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REVIEW

Natural history, fisheries, and conservation of the Pacific guitarfish: signs of trouble in Peruvian waters

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ABSTRACT: This review examines — with a focus on Peru — the distribution, life-history, ecology, fisheries, historic and contemporary cultural importance, commerce, and management of the Pacific guitarfish *Pseudobatos planiceps*. In the eastern Pacific, Peru represents its most important habitats. The only 2 identified Important Shark and Ray Areas for this species are in Peru for feeding purposes. Other critical habitats are unidentified (e.g. reproductive). Most demographic parameters are unknown, since only length-at-maturity and fecundity have been determined. This species is a mesopredator that feeds on benthic invertebrates but also on Peruvian anchoveta. This trophic plasticity is unique among species within this genus. Globally, Peru has one of the longest species-specific landing datasets (56 yr) and one of the largest catches among countries that report guitarfish landings. This dataset shows a 98% decrease in landings from a peak in 1981 to a low in 2004, while fishing effort increased during this period, suggesting that depletion occurred in the early 1980s. The Pacific guitarfish is the third most landed ray species by artisanal fisheries in Peru, mainly between the central and northern regions. Adults are mainly caught using gillnets and as bycatch in trawling fisheries. Mid-northern Peru has a millennia-old tradition in Pacific guitarfish capture and consumption, and catch is not regulated. Along its distributional range, fisheries in Peru are the main cause of population decline; therefore, there is an urgency to halt this trend to protect the Pacific guitarfish. This review establishes a baseline, identifies information gaps, and provides recommendations to guide research and management for the species.

KEY WORDS: Batoid · *Pseudobatos planiceps* · Small-scale fisheries · Traditional uses · Management · Endangered species

1. INTRODUCTION

Rhino rays (Rhinopristiformes) are considered the most threatened order of marine fishes, with some groups (i.e. sawfishes, wedgefishes, and giant guitarfishes) facing a high risk of extinction due to interactions with coastal fisheries (Dulvy et al. 2014, Moore 2017, Kyne et al. 2020b). These shark-like batoids are very vulnerable to overexploitation due to their life-history strategy, which includes late maturity, low fecundity, and slow growth. Rhino rays are being increasingly targeted or retained as incidental catch

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and have become an economically important component in fisheries globally (Dulvy et al. 2014). As a result, their fisheries (landings and catch rates) have greatly decreased in many locations worldwide despite increasing fishing effort (Kyne et al. 2020b, Seidu et al. 2022). The collapse of their populations from fisheries overexploitation could affect human food security and the livelihoods of coastal communities (Moore & Grubbs 2019, Seidu et al. 2022).

The amphi-American (i.e. distributed at both sides of the American continent) guitarfish genus *Pseudobatos* (family Rhinobatidae) is composed of 9 species distributed from California, USA, to northern Chile in the Pacific and from North Carolina, USA, to northern Argentina in the Atlantic. The genus is strongly divergent from the other guitarfish genera and may belong to a separate family (Last et al. 2016). In the eastern Pacific, there are 6 species (spadenose guitarfish *P. buthi*, grey-spotted guitarfish *P. glaucostigmus*, whitesnout guitarfish *P. leucorhynchus*, Pacific guitarfish *P. planiceps*, Gorgona guitarfish *P. prahli*, and shovelnose guitarfish *P. productus*) (Last et al. 2016, IUCN 2023) that are distributed in tropical and temperate waters (Last et al. 2016, Kyne et al. 2020b). In Peru, 2 species (Pacific guitarfish and Gorgona guitarfish) are officially recorded according to IUCN (2023), but only the Pacific guitarfish is regularly recorded in Peruvian fisheries, as it has the most widespread distribution along the Peruvian coast (González-Pestana et al. 2022b); the Gorgona guitarfish is only distributed around the border between Peru and Ecuador.

The eastern Pacific has been identified as a hotspot of Data Deficient guitarfish species worldwide (Moore 2017). The Pacific guitarfish has been little studied (i.e. biology, ecology, fisheries, and threats), and this was reflected in its listing as Data Deficient for 2 assessments of the IUCN Red List (Lamilla 2004, 2016). But the recent assessment listed this species as Vulnerable, with a decreasing population trend (Kyne et al. 2020a). One of the major identified threats to the species is fisheries in Peru, as this country reports the second largest historical landings of batoids in the eastern Pacific between 1950 and 2015, in which the Pacific guitarfish is one of the most landed species (González-Pestana et al. 2022b). Thus, along its distributional range, Peru represents its largest fishery.

Our goal is to summarize the information on the distribution, life history traits, trophic ecology, fisheries, historic and contemporary cultural importance, commerce, management, and conservation of the Pacific guitarfish. Readily available information (i.e. metadata available under request) was also analyzed to gain a better understanding of the situation of the Pacific guitarfish, such as overall historical landings, spatiotemporal dynamics of landings, and national commerce. This information is used to establish a baseline and identify information gaps and provide recommendations to guide future research and management priorities for the species.

2. DISTRIBUTION

The Pacific guitarfish is distributed from southern México (Last et al. 2016) to northern Chile (Bustamante et al. 2014), making it the species within the genus *Pseudobatos* with the southernmost distribution in the eastern Pacific. This guitarfish species is broadly distributed in 2 large marine ecosystems (LMEs): the Pacific Central-American Coastal LME and the Humboldt Current LME. Yet, it is only irregularly recorded in El Salvador (Fuentes & Hernández 2004), Costa Rica (Clarke et al. 2016, Espinoza et al. 2018), Colombia (Mejía-Falla et al. 2019), and Ecuador (Guerron-Chavez 2007, Tenelema et al. 2014, Macías 2022). This species is common in Peru, where it has been regularly caught and a cultural tradition of consumption exists. This suggests that its core distribution is in the southern areas of its range (Kyne et al. 2020a). The Pacific guitarfish occurs in shallow inshore and continental shelf waters, in which its maximum recorded depth is 50 m (Weigmann 2016). Several studies have reported that adults are primarily caught in shallow waters (see Table 1).

3. LIFE HISTORY TRAITS

Of the 6 *Pseudobatos* species distributed in the eastern Pacific, the Pacific guitarfish attains the second largest body size — after the shovelnose guitarfish *P. productus* — with a maximum total length (TL) of 125 cm (Silva-Garay et al. 2018). Reproduction is lecithotrophic viviparous (Conrath & Musick 2012). For the Pacific guitarfish, most reproductive parameters are unknown (i.e. gestation period, age and growth, population structure). Length-at-maturity and fecundity have been estimated in only 1 location (i.e. southern Ecuador) (Carrera-Fernández & Galarza 2017). This study determined that the litter size has a maximum of 9 embryos, and the mean length-at-maturity is 78.1 cm TL for males and 82.5 cm TL for females (Carrera-Fernández & Galarza 2017). As this study is from the southern end of the Pacific Central-American Coastal LME, future studies should determine its reproductive parameters in the Humboldt Current LME, which has different environmental conditions (e.g. colder waters). Different environmental variables might influence its reproductive traits, as has been observed in the different sizes at first sexual maturity of the shovelnose guitarfish (Juaristi-Videgaray et al. 2021). Thus, it is not advisable to extrapolate this demographic parameter to other LMEs.

Age-at-maturity is unknown, but based on a close relative (i.e. *P. productus*) that reaches similar maximum body size (156 cm TL) and is in a temperate habitat, it could be approximately 7 to 8 yr (Timmons & Bray 1997). Size-at-birth is poorly known for this species. Collected from the Piura and Ica regions, a small individual of 25 cm TL showed an umbilical scar and an embryo of 20.4 cm TL was well developed, including its teeth (Hildebrand 1946). Based on close relatives with the most similar body sizes (i.e. *P. productus* and *P. prahli*), size-at-birth could be approximately 20 to 25 cm TL. Gestation period is unknown, but based on a close relative (i.e. *P. productus*), it could last 4 to 5 mo (Márquez-Farías 2007).

