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REGULAR PAPER

The effect of Peruvian small-scale fisheries on sunfishes (Molidae)

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Reports were compiled of sunfish (family Molidae) by-catch in Peruvian small-scale fisheries and sunfish by-catch rates were estimated using data from shore-based and onboard monitoring programmes. A total of 114 sunfishes were reported in the longline and gillnet fisheries along the Peru coast from 2005 to 2017. Systematic monitoring effort of small-scale gillnets leads to an estimate of between 23 and 352 individuals captured annually by the fleet fishing from the northern port of Salaverry and central ports of Ancon and Chorrillos and suggests that the actual number captured by the Peruvian gillnet fleet is in the thousands of individuals. Thus, Peruvian small-scale fisheries have the potential to greatly affect populations of these still poorly studied species. Moreover, new occurrence locations are reported for the newly described *Mola tecta*, which was only observed south of 11° S. Because of physical similarities among *Mola* species it was difficult to identify sunfishes to the species level and thus further studies (*e.g.*, genetics) will be required to provide more detailed information on individual species vulnerability to by-catch in Peruvian waters.

KEYWORDS
by-catch, *Masturus lanceolatus*, *Mola*, *Mola tecta*, Molidae fishes, south-east Pacific Ocean

1 | INTRODUCTION

The Molidae, known as sunfishes, are found worldwide in tropical and temperate waters (Phillips *et al*., 2017) and are recognizable by their unique body shape and large adult body size. Even though sunfishes are considered the heaviest teleosts in the world and are subject to high levels of incidental catch (by-catch) worldwide, relatively little is known about their biology and ecology (Pope *et al*., 2010). The presence of some molids is still being reported in new areas (Todd & Grove, 2010) and previously known distribution ranges are being expanded (Palsson & Astthorsson, 2016). Moreover, recent genetic analysis revealed the existence of three species of *Mola* Koelreuter 1766 (*Mola* spp. A, B and C) (Yoshita *et al*., 2009; Yamanoue *et al*., 2010), which have now been recognized as *Mola alexandrini* (Ranzani 1839), *Mola mola* (L. 1758) and *Mola tecta* Nyegaard *et al*. (2017) (Nyegaard *et al*., 2018a; Sawai *et al*., 2018).

Of the five species of molids currently recognized, the ocean sunfish, *M. mola*, has been the most studied. Long thought to feed exclusively on gelatinous prey (Pope *et al*., 2010), *M. mola* now appear to have a more generalist diet, especially juveniles and sub-adults (Nakamura & Sato, 2014; Sousa *et al*., 2016). This being the case, Sousa *et al*. (2016) have suggested that they are likely to play an important role in coastal food webs. *Mola mola* was recently listed as Vulnerable by the IUCN as its numbers are considered likely to continue decreasing due to high rates of by-catch in various fisheries around the world (Liu *et al*., 2015). Much less is known about the other species of sunfishes, which are listed as Least Concern [*Masturus lanceolatus* (Liénard 1840) and *Ranzania laevis* (Pennant 1776)] or have not yet been assessed (*M. alexandrini* and *M. tecta*). Lack of understanding of basic sunfish biology and ecology highlights the need for increased information on their distribution and abundance, which is key to a better understanding of their ecosystem role and assessing how removal through fisheries by-catch may affect their populations.

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In the eastern Pacific Ocean, molid fishes, primarily *M. mola* have been reported as a common by-catch species in the California gillnet drift fishery for swordfish *Xiphias gladius* L. 1758 (Thys *et al*., 2015). However, records of sunfishes are scarce for the south-eastern Pacific Ocean (Alfaro-Shigueto *et al*., 2010; Britto, 2003) except for the Galápagos Islands, where a recent study identified an important sunfish hotspot (Thys *et al*., 2017). In Peru, *M. mola* and *M. lanceolatus* have been reported as by-catch in small-scale longline and gillnet fisheries (Alfaro-Shigueto *et al*., 2010). A third Molidae species, *R. laevis*, is also currently listed as occurring in Peruvian waters (Chirichigno & Cornejo, 2001), but no detailed assessment of the extent of by-catch of molid species has yet been conducted. Given the magnitude of fishing effort by Peruvian small-scale fisheries, in terms of the number of hooks and area of nets deployed (Alfaro-Shigueto *et al*., 2010), an assessment of molid by-catch is warranted.

In this study, fishery observer data from small-scale fisheries off Peru were used to: (a) identify Molidae species caught; (b) summarize Molidae sightings and fishery interactions reports; (c) provide a first estimate of fishery-level effects on sunfishes from this area. Such information could serve as a baseline for future detailed long-term studies that monitor how fisheries are affecting sunfishes in the area.

