



# Status of the largetooth sawfish in Ecuador and Peru, and use of rostral teeth in cockfighting

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**ABSTRACT:** Sawfish conservation is a critical concern, yet insufficient baseline data on their presence and status has hindered conservation efforts at national and regional levels. Between 2015 and 2017, interviews were conducted in fishing communities in Ecuador and Peru to assess the historical and current status of largetooth sawfish *Pristis pristis*. Interviews with cockfighting practitioners in Peru aimed to gauge the use and demand for cockfighting spurs made from sawfish rostral teeth. Our study confirmed the presence of largetooth sawfish in the waters of both countries. Importantly, some fishermen are aware of the value of rostral teeth, which may influence their decisions not to release sawfish alive. Of the interviewees (n = 188), a majority (88%) reported a perceived decline in sawfish abundance during their lifetimes. In this region, as in other sawfish habitats, bycatch and habitat loss pose significant threats. To address these challenges, potential actions include strategic conservation planning, reinforced national and international trade regulations, education campaigns targeting the cockfighting community, public outreach initiatives, and the live release of sawfish specimens. These efforts can enhance the conservation status of largetooth sawfish, particularly in a region isolated from other persisting populations that potentially harbours vital genetic diversity. Furthermore, safeguarding sawfish contributes to the implementation of national instruments like the National Action Plans for Sharks in both countries. Neglecting these threats could perpetuate sawfish capture and mortality in a region where local populations are already severely depleted, elevating the risk of regional extinction. Prioritizing sawfish conservation is imperative to prevent further decline and preserve their ecological importance.

**KEY WORDS:** Pristidae · Critically Endangered · Eastern Tropical Pacific · Bycatch · Sawfish spurs · Trade · Traditional knowledge

## 1. INTRODUCTION

Some species of sawfish (Pristidae) have become locally extinct in at least 52 countries (Yan et al. 2021).

In many other countries within the distribution range of these species, a lack of research means that the present conservation status of sawfish populations, including their distribution, key habitats, and the

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threats they face, remains uncertain. This limits the development of locally appropriate management and conservation strategies and confines our understanding of the regions where such efforts should focus for maximum conservation success (Dulvy et al. 2016).

Of the 5 extant sawfish species, only one—the largetooth sawfish *Pristis pristis*—has a circumtropical distribution and inhabits the Eastern Tropical Pacific (ETP; Faria et al. 2013, Kyne et al. 2014). It is listed as Critically Endangered on the IUCN Red List of Threatened Species (Kyne et al. 2013). Outside of the known persisting populations of largetooth sawfish in northern Australia (Kyne et al. 2021) and Papua New Guinea (Leeney et al. 2018, Grant et al. 2021), the status of this species is poorly understood. In the ETP, the species' range has been described as extending from Mazatlan, Mexico, southwards to northern Peru (Chirichigno & Cornejo 2001). Historical reports of sawfish in Ecuador and Peru can provide some insight into their past distribution as well as the ways in which humans and sawfish have interacted (e.g. White et al. 2017).

Recent research efforts suggest that this species is now extremely rare or locally extinct on Mexico's Pacific coast (Bonfil et al. 2018). Information on the status of largetooth sawfish in Central American countries is lacking, although several specimens have been caught along Costa Rica's coast in recent years (Valerio-Vargas & Espinoza 2019). There is a paucity of records from Nicaragua and Panama since the early 2000s (Carlson et al. 2013). Largetooth sawfish were present in Panama's human-made Lake Bayano in 1982 (Montoya & Thorson 1982), but an IUCN Shark Specialist Group survey of members and researchers in 2011–2012 suggested that there are no recent records from that site or other parts of Panama or nearby Colombia (Carlson et al. 2013). A published record of a largetooth sawfish capture was reported in 2007 on Colombia's Pacific coast (Caldas et al. 2017), and a recent capture occurred in 2021 in the Tribugá Gulf on Colombia's Pacific coast (F. Ladino & S. Bessudo pers. comm.). In Ecuador, a largetooth sawfish was captured by local fisherman in the south of Ecuador in 2014. This individual, which was ca. 5 m in total length, was taken to the fishing port of Salinas, Santa Elena Province, and then released (Rosas-Luis 2021). In Peru, recent reports of largetooth sawfish have been rare, but their captures by fishers in northern Peru were documented in 2014, 2015, and 2017, confirming that the species is still occasionally encountered in this region (Mendoza et al. 2017, Cabanillas-Torpoco et al. 2020).

Industrial and small-scale fishing fleets operate in both Ecuadorian and Peruvian waters. Ecuadorian industrial fishing comprises primarily purse seine fisheries, operating in offshore waters and targeting mainly large pelagic such as tuna, billfishes, and sharks (Martínez-Ortiz et al. 2015). Fisheries activity in Ecuador is composed of artisanal and industrial fishing fleets (Martínez-Ortiz et al. 2015, Rosas-Luis et al. 2017). The artisanal fishing fleet comprises small vessels operating between 37 and 130 km from the coast, mainly using handlines and nets; the primary target species include yellowfin tuna *Thunnus albacares*, mahi-mahi *Coryphaena hippurus*, billfishes *Kajikia audax* and *Makaira nigricans*, and South American pilchard *Sardinops sagax* (Pazmiño-Solys 2017, Rosas-Luis et al. 2017). The industrial fishing fleet operates in oceanic waters 50 km from the coast and beyond, consisting of larger vessels that incorporate cooling systems and modern technologies for navigation. This fishery targets yellowfin tuna, billfishes, sharks (*Isurus oxyrinchus* and *Prionace glauca*, amongst others), squids, and demersal and small pelagic fishes (e.g. sardine *S. sagax* and anchovy *Engraulis* spp.; Acebo-Plaza & Nuñez 2016, Rosas-Luis & Chompoy-Salazar 2016, Rosas-Luis et al. 2017). In Peru, industrial fisheries use purse seine and trawl nets between 30 and 180 km from the coast and primarily target anchovy *E. ringens* (Instituto Nacional de Estadística e Informática 2015). Small-scale coastal fishing is primarily conducted for local consumption and involves the use of gillnets, handlines, purse seine, and longlines (Ministerio de la Producción 2013). The Peruvian small-scale fleet comprised 17920 vessels in 2015 (Castillo et al. 2018). Thus the magnitude of the small-scale fleets in this region is vast, and there are concerns regarding the long-term sustainability of these fisheries and their interactions with large marine vertebrates (Alfaro-Shigueto et al. 2010). Sharks and rays are frequently caught, both as target species and as bycatch, in Ecuadorian and Peruvian small-scale fisheries (Gonzalez-Pestana et al. 2016, Rosas-Luis et al. 2017, Alfaro-Córdova et al. 2017, Cabanillas-Torpoco et al. 2019). Reconstructed shark landings for the Ecuadorian mainland between 1979 and 2004 averaged 6868 t yr<sup>-1</sup>, with small-scale fisheries accounting for 93 % of total landings (Jacquet et al. 2008). Between 1950 and 2010, the Peruvian small-scale fishery landed 372 015 t of sharks with a landing average of 6099 t yr<sup>-1</sup> and had the second highest landings in the eastern Pacific over this period (Gonzalez-Pestana et al. 2016).

All sawfish species are highly vulnerable to accidental capture in fishing nets (Harrison & Dulvy 2014). Their use of coastal waters and estuaries brings

them into frequent contact with fisheries (Leeney & Downing 2016) and, due to the high value of their fins in the shark fin industry (Moore 2017), they may only rarely be released alive by fishers in low-income developing nations. This makes sawfish conservation in these countries particularly challenging (Poulakis & Grubbs 2019), as impoverished or marginalized communities or those with limited opportunities for income generation may be more inclined to retain sawfishes. Sawfishes use mangrove and estuary habitats as nursery areas, and the degradation and loss of these habitats is thought to have caused the decline and even local extinction of numerous populations (e.g. Thorson 1982, Everett et al. 2015, Leeney & Downing 2016). Sawfishes have low fecundity (Thorburn et al. 2007) and reach sexual maturity relatively late (Scharer et al. 2012), meaning that recovery rates of depleted populations are slow. In addition, largetooth sawfish are euryhaline, regularly using both freshwater and marine habitats during their life cycle (Morgan et al. 2011). As a result, they potentially face a more diverse array of threats than do other sawfish species (Grant et al. 2019). Freshwater habitats, in particular, possibly face a greater threat from climate change, habitat degradation, and ecological disruptions from invasive species than marine environments, and overfishing is a considerable threat in both freshwater and marine habitats (Grant et al. 2022).