Understanding demographic parameters such as reproduction, age, growth, and population structure is essential for effective management (Cooke et al. 2018). For example, length-at-maturity and fecundity are commonly measured traits that are important for assessing population status (Jorgensen et al. 2022). D'Alberto et al. (2019) estimated the population productivity of 9 species from 4 families of Rhinopristiformes. The shovelnose guitarfish, which has a relatively similar maximum body length and shares a similar habitat, has been shown to be less productive and to have below-average rates of population increase compared to other chondrichthyans (D'Alberto et al. 2019). Therefore, we can expect that the Pacific guitarfish will have similar low productivity.

Between northern and central Peru, body size and sex information for this species in the coastal area has been collected primarily through fishery-dependent (using mostly bottom gillnets) studies, with a total of 1450 individuals sampled (Table 1). These studies indicate that mostly adults are caught (and distributed) in shallow waters. Newborns and juveniles are less frequently caught in shallow waters, which indicates that either these are mostly distributed in deeper waters, or their body size class is less targeted by the fishing gear, as variations in mesh sizes among fisheries can impact the size selectivity of the catch (Márquez-Farias 2005). Besides this information, there is little additional data that can help to understand the spatial ecology of the Pacific guitarfish through its ontogeny.

A study of the movement patterns of the shovelnose guitarfish in California has shown a seasonal philopatry with relatively limited movements (maximum distance travelled: 221 km) (Gong 2022). This result might imply that different populations occur at different LMEs due to limited dispersion. Thus, it is important to determine the population structure of the Pacific guitarfish along its distributional range.

4. TROPHIC ECOLOGY

The diet of the Pacific guitarfish has only been studied off the coast of Ecuador (Aguilar & Jennifer 2020) and Peru in mid-northern (Gonzalez-Pestana et al. 2021b) and central (Silva-Garay et al. 2018, García & Mantari 2021) regions. This species is a mesopredator (i.e. secondary consumer) that feeds mainly on invertebrates (i.e. crustaceans, mollusks) and teleosts (mainly Peruvian anchoveta *Engraulis ringens*). For the other *Pseudobatos* species, studies have reported a diet based mainly on benthic invertebrates (i.e.

Table 1. Body size range or average in total length (cm), sex ratio, and depth range or average (m) for the Pacific guitarfish in northern and central Peru. F: female; M: male; na: not available

Body size range	Body size average ±SD	Sex ratio (F:M)	Depth range or average ±SD	Sample size	Location	Reference
67–117	102.6 ± 10	1:1	na	205	Ica, central Peru	Galindo et al. (2017)
75–121	103.9	1:1	11 ± 8.5	141	Ica, central Peru	Manrique & Mayaute (2017)
99–135	109.7	3.2:1	na	42	Ica, central Peru	García & Mantari (2021)
51–125	92.2	1.6:1	0–5	36	Lima, central Peru	Silva-Garay et al. (2018)
27–125	85.0 ± 19.3	1:1.6	na	36	Lima, central Peru	Iannacone et al. (2011)
50–124	83 ± 15	1:0.41	5.4 ± 2	796	Piura, northern Peru	Jimenez et al. (in press)
30–120	96.2 ± 18	1.4:1	7–163	149	Lambayeque, northern Peru	Córdova-Zavaleta (2022)
64–117	84 ± 15	1:1	29 ± 13	40	Lambayeque, northern Peru	Gonzalez-Pestana et al. (2021b)
45–128	98 ± 29	na	5–200	5	Tumbes, northern Peru	Vera et al. (2021)

crustaceans, bivalves, gastropods, polychaete worms) and bottom-dwelling fishes (Navia et al. 2007, Polo-Silva & Grijalba-Bendeck 2008, Bornatowski et al. 2010, Payan et al. 2011, Navarro-González et al. 2012, De la Rosa-Meza et al. 2013, Valenzuela-Quiñonez et al. 2018). The diet of the Pacific guitarfish in Peruvian waters is unique, since it is preying on pelagic fish (i.e. Peruvian anchoveta). Peru is the most productive eastern boundary current system in the world in terms of fish catches (Chavez & Messie 2009). In the northern Humboldt Current System, the Peruvian anchoveta is the dominant and most ecologically important pelagic fish species (Espinoza & Bertrand 2008) and is an important prey item for seabirds, teleost fish, and marine mammals, sharks, and rays (Gonzalez-Pestana et al. 2022a). The consumption of Peruvian anchoveta by the Pacific guitarfish might be explained by the high availability of this schooling fish and the trophic plasticity of this guitarfish predator.

The diet of the Pacific guitarfish in Peru varies according to geographic locations (i.e. mid-northern and central Peru) which might be influenced by different oceanographic conditions (Gonzalez-Pestana et al. 2021b). Along the central coast (Pisco, Ica), an active year-round upwelling leads to high marine productivity (Gutiérrez et al. 2011) which supports the abundance of Peruvian anchoveta throughout the year independently of El Niño—Southern Oscillation (ENSO) conditions (Guardia et al. 2012). These conditions explain the high consumption of Peruvian anchoveta (up to 61% of prey-specific index of relative importance), resulting in a higher trophic position for the Pacific guitarfish, while along the northern coast (San Jose, Lambayeque), located below an ecotone zone where the cool upwelled waters encounter warm tropical waters, its diet is mainly composed of benthic invertebrates. Therefore, the diet variability between geographic locations shows insights of this batoid's trophic plasticity and opportunistic feeding behavior in response to differences in the local prey availability, an effect that may be amplified during ENSO (Gonzalez-Pestana et al. 2021b).

Habitat selection also appears to influence Pacific guitarfish diet. Two studies in central Peru assessed the diet of the species in similar oceanographic conditions but in different bottom types (Silva-Garay et al. 2018, Gonzalez-Pestana et al. 2021b). Individuals sampled in an extensive sand platform fed mainly on the sand crab *Emerita analoga*, while individuals sampled in a mixture of hard and soft bottoms fed mainly on the crab *Romaleon polyodon.* These studies show the importance of spatial scale in assessing the diet and trophic plasticity of this species in response to local prey availability.

Batoids and houndsharks are among the most powerful excavators, using a variety of behaviors (e.g. jetting water and beating pectoral fins) to access prey resources (e.g. O'Shea et al. 2012, Takeuchi & Tamaki 2014). This process, known as bioturbation, can have a significant impact on the physical and biological habitat properties of the benthic ecosystem, such as the density and distribution of benthic fauna (O'Shea et al. 2012). It has been suggested that the Pacific guitarfish has an ecological role in the bioturbation of benthic communities in Peru due to its diet of benthic invertebrates (Gonzalez-Pestana et al. 2021a). Additional research could elucidate the specific contribution that the Pacific guitarfish has as a bioturbator of the benthic ecosystem.