2 | MATERIALS AND METHODS

2.1 | Data collection

Data on molid sightings and by-catch were collected from small-scale longline and gillnet (driftnet) fisheries along the Peru coast from January 2005 to December 2017 through onboard and shore-based observer programmes (Table 1). The observed longline fisheries target dolphinfish *Coryphaena hippurus* L. 1758, blue sharks *Prionace glauca* (L. 1758) and mako sharks *Isurus oxyrhinchus* (Rafinesque 1810), while the gillnet fisheries target eagle rays *Myliobatis* spp., devil rays *Mobula* spp., sharks, *C. hippurus* and bonito *Sarda chilensis* (Cuvier 1832). Data were collected opportunistically in both longline and gillnet fisheries from 2005 to 2017 and systematically during 2013 on gillnet vessels based in Salaverry and from 2015 to 2017 on gillnet vessels based in Lima (Ancon and Chorrillos).

2.2 | Shore-based and onboard observer data

Shore-based observers were located at the ports of Constante, San Jose and Salaverry (Figure 1) and gathered information on the number of fishing trips conducted, the fishing areas used, target catch and marine megafauna sightings and by-catch events (*e.g*., small cetaceans, sea turtles, seabirds, sunfishes) through daily interviews with fishers upon landing and monitoring of dockside activity.

Onboard observers gathered information on fishing effort (km of net, number of hooks), date and location of all fishing sets and sunfish sightings and by-catch events during the fishing trips. Whenever possible, individuals were measured (total length, L_T) and the state (live or dead) and final fate of the individual captured sunfishes (*i.e*., retained, released alive, discarded dead) was recorded. Onboard observers monitored vessels based at the ports of Zorritos, Mancora, San Jose, Salaverry, Ancon, Callao, Chorrillos and Ilo (Figure 1).

2.3 | Data analysis

By-catch per unit effort (BPUE) from onboard observer data was calculated as sunfish catch per fishing trip and, to allow comparison with other studies, catch per net length (km) × net soak time (h) was also calculated for each driftnet set monitored systematically for sunfish by-catch between January 2015 and December 2017 at the ports of Ancon and Chorrillos. To estimate total number of sunfish individuals caught by the fleet of Ancon-Chorrillos during the study period, total fishing effort was estimated at those ports with data on total number of vessels obtained from the national census of small-scale artisanal fishers (Instituto Nacional de Estadistica e Informatica [INEI], 2012) and data on average net length per vessel and average sets per trip obtained in this study. Fishing effort for the Salaverry gillnet fleet was estimated using information on gillnet trips for *C. hippurus*, sharks and rays from a previous study (Mangel *et al*., 2010) and survey data collected in this study for *S. chilensis* fishing trips. Descriptive statistics are presented as mean ± SD or with 95% CI.

3 | RESULTS

3.1 | Species identification

A total of 114 sunfishes were incidentally captured (n = 106) or sighted (n = 8) by observers on small-scale longline and gillnet fisheries. Individual sunfish were rarely hauled aboard vessels and thus identification was mainly possible only to the family level (n = 60). Hauled sunfishes were categorized into two groups based on the clavus shape: rounded (*Mola* spp., n = 40) or with a projection (*M. lanceolatus*, n = 14; Figure 2). Close examination of physical features in photos of specimens with a rounded clavus was conducted when possible, leading to the identification of recently described *M. tecta* (n = 6; Figure 3). *Mola tecta* can be identified based on a combination of clavus features, specifically the presence of: (a) a rounded clavus with an indent; (b) a smooth band with pronounced back-fold at the indent; 5–7 small ossicles on the clavus edge (Nyegaard *et al*., 2018a), which were all present in the individuals examined. Four of these individuals were measured and ranged from 39.6 to 93.5 cm L_T. However, photographic evidence was not available for all individuals hauled. Because of this, individuals captured are reported as *Mola* spp., *M. lanceolatus* or unidentified Molidae. Additionally, even though reported to occur in Peruvian waters, no individuals of *R. laevis* were seen among the observed by-catch.

3.2 | Sunfish-fishery interactions

The majority of molid reports (53 out of 114) were from gillnet fishers based at the port of Salaverry, in northern Peru (Figure 1). Molids were captured or sighted year-round, especially in the austral summer (January–March) and spring (October–December; Figure 4) and in coastal as well as oceanic waters. Most of the records (77%) were from gillnet by-catch, with only 16% coming from longline by-catch

TABLE 1 Molidae sampling effort (shore-based or onboard) per port in Peru small-scale fisheries (gillnet or longline)

Port	n	Sampling coordinates S (°)	W (°)	Year	Fishery	Monitoring
Opportunistic monitoring						
Zorritos	4	03.66	80.62	2015	Gillnet	At sea
Mancora	6	04.08	81.07	2015	Gillnet	At sea
Constante	1	05.69	80.85	2010	Gillnet	Shore-based
San Jose	9	06.75	79.96	2010, 2013–2016	Gillnet	Both
Salaverry	30	08.23	78.98	2005–2012, 2014–2017	Both	Both
Callao	1	12.05	77.13	2007	Gillnet	At sea
Chorrillos	2	12.16	77.17	2014	Gillnet	At sea
Ilo	19	17.65	71.35	2005, 2007, 2009–2012, 2015–2016	Longline	At sea
Systematic monitoring						
Salaverry	23	08.23	78.98	2013	Gillnet	Shore-based
Ancon	13	12.44	78.35	2015–2017	Gillnet	At sea
Chorrillos	6	12.16	77.17	2015–2017	Gillnet	At sea

Note. Systematic monitoring effort was used to obtain capture per unit effort estimates.
n is the total number of Molidae reports per port.