In some parts of the world, especially Latin America and Asia, cockfighting is a common but usually illegal practice (Molina et al. 2013). The fighting birds (adult male *Gallus gallus domesticus*, referred to as roosters or cocks) usually have spurs (known as espuelas in Spanish) attached to their legs to inflict injury upon their opponent. The teeth from sawfish rostra are amongst the materials that have been used to make these spurs because of their strength and robustness (McDavitt 2014). These became favoured over other natural spur materials (e.g. deer and bull horn, hawksbill sea turtle shell, mammalian bone) after systematic testing revealed that sawfish teeth are more durable and can cause greater body damage to the opponent (Cogorno-Ventura 2001). Cockfighting practitioners (referred to in South America and hereafter in this paper as galleros) in South and Central America most often source their spurs from Brazil, Ecuador, Panama, and various Caribbean countries (McDavitt 2014). Rostral teeth from sawfish caught in Brazilian waters find their way into the international cockfighting market (McDavitt & Charvet-Almeida 2004). In Peru, sawfish rostral teeth have been the preferred material for making spurs on fighting cocks since the 1970s (Cogorno-Ventura

2001), although recent cockfighting competitions have also banned the use of this material given its potentially damaging nature, and instead promote the use of spurs made from synthetic materials (V. Negrete pers. comm.). Since rostral teeth for cockfighting spurs should be as strong as possible, large-sized juvenile and adult sawfish may be at particular risk, once caught, of retention for their rostral teeth (G. Poulakis pers. comm.). As sawfish numbers have declined and rostral teeth have become more difficult to source, their value has risen to the extent that the rostrum of a single sawfish may be worth up to several thousand US dollars, depending on the size and number of the teeth (McDavitt 2014). Whilst the demand for rostral teeth alone is unlikely to have driven the demise of sawfish, it may be an important factor in the willingness of individuals to release, alive, an accidentally caught sawfish.

The IUCN Sawfish Conservation Strategy highlighted the need for baseline data on the global distribution of sawfishes (Harrison & Dulvy 2014). Once common throughout the tropical and subtropical waters of the Atlantic, Indian, and Pacific Oceans, their distribution has gradually diminished due to the loss of critical habitat, growing demand for their fins and mainly, high levels of incidental capture in fisheries (Harrison & Dulvy 2014). The largetooth sawfish is categorised as Critically Endangered on the IUCN Red List of Threatened Species (Kyne et al. 2013) and listed on Appendix I of the Convention on International Trade of Endangered Species of Flora and Fauna (CITES; largetooth sawfish were listed in 2013), which prohibits international trade or transport of sawfish or their parts (except for research purposes when permitted). Sawfishes are also listed on Appendix I and II of the Convention on Migratory Species (CMS). Legal protection for sawfishes was enacted in Ecuador in February 2008, indicating that when incidental catches of live or dead specimens of this species occur, they must be immediately returned to the sea (Executive Decree No. 902). In Peru, legal protection was enacted in February 2020, prohibiting the extraction, fisheries landing, transportation, transformation, and commercialisation of this species in areas under Peruvian jurisdiction (Ministerial Resolution No. 056-2020 PRODUCE). However, largetooth sawfish are not equally protected throughout their range. More coordinated international protection is urgently required if the species' remaining populations are to persist in the longer term (Kyne et al. 2013).

The objectives of this study were to assess the historical and current distribution of largetooth sawfish on the coasts of Ecuador and Peru and to document

potential important habitat areas for the species; to assess the socio-economic value of sawfish to fishing communities, and to document any threats to sawfish in this region. The study also aimed to assess whether the practice of cockfighting generates a demand for sawfish products and whether this group of stakeholders should be engaged as part of any regional conservation strategy for sawfish. The findings offer new insights into the distribution of sawfish in the ETP and provide essential baseline information needed to develop locally relevant conservation and management actions for sawfish. Several conservation actions which target local threats to sawfish in the study region, and which the authors believe to be achievable in the near future (1–2 yr), are presented.

## 2. MATERIALS AND METHODS

### 2.1. Study area

The study area included the coastal localities of mainland Ecuador (640 km of continental coastline) and the north and central coastal departments of Peru (1330 km of coastline). In this study area there are large estuarine zones such as the Esmeraldas' mangroves, the Guayas River, and the Gulf of Guayaquil in Ecuador; and those of the Tumbes River and the Sechura River in Peru. For this study, coastal Ecuador was divided into 3 regions: northern Ecuador (including the fishery localities of Esmeraldas Province), central Ecuador (fishery localities of the Manabí Province), and southern Ecuador (fishing localities of Santa Elena, Guayas, and El Oro Provinces). Peru was likewise divided into 3 regions: northern Peru (Tumbes and Piura departments), north-central Peru (Lambayeque and La Libertad departments), and central Peru (Áncash and Lima departments; see Fig. 1).

The Equatorial Counter Current flows eastwards, bringing warm waters from the tropical Pacific, whilst the Humboldt Current (or Peru Current) is a cold ocean current that flows northwards along the coasts of Chile and Peru. The cold, upwelling waters of the Humboldt Current intersect with warm tropical waters to form the Equatorial Front (Montecino & Lange 2009), which supports a highly productive marine ecosystem (Bendix & Bendix 2006). The El Niño–Southern Oscillation (ENSO) also has significant impacts on this region. ENSO is an irregular periodic variation in winds and sea surface temperatures in the ETP region, which can have significant impacts on marine life.

### 2.2. Interviews with fishers

An introduction to sawfish ecology and conservation status, followed by training in interview techniques, was provided by R.H.L. during a training course and pilot study organized by the Peruvian non-governmental organization (NGO) Planeta Océano, in March 2015. Training was provided to one of the present co-authors (R.R.L.) and students from Universidad Laica Eloy Alfaro de Manabí (ULEAM); students from Universidad Nacional de Tumbes, Peru; volunteers and staff from Planeta Océano; and one visiting student from Chile. The course comprised one day of background to sawfishes, the theory behind interview data, and how they can provide useful baseline data for sawfish conservation. This was followed by 2 days in which interviews were conducted in the morning, followed in the afternoon by sessions where feedback was provided on the quality and usefulness of the data collected, initially by R.H.L. and later by the students themselves assessing their peers' interview data. The data collected on the first day of the study were not used for the analyses presented in this paper. Further interviews were then carried out over a period of 6 mo from June 2015 to December 2015 in Ecuador, and during several phases of work (February, March, and October 2015; January, October, and November 2016; January–March 2017) in Peru. Initially, the Peruvian component of this study focused on the northern coastal region (Tumbes and Piura departments), as only this area of warmer water was thought to provide suitable habitat for sawfish. However, initial results of the surveys in these regions indicated that sawfish may have been observed further south, and the range of the study was thus extended southwards as far as Lima (ca. 11° S).

Interviews were mainly carried out with fishers, but also included several fish buyers and others involved in fisheries throughout the study area, to assess the historical and current presence and distribution of sawfish and to assess the major threats to the species. In Ecuador, interviews were conducted by R.R.L. and 8 students from ULEAM. In Peru, interviews were conducted by 73 individuals, including Planeta Océano volunteers and students from ULEAM. To conduct interviews with fishers specifically operating near to and in the Tumbes Mangrove National Sanctuary, permission was secured from the National Service of Protected Areas (Servicio Nacional de Áreas Naturales Protegidas por el Estado, SERNANP).

Interviews were conducted in Spanish, by either 1 or 2 interviewers, using a questionnaire (Table S1

in Supplement 1; both supplements at [www.int-res.com/articles/suppl/n052p247\\_supp.pdf](http://www.int-res.com/articles/suppl/n052p247_supp.pdf)) based on questionnaires used in similar studies (Leeney & Poncelet 2015, Leeney 2017). Interviews were conducted according to the availability of each potential interviewee when approached by the research team and took place throughout the day, mainly in the mornings when it was easier to find fishers at landing sites. Interviews took place at landing sites and harbours, fisheries cooperative buildings, and, exceptionally, in the interviewee's home. The study sites—major fishing ports and landing sites—were selected based on the likelihood of encountering greater numbers of potential interviewees in these areas. The interviewers first introduced themselves and explained that they were collecting information about rare marine species but did not specifically mention sawfish. Each interviewee was assured that the interview was anonymous and that they were not obliged to answer any question they did not wish to. Permission to conduct the interview was requested verbally from each interviewee prior to starting the interview. If the interviewee agreed to participate, he or she was then shown a high-quality colour photograph of a sawfish and was asked whether she/he recognised the fish and had ever seen one before. If the respondent could not identify the sawfish or recognised the fish but had never seen one, the interviewer collected only basic data relating to the individual's age, job, number of years of experience in fisheries, and (for fishers) the types of fishing gear used. If the respondent recognised the image and had seen a sawfish at least once in her/his lifetime, the full interview was conducted (Supplement 1). A map of the coastline was provided to allow interviewees to indicate areas where they or others had encountered sawfish.