5. OVERFISHING AND OTHER THREATS

5.1. Trends in Peruvian landings for the Pacific guitarfish (1962–2018)

5.1.1. Analysis of landing data

The Food and Agriculture Organization of the United Nations (FAO, https://www.fao.org/fishery/en/statistics/software/fishstatj) reports the landings of guitarfishes in 23 countries (i.e. Albania, Benin, Brazil, Congo, Côte d'Ivoire, Ecuador, Eritrea, Greece, Indonesia, Iran, Israel, Italy, Lebanon, Liberia, Libya, Mauritania, Pakistan, Palestine, Peru, Senegal, Spain, USA, and Uruguay) under the common names of banded guitarfish, blackchin guitarfish, bowmouth guitarfish, Chola guitarfish, common guitarfish, giant guitarfish, Pacific guitarfish, whitesnout guitarfish, whitespotted wedgefish, and guitarfish nei. The second earliest records belong to Pacific guitarfish from Peru since 1962, preceded by Chola guitarfish from Brazil since 1955 and followed by giant guitarfish from Iran since 1997. Thus, the Pacific guitarfish has the oldest landing records for this group of fishes, with limited taxonomic ambiguity in the Pacific Ocean. Within the *Pseudobatos* genus, this species is the only one that inhabits the Humboldt Current LME; thus, misidentification is very rare along most of the coast of Peru. Yet, in northern Peru (Tumbes region), where the Pacific Central-American Coastal LME extends, overreporting might have occurred, as 3 other species also occur (i.e. grey-spotted guitarfish, whitesnout guitarfish, Gorgona guitarfish) (Last et al. 2016, IUCN 2023). Another limitation of using the FAO dataset is that the full extent of fishing mortality is incomplete due to underestimation (Pauly &

Zeller 2016). De la Puente et al. (2020b) reconstructed Peruvian catches reported by FAO between 1950 and 2014 and showed that landings represented 80% of the total catch. Theys also suggested that for the Peruvian guitarfish, FAO data represented 75% of the catch. Of the unreported catch caught by gillnets, it was assumed that 50% was discarded at sea, because this species is frequently headed and gutted before being weighed on docks (Sueiro & De la Puente 2015).

Landings of the Pacific guitarfish were accessed through the software FishStat J v4.03.05 (https://www.fao.org/fishery/en/statistics/software/fishstatj). To assess trends in landings over time (1962–2018), we used a generalized least squares (GLS) model to fit a linear model, maximizing the restricted log-likelihood (REML), with unequal variances to account for measurement uncertainty. The package 'nlme' (Pinheiro et al. 2014) in R v3.6.2 (R Core Team 2019) was used for this analysis. The CIs of the GLS model parameters were calculated using nonparametric bootstrapping with replacement (R = 1000) of the resulting coefficients with the R package 'boot' (Davison & Hinkley 1997, Canty & Ripley 2013). To maximize recognition of any significant trends in landings, we grouped the 1962–2018 dataset into 11 yr blocks, except for the last segment of 13 yr (2006–2018). The dataset reconstructed by De la Puente et al. (2020b) was obtained from the Sea Around Us (www.seaaroundus.org) and was used to compare trends in the historical landings between the FAO and De la Puente et al. (2020b) datasets (Fig. A1 in the Appendix).

5.1.2. Results and discussion

According to FAO landing statistics, 49 966 t of Peruvian guitarfish were landed in Peru between 1962 and 2018, with (mean ± SD) 892 ± 1052 t yr^{-1}. Landings peaked in 1981 with 4711 t and have diminished since, with some minor peaks, with the lowest landings in 2004 with 28 t (Fig. 1). Landings increased at an average of 19.0% per year (slope = 0.174; 95% CI: 0.061, 0.274) from 1973 to 1983. However, from 1984 to 1994, landings declined by an average of 36.6% per year (slope = −0.455; 95% CI: −0.691, −0.273, Table 2). Since 1994, landings have remained low,

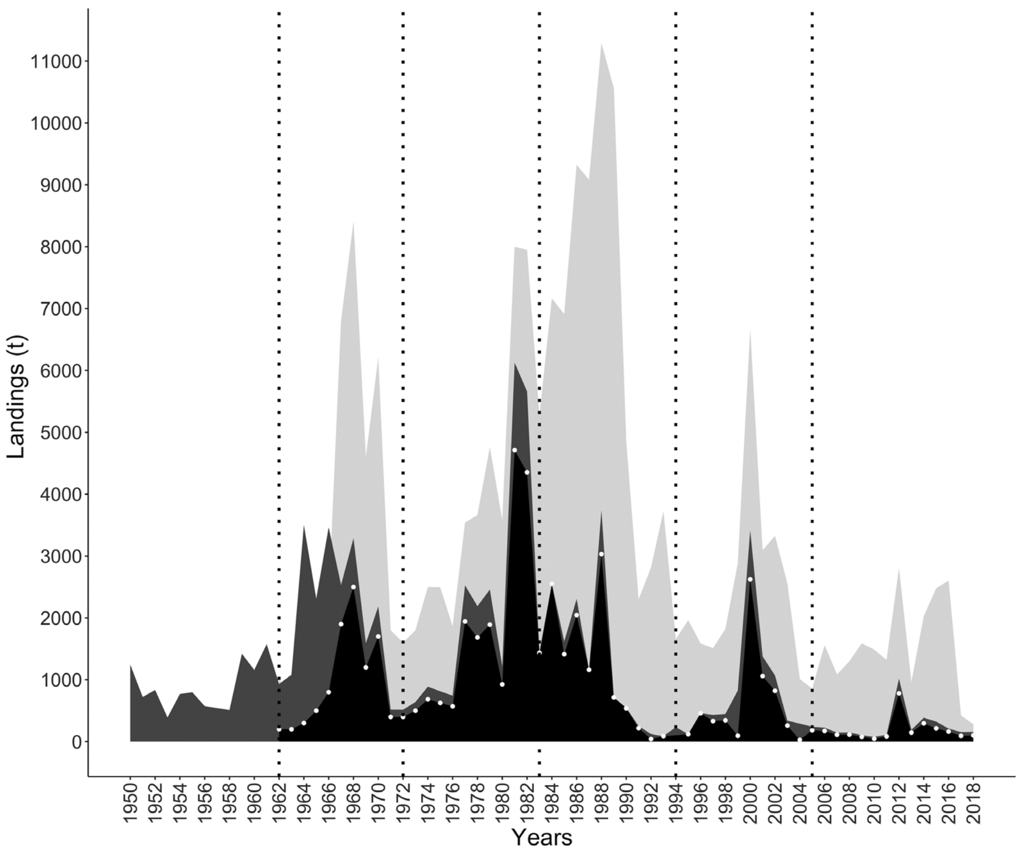

Fig. 1. Sixty-nine years (1950–2018) of Pacific guitarfish (black: FAO dataset; dark grey: Sea Around Us dataset) and marine batoid (light grey) landings in Peru. Dotted vertical lines are 11 yr blocks, except for the last segment of 13 yr, in which landings from the FAO dataset were assessed

except for a peak of 2624 t in 2000. The dataset reconstructed by De la Puente et al. (2020b) presented a total volume of 72 192 t between 1962 and 2018 and follows a similar trend, with the highest landing in 1981 with 6124 t and the lowest in 2010 with 77 t (Fig. 1).

For several different guitarfish species around the world, a similar trend has been observed. In Ghana, most fishers stated that catches of 2 guitarfish species (blackchin guitarfish *Glaucostegus cemiculus* and common guitarfish *Rhinobatos rhinobatos*) have declined by 80 to 90% based on their recollection (Seidu et al. 2022). At the same time, over half of the fishers indicated that the catches of the smaller guitarfishes (spineback guitarfish *R. irvinei* and whitespotted guitarfish *R. albomaculatus*) have declined by 40 to 60% (Seidu et al. 2022). In the Gulf of Thailand, the catch rates of the trawl fishery for Rhinobatidae declined by 93% between 1968 and 1972 (Ritragsa 1976, Pauly 1979). In Iran, landings of the category giant guitarfish declined by 67% between 1997 and 2016, and in Pakistan, landings for the category rhinobatid decreased between 72 and 81% between 1993 and 2011 (reviewed in Kyne et al. 2020b). In eastern India, landings for the category guitarfish decreased by 86% between 2002 and 2006 (Mohanraj et al. 2009). In Indonesia, landings for the whitespotted wedgefish declined by 88% between 2005 and 2015 (reviewed in Kyne et al. 2020b). Globally, Peru has one of the longest species-specific landing datasets (56 yr) among countries that report guitarfish landings. The peak of global guitarfish catches occurred in the early 1980s, among which the major guitarfish catching countries during the first peak were Peru and Brazil (Sherman et al. 2013). Therefore, Peru is, globally, one of the most important countries in terms of guitarfish landings. The results from Sherman et al. (2013) and from this study demonstrate that depletion might have occurred as early as in the 1980s.