(Table 2). Of the two groups of molids found in Peruvian waters, *Mola* spp. were more abundant (n = 40), while only 14 individuals of *M. lanceolatus* were identified (Table 2). Information about the state (live or dead) of the individuals was available for 52 sunfishes. Of these, 61% were captured and subsequently released alive or sighted alive. Among those sunfishes observed dead (n = 7), two were retained for sale, two were discarded dead and for three their post-capture fate was unknown.

Mola spp. were the most abundant species group captured, based on those individuals that were conclusively identified. Sharptail sunfish *M. lanceolatus* were rarely encountered in the area and all individuals were reportedly captured in central and northern Peru, from 6.75–16.20° S to 77.51–80.20° W (Figure 1). Five of the six *M. tecta* individuals were reported as by-catch in longline fisheries based at the port of Ilo (17.65° S, 71.35° W) in southern Peru and one was incidentally captured in gillnets in central Peru (11.56° S, 78.01° W; Figure 1).

3.2.1 | Fishing effort and sunfish by-catch from shore-based observer data

Shore-based observers gathered data from 641 gillnet trips targeting *S. chilensis*, *C. hippurus*, sharks and rays conducted at the port of Salaverry during 2013. Approximately 4% of gillnet trips reported sunfish by-catch with a total of 23 individuals reported caught during the austral summer and spring 2013. The gillnet fleet at this port consisted of 66 vessels (INEI, 2012). On average, gillnet vessels conduct a total of 668 trips per year in Salaverry; thus, the number of surveyed trips (641) and sunfish by-catch reported by shore-based observers in this study probably represents the total annual number of sunfishes reported as incidentally captured in Salaverry.

3.2.2 | Fishing effort and sunfish by-catch from onboard observer data

Onboard observers systematically monitored for molids on 60 gillnet trips (740 sets) targeting *C. hippurus*, sharks and rays, from January 2015 to December 2017 on vessels from the ports of Ancon and Chorrillos. The mean (± SD) number of sets per trip was 12.3 ± 2.4. Total net length per set deployed averaged 3.5 ± 0.7 km and average gillnet soak time was 14.3 ± 1.0 h. The fleet of driftnet vessels in Ancon and Chorrillos comprised 64 and 6 vessels, respectively (INEI, 2012). Average trip duration of driftnet vessels monitored was 14.3 ± 1.1 days, thus vessels are estimated to have conducted about two trips per month during the fishing season (10 months) for the years 2015 to 2017. Total annual effort for the driftnet fleets in Ancon and Chorrillos was estimated to be 35,158 $[\text{km} \times 24\ \text{h}]^{-1}$.

Sunfish by-catch (n = 19) was reported in 25% of the trips monitored. The number of molids captured remained constant and constituted <1% of the total catch in all years (Table 3). Individuals were caught almost year-round, but with most sunfishes caught during the austral autumn (April to June). Mean (±SD) BPUE was 0.01 ± 0.07 animals per [km × 24 h] or 0.24 ± 0.10 molids per trip. Most captured individuals (77%) were released alive. Given the total effort estimated for the fleet of 70 vessels in Ancon and Chorrillos, 352 (221–615 95% CI) sunfishes were estimated to be taken as by-catch annually from 2015 to 2017 and of those, approximately 81 individuals are estimated killed of which 23 were retained for sale.

4 | DISCUSSION

Reports of Molidae in the south-east Pacific Ocean are rare, except in the Galapagos Islands (Phillips *et al*., 2017). Much less information is available on the effect of small-scale fisheries in this area on sunfishes, fisheries that are known to have notable effect on other marine megafauna, such as sea turtles (Alfaro-Shigueto *et al*., 2010) and small cetaceans (Mangel *et al*., 2010). This study provides novel by-catch estimates for sunfishes in the south-east Pacific Ocean and reveals the presence of the newly described species *M. tecta*.