### 2.3. Interviews with cockfighting practitioners

Interviews were also conducted with galleros—individuals involved in some way with the practice of cockfighting. Throughout Peru, cockfighting is a legal sport and is considered by many as a cultural tradition, which has been practiced for several hundred years. In this study, interviews were conducted in the city of Trujillo (La Libertad Department) and 2 locations associated with the city of Lima (Lima Department), specifically the Comas District within Lima City and the locality of Lurín, south of Lima City (see Fig. 1). These 2 cities were selected because Lima has several cockfighting arenas whilst

Trujillo has a long history of cockfighting, originating with the Spanish viceroys who settled in this area. No cockfighting surveys were undertaken in Ecuador.

Before interviews were conducted, a comprehensive online search was carried out to further investigate the location of cockfighting arenas and the existence of associations or clubs. The president of the World Association of Breeders of Fighting and Exhibition Cocks (Asociación Mundial de Criadores de Gallos de Combate y Exhibición, AMCGCE), Mr. Victor Negrete, was contacted and interviewed to obtain an overview of the approach of his organisation to the use of a Critically Endangered species by its members. Mr. Negrete in turn connected the survey team to multiple representatives of cockfighting practice in Lima, who were subsequently interviewed. At the end of each interview, individuals were asked to suggest more galleros with whom interviews could be conducted, to increase the sample size. Following these initial interviews in Lima, the team visited arenas in Trujillo where cockfights take place and interviewed additional rooster breeders, galleros, and other individuals involved with cockfighting.

The same introductory questions and permission request used for interviews with fishers were used in interviews about cockfighting. The survey comprised open and closed questions related to each individual's cockfighting activity, such as the last time they saw sawfish spurs in Peru and the origin (capture locations, where known) of sawfish from which rostral teeth had been sourced for making spurs (Table S2 in Supplement 1). Interviews were conducted between January and March 2016, and in August 2017.

## 2.4. Analysis of interview data

### 2.4.1. Interviews with fishers

Only information from respondents who were familiar with sawfish and who had observed an individual at least once during their lifetime was analysed. For survey questions in which responses were not provided by all respondents, percentage values were calculated as proportions of the number of individuals who provided at least one response to that question (excluding the response 'I do not know'); hence the *n* value (representing the number of individuals who provided at least one response) is stated in each case. To facilitate analyses, quantitative responses, such as the age of respondents,



were binned, whilst qualitative responses, such as reasons for changes in sawfish abundance and uses of sawfish, were coded according to themes or specific responses. The dates of interviewees' last observations and catches of sawfishes were binned by decade to allow for some inaccuracies in remembering past events.

#### 2.4.2. Gallero interviews

Only data from interviewees who had observed sawfish spurs being used in cockfights were analysed. As with the information provided by fishers, in cases where not all interviewees responded to a question, percentage values were calculated as proportions of the number of individuals who provided at least one response to that question (excluding the response 'I do not know'); the *n* value is stated in each of these cases. To generate an estimate of the number of pairs of sawfish spurs purchased by each gallero per 5 yr period, each individual was asked to estimate how many years they had been involved in cockfighting and how many pairs of spurs of sawfish origin they had bought over that period. Both these values were rounded down to the minimum stated value (e.g. a response of 'between 10 and 20 pairs of spurs' was scored as 10 pairs of spurs; a response of 'over 20 years of cockfighting' was entered as 20 yr). The minimum total number of pairs of sawfish spurs purchased by the interviewee was then divided by the minimum number of years active in the cockfighting industry and multiplied by 5 to estimate the number of rostral spurs purchased over a 5 yr period.

### 3. RESULTS

A total of 395 interviews were conducted in 24 villages and landing sites in Ecuador, whilst 488 interviews were conducted in 47 villages and landing sites in Peru (Fig. 1). Interviewees were between 20 and 93 yr old. In total, the study interviewed 880 men and 3 women (2 women in Ecuador—a port manager and a fish vendor; and a single woman in Peru—a fish vendor). We acknowledge that this introduces a strong gender bias into the data set. Separately, a non-exhaustive list of historical records of sawfish in Ecuador and Peru was compiled and is reported in Table 1: a total of 14 historic sawfish reports were found in the literature for both countries: 6 reports in Ecuador (likely ranging from 1961–2014) and 8 reports in Peru (likely ranging from 1941–2017).

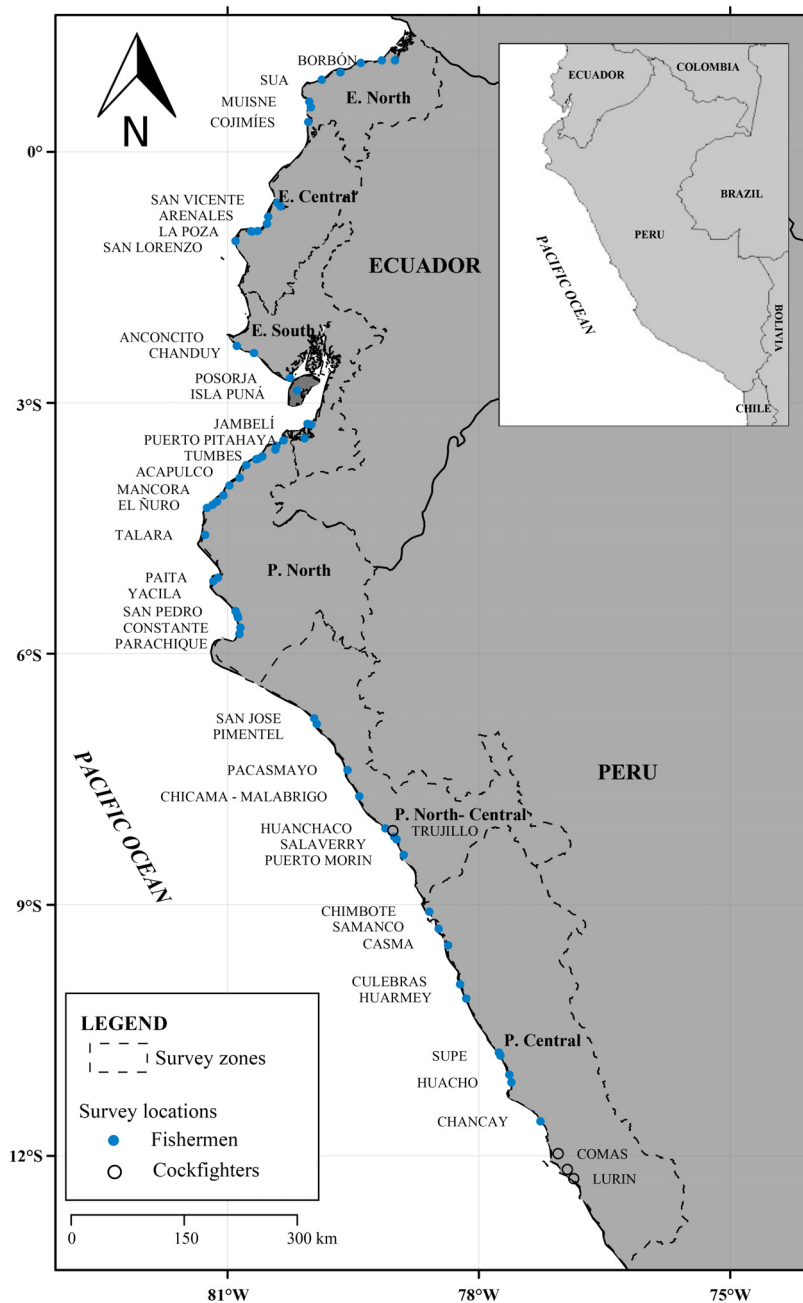


Fig. 1. Study area, showing all locations where interviews were conducted in Ecuador (E) and Peru (P). E. North: Esmeraldas Province; E. Central: Manabí Province; E. South: Santa Elena, Guayas and El Oro Provinces; P. North: Tumbes and Piura Departments; P. North-Central: Lambayeque and La Libertad Departments; and P. Central: Áncash and Lima Departments

Table 1. Historical records of sawfish and museum specimens from Ecuador and Peru

