and country. Scientists who replied but did not provide sawfish information (e.g. only recommended other colleagues or said they had no knowledge about sawfish) were not included in the acknowledgement section. When citing the personal communications of the contributing scientists, the year when the personal communication was provided is also given.

Data analysis

Sawfish records were entered into a Microsoft Access database, the ISED. Duplicate records, such as museum records that were also cited within the primary literature or multiple newspaper articles referring to a single specimen, were screened and removed. Species identifications were verified by examination of museum specimens, photographs, scientific notes, and/or interviews with relevant observers, unless already recently confirmed by an expert (Faria V., unpublished data). Dubious *P. pristis* records, such as records suspected to be misidentified *P. pectinata* or two records that were suspected (but not confirmed) to be from the same specimen (Springer and Woodburn, 1960), were included in the database. However, only confirmed (and not dubious) *P. pristis* records were included in the analysis.

Given the nature of the data available, the probability that local scale extinction has occurred was determined using the time series of incidental observations. The probability that local extinction has occurred follows a stationary Poisson process:

$$= 1 - \left(\frac{t_c}{T}\right)^n$$

where the number of time intervals in which the species was observed is n, the total number of intervals sampled is T, and the number of intervals up to the time the species was last observed is t_c (Solow, 1993a, b; Burgman *et al.*, 1995; Grogan and Boreman, 1998). Sensitivity analyses suggest using minimum probability levels of 0.75 for declaring a species to be in danger of local extinction and 0.95 for locally extinct (Grogan and Boreman, 1998). As estimates of the probability of extinction are point estimates, a Monte Carlo simulation was used to assess uncertainty in the model input parameters. Probability density functions were developed to describe the number of time intervals in which the species was observed and the number of intervals up to the time the species was last observed. The extinction risk was determined for six regions throughout the historical range of *P. pristis*: USA, Central America (Mexico to Panama), northern South America (Columbia to French Guinea), Brazil,

northern West Africa (Mauritania to Nigeria) and southern West Africa (Cameroon to Namibia).

For those areas with a high probability of extinction (≥ 0.95), the upper bound (the upper confidence limit at which the extinction probability reaches the nominal 0.05 value) of the timing of extinction was calculated using several methods evaluated by Rivadeneira *et al.* (2009). The first method made the strictest assumption that sightings are a Poisson stationary process (Strauss and Sadler, 1989; Solow, 1993a; McInerny *et al.*, 2006), with constant probabilities of occurrence and sampling through time, and an abrupt collapse to extinction. The other method (Roberts and Solow, 2003; Solow and Roberts, 2003) is least restrictive and does not make any distributional assumptions, although the independence of sightings is still required (Rivadeneira *et al.*, 2009).

In addition, the likelihood that *P. pristis* has become extinct was evaluated for the six distributional areas using the framework suggested by Butchart *et al.* (2006) and used for elasmobranchs by Luiz and Edwards (2011). This framework categorizes the level of confidence of extinction based on observational data by considering the time since the species was last reported and the evidence for and against extinction.

RESULTS

In total, 801 records of *P. pristis* throughout the Atlantic were compiled during this study. These comprised 41 US *P. pristis* records (from 1878 to 1961), 535 Mexico and Central America records (1877 to 1998), 162 South America records (1830 to 2009) and 48 records from the West coast of Africa (1841 to 2005) (Figure 1). Locality data were not available for 15 additional *P. pristis* records.

United States of America

Records of *P. pristis* in US waters (n = 41, Table 1) included 35 records from Texas, two 'Gulf of Mexico' records which were probably from Texas,

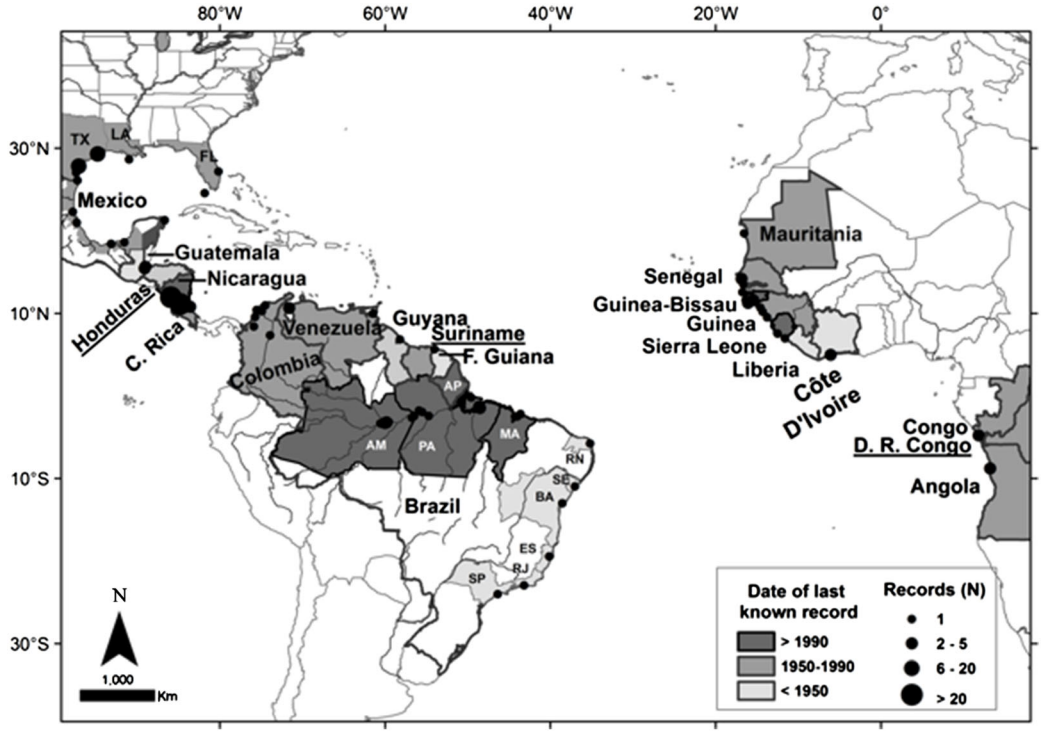

Figure 1. Records of *Pristis pristis* obtained in this study. All countries that have *P. pristis* records are coloured and are delimited by a thick line. Underlined country names represent countries for which there are records with only general location (i.e. country or state) available, thus the records cannot be represented in the map. AM=Amazonas, AP=Amapá, BA= Bahia, ES=Espírito Santo, FL= Florida, LA=Louisiana, MA=Maranhão, PA=Pará, RN=Rio Grande do Norte, RJ=Rio de Janeiro, SE=Sergipe, SP=São Paulo,TX= Texas.

