Marine Policy 121 (2020) 104193

Contents lists available at ScienceDirect

Marine Policy

journal homepage: http://www.elsevier.com/locate/marpol

Assessing the economic impact caused by South American sea lions based on onboard check versus fishermen's perception: The two sides of the same coin

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A B S T R A C T

Conflicts with fisheries are the major threat to South American sea lions (*Otaria flavescens*). The understanding of the gap between perceived economic impact by the fishermen and actual impact on the activity is crucial to avoid retaliations to the species. This is the first study conducted in Brazil that simultaneously assessed these both aspects of this complex issue. To assess the fisheries economic revenue and economic loss caused by sea lions, we conducted 58 onboard surveys between 2011 and 2012, covering 161 fishing operations. To assess socio-economic characteristics, perceptions of economic loss caused by the sea lions, and temporal changes in the fishing activity, we interviewed one hundred fishermen. Onboard observations indicated that sea lions interact with fishing boats throughout the year. This finding is in agreement with the reports of most fishermen (69%) who believed that this interaction occurs every day and the species is always present during fishing operations (80%). On the other hand, while onboard surveys revealed that only 3% of loss in the annual productivity was due to predation by sea lions (~US$ 1931.00 out of total catch of US$ 62,279.00), fishermen assigned a disproportionate economic loss to sea lions: 88% of the respondents believed that each sea lion consumed around 100 kg of fish per interaction. This misperception and consequent conflict would decrease if fishermen were aware of the actual losses caused by sea lions. To mitigate conflict, an effective communication strategy and open dialogue between fishermen and the local marine Consulting Council is recommended.

1. Introduction

The last two centuries have witnessed the decline of various populations of marine birds, reptiles and mammals that interact with people during fishing activities [1,2]. This is partially driven by a growing human population and its consequent increased demand for fishing products [2,3]. Interactions between pinnipeds (seals, walruses, fur seals and sea lions) and fishing activities, can be either operational or biological [4,5]. In operational interactions, pinnipeds can damage the captured fish and the fishing nets, get entangled in discarded fishing gear, or suffer aggression from fishermen [4,5]. Biological interactions, in contrast, refer to the indirect effects of competition for fishery resources [4–7].

Along the coast of South America, the only pinniped that interacts with all types of fisheries is the South American sea lion, *Otaria flavescens* (Shaw, 1800) [7], hereafter referred to as sea lions. Operational interactions between sea lions and fishermen are usually associated with the use of gillnets (in Peru [8], Chile [9], Argentina [6,7], Uruguay [10,

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https://doi.org/10.1016/j.marpol.2020.104193
Received 2 September 2019; Received in revised form 14 August 2020; Accepted 20 August 2020
Available online 6 September 2020
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11] and Brazil [12]), purse seine (in Chile [13–15] and Argentina [16]), trawls (in Chile [17], Argentina [6,18] Uruguay [19] and Brazil [20]), longlines (in Peru [8], Chile [21] and Uruguay [10]) and even salmon farms (in Chile [22,23]). Important prey items in the diet of the sea lions are fish of economic importance for fishing activities in southern Brazil [12,24,25], notably *Cynoscion guatucupa* (Cuvier, 1830), *Macrodon atricauda* (Günther, 1880), *Micropogonias furnieri* (Desmarest, 1823), *Umbrina canosai* (Berg, 1895), *Paralonchurus brasiliensis* (Steindachner, 1875), *Pomatomus saltatrix* (Linnaeus, 1766), *Urophycis brasiliensis* (Kaup, 1858) and *Trichiurus lepturus* (Linnaeus, 1758) [26]. The *U. canosai*, for instance, is responsible for more than half of the landings of local marine fish [31]. All these species are currently facing over-exploitation, while pelagic fish species such as *Mugil liza* (Valenciennes, 1836) and *P. saltatrix* are at the limit of their capacity for exploitation [31].