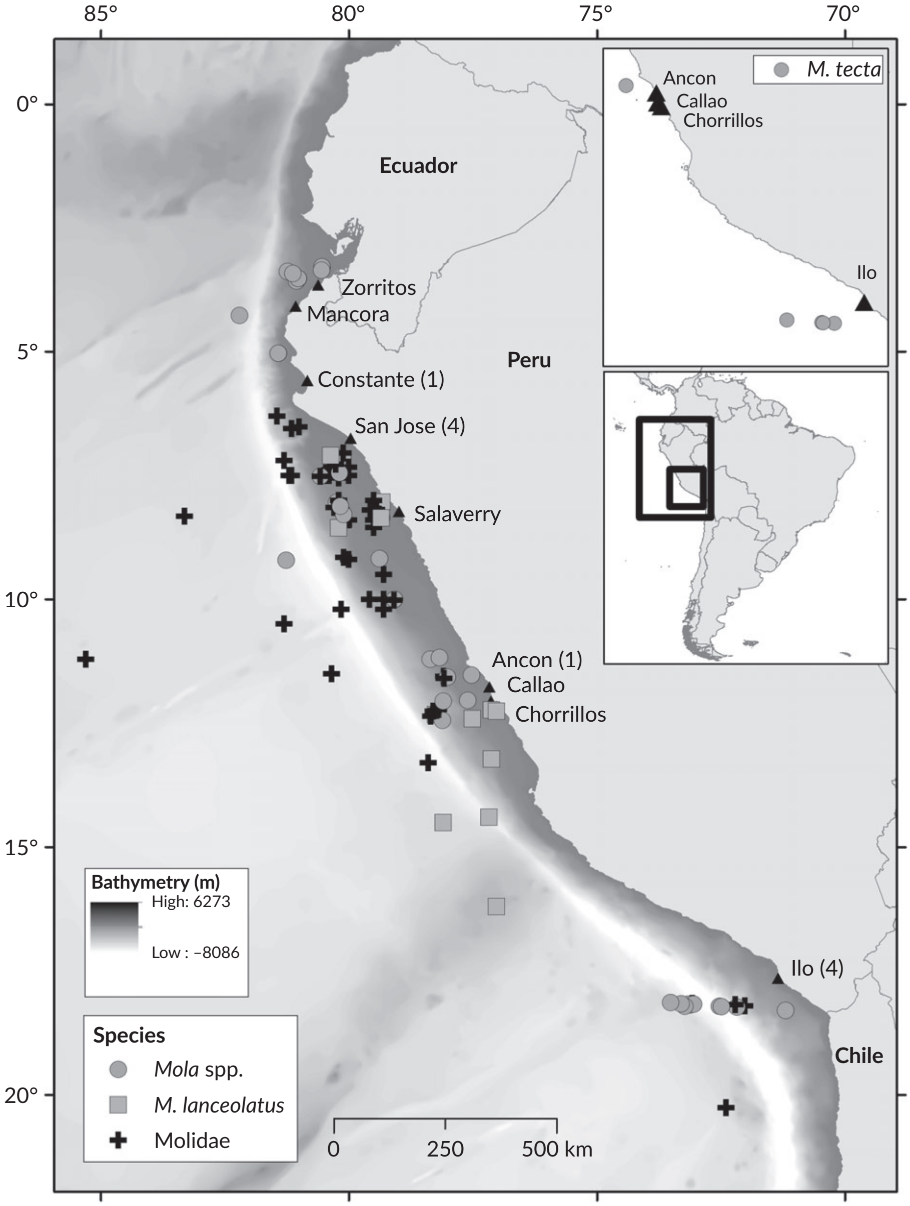

FIGURE 1 Ports (▲) where information was gathered on the locations of Molidae (*Mola* spp. and *Masturus lanceolatus*) by-catch and sightings reports in Peruvian waters from 2005 to 2017. Reports with no exact location are given in parentheses at the respective ports. Upper inset map shows the locations of *M. tecta* individuals incidentally captured

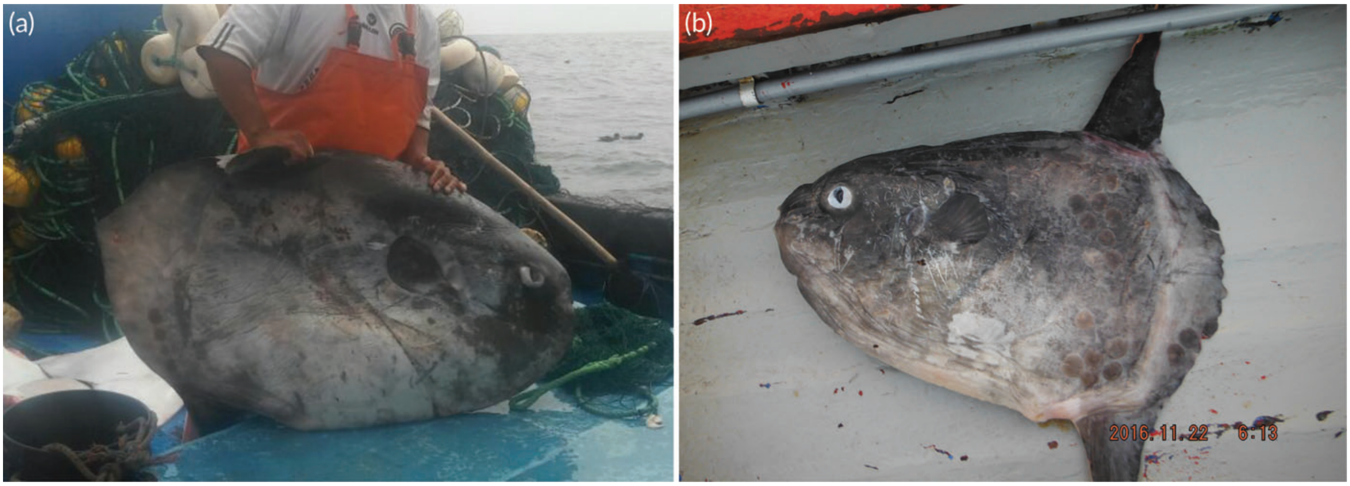

FIGURE 2 Molidae incidentally captured in Peruvian small-scale fisheries: (a) *Masturus lanceolatus* and (b) *Mola* sp