Table 1. List of US *Pristis pristis* records. Records lacking state data are listed under 'Gulf of Mexico'

State	County	Year	N	TL (cm)	Sex	Source	Mus. Cat. Num./ Reference
FL	Monroe	1910	1			MUS	AMNH 11
FL	Monroe	1941	1			LIT	Baughman (1943)
FL	Martin	1943-1952	1			LIT	Bigelow and Schroeder (1953)
LA	N/A	1918	1	488		MUS/MED	SUI 17512
TX	Aransas	1940	1	570		LIT	Baughman (1943)
TX	Aransas	1943	1	500		LIT	Baughman (1943)
TX	Brazoria	1942	1			LIT	Baughman (1943)
TX	Cameron	1925	1	520		MED	Hoover (2008)
TX	Galveston	1929	1	528		MED	
TX	Galveston	1938	1	594		MED	
TX	Galveston	1938	1	450	F	MED	
TX	Galveston	1940	1	450		MED	
TX	Galveston	1940	1	427	M	MED	
TX	Galveston	1940	1	528		MED	
TX	Galveston	1942	6	470		LIT	Baughman (1943) (Coll. by Reid, E. F.)
TX	Galveston	1943	1	430		LIT	Baughman (1943)
TX	Galveston	1943	1	450		LIT	Baughman (1943)
TX	Galveston	1943	1	460		LIT	Baughman (1943)
TX	Galveston	1951	1	700		MED	
TX	Galveston	1951	1			MUS	MRAC A4-45-P
TX	Galveston	1957	1	519	F	MED	
TX	Galveston	-	1			MUS	UAIC 4138.01-2
TX	Galveston	-	1			MUS	BMNH 1867.10
TX	Kleberg/Kennedy	1947	1	610		MED	
TX	Nueces	1917	1	549		MED	Hoover (2008)
TX	Nueces	1935	1			MED	
TX	Nueces	1938	1	500		MED	
TX	Nueces	1943	1	457		LIT	Baughman (1952); Baughmann (1943)
TX	Nueces	1943	1			LIT	Baughman (1952)
TX	Nueces	1947	1	498	F	MED	
TX	Nueces	1961	1	531		MED	
TX	N/A	1940	1			MUS	TAMUCC Uncat.
TX	N/A	1948	1	380		OTH	
TX	N/A	-	1	457		MED	
GOM	N/A	1878	1			MUS	ANSP 17388
GOM	N/A	-	1			LIT	Bigelow and Schroeder (1953)

TX = Texas, LA = Louisiana, FL = Florida and GOM = Gulf of Mexico. ENC = records from encounter reports, LIT = Literature records, MED = Media records, MUS = specimens from museums or other collections.

one record from Louisiana, and three records from Florida. All the documented records correspond to large animals ranging from 427 to 610 cm in total length (TL). An unmeasured Galveston Beach specimen documented in a 1951 home movie was estimated to have been of 700 cm TL.

Several records documented sawfishes being captured by commercial and recreational fishing gear. Specifically, fishing gear information was available for 21 records. Sawfishes captured in commercial fishing gear were associated with shrimp fisheries and caught either with trawl (14%), seine (5%), shrimp net (10%) or unclassified net (9%), while sawfishes captured recreationally were caught using rod and reel (62%). It can be inferred that most captures occurred in shallow inshore waters off the coast or occasionally within bays, since most of the shrimp trawling occurred near shore, and recreational fishing was shore-based.

In Texas, *P. pristis* was found primarily in three almost equidistant regions, from north-east to south-west: Galveston–Texas City–Freeport (n = 22), Corpus Christi–Port Aransas (n = 9) and Padre Island–Laguna Madre (n = 2). Captures occurred only in warm water months from May to October.

Pristis pristis was last recorded in the USA in Texas in 1961. The estimated probability of extinction in US waters was 0.99 (±0.16; Table 2). Depending on methodology, the upper limit of time of extinction

Table 2. Probability and timing of extinction for *Pristis pristis* from six subregions from their historic range. Numbers in parentheses are the 95% confidence intervals for probability of extinction. Abbreviations for extinction time indicate the method used: S&S = Strauss and Sadler (1989), SOL = Solow (1993a), MCY = McInerny *et al*. (2006), S&R = Solow and Roberts (2003) and R&S = Roberts and Solow (2003)

	US		Mexico and Central America	Northern South America		Brazil	Northern West Africa	Southern West Africa	
Decade	N	Time Extinct	N	N	Time Extinct	N	N	N	Time Extinct
1830				2					
1840							1*		
1850				1					
1860						3	2*		
1870	1		1	2		2	1*		
1880							1 + 3*		
1890				1					
1900				3			1 + 2*		
1910	3					1			
1920	2			1		1	1 + 1*		
1930	4					1*			
1940	23		9	5*					
1950	3					1 + 1*		8	
1960	1	1963 SOL,MCY 1967 S&S	496 + 4*	1 + 2*		4	1		
1970				1*	1976 SOL,MCY	2 + 3*			
1980			10	1*		1	10		
1990		1994 R&S	6			49 +1*	1		
2000			1 (years ago)			43	6 + 3*		
2010		2017 S&R	1 (nowdays)						2014 SOL, MCY
2020									2024 S&R 2025 R&S
2030									
2040					2047 S&S				2044 S&S
…									
2080					2083 S&R				
…									
2320					2326 R&S				
Probability Extinction		0.99 (±0.16)	0.64 (±0.29)		0.99 (±0.06)	0.11 (±0.21)	0.25 (±0.20)		0.99(±0.77)

*Only date of citation was available, thus the date of the record could be earlier.

ranged from 1963 to 1994, although most methods estimated dates in the 1960s. In addition, qualitative evidence regarding population extinction did provide evidence for local extinction (Table 3).

Mexico and Central America

Records of *P. pristis* from the Mexico and Central America region (n = 535) are primarily from Nicaragua and Costa Rica, with only 11 documented records of *P. pristis* found outside of those two countries (Table 4). The documented records include from north to south, Mexico (n = 5), Guatemala (n = 5), Honduras (n = 1), Nicaragua (n = 483) and Costa Rica (n = 37). Additionally, four old records were found with no year information and attributed to 'Caribbean Sea'.

Four Mexican historical records of *P. pristis* have been documented for Tamaulipas, Veracruz, Tabasco, and Campeche, all locations in the south-western Gulf of Mexico (Zarur-Ménez, 1962 in Castro-Aguirre, 1978, 1999). Although precise dates are not available, these records (particularly those from Campeche) are from the 1950s and sawfishes are no longer registered in literature from the l970s and 1980s (J. C. P. Jiménez, pers. comm., 2009). The last record of *P. pristis* from Mexico was a 540 cm

Table 3. Evaluation of the qualitative evidence for and against local extinction of *Pristis pristis* from six subregions from their historic range in the Atlantic Ocean, using the framework of Butchart *et al.* (2006)

	Observational data					
Types of evidence for extinction	US	Mexico and Central America	Northern South America	Brazil	Northern West Africa	Southern West Africa
For species with recent last records, the decline has been well documented	N/A	Yes	N/A	Yes	Yes	N/A
Severe threatening processes are known to have occurred	Yes	Yes	Yes	Yes	Yes	Yes[?]
The species possesses attributes known to predispose taxa to extinction	Yes	Yes	Yes	Yes	Yes	Yes
Recent surveys have been apparently adequate given the species' ease of detection, but have failed to detect the species	Yes	No[?]	No[?]	No	No	No[?]
Types of evidence against extinction						
Recent field work has been inadequate	No	Yes[?]	Yes[?]	Yes	Yes	Yes
The species is difficult to detect	No	No	No	No	No	No
There have been reasonably convincing recent local reports or unconfirmed sightings	No	Yes	No	Yes	Yes	No
Suitable habitat remains within the species' known range, and/or allospecies or congeners may survive despite similar threatening processes	Yes	Yes	Yes	Yes	Yes	Yes

[?]Existence of uncertainty owing to the scarcity of available information for the region.