Year	Place	Species	Report type	Notes
<b>Records from Ecuador</b>				
1961	Esmeraldas, Ecuador	<i>Pristis pristis</i>	Rostrum in museum	Collection number 210978 (UMML 10978). Field number ZDDS210978. Rostrum length: 49.53 cm; tooth count: 19/19. FLMNH <sup>a</sup>
1991	Ayangué, Ecuador	<i>P. pristis</i>	Photograph	Two sawfish. Photograph shows rostra were removed; unpubl. data (photograph on Facebook)
2014	Santa Rosa de Salinas, Ecuador	<i>Pristis</i> sp.	Journal article	Adult. Approx total length: 5 m. ULEAM (2014)
Unknown	Guayaquil, Ecuador	<i>P. pristis</i>	Museum specimen (rostrum)	USNM 00232697. Listed in Faria et al. (2013)
Unknown	Ecuador or Peru	<i>P. pristis</i>	Museum specimen (rostrum)	USNM 00021789. Listed in Faria et al. (2013)
<b>Records from Peru</b>				
1941	Peru (no details)	<i>Pristis</i> sp.	Journal article	Attacked a fisherman's boat off the coast of Peru. Became entangled in the net and was then harpooned. Caught with net and harpoon. Adult, 'over 14 ft'. Lubbock Auto Institutional <sup>b</sup>
1963–1964	Punta Sal, Tumbes, Peru	<i>Pristis</i> sp.	Photograph	Photo shows sawfish without its rostrum, dorsal fins and tail fin. Provided by M. McDavitt <sup>c</sup>
Pre-1991	Northern Peru (no details)	<i>Pristis</i> sp.	Museum specimen	Specimen(missing), Museum of Comparative Zoology, Harvard University. 'Hassler Expedition? Collector: Henry Meiggs'. Ichthyology S-671
Pre-2001	Mouth of Tumbes River, Tumbes, Peru	<i>Pristis</i> sp.	Scientific publication	Chirichigno & Cornejo (2001)
2014	La Cruz, Tumbes, Peru	<i>P. pristis</i>	Scientific publication	Mendoza et al. (2017)
2015	Cancas, Tumbes, Peru	<i>P. pristis</i>	Scientific publication	Mendoza et al. (2017)
2017	Máncora, Piura, Peru	<i>P. pristis</i>	Scientific publication	Cabanillas-Torpoco et al. (2020)
Unknown	Cabo Blanco Wharf, Talara	<i>Pristis</i> sp.	Photograph	Historical photograph labelled 'on the dock of Cabo Blanco Sawfish' <sup>d</sup>
<sup>a</sup> Florida Museum of Natural History collection (1961)				
<sup>b</sup> The Lubbock Avalanche Journal. Lubbock Auto Institutional. May 25th, 1941				
<sup>c</sup> Photograph titled 'Polo's family working & Sawfish PuntaSal 1962-64' and labelled as 'by stmercer01', on www.panoramio.com (site now discontinued)				
<sup>d</sup> Historical photograph in 'Talara antigua' album (account: deturismo talara) on Flickr				

### 3.1. Proportions of interviewees who had observed sawfish

In total, 39% of interviewees from both countries had observed largetooth sawfish at least once during their lifetime. In Ecuador, 137 interviewees (35%) had observed this species whilst in Peru, 205 (42%) had observed sawfish.

In Peru, of the respondents aged 70 yr or older, 96% stated that they had observed a largetooth sawfish at least once (Fig. 2). This declined to 56% of the respondents aged between 60 and 69 yr, 50% of those between 50 and 59 yr, 36% of those between

49 and 40 yr, and 21% of those between 39 and 30 yr. Only 18% of the respondents who were between 20 and 29 yr old recognised the image of a sawfish and said they had seen one at least once. Over 20 locally used names for sawfish were documented during the study; these are listed in Table S3 (Supplement 2).

### 3.2. Fishing gears used by interviewees

A total of 358 interviewees in both countries provided information on the fishing gears they used. In Ecuador, gillnets were the most commonly used gear

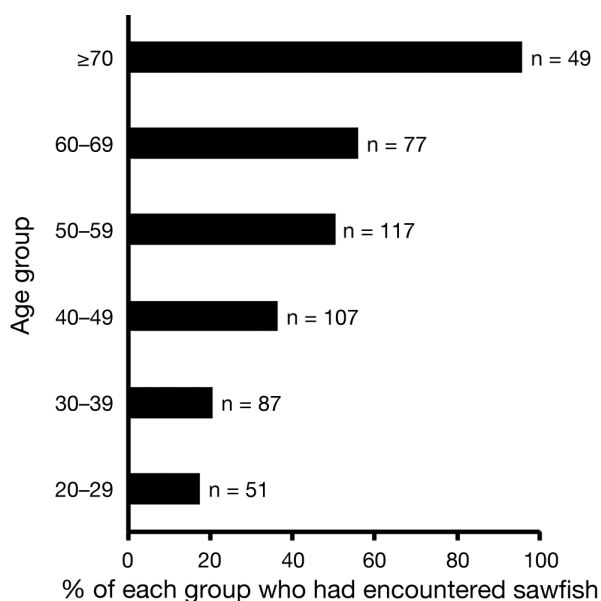


Fig. 2. Proportion of all respondents in each age group who had encountered at least one sawfish during their lifetime; n indicates the total number of interviewees in that age group. Interview data from Peru (n = 488) only

by interviewees (56 % of 98 respondents). Other gear types used in Ecuador included lobster nets, beach seines, and longlines. In Peru, the most frequently used gear by interviewees was also gillnets (47 % of 260 respondents), and other gears included nets (unspecified types), handlines, purse seine nets, and longlines (Fig. 3).

### 3.3. Most recent observations of sawfish

In total, 273 individuals provided information on their most recent sawfish observations. In Ecuador, 27 % of respondents who had seen a sawfish at least once, had most recently seen a sawfish between 2010 and 2017 (n = 97; Fig. 4). In the north, the highest proportion of interviewees (30 %) had last seen a sawfish between 2000 and 2009, whilst in the central region the highest proportion (27 %) had last seen a sawfish between 1990 and 1999 and in the south, 33 % had last seen a sawfish between 2010 and 2017 (Fig. 5). In Peru, 36 % of respondents who had seen a sawfish at least once last observed a sawfish between 2010 and 2017 (n = 176; Fig. 4). By region, the highest proportion of interviewees (north: 32 %; north-central: 67 %; central: 60 %) had most recently seen a sawfish between 2010 and 2017 in all 3 regions (Fig. 5).

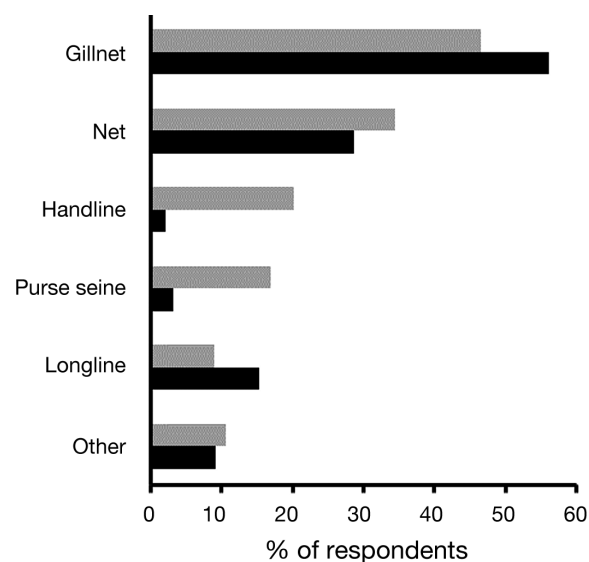


Fig. 3. Gear types used by interviewees as proportions of the total number of fishers interviewed in each region, in Ecuador (black bars; n = 98) and Peru (grey bars; n = 189). The proportions sum to more than 100 % as some interviewees used more than one gear type. 'Net' refers to all net types and may include some gillnets; 'other' includes beach seine, fishing rod, croaker net, 'atarraya' (a cast net), traps, diving, harpoon and trawl net