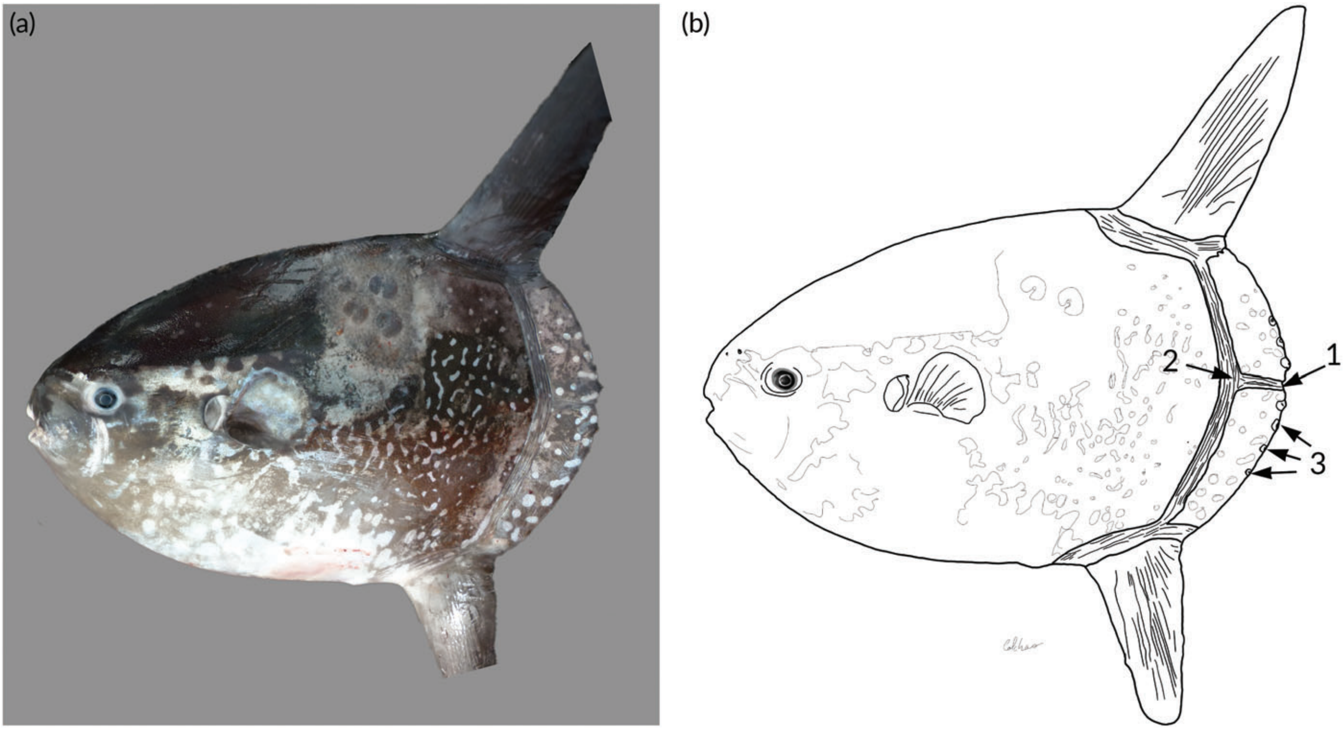

FIGURE 3 *Mola tecta* captured in Peruvian small-scale fishery: (a) photographed (tips of the dorsal and anal fins are missing from original photo) and (b) drawing to show: 1, a rounded clavus with an indent; 2, a smooth band with pronounced back-fold at the indent; 3, 5–7 small ossicles on the clavus edge (Nyegaard *et al*., 2018)