TL specimen landed at Mujeres Island, Quinta Roo in 1997 (J. L. Castillo-Geniz, pers. comm., 2009).

All Guatemalan records (n = 5) are the result of Robert Rush Miller's scientific collecting in Lake Izabal in 1946–1947, with specimens catalogued and curated at the National Museum of Natural History (Table 4). In addition, Lake Izabal was described by Saunders *et al.* (1950) as the only Guatemalan lake where sawfishes were present, being described as the most important inland fishes of the country. No records were found for any other Guatemalan Lake while conducting this study. A historical *P. pristis* rostrum (UF uncat.) lacking date and location information originated from Honduras, and is the only record from that country.

Historically, the Lake Nicaragua–San Juan River–Colorado River system, in Nicaragua and Costa Rica, was of particular importance for *P. pristis* and the species was recorded from that system in several studies (Gill and Bransford, 1877; Meek, 1907; Marden, 1944; Bigelow and Schroeder, 1953; Thorson, 1982b). However, neither historical nor modern records were found from the Atlantic coast or drainages in Nicaragua, other than the records of Lake Nicaragua and San Juan River system (Montoya and Thorson, 1982; H. Guzmàn, pers. comm., 2009). Besides San Juan and Colorado Rivers, *P. pristis* is known in Costa Rica also from the Tempisque River and tributaries of the San Juan River basin (Bussing, 2002). In addition, one isolated rostrum examined in this study (UF uncat.) is from a specimen caught in Tortuguero during the 1960s.

In total, 384 specimens caught by commercial longliners were reported captured near the source of the San Juan River at Lake Nicaragua, Nicaragua (Thorson, 1976, 1982b). Nineteen of these were large individuals, ranging in length from 324 to 394 cm TL (Thorson, 1982b). In addition, 34 specimens were reported taken by commercial longline fishers in the lower reaches of the Colorado River near Barra del Colorado (Costa Rica) between June 1966 and February 1977 (Thorson, 1982b). Two of these animals were juveniles (127 and 130 cm TL).

Recent records of *P. pristis* in Nicaragua and Costa Rica include immature animals. One neonate was caught in the San Carlos region (near the origin of the San Juan River on the southernmost part of Lake Nicaragua), offering tangible evidence that at least some pupping or nursery areas still occur in the region. Additionally small specimens (30 to 60 cm long) have been encountered during Adpesca investigations in the western part of the

Table 4. Records of *Pristis pristis* from Mexico and Central America. Countries are ordered from north to south. MEX = Mexico, GTM = Guatemala, HND = Honduras, NIC = Nicaragua and CRI = Costa Rica. CAR = Caribbean Sea. ENC = records from encounter reports, LIT = Literature records, MED = Media records, MUS = museums or collections, PLIT = specimens from private collections cited in the literature

N	Country	State / Loc	Year	TL (cm)	Sex	Source	Mus. Cat. Number/Reference
1	MEX	Quintana Roo	1997	540	F	ENC	
1	MEX	Campeche	Pre-1962			LIT	Castro-Aguirre (1978, 1999)
1	MEX	Tamaulipas	Pre-1978			LIT	Castro-Aguirre (1978, 1999)
1	MEX	Veracruz	Pre-1978			LIT	Castro-Aguirre (1978, 1999)
1	MEX	Tabasco	Pre-1978			LIT	Castro-Aguirre (1978, 1999)
2	GTM	Izabal	1946	137.6		MUS	USNM 00111423
1	GTM	Izabal	1947			MUS	USNM 00111443
1	GTM	Izabal	1947	140	F	MUS	USNM 00393616
1	GTM	Izabal	1947			MUS	USNM 00146543
1	HND	-	-			MUS	UF Uncat.
1	NIC	Granada	1877			LIT	Gill and Bransford (1877)
1	NIC	R.San Juan/Lk. Nicaragua	1942	732		LIT	Thorson (1976)
1	NIC	Lk. Nicaragua	1943			MUS	USNM 00111367
1	NIC	Lk. Nicaragua	1943			MUS	USNM 00111369
1	NIC	Lk. Nicaragua	1943	137.6	M	MUS	USNM 00120468
1	NIC	Lk. Nicaragua	Late 1960s			PLIT	Faria *et al.* (2013)
1	NIC	Rivas	1960			MUS	TU 22989
36	NIC	Granada/ Lk. Nicaragua	1968	Juv	F	LIT	Thorson (1982b)
25	NIC	Granada/ Lk. Nicaragua	1968	Juv	M	LIT	Thorson (1982b)
1	NIC	Granada/ Lk. Nicaragua	1968	Juv	-	LIT	Thorson (1982b)
6	NIC	Granada/ Lk. Nicaragua	1968	Adult	F	LIT	Thorson (1982b)
3	NIC	Granada/ Lk. Nicaragua	1968	Adult	M	LIT	Thorson (1982b)
1	NIC	R.San Juan/Lk. Nicaragua	1969		M	MUS	AMNH 55624A
384	NIC		1966-1977			LIT	Thorson (1976, 1982b)
6	NIC	Rivas/ Lk. Nicaragua	1980	226-283	M	LIT	Thorson (1982b)
3	NIC	Rivas/ Lk. Nicaragua	1980	226-284	F	LIT	Thorson (1982b)
1	NIC	Rivas/ Lk. Nicaragua	1985			MED	
1	NIC	Chontales/ Lk. Nicaragua	1991			PLIT	Faria *et al.* (2013)
2	NIC	Granada/ Lk. Nicaragua	1998			PLIT	Faria *et al.* (2013)
1	NIC	Lk. Nicaragua	1998			PLIT	Faria *et al.* (2013)
1	NIC	Rivas/ Lk. Nicaragua	1998			PLIT	Faria *et al.* (2013)
1	NIC	Lk. Nicaragua	"Nowdays"	100		MED	www.nicaraguafishing.com
1	NIC	Lk. Nicaragua	"years ago"			MED	www.nicaraguafishing.com
1	NIC	Lk. Nicaragua	-			LIT	Gill and Bransford (1877)
1	NIC	Lk. Nicaragua	-			LIT	Meek (1907)
1	NIC	Lk. Nicaragua	-			LIT	Bigelow and Schroeder (1953)
1	CRI	-	1960			MUS	UF Uncat.
34	CRI		1966-1977			LIT	Thorson (1976, 1982b)
2	CRI	Limon	-			MED	www.jjphoto.dk
2	CAR					LIT	Bigelow and Schroeder (1953)
1	CAR				F	MUS	BMNH 1923.11.13.1
1	CAR				F	MUS	BMNH 1843.2.1.8

lake (no adults have been observed) (Moncada, 2006). Finally, two records for Costa Rica correspond to two isolated rostra (one of them probably from a young-of-the-year).