Coastal demersal fishing in southern Brazil has intensified since the 1970s [12,24,25,27,28], resulting in a decreased population and body size of these target species [29–31]. As a collateral result of this scenario, fishermen tend to see the sea lions as competitors for the same resources [12,32]. Fishermen in general believe that their fish production could decrease because of sea lion's predation, thus causing great economic damage for local fisheries [33]. Interactions between sea lions and fisheries have been observed for decades in southern Brazil [12,20, 34–36], mainly close to the Wildlife Refuges of Ilha dos Lobos (WRIL) [12,33]. The WRIL is a marine protected area (MPA) used regularly during austral winter and spring months [37] as a haulout site for sea lions and South American fur seals, *Arctocephalus australis* (Zimmermann, 1783). Despite the available literature, few studies have evaluated the economic aspect of these interactions, precluding a better understanding of the magnitude of these losses [9,33]. Pont et al. [33] reported an exaggerated perception of damage among local fishermen as well as an exaggerated perception of the economic loss caused by these interactions with the sea lions. According to these authors, distorted perceptions are likely to be the most important driver of human-sea lion conflict in the region. Despite the awareness about this conflict [33], there has been no analytical or detailed quantitative study about the economic losses that could be considered as evidence that sea lions are, in fact, causing significant economic impact on the local fisheries.

This is the first study to simultaneously examine fishermen's perception and actual economic losses caused by sea lions in Brazil and represents a methodological innovation in marine mammals monitoring interactions. In order to contrast actual economic loss and perceived impact, we assessed the fisheries' revenue and the actual financial damage caused by the species, and evaluated fishermen's knowledge about sea lions, and their perceptions of conflict. We hypothesized that the perceived economic impact of sea lions on local fisheries is higher than the actual loss. In addition, we predicted that perceptions of fish consumption, intensity of attacks on fishing nets, and frequency of interactions with sea lions are greater than that documented by onboard survey.

2. Material and methods

2.1. Experimental design

This study was divided in two lines of action: onboard surveys and interviews. This approach was used in order to compare real and perceived economic losses caused by sea lions during the same period of time and in the same region:

1) From April 2011 to March 2012: one onboard researcher (RM) monitored local fishing operations in boats from Torres/Passo de Torres harbor (see details in study area section), in order to assess the frequency of interactions between sea lions and local fisheries, as well as the levels of fish predation and economic loss caused by the sea lions. The assessment of the intensity of attacks on fishing nets and productivity of each fishing boat by the onboard researcher allowed us to estimate the economic losses caused by sea lions in the region.
2) From October 2011 to February 2012: two social researchers (ACP and MTE) were introduced by the onboard researcher (RM) to 100 fishermen from the same fishing boats monitored. Face-to-face interviews were then conducted with these fishermen, in order to assess their perceptions of the economic loss caused by sea lions to the local fishing as well as their knowledge about sea lions in the region. The questions were designed to evaluate the beliefs about and attitudes toward the conflict, as well as the perceptions about the current situation of the fishing activity locally.

The time-lapse of six months between the start of the onboard surveys and of the interviews was due to the need of the onboard researcher to establish a relationship of trust with the local fishermen before introducing the interviewers to them. It is important to mention that onboard surveys continued during the time that the interviews were conducted, ending only one month after the last interview.

Our hypothesis is that the perceived economic impact of sea lions on fisheries is higher than the actual loss recorded by the onboard researcher. We also expected that perceptions of fish consumption, intensity of attacks on the nets, and frequency of interactions with sea lions reported by the fishermen to the interviewers to be greater than that documented during the onboard surveys. In order to test this hypothesis, we collected information during onboard surveys about characteristics of the fishing operations (e.g. effort, target species, productivity), of sea lion interactions (number, age class and frequency of sea lions interacting with the fisheries) as well as about fishermen's perception, knowledge and attitudes towards the sea lions. Finally, we compared the results of economic losses estimates based on onboard data and fishermen's answers.