Several factors can explain the, most likely, overexploitation of the Pacific guitarfish. Between 1950 and 2018, the fishing effort of Peruvian small-scale fisheries increased greatly and at much faster rates than the catches, and by 2006, this fishery was suggested to have become unsustainable and uneconomic (De la Puente et al. 2020a). Between 1996 to 2015, there was considerable growth in Peruvian small-scale fisheries, with an increase of 186% in vessels and 140% in fishers (Escudero 1997, Castillo et al. 2018). (Escudero 1997, Castillo et al. 2018). The average lengths of gillnets have also increased with time, from 72–81 m in 1970 to 0.8–3.3 km in 2005 (Castillo 1970, Alfaro-Shigueto et al. 2010). As demonstrated by De la Puente et al. (2020a), the Peruvian small-scale fleet experienced a slow technological creep over time, resulting in larger fishing areas, longer fishing trips, and reductions in the time spent searching for target species (Alfaro-Shigueto et al. 2010, Estrella Arellano & Swartzman 2010, Sueiro & De la Puente 2015, Marín et al. 2017, Castillo et al. 2018). Specifically, vessels using gillnets and trawling, which are the most common fishery gear used for the Pacific guitarfish, show consistent declines in catch per unit effort (CPUE) (De la Puente et al. 2020a). In 2000, the peak in Pacific guitarfish landings could be explained by a further increase in fishing effort. From 1950–1999 to 2000–2009, technological power doubled for nonmotorized vessels (De la Puente et al. 2020a). Also, increases in the use and coverage area of cellphones led to a faster technological creep between 2000 and 2018 (De la Puente et al. 2020a).

The Pacific guitarfish is distributed in coastal and shallow habitats. As the impact of humans was first most strongly felt in coastal benthic communities and fisheries worldwide began in nearshore environments and then expanded offshore (Aronson 1990), this species has been exploited by Peruvians for millennia, with an increasing threat of overfishing as fisheries effort increased through time (Parsons 1970, Pozorski 1979, Pozorski & Pozorski 1979, Cutright 2015, Alcalde & Segura 2017). As a result, overexploitation might have occurred as early as the 1980s. There is some evidence to support this, as the overall effective CPUE for gillnets in Peru dropped drastically in the 1950s (De la Puente et al. 2020a), a decade before landings

Table 2. Trends and variations in guitarfish landings in Peru (1962–2018) from the FAO dataset. ns: nonsignificant p-value (>0.05); RSE: model residual SE. The lower (2.50%) and upper (97.5%) limits of 95% CI are shown. Mean annual change in landings was calculated as $[(e^{slope} - 1) \times 100]$. The upper and lower limits of change in landings were calculated as $[(e^{slope \pm 1.96\ SE} - 1) \times 100]$

Year	Year predictor					95% CI of slope		Change in landings		
	Slope	SE	*t*	p	RSE	2.50%	97.50%	Mean	2.50%	97.50%
1962–1972	0.128	0.074	1.719	ns	0.324	−0.073	0.3523			
1973–1983	0.174	0.050	3.491	0.0068	0.198	0.061	0.274	19.0	7.9	31.3
1984–1994	−0.455	0.081	−5.581	0.0005	0.306	−0.691	−0.273	−36.6	−45.9	−25.6
1995–2005	−0.089	0.120	−0.747	ns	0.565	−0.386	0.186			
2006–2018	−0.255	0.163	−1.565	ns	1.11	−0.710	0.042			

started to be recorded for the Pacific guitarfish. Also, the fact that the species in their genus have shown below-average rates of population increase compared to other chondrichthyans (D'Alberto et al. 2019) makes them very vulnerable to overexploitation. Thus, the high spatial overlap with fisheries provides the species little refuge from fishing activities (Kyne et al. 2020a), increasing its vulnerability to overexploitation.

5.2. Pacific guitarfish landings in Peru (1997–2015): species contribution, seasonality, landing points, and fishing gears

Batoid landings in Peru were assessed at the species level between 1997 and 2015 using national official data from the Instituto del Mar del Peru (IMARPE), a government institution responsible for marine research (González-Pestana et al. 2022b) (Fig. A1). The landings reported by IMARPE are usually lower than those reported by FAO, as these only include a sample from the total landings. Yet, IMARPE data is collected consistently through time, so trending and proportions must be accurate.

This study identified that the Pacific guitarfish is the third most landed ray species in Peru (after eagle and mobulid rays). These landing reports are from the Peruvian small-scale fishing fleet (i.e. fishing vessels with a maximum of 32.6 m^3 of gross registered tonnage, up to 15 m length, and operating with little mechanization) (El Peruano 2001). González-Pestana et al. (2022b) showed that landings of the Pacific guitarfish occurred year-round but were significantly higher during the austral summer season. Landings were not homogeneously distributed among the 115 official landing sites distributed along the Peruvian coast (INEI 2012); 70% of total landings were distributed in northern and central Peru between 1997 and 2015 (González-Pestana et al. 2022b). The Pacific guitarfish was most frequently captured by gillnets (51.7% of total landings), followed by beach seines (18.2%) and trawls (8.2%) (González-Pestana et al. 2022b). In a review that evaluated interactions between rhino rays and fisheries, Pytka et al. (2023) identified that a variety of gear types was used, yet trawl and gillnet were predominant.

Misidentification could be occurring in northern Peru (Tumbes region) where the Pacific Central-American Coastal LME extends, due to a higher diversity of guitarfish species which has become relevant in the last years, as currently the second highest landing site is near the border with Ecuador (i.e. Puerto Pizarro). Therefore, future studies should verify if the Pacific guitarfish is the only species landed, and if not, determine the contribution of the guitarfish species that inhabit the southern limit of this LME (i.e. grey-spotted guitarfish, whitesnout guitarfish, Gorgona guitarfish).

Several other studies located along the northern and central coast of Peru have also reported on the fishery of the Pacific guitarfish. Off central Peru (Pisco, Ica, and Casma, Ancash), this species was the second most landed batoid in which gillnets were used (Galindo et al. 2017). Off San Jose (Lambayeque, northern Peru), this species was the third most landed batoid species using gillnets with mesh openings between 101.6 and 330.2 mm (Córdova-Zavaleta 2022). In Sechura Bay (northern Peru), 2016 and 2019 were the years with the highest and lowest fishing effort, with 107.6 ± 47.8 and 87.2 ± 30.0 h km^{-2}, respectively (Jimenez et al. in press). Alfaro-Shigueto et al. (2010) characterized fishing gears in 2004 for Constante—a traditional fishing community for Pacific guitarfish in northern Peru (Anton Ruiz 2021)—in which bottom gillnets measured 2.2 ± 0.7 (range: 1.3–3.3) km in length. These and other studies have determined that most of the specimens collected were mature (Table 2), suggesting that coastal fisheries mainly catch adults.

5.3. Spatiotemporal dynamics of landings

5.3.1. Methods

The landing volumes of the Pacific guitarfish between 1996 and 2020 (25 yr) per landing port and year were obtained from IMARPE's public information access website (www.imarpe.gob.pe/imarpe/acceso informacion/) (Fig. A1). The landing locations were grouped in 4 clusters: northern Peru (Tumbes region), mid-northern Peru (Piura and Lambayeque regions), central Peru (Lima and Ica regions), and other regions (representing a small contribution). The regions were organized based on their proximity, location within LMEs, and historical uses (e.g. Piura and Lambayeque have a strong traditional use of Pacific guitarfish). The period was grouped into 2 datasets of 12 and 13 yr blocks (1996–2007 and 2008–2020, respectively). The 'ggalluvial' package (Brunson & Read 2018) in R v3.6.2 (R Core Team 2019) was used to visualize how the landings by region have varied through time.