Overall for Mexico and Central America, the probability of extinction from this area is 0.64 (±0.29; Table 2). The qualitative analysis showed evidence both for and against extinction in the region, highlighting that although there are some recent local records the status of the species seems very threatened (Table 3). The existence of adequate field surveys is uncertain owing to the lack of information available for most of the countries in the region.

Table 5. Records of *Pristis pristis* from South America. Countries are ordered geographically from north to south. COL = Colombia, VEN = Venezuela, TTO = Trinidad, GUY = Guyana, SUR = Suriname, GUF = French Guiana. ENC = records from encounter reports, LIT = literature records, MUS = specimens from museums or other collections

N	Country	State / Loc	Year	TL (cm)	Source	Mus. Cat. Number/Reference
1	COL	Atlántico	1967	600	LIT	Martínez [1978] in Grijalba-Bendeck *et al.* (2009)
2	COL	Bolívar	Pre-1945		LIT	Miles (1945)
1	COL	Santander	Pre-1945		LIT	Miles (1945)
2	COL	Córdoba	Pre-1964		LIT	Mejía and Acero (2002)
1	COL	Bolívar	Pre-1976		LIT	Mejía and Acero (2002)
1	COL	Magdalena	Pre-1985		LIT	Mejía and Acero (2002)
1	VEN	-	1894	610	ENC	
1	VEN	Zulia	1900		MUS	USNM 00232690
1	VEN	Zulia	1903		MUS	USNM 00232688
1	VEN	Zulia	1903		MUS	USNM 00232689
1	VEN	Delta Amacuro	1962	250	LIT	Cervigón (1966)
1	VEN	-	Pre-1942		LIT	Bigelow and Schroeder (1953)
1	TTO	-	Pre-1940		LIT	Ramjohn (1999)
1	GUY	-	-		MUS	BMNH 1889.11.15.1
1	SUR	-	1830		LIT	Fowler (1919)
1	SUR	-	1856		LIT	Fowler (1919)
1	SUR	-	1878		MUS	ANSP 17390
1	SUR	-	1962		MUS	RMNH D3079
1	SUR	-	-		MUS	RMNH D2674
1	GUF	Maroni river	1830		MUS	USNM 00111169
1	GUF	Cayenne river	1929		LIT	Puyo (1949)

South America

In total, 162 *P. pristis* records were found for South America, with the vast majority of records coming from Brazil (Tables 5 and 6). Much lower numbers of *P. pristis* were recorded in the remaining countries of the species' range in South America: Colombia (n = 8), Venezuela (n = 6), Guyana (n = 1), Suriname (n = 5), French Guiana (n = 2), Trinidad (n = 1) and Brazil (n = 139).

Eight records were found for Colombia in the Caribbean states of Córdoba (n = 2), Bolívar (n = 3), Atlántico (n = 1) and Magdalena (n = 1), and the neighbouring inland state of Santander (n = 1) (Table 5). The only record for which specific date and size are available is a 600 cm TL specimen captured in a competition in 1967 in Barranquilla (Atlántico) (Martínez, 1978 in Grijalba-Bendeck *et al.*, 2009). Despite this low number of specific records, several texts document the species' occurrence in Colombia (Miles, 1945, 1947; Acero *et al.*, 1986; Flórez-González, 1986; Mejía and Acero, 2002). Listings of *P. pristis* (as *P. microdon*) from the Magdalena River estuary (Miles, 1945, 1947) reported differences in rostral tooth counts and dorsal fin placement, clearly indicating that both *P. pristis* and *P. pectinata* were present. The species was present in the marine environment (Frank and Rodriguez, 1976 in Mejía and Acero, 2002; Alvarez and Blanco, 1985) and in fresh water (Dahl, 1971; Sinú River). Miles (1947) referred to a Magdalena River record 'some 600 km from the mouth' as *P. pectinata*, but a record this far upriver likely refers to *P. pristis*. Sawfishes (*Pristis* spp.) in Colombia have been described in the literature both as having low economic value (Dahl, 1971; Grijalba-Bendeck *et al.*, 2009) and as commercial species with importance in the exportation to Asian countries (Salazar, 1978 in Caldas *et al.*, 2009). However, no sightings or captures of the species have occurred recently (Mejía and Acero, 2002; Grijalba-Bendeck *et al.*, 2009) and local scientists state that *P. pristis* has been eradicated from Colombian waters long ago (A. Acero, pers. comm., 2009; F. Gomez, pers. comm., 2009).

Table 6. Records of *Pristis pristis* from Brazil. States are ordered geographically from north to south and from west to east. ENC = records from encounter reports, LIT = literature records, MUS = specimens from museums or other collections. PLIT = specimens from private collections cited in the literature

N	State / Loc	Year	TL (cm)	Sex	Source	Mus. Cat. Number/Reference
48	Northern Brazil	1999			PLIT	Faria *et al*. (2013)
40	Northern Brazil	2000			PLIT	Faria *et al*. (2013)
13	Northern Brazil	-			PLIT	Faria *et al*. (2013)
1	Amazon River	-			PLIT	Faria *et al*. (2013)
2	Amapá	-			PLIT	Faria *et al*. (2013)
1	Amazonas	Pre-1934	154		LIT	Thorson (1974)
1	Amazonas	Pre-1953			LIT	Bigelow and Schroeder (1953)
1	Amazonas	1955	255		LIT	Thorson (1974)
1	Amazonas	1964	175		LIT	Thorson (1974)
1	Amazonas	1965	235		LIT	Thorson (1974)
1	Amazonas	1966	160		LIT	Thorson (1974)
1	Amazonas	1967	116		LIT	Thorson (1974)
1	Amazonas	1971	225		LIT	Thorson (1974)
3	Amazonas	Pre-1974	190		LIT	Thorson (1974)
1	Amazonas	-		F	MUS	INPA Uncat.
1	Pará	1865	86.2	M	MUS	MCZ-302
1	Pará	1865	95.6	M	MUS	MCZ-302
1	Pará	1873	81	F	MUS	MCZ −668
1	Pará	1878			MUS	USNM 00110174
2	Pará	2002			MUS	INPA uncat 1 to uncat 2
1	Pará	Pre-1998			LIT	Carvalho and McEachran (2003)
4	Pará					Charvet Almeida and Almeida (2008); Faria *et al*. (2013)
1	Maranhão	1998	700	F	ENC/LIT	
1	Maranhão	2009	700	F	ENC	
1	Maranhão	1983-1986			LIT	Almeida *et al*. (2006)
1	Rio Grande do Norte	1913			MUS/LIT	SU 34468
1	Sergipe				MUS	ZMB 32533
1	Bahia				MUS/LIT	ANSP 17389
1	Espírito Santo	1865		F	MUS	MCZ-667
1	Espírito Santo	-			PLIT	Faria *et al*. (2013)
1	Rio de Janeiro				LIT	Bigelow and Schroeder (1953)
1	São Paulo				LIT	Bigelow and Schroeder (1953)
1	-	1929			MUS	AMNH 49528
1	-	1978			MUS	NCSM 46131

The earliest of the six *P. pristis* records from Venezuela is a rostrum from a large adult. This specimen (believed to be from Venezuela) is estimated to have been in the possession of a US family since 1894. Three of the records were from the Maracaibo region, an area where the species was reported to have been abundant and frequently taken (Cervigón, 1966). The last documented record of *P. pristis* in Venezuela was an individual captured in 1962 (Cervigón, 1966), and an additional record from before 1942 has no specific locality data.