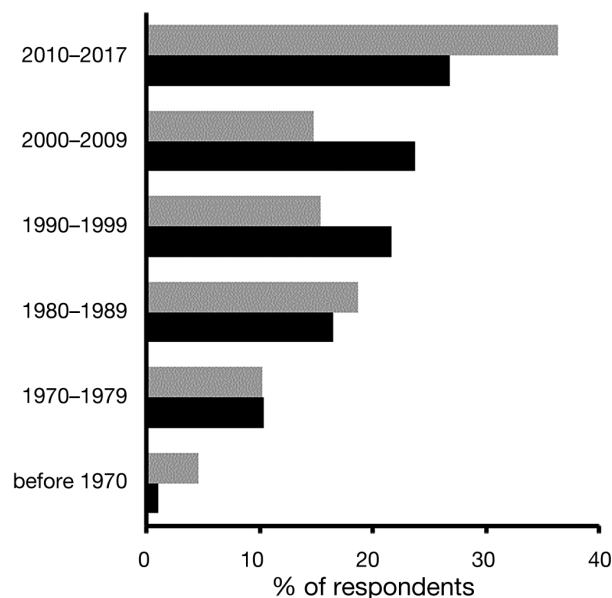


Fig. 4. Decade in which respondents in Ecuador (black bars; n = 97 respondents) and Peru (grey bars; n = 176) had last observed a sawfish. Data are proportions of all interviewees who had seen a sawfish at least once and who provided a year for their most recent observation

### 3.4. Perceived changes in abundance

For both Ecuador and Peru combined, 88 % of the interviewees who provided a response regarding



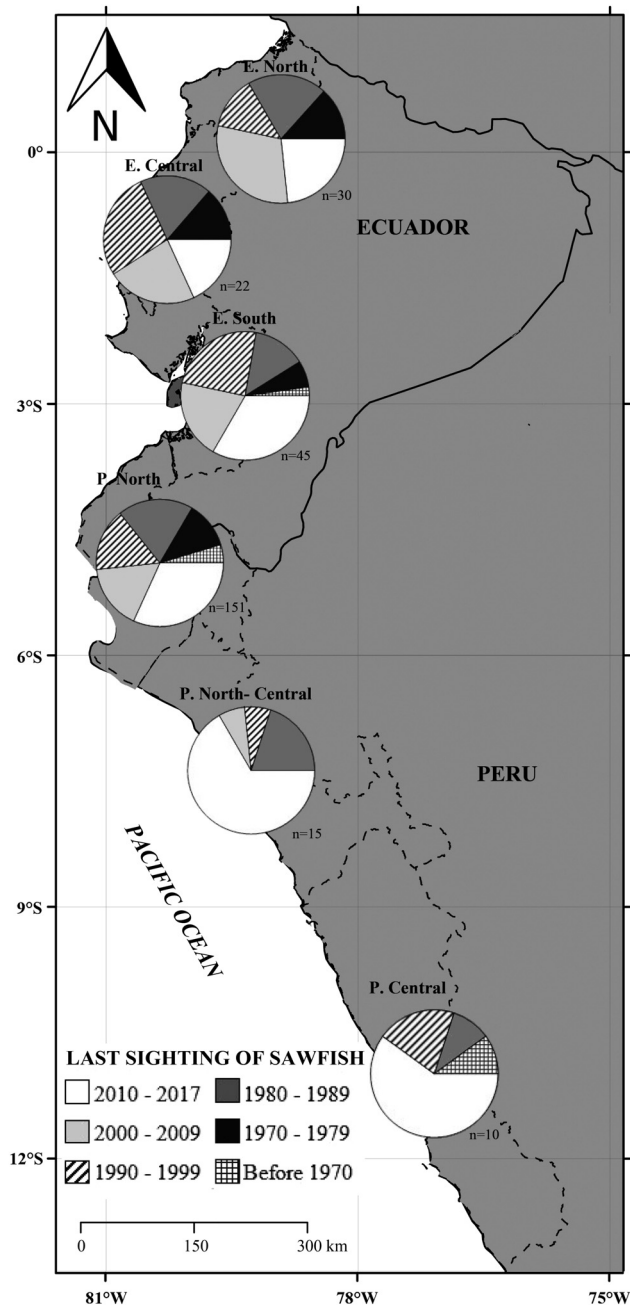


Fig. 5. Decades in which interviewees had most recently observed a sawfish in Ecuador ( $n = 97$ ) and Peru ( $n = 176$ ). Inset shows periods of the last sighting of sawfish by interviewees. Data are presented as proportion of the number of interviewees in each region (as indicated next to each region's pie chart) who provided a response

perceived abundance changes ( $n = 188$ ) had perceived a decline in largetooth sawfish abundance. In Ecuador ( $n = 82$ ), 99% had perceived a decline in this species abundance over the course of their lifetime, while one individual (1%) had perceived an in-

crease. In Peru ( $n = 106$ ), 79% of respondents had perceived a decline in abundance, 2% had perceived an increase, and 19% felt that there had been no change. Of the respondents who had perceived a decline in sawfish numbers, suggested causes for the decline included fishing activities such as overfishing (Ecuador 60%; Peru 48%), sawfish moving to other areas (Ecuador 26%; Peru 11%), pollution (including plastics) in rivers and the sea (Ecuador 8%; Peru 13%), and environmental factors such as climate change and El Niño events (Ecuador 6%; Peru 28%).

### 3.5. Fishing gears responsible for sawfish catches

Interviewees were asked which type of fishing gear they had used when they caught their most recent sawfish. Responses were provided by 98 interviewees from both countries (36 interviewees in Ecuador and 62 interviewees in Peru; Fig. 6). In Ecuador, the most commonly mentioned gears were gillnets (36%), other nets including shrimp/lobster nets (14%), trawl nets (11%), and nets of unspecified type (25%). Other gears reported to have caught sawfish included longlines and seine nets. In Peru, gillnets were also the most cited gear (37% of respondents), followed by other (unspecified) nets (21%), purse seines (16%), shrimp/lobster nets (11%), and other gears such as harpoons, handlines, trawls, and longlines.

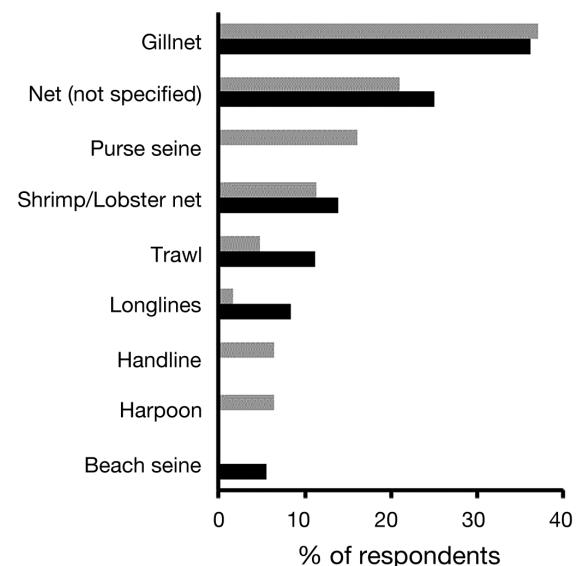


Fig. 6. Gear types used by interviewees when they caught a largetooth sawfish as proportions of the number of interviewees that had encountered a sawfish at least once, in Ecuador (black bars;  $n = 36$  respondents) and Peru (grey bars;  $n = 62$  respondents)

### 3.6. Distribution

Of all the interviewees ( $n = 488$ ), 32% indicated where they had observed largemouth sawfish. In Ecuador, 97 interviewees named one or more sites where they had observed sawfish in the past. The most frequently mentioned regions were Esmeraldas Province (31%), Guayas Province (24%), Manabí Province (23%), and Santa Elena Province (22%). In Peru, the Tumbes Department (59%), Piura Department (26%), La Libertad Department (6%), Áncash Department (3%), Lima Department (3%), and Lambayeque Department (2%) were mentioned most frequently by the 189 interviewees who provided locations of sawfish observation.

### 3.7. Uses of sawfish

In total, 238 interviewees mentioned uses of sawfish and 415 responses on specific uses were obtained. In Ecuador (198 responses from 100 interviewees), 90% of those who provided a response regarding sawfish use indicated that the rostrum was used, although specific details on how they were used were not collected. The sale and consumption of sawfish flesh was mentioned by 59% of respondents, while 17% of respondents mentioned that the rostral teeth were used for the manufacture of spurs for cockfighting and 9% mentioned that the fins were used (Fig. 7). In Peru (217 responses from 138 interviewees), the use of sawfish flesh as food (either directly by the fisher or sold for consumption) was mentioned by 59% of interviewees, whilst the use of the rostrum was mentioned by 42% of interviewees and 12% of interviewees mentioned using the fins (Fig. 7). The use of rostral teeth was mentioned by 22% of interviewees and 17% specified that they were used to make spurs for cockfighting.