2.2. Study area

Data were collected in the fishing community of Torres/Passo de Torres (29°19′S; 49°43′W), located at the border of Santa Catarina State (SC) and Rio Grande do Sul State (RS), southern Brazil (Fig. 1). The southern Brazilian coast is one of the greatest regions in terms of fishing potential in the country [38]. The main type of fishing activity by the local fleet in this area is medium-scale gillnet fishing [12,24,25]. According to the local fishermen's association, in November 2012, this community had approximately 350 fishermen, and 30 active vessels: 15 boats longer than 14 m (with trip autonomy of 10 days and capacity for nine fishermen); 14 boats with 10–14 m long (with five days of autonomy and capacity for seven fishermen); and one boat smaller than 10 m long (with an autonomy of two days and capacity for four fishermen) (data collected in the present study).

The fishing community is roughly 2 km away from the WRIL. The WRIL was established in 1983 as an MPA (equivalent to IUCN's category III [39]), and in 2005 it extended its protected area to a no-take zone (NTZ) of 500 m around the island [39]. Around 150 sea lions use the WRIL as a winter haulout site [40]. Due to this geographical proximity to the fishing community, sea lions usually follow the fishing boats when they depart for fishing. Consequently, interactions between sea lions and fishermen are inevitable [33]. For a comprehensive description of the study area and the fishing activity of Torres/Passo de Torres see Machado et al. [12].

2.3. Onboard surveys

In order to evaluate the frequency of interactions with sea lions and local fisheries during the study period, as well as intensity of attacks on fishing nets, we conducted 58 onboard surveys in 10 medium-scale gillnet fishing boats. Onboard surveys were considered fishing trips that lasted from one to three days (mode = 1). In this study, it