Although the documented records of *P. pristis* in Venezuela lack detailed locality data, the species has been reported to be abundant and frequently taken in fisheries in the Gulf of Venezuela and Lake Maracaibo (north-western Venezuela), as well as the Gulf of Paria (north-eastern Venezuela) and the area south of Trinidad, but it was rare and only captured occasionally in the Margarita

region (north-eastern Venezuela) (Cervigón, 1966). Before their decline, sawfishes (*Pristis* spp.) were mostly caught in the mouth of the Orinoco River and nearby waters (R. Tavares, pers. comm., 2009). They were also reported as frequently caught in north-west Venezuela, specifically on the coast of Falcon state and in the Gulf of Venezuela, where interviewed fishermen still have rostra (R. Tavares, pers. comm., 2009). According to Cervigón (1993), the main threat to the species was shrimp trawling. Both species of sawfishes stopped being caught in artisanal fisheries in the early 1990s, according to fishermen, and there is no recent information about sawfishes in the country (R. Tavares, pers. comm., 2009).

There is a single 19th century museum record of *P. pristis* from Demerara, Guyana. Regarding Suriname, three museum specimens held in public collections were located. In addition to these, Fowler (1910, 1936) noted the species from Suriname and later recorded an additional Suriname *P. pristis* specimen from about 1830 (Fowler, 1919). Two records from French Guiana were found, an 1830 museum specimen from the Maroni River, which forms the border between French Guiana and Suriname, and one 1929 record from the Cayenne River (Puyo, 1949).

Ramjohn (1999), citing Mendes (1940), listed the *P. pristis* (as *P. microdon*) without comment from Trinidad. However, local scientists haven't heard of any sighting of the species in the recent decades while scientific diving around the Dutch Antilles and Aruba (M. G. G. Grol, pers. comm., 2009). In Curaçao, only one sawfish specimen (*Pristis* sp.) was collected during scientific sampling from the country's largest mangrove bay (Schottegat Bay) at the turn of the 20th century and another single specimen was encountered in St. Joris Bay in the early 1970s, but no species is detailed in either case (A. O. Debrot, pers. comm., 2009). Although sawfishes were probably never abundant in Curaçao, they should now be considered extirpated in that country (A. O. Debrot, pers. comm., 2009).

According to qualitative analysis there seems to be more evidence supporting local extinction than against it for the northern areas of South America, although there is some uncertainty caused by the lack of information available for this subregion. The reduced number of records found resulted in the probability of extinction of 0.99 (±0.06; Table 2). Consequently, the timing of extinction varied considerably and ranged from 1976–2326.

Brazil's historical and recent records bearing location data come from the following states (west to east and north to south): Amapá (n = 2), Amazonas (n = 12), Pará (n = 11), Maranhão (n = 3), Rio Grande do Norte (n = 1), Sergipe (n = 1), Bahia (n = 1), Espirito Santo (n = 2), Rio de Janeiro (n = 1), and São Paulo (n = 1). In addition, there are 101 more records from 'northern Brazil' for which there is no state information (Table 6).

As these numbers suggest, *P. pristis* has been historically more abundant in the northerly tropical fraction of its range in Brazil, a region comprising the Amazon River and the states of Amazonas, Amapá, Pará and Maranhão. In this region, neonates, juveniles and adults can be found (Santos and Val, 1998; Almeida and Carneiro, 1999; Charvet-Almeida, 2002; Nunes *et al.*, 2005; Charvet-Almeida and Faria, 2008). The Amazon River basin area and adjacent waters have long been recognized as an area inhabited by sawfishes, and *P. pristis* specifically (Bates, 1964; Marlier, 1967; Furneau, 1969; Thorson, 1974). In the Amazonas state, which includes the middle section of the Amazon basin, *P. pristis* have been taken as far inland as 2000 km from the coast (Santos and Val, 1998) as well as several other locations downstream to the Amazonas–Pará state border.

The earliest records from Brazil come from Pará, which contains the estuary and lower reaches of the Amazon River. Two relatively recent records of *P. pristis* were reported from Maranhão, one adult female caught by gillnet in 1998 (Almeida and Carneiro, 1999; Nunes *et al.*, 2005) and another adult female caught in 2009, which was reported aborting 20–25 young (Jorge Nunes, pers. comm., 2009). To the south, documented reports are far more limited and historic in nature, with only one record per state. The southernmost record is a historical specimen from São Paulo (Ribeiro, 1918 in Bigelow and Schroeder, 1953; Gadig, 1998). At present, there is no quantitative information on the current status of *P. pristis* in northern Brazil. Fishermen have

Table 7. Records of *Pristis pristis* from Africa. North to south: MRT = Mauritania, SEN = Senegal, SENG = Senegambia, GMB = Gambia, GNB = Guinea Bissau, GIN = Republic of Guinea, SLE = Sierra Leone, LBR = Liberia, CIV = Côte D'Ivoire, COG = Congo, COD = Democratic Republic of the Congo, AGO = Angola. LIT = literature, MUS = museum