### 3.8. Sawfish and cockfighting in Peru

The World Association of Breeders of Fighting and Exhibition Cocks is an international organisation present in approximately 40 countries of America, Europe, Asia, and Africa. According to the president of this organisation, spurs made from sawfish rostral teeth were sourced from Peru in the past, but in recent times they have been imported from Costa Rica and Nicaragua. He stated that 10–15 yr ago, sawfish rostra were on display in cockfighting arenas, where it was possible to buy rostral teeth. Spurs made

from rostral teeth were reported to cost up to \$250 USD per pair (in 2015), whilst teeth made of synthetic material cost \$3–\$5 USD per pair. He also stated that to make these spurs, sawfish rostral teeth are split longitudinally once or twice, and then ground and shaped to a sharp point. The synthetic teeth are manufactured in Puerto Rico and are intended as single-use items (i.e. for one cockfight only), whereas sawfish spurs can reportedly be used multiple times. In 2012, this organisation put in place a rule to prohibit the use of spurs of animal origin (such as sawfish and hawksbill turtles) in the association's official tournaments. In addition, there are around 200 official and unofficial cockfighting arenas in Lima and ca. 1600 throughout Peru, of which ca. 95% use synthetic spurs in their fights (V. Negrete pers. comm.).

Although it was not difficult to find galleros to interview since this activity is legal in Peru, many of those approached declined to be interviewed. A total of 49 individuals were interviewed in Lima ( $n = 31$ ) and Trujillo ( $n = 18$ ). Of these individuals, 43 interviewees (88%) indicated having seen sawfish rostral teeth used as spurs in cockfights, whilst 4 individuals (8%) stated that they had never seen them, and 2 individuals did not provide a response. From the galleros that provided information on purchasing sawfish spurs ( $n = 41$ ), 37% indicated that they had

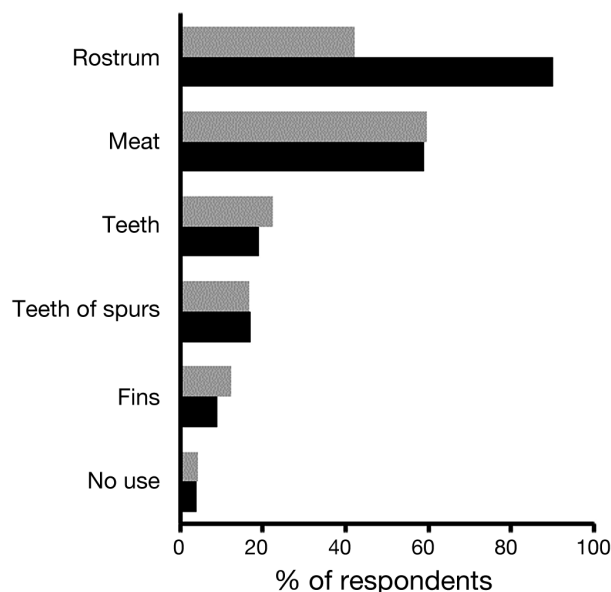


Fig. 7. Frequency with which sawfish parts were used, as stated by respondents who had observed sawfish at least once during their lifetimes and provided at least one response regarding possible uses, in Ecuador (black bars;  $n = 100$  respondents) and Peru (grey bars;  $n = 138$ ). 'Teeth' indicates that the interviewee stated that rostral teeth were used in some way but did not specify how, and thus may include manufacture of spurs

never bought these items whilst the remainder had purchased sawfish spurs with various frequencies, including 10% who stated that they bought more than 30 pairs of sawfish spurs every 5 yr (Fig. 8).

In both cities surveyed (Lima and Trujillo), the interviewees confirmed the use of sawfish spurs in cockfights. The respondents who provided information about the origin of the spurs frequently mentioned more than one region of origin, indicating that spurs came from the north of Peru (65%), Brazil (42%), Ecuador (29%), and parts of Central America (16%). Galleros also buy spurs made from synthetic materials (popularly called ‘mandinga’) instead of those made with sawfish teeth or other materials of wild animal origin. However, 61% of interviewees mentioned that sawfish teeth are thought to be stronger than those made with other materials, and thus are thought to be more damaging in cockfights, giving the bearer an advantage.

### 3.9. Caveats

The authors recognise the need to better document the experiences of women involved in fisheries, as well as men, in future studies of this type.

## 4. DISCUSSION

The current study gathered valuable data on the distribution of largetooth sawfish in Ecuador and

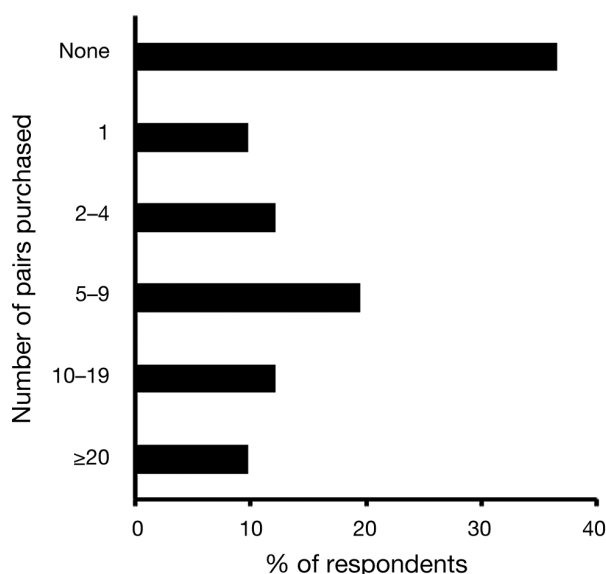


Fig. 8. Number of pairs of spurs purchased per 5 yr period per gallero (n = 41)

northern Peru. Fishers' ecological knowledge can be used to assess species declines or extinction and is particularly useful for marine species, for which extinctions often go unnoticed for some time (Dulvy & Polunin 2004). Interviewees suggested that largetooth sawfish were caught more frequently about 3 decades ago but are now encountered only rarely, suggesting a considerable change in the abundance of sawfish in this region over time. Some of the sawfish observations reported by interviewees could also coincide with historical published reports (Table 1).

In addition, this study provides encouraging evidence that largetooth sawfish persist in Ecuador and northern Peru and that they were once a commonly encountered species on the coasts of both countries. Furthermore, continued observations of sawfish by fishers in recent decades suggest that rather than being occasional or seasonal visitors to the Peruvian coast as had previously been suggested (Mendoza et al. 2017), sawfish were present year-round, at least historically. Enforcement and efforts to discourage the capture and retention of accidental catch of sawfish are required; for example, through the development of alternative livelihoods in communities interacting with sawfishes (e.g. Leeney 2022). Moreover, this study shows evidence of international traffic of rostral teeth of sawfish for the manufacture of spurs of fighting cocks, which would be destined mainly for Peru. To protect sawfish in the region, several potential actions can be taken. These include strategic planning for conservation, stronger enforcement of trade regulations, educational campaigns targeting the cockfighting community, public education and outreach programs, and promoting the live release of sawfish. These actions aim to improve the conservation status of the largetooth sawfish, which is isolated in this region and may possess important genetic diversity.

### 4.1. Recent catches of sawfish in Ecuador and Peru

Several sawfish landings which occurred just prior to and during the study period were recorded as part of this study. In Ecuador, a sawfish of 5.1 m total length was caught and released alive near Santa Rosa in Salinas, on 24 July 2014 (ULEAM 2014). In Peru, a largetooth sawfish was landed in Máncora in March 2017, caught by an artisanal fishing boat (targeting tuna with 7 inch [17.8 cm] mesh nets) approximately 3 km offshore of El Ñuro, Piura. The fishers indicated that they knew of the exis-

tence of this species through stories told by older fishers, but that it was the first time they had personally encountered a sawfish. The fins of this animal were sold for \$35 USD. The senior fishers indicated that people involved in the sale of rostral teeth from sawfish, to be used as spurs for cockfighting, had expressed interest in purchasing the rostrum. Although the fisherman initially stated that he intended to keep the rostrum, he later sold it for ca. \$1180 USD (Cabanillas-Torpoco et al. 2020). In addition to these reports, 2 additional largetooth sawfish landings have recently been documented from Peru, in January 2014 (3.5 m total length) and February 2015 (ca. 6 m total length). Both landings occurred in Tumbes Department and the sawfish caught in 2015 was released alive (Mendoza et al. 2017).