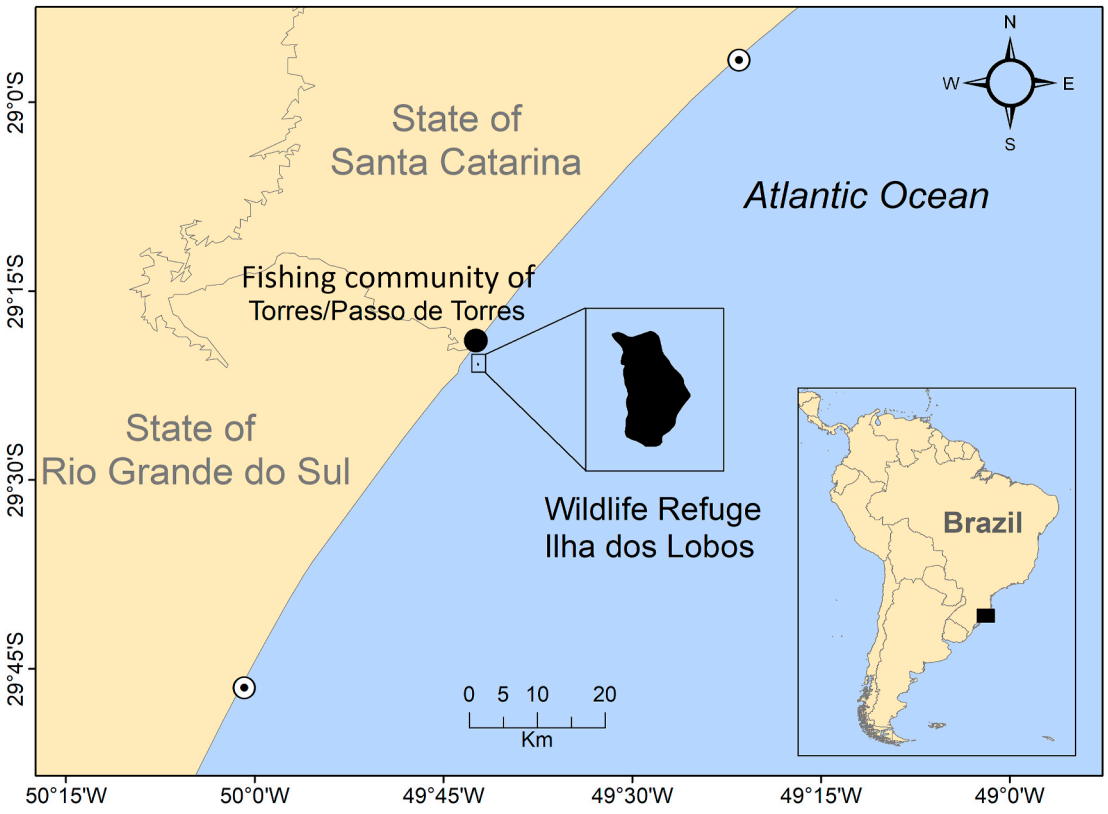

Fig. 1. Map of the study area in southern Brazilian coast, including the fishing community of Torres/Passo de Torres (black circle), where the interviews were conducted and in detail the Wildlife Refuge of Ilha dos Lobos, close to Rio Grande do Sul (RS) and Santa Catarina (SC) states.

corresponds to 161 fishing operations (each operation resembles the recovery of the net from the water). The 10 fishing boats ranged from 9 to 14 m long, representing 33% of the total local fleet [12]. The average size of the total fishing crew was 5.6 fishermen per boat. The fishing area monitored extended along 110 km (60 mn) of the coastline, between the localities of Araranguá (28°57′S, 49°21′W) and Capão da Canoa (29°47′S, 49°46′W). The maximum distance covered during a fishing trip was 10 nm (from the coast to the fishing area) and the depth of the fishing area varied from 5 to 42 m deep.

Two types of fishing gear were used by the monitored fishing fleet: surface drift gillnets for bluefish, *P. saltatrix*, and bottom fixed gillnets for the main target fish: hake, *U. brasiliensis*; weakfish *Cynoscion* spp. and *M. atricauda*; king croakers, *Menticirrhus* spp.; flounders, *Paralichthys* spp. and Brazilian guitarfish, *Pseudobatos horkelii* (Müller and Henle, 1841). The fishing effort of the local monitored fleet is summarized in Table 1, including the length of the nets, soak time, and an average price for the main target fish. The information related to fishing was recorded on a logbook by only one onboard researcher (RM).

During the onboard surveys, the following data were collected: 1) boat characteristics (boat size and number of fishermen onboard); 2) type and amount of nets used; 3) fishing effort (length of the nets and soak times); 4) number of fishing operations (each operation refers to the recovery of the net from the water); 5) amount of prey species captured (productivity in kg), and 6) number and age category of sea lions that interacted with each fishing operation (one interaction was considered to be the presence of at least one sea lion near a net during a fishing operation). The sea lions observed in these interactions were categorized in three age groups: young males (1–5 years), subadult males (6–8 years), and adult males (older than 9 years) [41,42]. When it was not possible to determine the sex and the age category of the specimens, sea lions were classified as undetermined. The onboard observer only reported the interactions with sea lions when the fishermen were removing the nets from the water, and not during the entire soak time (see details in the section *Interactions between South America sea lions and local fisheries*).

Table 1
Detailed fishing characteristics in the study area, including local prices for fish during the study period.

Target species	Characteristics of the fishing gillnets					
	Type of net	Average length (m)	Mesh size (mm)	Soak time (hours)	Fishing Period	Average value per kg (US$)
Bluefish (*Pomatomus saltatrix*)	Surface drift gillnets	1700	80/90	2.2	June to December	2.33
Hake (*Urophycis brasiliensis*) Weakfishes (*Cynoscion* spp./ *Macrodon atricauda*)	Fixed bottom gillnets	7000	80/90/100	21.2	March/June	1.57
King croakers (*Menticirrhus* spp.)	Fixed bottom gillnets	5400	70	17.4	December to July September/ October	1.87
Flounder (*Paralichthys* spp.) Brazilian guitarfish (*Pseudobatos horkelii*)	Fixed bottom gillnets	3200	180/200/ 220	30.5	December to March	4.52

2.3.1. Evaluation of economic losses caused by sea lions based on onboard surveys data

With the purpose to estimate the total economic loss in the local fishing activity based on the data of interactions with sea lions and reported by the onboard researcher, we first have to calculate the local productivity. Afterwards, we calculate the frequency of these interactions during the study period, the mean size of sea lions group involved in predatory behavior (see details below), the amount of fish predated by different age classes of sea lions and their food daily capacity (= daily food intake).