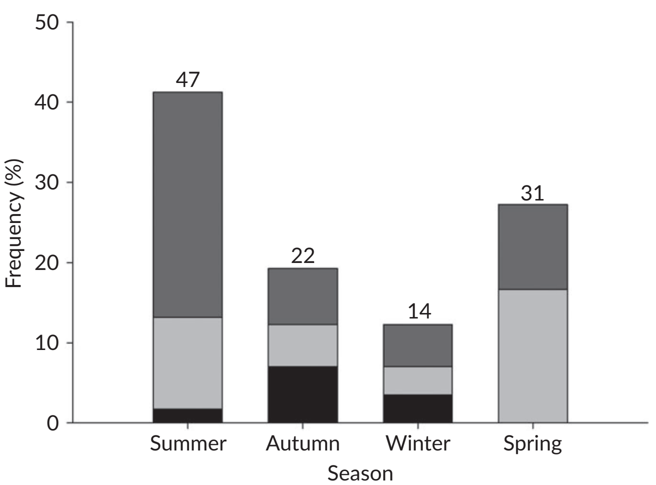

FIGURE 4 Seasonal frequency distribution of small-scale fishery Molidae by-catch from monitoring reports from nine ports along the Peruvian coast 2005 to 2017; reports combine all shore-based and systematic onboard observer records. *Mola* spp. includes the identified *M. tecta*. Numbers above histograms are number of individuals reported. UID, unidentified. (■) *Masturus lanceolatus*, (□) *Mola* spp. and (■) UID. Molidae

4.1 | Small-scale fisheries interactions of sunfishes in Peru

The low percentage (<1%) of sunfishes caught annually in relation to the total catch in the Peru small-scale gillnet fishery (*c.* 352 estimated sunfishes caught annually at one fishing area in Peru) is considerably lower than for the Californian *X. gladius* gillnet fishery (*c.* 6,000 individuals year^{-1}; NMFS, 2013), where sunfishes comprised 29% of the total catch (Cartamil & Lowe, 2004). High by-catch numbers have also been reported in driftnet fisheries in the Mediterranean, where sunfishes represented up to 93% of the catch (1,737 individuals; Silvani *et al*., 1999) and in the South African midwater trawl fishery for Cape horse mackerel *Trachurus capensis* Castelnau 1861 where *c.* 50% of all by-catch consisted of sunfishes (S. Petersen & Z. McDonell, unpublished data, 2007).

Nevertheless, the fleet sizes in the ports of Salaverry, Ancon and Chorrillos represent *c.* 9% (136 out of 1580) of the Peruvian small-scale gillnet fleet (INEI, 2012), for which annual fishing effort is conservatively estimated to exceed 100,000 km of fishing nets used and is several times larger than those of the now closed Taiwanese and Mediterranean Sea driftnet fisheries (Alfaro-Shigueto *et al*., 2010). Thus, it is possible that the effect of the Peruvian small-scale fishery, at the national level, may be considerable (*i.e.*, of the order of thousands of sunfishes captured annually) and may represent a significant fishing mortality on the sunfish populations in this area. Even though most sunfishes observed in this study were released alive, they could have experienced fishery-induced trauma such as loss of protective mucus coating, abrasions and bleeding, which have been observed in molids captured in driftnets elsewhere (Cartamil & Lowe, 2004). However, no information is yet available on the post-capture survival rates of sunfishes released from gillnets or longlines.

Differences were noted in the annual sunfish gillnet by-catch estimates between the central Peru ports of Ancon and Chorrillos and the northern Peru port of Salaverry, the two areas monitored systematically in this study. While these by-catch assessments relied on different monitoring methods (shore-based *v.* onboard observer), it is possible that they could also be reflecting differences in temporal or behavioural patterns of sunfishes. By-catch events reported for Ancon

TABLE 2 Summary of Mollidae by–catch and sightings (listed under other) per fishery: Information on the condition and fate (live or dead, retained, released or discarded) of sunfishes were from a subset of individuals captured or sighted in gillnets and longlines (*n* = 52)

				Fate (%)						
				Live				Dead		
Report source	Group or species	Total reported	n	Retained	Released	Unknown	Other	Retained	Discarded	Unknown
Bycatch										
Gillnet	*Mola* spp.	25	22	–	50 (11)	36 (8)	–	–	9 (2)	5 (1)
	Mola tecta	1	1	–	–	–	–	–	100 (1)	–
	Masturus lanceolatus	12	10	–	50 (5)	30 (3)	–	10 (1)	–	10 (1)
	UID Molidae	51	7	–	71 (5)	14 (1)	–	14 (1)	–	–
Total gillnet		88	39		54 (21)	31 (12)		5 (2)	5 (2)	5 (2)
Longline	*Mola* spp.	13	4	–	50 (2)	25 (1)	–	–	–	25 (1)
	M. tecta	5	2	–	33 (1)	33 (1)–	–	–	–	33 (1)
	M. lanceolatus	1	–	–	–	–	–	–	–	–
	UID Molidae	4	1	–	100 (1)	–	–	–	–	–
Total longline		18	5		60 (3)	20 (1)				20 (1)
Sightings										
Gillnet fishery	*Mola* spp.	1	1	–	–	–	100 (1)	–	–	–
	M. lanceolatus	1	1	–	–	–	100 (1)	–	–	–
	UID Molidae	3	3	–	–	–	100 (3)	–	–	–
Longline fishery	*Mola* spp.	1	1	–	–	–	100 (1)	–	–	–
	M. lanceolatus	–	–	–	–	–		–	–	–
	UID Molidae	2	2	–	–	–	100 (2)	–	–	–
Total sightings		8	8				100 (8)			
Grand total		114	52	–	46 (24)	25 (13)	15 (8)	4 (2)	4 (2)	6 (3)