#### 4.2. Sighting areas

Interview data, as well as historic data (Table 1), revealed that sightings of sawfish appeared to be more common from the northern part of Peru's coastline. Mangroves, freshwater, and brackish habitats have been suggested as good indicators of the presence of *Pristis pristis* (Fernandez-Carvalho et al. 2014), and the estuaries and mangroves in the Tumbes Department may have provided or may still provide suitable habitat for sawfish. The southernmost limit of sawfish distribution, according to interviewee reports, appears to have been the Ica Department (14° S; Fig. 1), meaning that sawfish may have had a far greater distribution along Peru's coastline than was previously thought (Chirichigno & Cornejo 2001). The cold waters of the Humboldt Current likely form a barrier for sawfish along the Peruvian coastline (V. Faria pers. comm. 2012, cited in Kyne et al. 2013), and the warm Equatorial Current and cold Humboldt Current are known to usually converge around ~4° S (Montecino & Lange 2009). However, when strong El Niño events take place, warm waters can extend further south, and thus in years when the Humboldt Current was restricted to more southerly latitudes, sawfish may have been able to range further south along Peru's coastline. Given that interviews were conducted largely with individuals fishing some distance from the coastline, the results presented likely pertain solely to sub-adult and adult sawfish and may not include potential encounters with neonate and juvenile sawfish, which would likely only be encountered in pupping and nursery habitats.

#### 4.3. Uses of sawfish

Sawfish have been used by fishers in Peru and Ecuador as sources of meat, fins for the shark fin trade, rostra (kept by the fisher or sold for decorative purposes), and rostral teeth (to be made into spurs for cockfighting and either sold locally or traded internationally). Nevertheless, the use of sawfish meat and fins is opportunistic rather than forming part of a targeted fishery. Some fishers knew that rostral teeth could be sold to make cockfighting spurs. Some interviewees stated that since sawfish landings are unusual, news of a sawfish capture could travel from within local fishing communities to individuals who trade in sawfish spurs, who may then contact the fishers to purchase the rostrum.

It appears as if the use of sawfish teeth to make cockfighting spurs in Peru has decreased over the last 10–20 yr and that a reduced supply has led to increased prices in spurs (V. Negrete pers. comm.), a trend that may be due to consumer choices as well as the increasing rarity of sawfish in recent years.

#### 4.4. Threats to sawfish in the ETP

Mangrove forests in Ecuador and Peru have been reduced in size (Valiela et al. 2001) due to deforestation, habitat modification and the creation of shrimp ponds (Oficina Nacional de Evaluación de Recursos Naturales 1992, Parks & Bonifaz 1994). Largetooth sawfish use rivers, estuaries and mangroves as pupping and nursery sites (e.g. Thorson 1982, Whitty et al. 2008, 2009) and thus any impacts on these habitats may negatively affect the survival of juveniles. The Tumbes National Mangrove Sanctuary in northern Peru has been a protected area since 1988 and covers ca. 30 km<sup>2</sup> of mangroves and creeks; however, none of the interviewees in this study mentioned having encountered any sawfish there.

One of the most common fishing gears used by artisanal fishers in Ecuador is gillnets (Martínez-Ortiz et al. 2015). There were a reported 1532 fishers using gillnets in Ecuador in 1987 (ESPOL 1987), and this number has increased over the years (Herrera et al. 2013, Subsecretaría de Recursos Pesqueros 2014, Félix et al. 2015). Gillnets are also the most commonly used gear amongst artisanal fishers of Peru and are frequently used to capture both coastal and pelagic species. Gillnets are increasingly being used by the artisanal fleet in Peru: 44 151 fishers used gillnets in 2012 and that number had increased to 67 427 fishers by 2015 (Castillo et al. 2018). The findings of the pre-

sent study suggest that gillnets have been responsible for a large proportion of sawfish captures in the study region and pose a significant threat to sawfish populations. Therefore, addressing the impacts of gillnet use and implementing effective management strategies are crucial for the conservation and protection of any remaining sawfish in the region.

Interviewees indicated that they had sold the flesh, rostral teeth, and fins of sawfish, suggesting that there may still be financial incentives for landing sawfish rather than releasing them alive. These incentives could be removed, for example, by raising awareness and increasing enforcement of legislation that makes sawfish capture illegal, and by encouraging fishers to release incidentally caught individuals. Sawfish do not provide an important form of regular income for Ecuadorian and Peruvian fishers because there is no fishery targeting sawfish (most likely because they are too rare to warrant one). Nonetheless, there may be a significant economic incentive for fishers who accidentally catch this species to sell the fins, rostra, and rostral teeth, as they can fetch high prices. The Asian market for shark fins (including those of sawfishes and some guitarfish species) and the high prices paid for fins continue to be drivers for catching sharks and shark-like rays (Clarke et al. 2006, Dulvy et al. 2014). Ecuador and Peru are among the principal suppliers of shark fins from the eastern Pacific to the Asian market (Gonzalez-Pestana et al. 2016). In addition, spurs stated to be of sawfish origin were found for sale online, after the protective legislation for sawfish was implemented in Peru. The costly damage to fishing nets that can be caused by the capture of a sawfish (and possibly more so by attempting to release it), alongside any knowledge of potential income to be made from the sale of rostral teeth and fins in particular, may discourage fishers from releasing sawfish alive.

#### 4.5. Cockfighting

The refusal of some galleros to be interviewed may be in part because in recent years, there has been a movement in Peru to ban cockfighting (TVPerú 2015) and as such, practitioners may have been concerned that information they provided might be used to support that objective. According to the galleros interviewed, sawfish rostral teeth are valued for making spurs in Peru but are less commonly used in Ecuador. In Ecuador, each municipality is allowed to regulate cockfighting independently (Código Orgánico del Ambiente 2017) and it currently continues through-

out much of the country as a traditional pastime (R. Rosas-Luis pers. obs.). In Peru, galleros mentioned that some cockfighting associations have rules that prohibit the use of spurs made from metals and recently, from natural materials (such as turtle shells or sawfish rostral teeth), meaning that only synthetic materials (e.g. acrylic, plastic) can be used. This is supposed to ensure 'fair play' among galleros, as sawfish tooth spurs are thought to be harder and thus more harmful to the opponent (V. Negrete pers. comm.). A brief assessment of online marketplaces revealed that sawfish spurs are available for purchase via social media and on specific websites. A pair of sawfish spurs for sale (October 2020) on social media was found to cost ca. \$80 USD and most appeared to be sold by individuals in Lima. Endangered species (including hawksbill turtle and largetooth sawfish) are legally protected in Peru (Ministerial Resolution No. 103-95-PE, Ministerial Resolution No. 056-2020 PRODUCE). National legislation in Peru prohibits the capture of largetooth sawfish, as well as the retention, transformation, transportation, and sale of its parts. Despite the ban on the sale of sawfish parts, spurs made from rostral teeth may still be available for sale at least occasionally; for example, some individuals may sell spurs made from the rostral teeth of sawfish captured prior to this species gaining national protection (V. Negrete pers. comm.). However, some of the sawfish rostral tooth spurs may also be made from individuals captured after the enactment of the law in both Peruvian and foreign waters (Costa Rica, Brazil, Colombia). Moreover, the current rarity of the sawfish could motivate the smuggling of old rostra to supply rostral teeth for cockfighting in Latin American countries (M. Cabanillas-Torpoco unpubl. data). An education campaign targeting galleros and their associations to highlight the critical conservation status of sawfish and the laws relating to the use of sawfish products may be helpful in addressing some of these issues.

#### 4.6. Sawfish conservation regulations in Ecuador and Peru

The largetooth sawfish is a nationally protected species in Ecuador (Executive Decree No. 902), but there is no plan of action for the conservation of this species at present. It is legally protected in Peru's territorial waters, where the capture, landing, transportation, retention, processing, and sale of sawfish are prohibited (Ministerial Resolution No. 056-2020 PRODUCE). The largetooth sawfish has been listed



on Appendix I of CITES since 2013, prohibiting trade in this species in all but exceptional circumstances. Both Peru and Ecuador are signatories to CITES. Ecuador has banned finning (CPPS 2010) and Peru has prohibited the landing or trans-shipment of unattached fins and/or trunks without fins attached of any species of shark (Supreme Decree No. 021-2016-PRODUCE; this, however, does not include other elasmobranchs). However, large quantities of shark fins of suspected illegal origin continue to be confiscated from both countries (Sociedad Peruana de Derecho Ambiental 2019). Furthermore, the findings of this study suggest that rostral teeth may still be imported into Peru from other countries in Central and South America (such as Brazil, Colombia, Ecuador, and Panamá). The small size of spurs and the fact that once shaped and polished they do not resemble rostral teeth, has likely facilitated the continued trade in this product. This illegal trade could be reduced through a commitment between the Customs and International Trade officials of both countries, who should be trained to identify sawfish rostra, rostral teeth, and spurs made from rostral teeth, and should be encouraged to stop cross-border movements of these items. Customs officials must also be able to distinguish sawfish spurs from other types if they are to be able to enforce trade restrictions (Frida Rodríguez pers. comm.). Tackling the demand for sawfish spurs amongst cockfighting practitioners and associations may reduce the market demand for, and thereby the value of, sawfish rostral teeth. Furthermore, these CITES signatory nations have an obligation to the international community to act on this international trade of largetooth sawfish parts as it contravenes their current Appendix I listing.