N	Country	Location	Year	RTL (cm)	Source	Museum Catalogue Number
			Nothern West Africa			
1	MRT	Tidra	1980s		LIT	Robillard and Séret (2006)
1	SEN		Pre-1841		LIT	Bigelow and Schroeder (1953)
1	SEN		Pre-1861		LIT	Bigelow and Schroeder (1953)
1	SEN		Pre-1865		LIT	Bigelow and Schroeder (1953)
1	SEN		Pre-1870		LIT	Bigelow and Schroeder (1953)
1	SEN		Pre-1882		LIT	Bigelow and Schroeder (1953)
1	SEN		Pre-1902		LIT	Bigelow and Schroeder (1953)
1	SEN	Fadiouth	1980s		LIT	Robillard and Séret (2006)
1	SEN	Casamance	1990	19	LIT	Robillard and Séret (2006)
1	SEN	Joal	Pre-2005	106	LIT	Ballouard *et al*. (2006); Robillard and Séret (2006)
1	SEN	Joal	-		MUS	MNHN A-9699
1	SEN		-		MUS	IFAN R977
2	SENG		Pre-1885		LIT	Bigelow and Schroeder (1953)
1	GMB		Pre-1909		LIT	Bigelow and Schroeder (1953)
1	GMB		Pre-2005	105	LIT	Ballouard *et al*. (2006); Robillard and Séret (2006)
1	GMB		-		MUS	BMNH 1885.1.31.30
1	GNB		1980	11	LIT	Ballouard *et al*. (2006)
1	GNB	Bissagos Arch.	1980′s		LIT	Robillard and Séret (2006)
3	GNB		1983	117	LIT/MUS	Ballouard *et al*. (2006); Robillard and Séret (2006)
2	GNB	Bolama	2003	92	LIT/MUS	Ballouard *et al*. (2006); Robillard and Séret (2006)
2	GNB	Bolama	2004	92	LIT/MUS	Ballouard *et al*. (2006); Robillard and Séret (2006)
1	GNB	Bissagos Arch.	2005	9	LIT	Ballouard *et al*. (2006)
1	GNB	Bissagos Arch.	Pre-2005	86	LIT	Ballouard *et al*. (2006); Robillard and Séret (2006)
1	GNB	Gêba River, Gêba	-		MUS	BMNH 1912.4.1.1
1	GIN	Soro	1965	108	LIT	Ballouard *et al*. (2006); Robillard and Séret (2006)
1	GIN	Kamsar	1980′s		LIT	Robillard and Séret (2006)
1	GIN	Bongolon	1983	89	LIT	Ballouard *et al*. (2006); Robillard and Séret (2006)
1	GIN		1989	74	LIT	Ballouard *et al*. (2006); Robillard and Séret (2006)
1	SLE	Bonthe	2003	8	LIT	Ballouard *et al*. (2006)
1	SLE		-		MUS	BMNH 2004.11.27.51
1	LBR		1881		MUS	RMNH D3075
1	LBR		1927		MUS	RMNH D3078
1	CIV	Sassandra	1902		MUS	MNHN 1902-255
1	CIV	Sassandra	Pre-1923		LIT	Bigelow and Schroeder (1953)
			Southern West Africa			
3	COG	Pointe-Noire	1958	80-103	MUS	MNHN 2003–2612 to 2613
1		CongoBasin	1951		MUS	MRAC 66639
2	COD	Banana	1951		MUS	MRAC 68038 and 68039
1	COD	Banana	1959		MUS	MRAC A4-45-P-12
1	COD	Congo R. estuary	-		MUS	MRAC-A4-45-P-2
1	AGO	Luanda	1951		MUS	MRAC 74723
1	AGO	Luanda			MUS	ZMB 16109

reported a decline in the region beginning as early as the late 1980s (Charvet-Almeida, 1999, 2002).

Qualitative evidence against population extinction did not support local extinction for Brazil (Table 3). It should be noted that although we acknowledge the existence of some research in the area when compared with other subregions of the Atlantic, surveys and field work were considered to be inadequate in the qualitative analyses due to the vast extent and complex morphology of the area. Regarding the quantitative analysis, given the recent records of *P. pristis* from the Amazon estuary, the probability of extinction is 0.11 (±0.21).

West Africa

Historical museum specimens and literature records of *P. pristis* on the west coast of Africa exist from Mauritania (n=1), Senegal (n = 11), Gambia (n = 3), Guinea-Bissau (n = 12), Republic of Guinea (n = 4), Sierra Leone (n = 2), Liberia (n = 2), Côte d'Ivoire (n = 2), Congo (n = 3), Democratic Republic of the Congo (n = 4), and Angola (n = 2) (Table 7). In addition there is a 1951 record from the 'Congo Basin' that could be from either Congo, Democratic Republic of the Congo or Angola. Virtually all these records lack definitive locality and date, and specimens from this period often have been lost. That said, *P. pristis* was at one time relatively common along the west coast of Africa, particularly in areas with riverine estuaries.

Robillard and Séret (2006) reported the unpublished historical notes gathered by Jean Cadenat, founder of the Musée de la Mer in Gorée (Senegal) in the 1950s. In addition, the same authors and Ballouard *et al*. (2006) examined 13 *P. pristis* rostra from 1965–2005 found at various locales along the coast of West Africa. Their reviews of the recent status of sawfishes from Mauritania to Republic of Guinea revealed that sawfishes, *P. pectinata* and *P. pristis* (referred to as *P. microdon*), were relatively common in the past but are now rarely caught or observed. The last documented regional capture the authors found was from 2005 in Nord de Caravela at Guinea-Bissau. Because of these recent records in areas around Guinea-Bissau, the likelihood that *P. pristis* is extirpated from areas in northern West Africa is 0.25 (±0.20). Accordingly, qualitative evidence against population extinction did not support local extinction for this subregion (Table 3).

However, in southern areas of West Africa (Cameroon to Namibia) qualitative evidence seems to be stronger for extinction than against, although uncertainty because of the absence of data in this subregion should be acknowledged. It is likely that *P. pristis* has been extirpated (0.99 ± 0.77) but the upper limit of the projected time for regional extinction calculated was highly variable, probably a result of the lack of records (2014–2044).

DISCUSSION

Historically, *P. pristis* ranged from the Gulf of Mexico to south-east Brazil in the western Atlantic, and from Mauritania to Angola in the eastern Atlantic. Over the last century this distribution has been considerably truncated and abundance levels appear to have significantly decreased, based on encounter data, museum records, literature, personal communication with scientific colleagues, and quantitative and qualitative analyses performed. Nevertheless, it should be acknowledged that even though a thorough and intensive search for records was conducted in the present study, there are catches and sightings that go unreported, especially in more isolated regions of Central and South America and of Africa. Even in the regions where sawfish are still caught or landed periodically, owing to remoteness and consequent lack of documentation very few records reach the media and very often only large specimens are reported since juveniles receive less attention. As a result, information reported in this study should be used with caution.

That said, the decline of *P. pristis* seems to follow a similar pattern exhibited by *P. pectinata* in the USA, with the extremes of its distributional ranges having sequentially disappeared in the face of fishing pressure and habitat loss (NMFS, 2009a, b). Historical centres of abundance of *P. pristis* were generally equatorial and influenced by water temperatures, but the presence of large rivers and

riverine and lacustrine estuaries appears to have been equally essential. *Pristis pristis* seems to prefer freshwater and brackish water habitats more than its relative *P. pectinata*, although adults frequently occur in higher salinity, nearshore continental waters (Compagno and Cook, 1995; Zorzi, 1995). As is the case with *P. pectinata* (Poulakis and Seitz, 2004; Carlson *et al.*, 2007), in addition to estuaries and inshore bars, the presence of mangroves seems to be an indicator of good habitat for *P. pristis*, since several records occurred in areas known to have mangroves (e.g. Amazon river estuary, Bissagos Archipelago). Furthermore, it is possible that the habitat of the Amazon estuary and the Bissagos Archipelago in Guinea-Bissau, might have served as refuges for the species, offering protection in the form of complex coastlines heavily indented by inlets and extensive mangroves.