5.3.2. Results and discussion

Between 1996 and 2007, the most important landing sites were from mid-northern Peru (mainly from

Sechura Bay in Piura and San Jose in Lambayeque) with 218 t, followed by central Peru (Huacho in Lima and San Andres in Ica) with 212 t, with these 2 clusters comprising 79% of total landings. Between 2008 and 2020, the most important landing sites were from central Peru (Huacho in Lima and San Andres in Ica) with 316 t, followed by northern Peru (mainly from Puerto Pizarro, Tumbes, bordering Ecuador) with 219 t, with these 2 clusters comprising 76% of total landings (Fig. 2). On a 1941–1943 mission by the US Fish and Wildlife Service, fishes were collected at 54 sites along the Peruvian coast. The Pacific guitarfish was taken in larger quantities at Piura (Lobos de Tierra, Sechura Bay, Paita Bay, Nonura Bay, Talara Bay), Lima (Chilca), Ica (Paracas), and Tumbes (Puerto Pizarro) (Hildebrand 1946). This study also mentions that according to local statistics records, the catches come principally from Piura (Paita and Sechura) and in some quantity from Ica (Pisco). Mid-northern Peru has declined in importance, which might have been caused by overfishing leading to resource depletion. Mid-northern Peru has the highest number of fishers and one of the highest levels of dependence on fish protein for nutrition in coastal Peru (PRODUCE 2021). Thus, local resources with limited management and enforcement can be expected to be at risk of depletion, especially considering that guitarfishes are very sensitive to overfishing.

5.4. Pacific guitarfish as fishery bycatch

The Pacific guitarfish is also caught as bycatch in the industrial trawl fishery for Peruvian hake, which legally operates beyond 5 nm from the coast, primarily off Piura (El Peruano 2003). According to the fisheries management plan for Peruvian hake, only 2 batoid species are caught as bycatch, yet studies have identified 8 batoid species, including the Pacific guitarfish, as bycatch in this trawl fishery (Céspedes 2013, Zavalaga et al. 2018). Céspedes (2013) indicates that most of the rays and sharks caught by industrial trawl fisheries were discarded; thus, these types of fisheries are most probably not included in landing statistics. This author estimated that the Pacific guitarfish represented the fifth most important in terms of biomass and the third most important in terms of frequency among the ray species identified. At the national level, the Peruvian hake fishery is one of the main fisheries (Estrella Arellano & Swartzman 2010), so the impact on Pacific guitarfish populations could have been substantial, since trawling has the highest level of discards of all fisheries (Pérez-Roda et al. 2019). Currently, it is most probable that the species has already been depleted by trawling. In a review, Pytka et al. (2023) identified that for the Rhinobatidae family, the highest number of fishery interactions were from trawling. Therefore, estimating the volume of the Pacific guitarfish from industrial trawling is important to determine its contribution to total Peruvian catches.

The Pacific guitarfish is also reported as discarded bycatch in the small-scale trawl fishery off Tumbes, which targets searobin *Prionotus stephanophrys* and sand perch *Diplectrum conceptione* (Salazar et al. 2015), and off northern Piura, which targets brown shrimp *Penaeus californiensis* (Mendo et al. 2022). In this last fishery, the Pacific guitarfish is a commercial species that is retained and sold. In both studies, this species represented a minimal proportion of the total catch (Salazar et al. 2015, Mendo et al. 2022). However, these 2 studies are recent, so the Pacific guitarfish could have been an important component in these fisheries, but might be currently depleted.

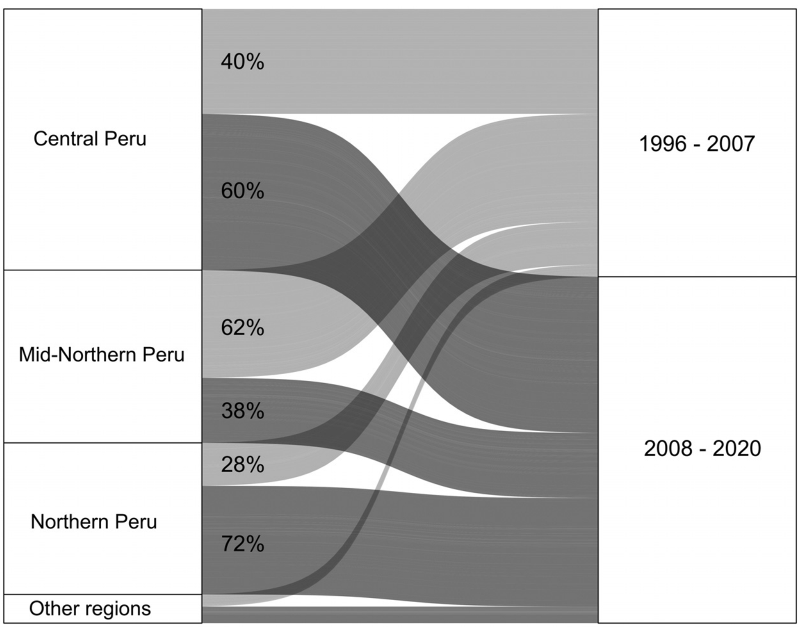

Fig. 2. Peruvian landings of Pacific guitarfish (1996–2020) organized by cluster (central: Lima and Ica; mid-northern: Piura and Lambayeque; northern: Tumbes) and in 2 block periods

5.5. Other threats

Beyond fishing, the Pacific guitarfish faces other threats, such as habitat degradation in key areas identified for this species. One of their most important habitats, Sechura Bay, has been degraded. This is a shallow coastal system in mid-northern Peru at the convergence of Humboldt and tropical waters. Over the past 2 decades, Sechura Bay has undergone a warming trend with higher chlorophyll concentrations that could lead to eutrophication; furthermore, Sechura Bay will continue to be disturbed by El Niño and ongoing human-driven activities (i.e. fisheries and aquaculture), reducing its overall stability and functionality (Del Solar et al. 2022). This poses a threat to the Pacific guitarfish. In contrast, another important habitat, Independencia Bay in central Peru (under typical upwelling conditions), has maintained its cold water conditions and high productivity (Del Solar et al. 2022). Future studies should prioritize these areas (both identified as Important Shark and Ray Areas [ISRAs]) and assess the impact of climate change and other anthropogenic threats to the Pacific guitarfish to design and implement conservation actions.

6. HISTORIC AND CONTEMPORARY CULTURAL IMPORTANCE

Along the north coast of Peru, shallow-water fishing was well established before 9200 BC (Sandweiss 1996). The Pacific guitarfish has been fished and consumed for millennia by the indigenous peoples of modern-day Peru. The earliest records are from mid-northern (Gramalote, 1800–400 BC) (Pozorski & Pozorski 1979) and central (Asia settlement, 1314 BC) (Parsons 1970) Peru. Later, pre-Incan cultures continued with this tradition in mid-northern Peru, such as the Moche (100–750 AD) (Pozorski 1979) and Chimu (1000–1470 AD) cultures (Cutright 2015), and in central Peru, such as the Chincha Kingdom (1200 AD) (Alcalde & Segura 2017). Some batoid species, including guitarfish, had cultural and culinary importance. For example, in images of divinities such as the Mochica iconography, guitarfish are stylistically represented (see Makowski 2000). In murals and ceramics of the Moche civilization, rays are frequently found. In Trujillo, representations of guitarfish have been found in Moche ceramics (Roca-Rey 2018). In the Moche Valley, fishing implements used to catch batoids have been recovered during archaeological excavations, including stone nets and several small- and large-mesh cotton net fragments (Pozorski & Pozorski 1979).