The largetooth sawfish of the ETP are located at a considerable distance from populations of this species in the Western Pacific Ocean, including the 2 persisting populations of this species in northern Australia and Papua New Guinea (Leeney et al. 2018, Yan et al. 2021). Although our knowledge of the distance adult sawfish can travel is limited, it is unlikely that they cross the Pacific Ocean, and thus largetooth sawfish found in Ecuadorian and Peruvian waters may be considered a discrete stock. The geographical isolation of sawfish in the ETP, along with the female reproductive philopatry documented for largetooth sawfish in northern Australia (Feutry et al. 2015), suggests that if sawfish populations in the ETP were to decline to critical levels, they would be unlikely to be repopulated via dispersal of sawfish populations from other regions.

#### 4.7. Recommended conservation actions

Although numerous baseline studies to assess sawfish presence and status have been conducted in recent years, few have led to meaningful, location-specific and threat-specific conservation planning (Haque et al. 2020). This study allowed us to identify the likely key threats to sawfish in Ecuador and Peru: incidental capture in fishing gears and the incentive to land sawfish because of the value of rostral teeth in particular. Sawfish use in cockfighting has been highlighted in the past (Cogorno-Ventura 2001), yet there has been little effort to expand and update new findings based on this literature and little effort to translate this scientific information into public knowledge and management. This study demonstrates that this practice still occurs, and the full extent of this practice should be further documented. Similarly, although national legislation and CITES listings exist, there is a need to further strengthen enforcement and protection of sawfish at the grassroots level.

The following conservation actions are proposed specifically to address these threats and, if implemented immediately, may improve the outlook for sawfish in Peru and Ecuador. These actions are listed in a suggested order of urgency; nevertheless, it is important to note that they can also be implemented in parallel given the multi-disciplinary nature of conservation actions:

(1) Strategic planning for sawfish conservation. Despite national legislation protecting sawfish in both Ecuador and Peru, research and conservation actions for largetooth sawfish are scarce in the ETP, and bi-national collaboration for sawfish conservation is limited. There is a need to develop both regional and national conservation strategies and plans for sawfish conservation, and to further engage national and local authorities, NGOs, and researchers, among others. This is an important approach in Peru and Ecuador, as these organizations recognise the importance of strategic planning and technical working groups in the management process for threatened species. An effort is currently underway to develop a regional workshop and strategic planning process for sawfish, which will in turn allow for the adoption of locally relevant and participatory conservation actions. The recommendations below could also be prioritised in these strategies and workshops.

(2) Strengthen enforcement of national and international trade. Although not common, sawfish products (e.g. rostra, fins, teeth) are likely traded throughout the ETP region. Domestic trade is prohibited by national legislation, whilst international trade is

regulated by CITES, an international agreement between governments. Training in the identification of sawfish products along with national and CITES legislation relating to sawfishes and enforcement processes should be developed and provided to trade and government officials and enforcement authorities. Protocols and tools (e.g. a visual guide) to help identify the sawfish products circulating in the ETP region should be developed and disseminated. Similar efforts, for example, have been developed by Peru's Ministry of Environment to support species identification and trade enforcement of CITES-listed shark species (MINAM 2016). The prohibition of sawfish parts for use in cockfighting, including those originating from historically captured individuals, should also be enforced. Collaboration between trade officials, researchers (e.g. taxonomists, geneticists), CITES authorities, and others could help improve enforcement and reduce threats to sawfish imposed by local and international commerce.

(3) Education campaign for the cockfighting community. Sawfish rostral teeth are not the most commonly used material for cockfighting spurs, but the continued use and perhaps demand for these spurs in some parts of Peru may be a driver for some level of sawfish mortality in the ETP. An educational campaign targeting galleros should be developed, potentially through partnerships with larger cockfighting associations but which can also reach galleros who may not be part of an association. The campaign should explain, in accessible language, the critical conservation status of sawfish in the ETP and the link between sawfish mortality and demand for spurs made from rostral teeth. It should clarify the legalities around the sale, export, and import of sawfish products, including spurs (which is prohibited for all CITES signatory nations), and encourage galleros to exclusively use alternative types of spurs. Furthermore, the message should highlight the role of sawfish in local ecosystems, and how sawfish can be flagship species to help ensure healthy ecosystems, as these, in turn, can benefit a wide range of human activities. In areas where cockfighting is prohibited, this type of campaign may have to be developed solely as an information campaign in collaboration with government and enforcement authorities.

(4) Public education and outreach campaigns. Inspiring public interest in and understanding of sawfishes and the threats they face may help to develop interest and a sense of pride in supporting the survival of a unique and Critically Endangered species. In Peru, Planeta Océano engages members of coastal communities (including fishers, educators,

and youth) in multi-disciplinary and participatory marine conservation efforts, showcasing citizens as primary leaders in conservation. This approach involves identifying and supporting local leaders, jointly identifying conservation challenges and co-designing conservation projects, promoting knowledge exchange, and fostering ownership and multiplier effects for conservation within the community (K. Forsberg unpubl. data). These models of public participation allow for locally relevant actions to be developed by the communities themselves. Education and outreach for sawfish conservation should be carried out, particularly in localities where sawfish have been encountered. Education and outreach efforts could highlight sawfish as flagship species, the role of sawfish in local ecosystems, and the importance of sawfish habitats for local communities and livelihoods. Activities could include participatory monitoring and citizen science schemes, to provide fishers and community members with the skills and means for reporting sawfish observations and interactions with fishing gear.

(5) Ensuring live releases. Ensuring live releases of incidentally captured sawfish should be a priority whenever possible, and exploring the feasibility of implementing these actions within a broader marine megafauna release program should be considered. This will entail collaboration between responsible authorities and fishers, based on safe handling, adequate release protocols, and locally adapted guidelines. Adequate infrastructure, capacity, and equipment should be made available to conduct sawfish releases, to be carried out by trained individuals. Networks including government, local fishers, and civil society can support these release efforts, and protocols for rapid responses should be developed. For example, Peru's Technical Groups of the Peruvian Multi-sectoral Commission on Marine Environments (COMUMA) have proven successful when providing responses to marine fauna entanglements and strandings. Similarly, Planeta Océano's community-based efforts for marine conservation in northern Peru have promoted fishers to release incidentally caught manta rays and sea turtles, while valuing the importance of these flagship species for ocean conservation. Ensuring community engagement and participation will be critical for a live-release program for sawfish. Furthermore, given that fishing nets can require costly repairs as a result of releasing sawfish alive, a compensation scheme may be required to incentivise fishers in Peru and Ecuador, but this should first be assessed via stakeholder consultations.

#### 4.8. Future research recommendations

Although sawfish exist in the ETP, they are encountered rarely and therefore are challenging to investigate. Trans-disciplinary approaches to researching and protecting sawfish will thus be essential in the region. This may also include social science and fisheries science approaches, as well as using genetics techniques such as DNA barcoding (Cabanillas-Torpoco et al. 2020), environmental DNA (e.g. Lehman et al. 2022), and other methods to help identify critical sawfish habitats. All of these actions will require ample collaboration between multiple sectors, as well as ensuring that scientific and traditional knowledge is incorporated into management and available public information. It will also be essential to incorporate local cultural context, values, and perceptions of sawfish into the design of any such activities.

Ultimately, contributing towards sawfish protection will support the implementation of national instruments; for example, the Peruvian National Action Plan for Sharks, Rays, and Related Species (PAN-Tiburón) and National Policies on Biodiversity. A failure to implement actions to address threats to sawfish will likely lead to continued capture and mortality of sawfish in a region where local populations are already seriously depleted, pushing them ever closer to local extinction.

#### 5. CONCLUSIONS

This study highlights the continued occurrence of largemouth sawfish in both Peru and Ecuador, providing the most in-depth study on this species to date for both countries. Whilst northern Peru is the southernmost limit of largemouth sawfish in the ETP and this region was previously thought to have been only occasionally used by sawfish, interview results suggest that in the past, sawfish encounters in the area were not uncommon. Our results also suggest that the range of sawfish distribution in the ETP may have extended further south than previously hypothesised. Locally adapted conservation strategies for largemouth sawfish urgently need to be implemented in both Ecuador and Peru. Initial recommendations have been made for feasible actions which we consider will directly address the main threats to sawfish in this region: incidental capture in fishing gear and the value of rostral teeth for cockfighting practitioners, which likely prevent some accidentally caught sawfish from being released alive.

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