United States of America

All *P. pristis* captured in US waters were large individuals occurring at the northern extremity of their distributional range only during warm water months (May to October). It is apparent that this species historically was represented in the Gulf of Mexico by seasonal transients that took advantage of Texas waters, only occasionally wandering eastward to Louisiana and Florida. Texas historically has had more documented *P. pristis* encounters than any geographic region outside of Nicaragua and Brazil, although this probably is partially an artefact of the maturation of regional journalism and fishing pressure (both commercial and recreational) between 1917 and 1961. Nevertheless, when considered in conjunction with its regularity of occurrence before its marked reduction in abundance, it appears that at one time the western Gulf of Mexico was an important area for this species, especially for adults and subadults.

The highest number of *P. pristis* records in Texas was from the north-east coast, followed by the central coast, with few records from the south-western region adjacent to the Mexican border. Although it might be expected that the south-west would have more records, the lower number of encounters may correspond with the historical freshwater inflow pattern of the region. This pattern has a gradient from highest inflows in the north-east to lowest along the south-west coasts of the state (Longley, 1994). Freshwater inflow is important to productivity of the region (TDWR (Texas Department of Water Resources), 1982) and the influence of lower salinity water is especially important to *P. pristis* (Thorson, 1974). Thus the presence of higher-flow riverine estuaries may have played a role in attracting larger numbers of *P. pristis* to the Galveston–Texas City–Freeport and Corpus Christi–Aransas regions, than areas to the south-west. However, in the absence of catch-per-unit-effort data, the encounter records may simply be reflective of higher fishing efforts associated with higher human densities along the north-east and central Texas coastline.

The ratio of *P. pectinata* to *P. pristis* records from Texas in the ISED is roughly 1:1, so it is likely that scientific literature and print media reports from the region currently unattributed to species represents both species in approximately equal numbers. This is consistent with the observations of fishermen who told Baughman (1943) that the two species were present in equal proportions. Perhaps half of the 178 *Pristis* spp. records found for Texas could represent *P. pristis* records, highlighting the former presence of the species in Texas waters. Unlike *P. pectinata*, which has a refugium in the waters of southern Florida, *P. pristis* apparently is extinct in US waters, with last documented records in Florida in 1941, Louisiana in 1917, and Texas in 1961. Since the evidence suggests that *P. pristis* encountered in US waters were probably seasonal migrants from core areas of their range, it is possible that the decline of the species in this peripheral region of its range is a result of its decline in Central America, with a smaller core population translating to a smaller number of seasonal migrants. In addition, extensive commercial shrimp trawling activities and recreational fishing may have played a role in the decline of the species in US waters.

Mexico and Central America

Given the habitat available along the Mexico and Central America coastlines, it might have been expected that more historical records of *P. pristis*

would have been found. However, the potential for taxonomic confusion with *P. pectinata* is high, and scientific collecting and popular reporting during times of former relative abundance may have caused *P. pristis* to be under-represented in museums and the media. A unifying theme presented by regional biologists is 'no information available'. While this may be partially attributable to lack of regional data on *P. pristis*, even those with good knowledge of local fauna and fisheries indicate that the species is seldom if ever encountered. The lack of flowing rivers in some areas of the region (especially the Yucatán) may have limited available habitat for the species. However, it is clear that the decline observed in Texas has also occurred to the south. The most recent sawfish capture in Mexico (1998) was the first encounter in 15 years of observing artisanal fisheries (J. L. Castillo-Geniz, pers. comm., 2009).

The importance of the rivers of Costa Rica and Nicaragua to *P. pristis* cannot be overestimated. Clearly this was and potentially still is a core area that provides both nursery and adult habitat critical to *P. pristis* (Thorson, 1976, 1982a, b; Bussing, 2002; McDavitt, 2002). It also may very well have served as a population source for adult movements to the north and south-east, much as south Florida has served that function for *P. pectinata* movements along the US Atlantic coast (and probably north-eastern Gulf of Mexico) (NMFS, 2009b).

The decline in this region has occurred as a direct result of overfishing as the species was heavily fished along this lake–river system in the 1970s, reaching population collapse in the 1980s (Thorson, 1982a; McDavitt, 2002). As a result, the Nicaraguan government imposed a temporary moratorium on targeted fishing for sawfish in Lake Nicaragua in the early 1980s (Thorson, 1982a). However, despite the ban sawfishes continued to be killed as bycatch in gillnets (McDavitt, 2002). For example, a local artisanal fisher indicated he usually captures four to six sawfishes per year (1998 interview, McDavitt, 2002). Protection was strengthened in 2006 with a Nicaraguan ban on fishing for sawfish, but only in Lake Nicaragua (Charvet-Almeida *et al.*, 2007) and this ban still does not decrease the bycatch in other fisheries. It is probably because of the problem of bycatch in fisheries and the low productivity of sawfish (Simpfendorfer, 2000) that recovery of *P. pristis* will be slow in the region.

South America

There is little indication that *P. pristis* are found in anything other than low and declining numbers across the northern rim of South America from Colombia to the Guianas or in the continental islands of Aruba, Curaçao and Trinidad. One would expect that the Orinoco River in Colombia and Venezuela would have been an important area but records fail to pinpoint this area as equal in importance to higher abundance areas to the west and south, particularly the Amazon River basin. Nevertheless, the lack of recent *P. pristis* records in northern South America may be a partial artefact of limited reporting, but given the declines of this species throughout the remainder of its Atlantic range, and the patterns exhibited by other pristid species worldwide, it seems safe to interpret an occurrence pattern lacking in recent observations as a significant decline in abundance. However, further studies are needed to permit a more complete assessment of the area.

By contrast, although information about historical and current levels of *P. pristis* abundance in Brazil is unavailable, recent records, personal accounts and qualitative analysis (Charvet-Almeida and Faria, 2008; Charvet, pers. comm., 2008/2009; Faria *et al.*, 2013), indicate that the Amazon estuary is presently the location with the highest number of recent records and more information available for the species in the Atlantic, with the present distribution being possibly restricted to the states of Amapá, Pará and Maranhão (and maybe Amazonas).

The remaining population of *P. pristis* in northern Brazil has faced several threats in past decades (between late 1990s and mid-2000s). The species has been a major component of bycatch in commercial and artisanal fisheries (Charvet-Almeida and Faria, 2008) with meat and fins traded in markets (Charvet-Almeida, 1999, 2002; McDavitt and Charvet-Almeida, 2004). In addition, small saws were sold as curios for tourists and as folk medicine

to treat asthma (Charvet-Almeida, 1999, 2002) while large saws brought high prices in international trade (Charvet-Almeida, 2002; McDavitt and Charvet-Almeida, 2004; Charvet-Almeida and Faria, 2008). Additional threats included habitat destruction and modification and the interest of the ornamental trade (aquaria) in *P. pristis* neonates (Charvet-Almeida and Faria, 2008).