A key ancient process associated with the successful use and commerce of the Pacific guitarfish is drying fish as a means of food preservation (Fig. 3). The warm and arid environment of mid-northern Peru is an ideal environment for this process, so fish can be preserved for months or up to a year (Turan 2015). After the dehydration process, the weight and volume of the fish are reduced, which contributes to its storage and transportation, thus facilitating its exchange with other products in distant regions from the coast such as the Andes and the Peruvian Amazon. In Huánuco, at an altitude of more than 4000 m, there is evidence of the use and consumption of dry and salty marine products dating from 8000 BC (Roca-Rey 2018).

In modern times, the Pacific guitarfish is an important marine resource and a cultural element of mid-

Fig. 3. Modern drying of Pacific guitarfish in Lambayeque, northern Peru (photo: D. Sarmiento)

northern Peruvian cuisine. In the southern Piura region in mid-northern Peru, Sechura Bay, the largest bay in Peru (89 km^2), is influenced by the coastal marine wetland system of Virrilá. In this bay and its associated estuary, the Pacific guitarfish has been an important marine resource, as this species was very abundant according to Anton Ruiz (2021) until at least 1970. One fishery town, Constante, is renowned for its coastal fishery for elasmobranchs (smoothhounds, angelsharks, and batoids), which were caught using artisanal balsillas or rafts (i.e. 2–2.5 m long logs, tied tightly with vine ropes, which can be propelled by sails or oars; Guevara-Carrasco & Bertrand 2017) (Anton Ruiz 2021). In Constante, the Peruvian guitarfish was one of the main target species and economic resources (Anton Ruiz 2021).

Along the coast of Lambayeque, in which the Moche and Chimu cultures flourished, a traditional and popular dish is chinguirito. This is a ceviche (i.e. raw fish cured in fresh citrus juices) using guitarfish that has been previously dehydrated by the sun. According to Peruvian chefs, this process of drying fish concentrates and intensifies the umami flavors (Roca-Rey 2018). Chinguirito has become a typical product of mid-northern Peruvian cuisine, in which at least 4 recipes use it as one of the main ingredients (Roca-Rey 2018). As Juana Zunini, owner of a restaurant with more than 4 decades of tradition in Lambayeque, stated, 'The guitarfish is part of our centuries-old culture, and this species must be protected with closed seasons so that Chiclayo [northern Peruvians from Lambayeque] can once again have on its coasts this fish in abundance' (Roca-Rey 2018).

7. NATIONAL COMMERCE

7.1. Methods

Peru's Ministry of Production (PRODUCE) reports the daily volumes, average prices, and source (i.e. collection site) of hydrobiological resources commercialized at 12 wholesale markets (WSMs) at the species or taxonomic group level (Fig. A1). This information was obtained from PRODUCE's public information access website (https://transparencia.gob.pe/) in which the guitarfish was recorded between 2014 and 2020. This data was used to assess the national market in terms of (1) the most important WSMs along the Peruvian coast and the total volumes traded between 2014 and 2020 (7 yr), (2) the most important sources (i.e. collection sites), and (3) the price structure of the resource. For comparison, the average value for all other hydrobiological resources was calculated between 2014 and 2020. The value from Peruvian soles to US dollars (USD) was converted by using the annual official exchange rate reported by the World Bank (https://data.worldbank.org/). This information can increase our understanding of the hotspot regions in which the Pacific guitarfish is used and consumed and thus where its cultural importance is highest. For this assessment, a trade map was created by using the following packages in R v3.6.2 (R Core Team 2019): 'ggplot2' (Wickham 2016), 'ggrepel' (Slowikowski 2022), 'tidyverse' (Wickham et al. 2019), and 'mapdata' (Deckmyn 2018).

7.2. Results and discussions

Between 2014 and 2020, 353 t of Pacific guitarfish were commercialized in WSMs. Of the 11 WSMs that trade Peruvian marine resources, 8 WSMs commercialize Pacific guitarfish along the Peruvian coast (Fig. 4A). These 8 WSMs are located in northern, mid-northern, and central Peru. The 2 most important WSMs are located in mid-northern Peru in the regions of Piura and Lambayeque: Piura-TERPESA is the most important with 57% of all volume traded at WSMs nationally, followed by Santa Rosa-ECOMPHISA with 42% (Fig. 4B). Between 2014 and 2020, the Tumbes region was the most important source (i.e. collection site), providing 66% of the volume traded at WSMs, for which Puerto Pizarro was the most important fishing site. This was followed by the Lambayeque region with 18%, with San Jose as the most important fishing site, and finally by the Piura region with 7%, with Bayovar as the most important fishing site.

Between 2014 and 2020, the average economic value of Pacific guitarfish at the WSMs was (mean ± SD) 1.5 ± 0.47 USD kg^{-1}, with a range between 0.4 and 4.4 USD kg^{-1}. In comparison, the average value of the hydrobiological resources at the WSMs for those same years was 3.2 ± 2.5 USD kg^{-1}. The Pacific guitarfish occupied the 72nd position in economic value (in increasing order of value) from 330 hydrobiological resources. This species has been a low-value resource at least since the 1940s; yet important for food security for low-income families (Hildebrand 1946). The price has remained low, although its abundance has apparently diminished.

These results indicate that mid-northern Peru (Piura and Lambayeque) is the hotspot of national commerce for Pacific guitarfish, where it is also consumed. This pattern has also been observed for sharks. López de la Lama et al. (2018) surveyed Peruvians along the coast and determined that shark meat consumption is high-

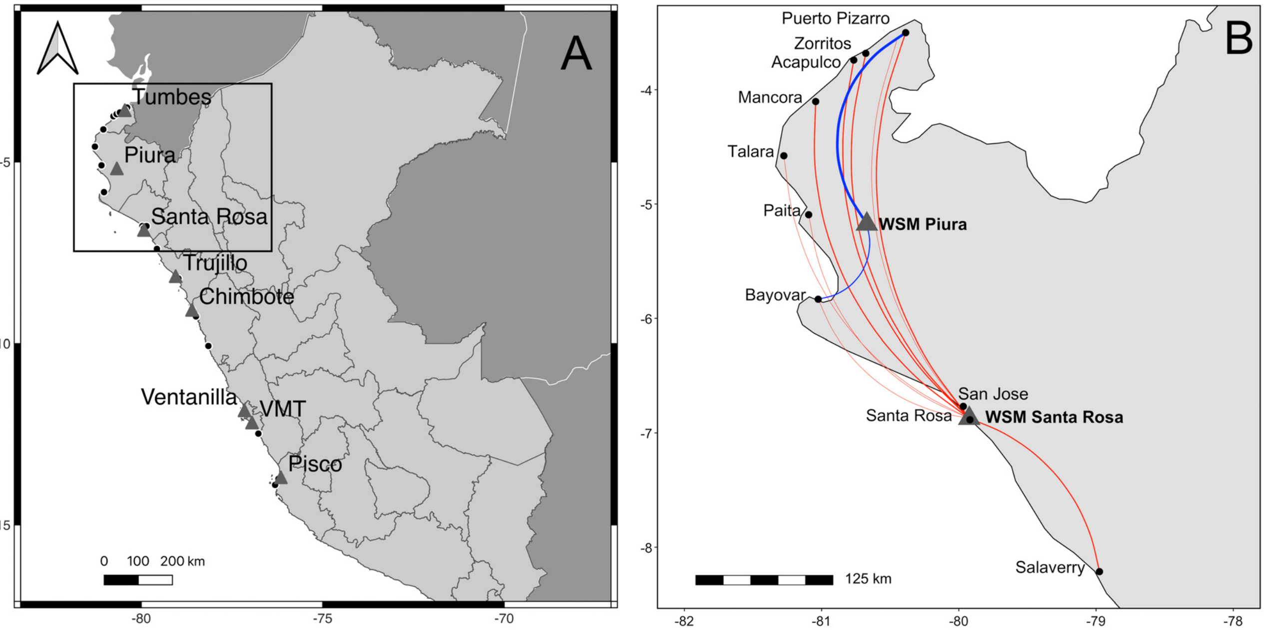

Fig. 4. National commerce of Pacific guitarfish in Peru between 2014 and 2020 (7 yr). Gray triangles: wholesale markets (WSMs) where Pacific guitarfish are sold; black circles: Pacific guitarfish collection sites. In (A), black rectangle represents the area where most of the Pacific guitarfish are sold (expanded in B). In (B), lines represent routes between collection sites and the WSMs of Piura (blue lines) and Santa Rosa (red lines); line thickness represents the importance of each route (by volume)