Note. UID: Unidentified molids.

and Chorrillos, in central Peru, occurred during the intense 2015–2016 El Niño southern oscillation (ENSO) event (National Oceanic and Atmospheric Administration [NOAA], 2018). Studies have reported changing distributions of several fishes including *M. mola* during ENSO events (Lluch-Belda *et al.*, 2005; Sielfeld *et al.*, 2010). Thus, it is likely that the 2015–2016 ENSO would have affected sunfish distribution in Peruvian waters. In this study, the numbers of marine megafauna captured appeared to vary, with higher numbers of *C. hippurus*, tuna (Thunnidae) and barracuda *Sphyraena barracuda* (Edwards 1771) being caught during the ENSO event. However, even though no changes in the number of sunfishes captured from 2015 to 2017 were observed, sunfish by-catch during the 2015–2016 ENSO occurred during the autumn and winter months while in 2017 most individuals were captured in the summer. This may have been related to changes in temperature or food availability driven by the ENSO event that can affect the distribution and composition of the Peruvian marine communities, from plankton to teleosts (Taylor *et al.*, 2008), which some sunfishes are known to prey upon (Sousa *et al.*, 2016).

TABLE 3 Total number of individuals of each group of mega fauna or species caught during small-scale gillnet trips (*n* = 60) systematically monitored from 2015 to 2017 in the ports of Ancon and Chorrillos

Group or species				
Common name	Scientific	2015	2016	2017
Sharks	Selachimorpha	204	387	515
Rays	Batoidea	9	2	2
Dolphin fish	*Coryphaena hippurus*	688	1337	271
Swordfish	*Xiphia gladius*	18	52	17
Tunas	Thunnidae	9	539	126
Barracuda	*Sphyraena barracuda*	11	123	53
Sailfish	Istiophoridae	22	46	75
Marlin	Istiphoridae	26	18	10
Mammals	Mammalia	9	20	25
Sea turtles	Chelonioidea	13	30	11
Sunfishes	Mollidae	7	6	6

Moreover, it is likely that given the changing oceanographic conditions during the ENSO event that certain sunfish species may have been more prevalent than others, as sunfish species appear to exhibit separation in their distribution due to environmental factors (Nyegaard *et al.*, 2018b). Various satellite tracking studies have revealed the influence of temperature and food availability on the seasonal movements of *M. mola* in the North Pacific Ocean and North Atlantic Ocean basins (Dewar *et al.*, 2010; Potter *et al.*, 2010; Sims *et al.*, 2009; Sousa *et al.*, 2016; Thys *et al.*, 2015) and of *M. alexandrini* in the eastern tropical Pacific Ocean (Thys *et al.*, 2017). For instance, in Japan *M. alexandrini* are found using, on average, waters with higher temperatures than those where *M. mola* occur (19.9 *v.* 17.7°C; Sawai *et al.*, 2011). Similarly, a study based on observer data also revealed temperature separation between *M. alexandrini* and *M. tecta*, the former found in more subtropical–warm temperate waters than the latter (Nyegaard *et al.*, 2018b). In this study, almost all *M. lanceolatus* reportedly captured in systematically monitored trips occurred during autumn and winter months of the 2015–2016 ENSO and only one individual was captured in May of 2017. However, more than half of the sunfishes caught almost year-round were not identified to the species level, which may be masking any seasonal differences in the occurrence or by-catch of the various sunfish species. It is possible though that the distribution and year-round by-catch of sunfishes may be linked to the habitat preferences of the different molid species.

It is reasonable to expect also that by-catch estimates at one or two ports may not be representative of the small-scale gillnet fishery as a whole. However, it is possible that by-catch numbers may have been underestimated when using the shore-based monitoring method. For instance, by-catch estimates for sea turtles at two ports in Peru showed discrepancies, where CPUE values obtained through interview surveys underestimated the number of turtles captured compared with estimates obtained using onboard monitoring programmes (Alfaro-Shigueto *et al*., 2018). Thus, while shore-based data can provide valuable initial information, future observer data will allow for validation of the by-catch estimates acquired through shore-based monitoring in this study.

Although sunfish by-catch events in longlines were scarce, this is due in part to sporadic observer effort in this study for that fishery. The estimated annual effort for small-scale longline fisheries in Peru is 80 million hooks (Alfaro Shigueto *et al*., 2010). Thus, sunfish by-catch could still be considerable and represent another source of fishing pressure on molids in the area. No direct take of sunfishes was observed, but at least two dead by-catch individuals were retained to be sold for human consumption. Interestingly, fishers stated that they do not consume sunfishes themselves because of the heavy parasite load these fish exhibit, but some fishers are apparently willing to occasionally land the fish for sale.