Since the mid-2000s, modifications to Brazilian legislation may have enabled some protection to *P. pristis* in northern Brazil. In 2004, *P. pristis* became a protected species under the Brazilian legislation (IN – MMA # 5), and capture or trade of any kind is prohibited. In addition, at least three subsequent new rules regulating gillnet fisheries (IBAMA # 166; 2007), and banning ornamental trade (IN- MMA # 202; 2008) and shark finning (INI - MPA # 14; 2012) may also provide further protection. Finally, several marine protected areas in northern Brazil may offer protection to the species (Charvet-Almeida and Faria, 2008). In summary, the current protection measures in place for *P. pristis* in Brazil seem to be stronger than in the preceding decades, although enforcement is expected to be difficult in that region. For example, recently *P. pristis* (as *P. perotteti*) meat was on sale in two fish markets of Pará labelled as 'shark' fillets even though its sale in Brazil is prohibited (Melo Palmeira *et al.*, 2013).

West Africa

The west coast of Africa encompasses a large geographic area and though museum records and recent directed sawfish literature are available, reports are particularly rare in this region. Historically, however, certain parts of the west coast of Africa yielded higher catches of sawfishes, especially Tidra (Mauritania), Casamance (Senegal), the Bissagos Archipelago (Guinea-Bissau) and Kamsar (Republic of Guinea), although currently the species is largely restricted to the Bissagos Archipelago (Guinea-Bissau) (Ballouard *et al.*, 2006; Robillard and Séret, 2006). Unfortunately, the lack of size data for sawfish records prevent speculation on any migrations that might occur in the eastern Atlantic.

Fishers indicated that sawfishes were once common ('a few decades ago') on the west coast of Africa, with catches of one or two specimens per net made regularly and even up to 10 specimens captured occasionally (Robillard and Séret, 2006). Fisheries, human population increase along rivers and habitat degradation have been described as the causes of the drastic disappearance of sawfishes in the region within the last three decades (Ballouard *et al.*, 2006; Robillard and Séret, 2006). Although there have been sporadic reports of sawfish captures in 2006 and 2008 from the islands of Orango and Formosa in Guinea-Bissau, there are no pictures or evidence to identify the sawfish species (J. Huet, pers. comm., 2009). The fact that Guinea-Bissau's coastal populations have no strong fishing tradition when compared with the neighbouring countries may have, in part, helped protect the species in the region. However, in the last two decades an increasing number of fishermen from other nearby countries have been attracted to the rich Bissagos Archipelago, with most participating in the shark fishing fleet (Campredon and Cuq, 2001). Thus, urgent protection for sawfish is needed for Guinea-Bissau, and in particular for the Bissagos Archipelago.

CONCLUSIONS

Pristis pristis appears to be threatened in all of its six distribution areas in the Atlantic. Extinction risk was detected quantitatively for three of these areas: the USA, northern South America and southern West Africa. The US population is now probably extinct, since the best scenario for estimated date of extinction was the present decade and the qualitative evidence supported local extinction in this region. Regarding northern South America and southern West Africa, the results must be taken with caution, as even though quantitative analyses were robust enough to indicate extinction risks, the estimated date of extinction encompassed a wide time-span or the qualitative evidence for extinction was not strong.

Although *P. pristis* has been extirpated from several areas, the species can still be found in some regions of the Atlantic. The Amazon

estuary in Brazil appears to have the highest remaining abundance of *P. pristis* in the Atlantic, although there are indications of low presence of the species in the Colorado River–San Juan River system in Nicaragua and Costa Rica, and in the Bissagos Archipelago in Guinea-Bissau. Evidence from the literature suggests that the decline of *P. pristis* in the Atlantic is mostly associated with fisheries activities, both direct (target) and indirect fisheries (bycatch), principally commercial (industrial) and artisanal trawling and longline fisheries. In addition, habitat degradation may also have played a role in this decline, since it has been associated as a secondary cause of depletion of other sawfish species that occur in the Atlantic (e.g. *P. pectinata*).

Conservation and management implications

The depletion of *P. pristis* throughout its Atlantic range is of concern. The situation is even more dramatic when considered in the context of the biological limitations of the species: long life span, late sexual maturity, and low fecundity, which in combination result in low reproductive potential and reduced capacity for recovery following population depletion (Thorson, 1976, 1982a, b; Simpfendorfer, 2000). The recovery of the related *P. pectinata* in the USA is estimated to require 100 years even with zero fishing mortality and concerted action to conserve critical habitat during that long time period (NMFS, 2009b). Although *P. pristis* shares similar biological attributes, conservation efforts are predicted to produce an even slower recovery for *P. pristis* than for *P. pectinata* populations owing to its lower intrinsic rate of increase caused by their smaller litter size (Simpfendorfer, 2000). In addition, given that some of the remaining refugia of *P. pristis* are located in areas with currently minimal to no legal protection and difficult enforcement, a similar recovery time frame for this species would probably be over-optimistic. Even though it is very encouraging that international recognition of the need for conservation and management measures already exists for the species (e.g. CITES, IUCN Red List), it is crucial that measures at national or regional levels are created and that legal protection is enforced soon, if the extinction of the species in the Atlantic Ocean is to be prevented.

The three areas that still have potentially viable populations of *P. pristis* (i.e. Amazon estuary, Colorado River–San Juan River system and Bissagos Archipelago) should be considered priority areas for conservation and law enforcement. Areas with only historical abundance records should also be taken into consideration in any conservation actions, as these may serve as refugia for *P. pristis*, and may be vital for the potential recovery of the species.

To our knowledge, only four countries within the Atlantic range of *P. pristis* have national protection to date. In the USA the species has been listed under the Endangered Species Act since 2011 making it illegal to capture, harass or harm any specimen (NMFS, 2009a). In Mexico, there is a fishery ban since 2006 on all take of sawfish (Fordham, 2012). In Nicaragua, a fishery ban on targeted sawfish on Lake Nicaragua was implemented in 2006 although it does not address bycatch (Charvet-Almeida *et al.*, 2007; Fordham, 2012). Finally, in Brazil, a federal law by the Ministry of Environment (MMA-IN05/2004) mandates no take of smalltooth and largetooth sawfish since 2004. No national laws for countries in the west coast of Africa were found.

Although it is positive that laws protecting *P. pristis* already exist in the countries identified in this study as the areas with the largest remaining populations of the species (Brazil and Nicaragua), enforcement is still a critical problem (Charvet-Almeida *et al.*, 2007; Melo Palmeira *et al.*, 2013). Although protective laws are the first step in the conservation of a species, more conservation measures should follow in order to achieve the desired recovery of a slow-growing species such as *P. pristis*. For example, as was done in the USA for the smalltooth sawfish (NMFS, 2009b), it is advised that national recovery plans be developed and implemented for *P. pristis* in order to assess how to minimize human interactions (injury and mortality), identify the critical habitat for the species, and protect (or restore) those habitats to promote considerable increase in abundance to allow the

species to reoccupy areas from which it has been extirpated. Thus, research on *P. pristis* should be encouraged in order to gather information crucial for developing such recovery plans, namely attempt to increase the available knowledge about the basic biology of the species (reproduction, growth rates, movement patterns, etc.), assess the threats quantitatively (e.g. fishing effort, landing data) and identify possible nursery areas which, if protected, can facilitate adult recruitment. Finally, public outreach and education would be useful tools to aid the recovery of this endangered species.

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