est in the mid-northern regions of the country. This pattern can be explained by the historical and traditional consumption of this species in both regions (Piura and Lambayeque), discussed in Section 6. This also indicates that mid-northern Peru is an important habitat for the Pacific guitarfish, as this species used to be very abundant — compared to recent decades — and supported the economic activities and livelihoods of Peruvians for millennia, yielding ancient cultural practices for its preservation and consumption.

The spatiotemporal dynamics of national landings and commerce assessed in this study suggest that the focus of overexploitation and consumption of the Pacific guitarfish is in mid-northern Peru. Mid-northern Peru has an ancestral tradition in the capture and consumption of the Pacific guitarfish that is still very strong. The most important WSMs are located in mid-northern Peru, where 97% of all volume is traded. Interestingly, northern Peru was the most important source (i.e. collection site) between 2014 and 2020, providing 66% of the volume traded. So even today, mid-northern Peru acts as an engine for the demand for this traditional resource, with fishing areas farther away to sustain their demand (i.e. Tumbes). This case for overexploitation in the mid-north is reinforced by the high effort and low landings in the mid-northern region compared with northern Peru. The largest population of fishers is in mid-northern Peru, with 12 141 fishers in 1995 and 25 526 in 2015, while in northern Peru, it was 2125 in 1995 and 5601 in 2015. Although the fisher population (indicative of fishing pressure) has been greater in mid-northern Peru, landings for the Pacific guitarfish have decreased (Castillo et al. 2018). All this evidence implies that Pacific guitarfishes are more depleted in mid-northern Peru, and that this area creates the largest demand for this species.

8. MANAGEMENT AND RECOMMENDATIONS FOR CONSERVATION

8.1. National Plan of Action and current fishery regulations

In the southeastern Pacific, Peru's National Plan of Action (NPOA) for the conservation and management of elasmobranchs (approved in 2014; El Peruano 2014) is the most recent management measure. In this NPOA, no specific priorities are established for the most caught species, yet the most caught species in Peruvian waters are mentioned, of which only 1 species of batoid is included (Peruvian eagle ray *Myliobatis peruvianus*). The Pacific guitarfish is only mentioned as one of the 35 species of elasmobranchs that interact with Peruvian fisheries. In 2018, the progress of the NPOA was evaluated. This evaluation found that the goals established for the 2014–2015 and 2016–2017 periods had not been fully met and that IMARPE (responsible for research), one of the largest institutions involved, had failed to meet 60% of programmed goals. Therefore, the NPOA should prioritize the most captured species, which includes the Pacific guitarfish, for its research and management. Due to the limited capacity of government institutions and the complexity of the problem, collaborations should be encouraged with universities, NGOs, and community-based efforts to halt the perilous situation of the Pacific guitarfish.

No specific regulation is in place for the management and conservation of the Pacific guitarfish. However, some fishery regulations might have improved its conservation within the first 5 nm from the coast. The government has prohibited the use of bottom trawling (within 5 nm from the coast) and mechanized (El Peruano 2001) and manual (El Peruano 2009) beach seines, both of which operate in the littoral zone. Beach seines (i.e. mechanized and manual) and trawling reported high landings for the Pacific guitarfish, but since 2009, national records from IMARPE stopped reporting trawl and beach seine landings. Yet, in northern Peru, illegal small-scale trawling — within 5 nm from the coast — and beach seines are known to occur (Ganoza et al. 2021), and landings take place at clandestine and isolated locations which are underreported by national authorities. However, clandestine landings that came from these prohibited fisheries most probably have a limited contribution to the overall catch, as landings during the period in which these were prohibited have stayed low without a marked difference (Fig. 1).

8.2. Area-based conservation

Investigating the spatial ecology of the species has direct application to spatial management, as the identification of key habitats is critical for effective conservation (Becerril-García et al. 2022). Towards that end, the IUCN Species Survival Commission Shark Specialist Group has developed the ISRA framework (Kyne et al. 2023). The ISRA approach identifies discrete 3-dimensional portions of critical habitat (e.g. reproductive, feeding areas) important for 1 or more shark species that have the potential to be delineated and managed for conservation (Hyde et al. 2022). The identification of ISRAs will guide the development, design, and application of area-based conservation initiatives for sharks, rays, and chimaeras and contribute to their recovery (Hyde et al. 2022).

A regional expert workshop in the Central and South American Pacific countries (which cover the range distribution of the Pacific guitarfish) identified 65 ISRAs, of which 2 belong to the Pacific guitarfish (Jabado et al. 2023). These 2 ISRAs are located in mid-northern (Piura and Lambayeque) and central (Lima and Ica) Peru (i.e. coastal northern Humboldt Current and central Peru Major Upwelling System, respectively) within the Humboldt Current LME (Jabado et al. 2023). These 2 ISRAs represent an important habitat for the Pacific guitarfish, as these function as feeding areas due to their food availability. These ISRAs overlap with an Ecologically or Biologically Significant Marine Area (EBSA) known as Upwelling Major Centers of the Peruvian Humboldt Current, which have been identified by the Convention on Biological Diversity (CBD 2020). Thus, these 2 ISRAs should be prioritized for the spatial management of the Pacific guitarfish in the eastern Pacific. Fishing pressure is high in the 2 ISRAs identified for the Pacific guitarfish, as these are traditional fishing zones in which the largest number of Peruvian landings have been registered. Therefore, fisheries management should prioritize these areas.

Other critical areas with vital functions (e.g. reproductive areas) are unknown. Rhino rays captured within their reproductive period or in the early life stages are most sensitive to capture mortality (Wosnick et al. 2019, Finotto et al. 2021, 2023, Prado et al. 2022). Therefore, future research should focus on identifying those critical habitats for the Pacific guitarfish to prioritize its spatial management (Pytka et al. 2023).

8.3. Recommended management measures

As the Pacific guitarfish is a target (mainly bottom gillnets) and bycatch (mainly trawling) species, fisheries management can include the following strategies (individually or integrated): modifying fishing gear (e.g. increase gillnet tension and adjust mesh size; use bycatch reduction devices and grids in trawl fisheries), modifying fishing methods (e.g. alter the case-specific depth and time of day of fishing), adopting temporal and spatial management measures (e.g. restrict fishing at spatial and temporal areas or periods with relatively high ratios of this species), adding input and output controls (i.e. limit fishing effort or catch), and releasing catch (Jorgensen et al. 2022). Further research would be needed to select which strategy is the best for the sustainable fishery of the Pacific guitarfish.