4.2 | *Mola tecta* in Peru

The newly described *M. tecta* is thought to be widely distributed in temperate waters of the southern hemisphere (Nyegaard *et al*., 2018a). The report here of *M. tecta* in Peruvian waters adds a new occurrence location for the species in the south-east Pacific. Photographic evidence also suggests its presence in Chilean waters (Nyegaard *et al*., 2018a), but no other records of *M. tecta* have been reported north of 11° S (this study) in the south-east Pacific Ocean, not even in the Galapagos Islands where a recent genetic study revealed the prevalence of *M. ramsayi* (Thys *et al*., 2013), which, based on key morphological characters observed, corresponds to the recently redescribed *M. alexandrini* (Sawai *et al*., 2018). The limited distribution of *M. tecta*, mainly in southern Peru waters reported here, supports the idea that they are probably distributed in temperate waters (Nyegaard *et al*., 2018a,b).

The physical similarities between all three *Mola* species have led to the misidentification of *M. tecta* and *M. alexandrini* as *M. mola* (Nyegaard *et al*., 2018a; Sawai *et al*., 2018; Thys *et al*., 2017). *Mola mola* has been reported in Peruvian waters (Chirichigno & Cornejo, 2001) and a specimen of the species is exhibited in the Museum of Natural History of Lima and it was assumed that this was the only species of *Mola* present in the area. However, although *M. alexandrini* has not been reported in Peruvian waters before, it is likely this species is also using these waters as it has been reported off Chile (Brito, 2003) and the Galapagos Islands (Thys *et al*., 2013). Both *M. mola* and *M. alexandrini* share physical similarities (Sawai *et al*., 2018) and it is possible that some of the unidentified individuals with a rounded clavus could have been *M. alexandrini*.

In this study, *M. tecta* were mistaken for *M. mola* when first observed directly and were only recently correctly identified after close inspection of photos, when the indent in the rounded clavus, as well as other clavus features, were evident. However, photos were not available for every captured sunfishes with a rounded clavus, thus it was not possible to determine how common the by-catch of *M. tecta* is in Peruvian small-scale fisheries.

4.3 | Future directions

Due to the physical similarities among *Mola* species, a comprehensive morphological and genetic study of the *Mola* population present in Peruvian waters is needed and will allow for the determination of the prevalence of *M. mola or M. tecta*, or whether *M. alexandrini*, present in Chile (Brito, 2003) and the Galapagos Islands (Thys *et al*., 2013), also occurs in Peruvian waters. This information will be important for assessing which of these species is most vulnerable to fisheries in Peruvian waters.

Additionally, even though most sunfishes were caught and released alive, future studies should also assess the post-release mortality rates of sunfishes, such as through the use of satellite tracking, which could help to better understand the effect of injuries to released sunfishes. Such information has proved useful in evaluating survival of incidentally captured fishes such as *P. glauca* (Moyes *et al*., 2006) and other marine megafauna including sea turtles (Mangel *et al*., 2011).

This study describes the potential effects of the Peruvian small-scale gillnet fishery on Molidae. However, molids also appear to be interacting with other fisheries such as the Peruvian industrial purse-seine anchovy *Engraulis ringens* Jenyns 1842 fishery (R. Vinatea, September 2018, personal communication), the largest single species fishery in the world by capture tonnage (Fréon *et al*., 2014). No data on capture or mortality rates are available yet, but there is evidence of by-catch of juvenile and adult-size Molidae in this fishery. Unlike small-scale gillnet and longline fisheries, data on by-catch of endangered and threatened species or other marine megafauna are rarely reported for industrial or small-scale purse-seine fisheries in Peru. Recently, similar systematic monitoring efforts such as those presented in this study for vulnerable and protected species, including sunfishes, are currently underway in the industrial purse-seine fishery (TASA, 2017) and results will add to our understanding of fisheries on sunfishes in the south-east Pacific Ocean. Nevertheless, sunfishes as well as other large marine vertebrates such as seabirds, marine mammals and sea turtles are not reported when incidentally captured or considered as by-catch in many fisheries, including the industrial purse-seine anchovy fishery. For instance, Peruvian legislation regulating the *E. ringens* fishery relates by-catch to under sized – *E. ringens* or other fishes [*e.g.*, hake *Merluccius gayi* (Guichenot 1848); El Peruano,

2018) but there is no mention of other accompanying endangered marine megafauna or how to report this type of by-catch. Evaluating the effect of various types of fisheries on these unreported and under-reported marine megafauna, many of which are threatened or endangered, will not only help understand the effect of fisheries on their populations, but also how sunfish removal affects their role in their ecosystems. This type of knowledge helps managers and scientist focus efforts to mitigate fisheries effects on non-target species. This is an important step towards securing the sustainability of Peruvian fisheries.

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CONFLICTS OF INTEREST

The authors have no conflict of interest.

Contributions

J.C.M. and J.A.S. conceived and implemented the study; J.C.M. and M.P. wrote the paper with input from all authors; M.P. and E.S. performed the calculations and analysed the data; and G.V. and A.P. contributed with data collection and processing.

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