Technical modifications of fishing gear provide options for reducing bycatch in fisheries where utilization and trade do not necessarily drive retention or where legislative requirements prohibit retention (Pytka et al. 2023). In Peru, such is the case of commercial industrial trawling fisheries. For these fisheries, turtle excluder devices have been very effective at reducing shark and ray bycatch including rhino ray bycatch (Brewer et al. 2006, Campbell et al. 2021). Furthermore, proper handling and release are essential next steps (Pytka et al. 2023). This is important for rhino rays, as evidence has shown high survival rates among buccal pumping species in various gear types (Ellis et al. 2017, Wosnick et al. 2019, Prado et al. 2022). Therefore, it is advisable to increase policies towards safe release and the development of context-specific safe release guides (Grant et al. 2023, Pytka et al. 2023).

8.4. Management of social–ecological systems

Rhino rays are retained in fisheries for a variety of uses and trade which can support food security and livelihoods (Kyne & Jabado 2021). Incorporating the human dimensions by understanding the socioeconomic value of rhino rays for traditional fishing communities is key to proposing effective mitigation strategies (Pytka et al. 2023). Working with fishing communities to understand what drives retention or release will contribute to designing appropriate interventions aimed at behavioral change to reduce fishing mortality (Pytka et al. 2023).

Peruvian small-scale fisheries produce 96% of the seafood consumed domestically (Palacios-Abrantes et al. 2018). These fisheries will also likely continue to grow in importance, as Peru has one of the fastest rates of growth in fish consumption worldwide (FAO 2016), with mid-northern Peru — one of the most important regions for guitarfish fisheries — having the second highest fish consumption along the Peruvian coast (PRODUCE 2021). Peru also reports the highest fish consumption among the countries of the Eastern Pacific region (FAO 2016). The Pacific guitarfish has supported economic activities and livelihoods for millennia. Due to its low economic value, this species is most probably important for food security. Moreover, its fishery and consumption are intertwined with ancient cultural practices becoming traditional in mid-northern Peruvian cuisine. Therefore, managing the Pacific guitarfish fishery is much more than a biological and technical issue; it is also a human issue (Booth et al. 2019). As management is complex in small-scale fisheries, risk assessments are a crucial process to identify, analyze, and evaluate potential risks that will inform decision makers to mitigate those risks. Shark and ray fisheries require holistic management frameworks that integrate socioeconomic aspects from planning to implementation to monitoring (Booth et al. 2019). Therefore, risk-based shark and ray management should also include socioeconomic dimensions — as well as biological and technical dimensions — to identify the most problematic fisheries in terms of fishing mortality risk and strategic leverage points for maximizing conservation impact for guitarfishes while minimizing cost to people (Booth et al. 2019).

This species was once very abundant in Peru and has been steadily depleting for decades. Yet, Peruvians might be unaware of this perilous situation. Further studies should identify if Peruvians (local communities and managers) suffer from shifting baseline syndrome (SBS) (Pauly 1995). The consequences of SBS include an increased tolerance for progressive environmental degradation, changes in people's expectations as to what is a desirable state of the natural environment, and the establishment and use of inappropriate baselines for nature conservation, restoration, and management (Soga & Gaston 2018). This can be reduced by developing frameworks that incorporate earlier knowledge (e.g. traditional ecological knowledge) into the present models of fisheries (Pauly 1995). Earlier knowledge should be focused in areas where this species has been traditionally caught and consumed (i.e. mid-northern Peru). Recognizing a potential long trajectory of overexploitation is vital for protecting this endangered species. In this direction, education and awareness of the vulnerable situation of the Pacific guitarfish and its ancient cultural importance are key elements for the conservation of this species. Therefore, further studies should assess the use of this cultural heritage as a tool to promote the conservation of this symbolic species for northern Peruvians (Parsons et al. 2014).

8.5. Conservation status

The Pacific guitarfish had been little studied, and this was reflected in its listing as Data Deficient for 2 former assessments of the IUCN Red List (Lamilla 2004, 2016). The most recent assessment, however, has listed this species as Vulnerable as more information has become available (Kyne et al. 2020a). The latest assessment concluded that, due to the intensity of fishing pressure throughout its range and its susceptibility to capture, it is suspected that the Pacific guitarfish has undergone a population reduction of 30 to 49% over the last 3 generations (15 yr) due to the levels of exploitation. This review brings together historical information that could be used in future assessments of the IUCN Red List to update the conservation status of the Pacific guitarfish and justify a more threatened category.

9. CONCLUSIONS

Along its distributional range, between the coasts of southern México and northern Chile, Peru represents the most important habitat for the Pacific guitarfish. In this review, compelling evidence is provided to prove that high fishing pressure within jurisdictional Peruvian waters makes this species vulnerable to overexploitation, which is driving population decline. The coastal and accessible distribution of this medium to large fish provided an opportunity for early Peruvians who fished and consumed this guitarfish for millennia, developing a cultural and economic importance for the Pacific guitarfish that reinforced and drove its exploitation. Fishing effort has been progressively increasing through time without a species-specific fishery management. These factors, coupled with its low biological productivity, limited refuge from fisheries, and habitat degradation, have depleted the Pacific guitarfish population, and this trend is continuing. This calls for an urgent action to protect this member of the most threatened order of marine fishes. To help reduce its high risk of extinction, this review aimed to establish a baseline for the Pacific guitarfish and provide recommendations that researchers, policy makers, resource managers, and conservationists can use to promote the recovery of this iconic species.

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Appendix.

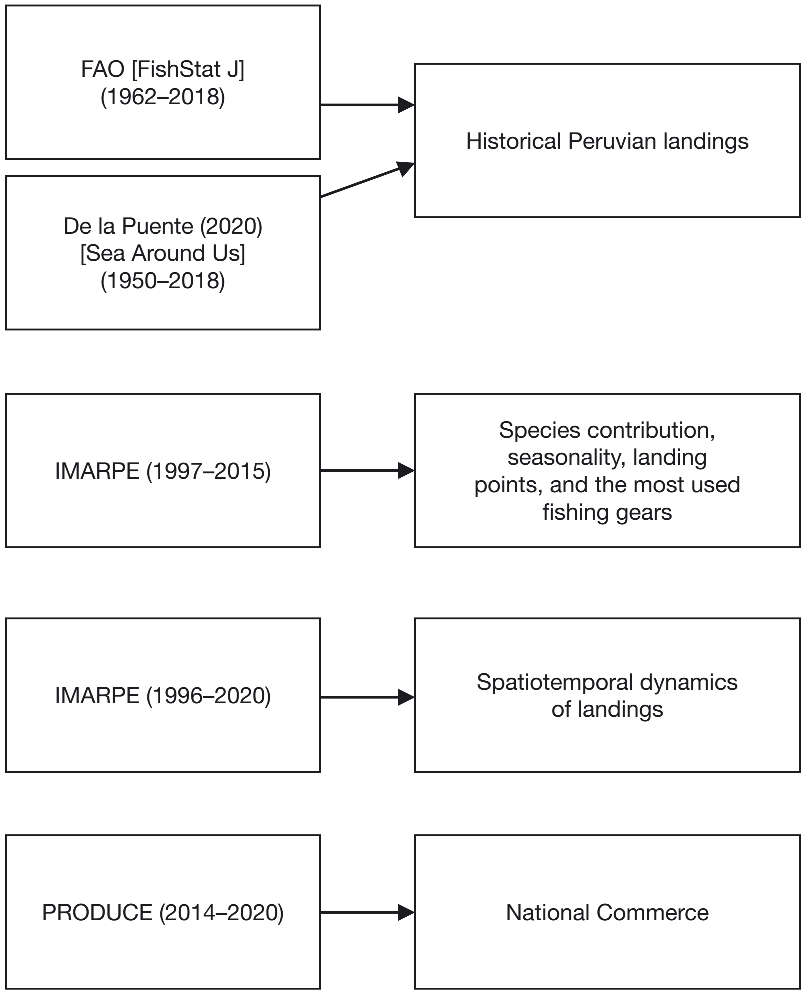

Fig. A1. Data sources and period for the corresponding topics

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