2.3.1.1. Local productivity. In order to estimate the local productivity in terms of total fish caught by the 10 local monitored boats (productivity in kg), at the end of each onboard survey the amount of fish caught by species and its commercialization value (US$) by fishermen were recorded. During this period, the productivity was also calculated in terms of catch per unit of effort (CPUE). To calculate the CPUE we used the following formula: CPUE kg/h/1000 m^2 = kg/h/m^2 *1000, where "kg" is the catch productivity in kilograms, "h" is the number of hours that the fishing net remained at sea (soak time), and "m^2" is the area of the fishing net (length multiplied by height). Since the analyzed CPUE data presented no normal distribution, a median was used as a measure of central tendency. The Mann-Whitney test was applied to compare the CPUE of the fishing operations that involved interactions with the sea lions and those operations that did not, thus allowing us to evaluate if the interactions with the sea lions actually reduced fish catches.

2.3.1.2. Interactions between South American sea lions and local fisheries. With the aim to quantify the interactions between sea lions and local fisheries, the observation of these events was accompanied by one onboard observer (RM). The observer reported the interactions and calculated their frequency in 10 monitored boats by analyzing the fishing operations with the presence of sea lions. The group size of sea lions was counted and assumed as the total number of individuals observed at the same time in a fishing operation. In addition, sea lion's behavior was observed during the interactions and classified in two types: (1) predatory behavior (sea lions consuming fish from the nets), and (2) search behavior (sea lions around the nets searching for fish but with no direct evidence of consumption of fish) [43].

2.3.1.3. Estimation of fish predation and economic loss caused by sea lions. For the estimation of economic losses, we only considered the number of sea lions observed in predatory behavior by the onboard researcher as previously described. The percentage of fish predation by sea lions was calculated based on the number of sea lions interacting with the fishing boat multiplied by the daily feeding capacity [kg] in four different scenarios according to their age class and only for sea lions that were in predatory behavior (consuming fish from the nets): (i.) the minimum (conservative), (ii.) the mean and (iii.) the maximum daily food consumption for wild animals, and (iv.) the daily feeding capacity reported for animals in captivity. The three former scenarios of estimates of daily feeding capacity used the prey biomass estimated taking into account the analysis of 39 stomach contents collected from dead male sea lions in the same study area [26]. The last scenario estimated the daily feeding capacity and was based on published data from sea lions in captivity; which is about 4% of its body weight [44].

Based on the four different scenarios of daily food consumption of the sea lions, we estimated the fish predation by them and its percentage using the following equations [10]:

1) fish predation by sea lions = number of sea lions interacting with fishing(boat) * daily feeding capacity [kg] of a sea lion
2) % fish predation by sea lions = (predation per unit of effort [kg]/(predation per unit of effort + catch per unit of effort)) x 100

The predation per unit of effort (PPUEkg/h/1000 m^2) is similar to the CPUE. However, instead of catch, it estimates the predation by sea lions in kilograms, divided by time (in hours that the fishing net remained at sea - soak time) and fishing net area (m^2). The prey species consumed by sea lions were not identified during the interactions, because diagnostic parts of the external morphology of the fish were not always visible for the onboard observer. The total economic loss of the local fishing activity caused by the interactions was calculated taking into account the total value (in US dollars) of all fish sold by the fishermen for the first time during the monitored period in onboard surveys, multiplied by the estimated percentage of fish predated by sea lions. The following equation was used:

Economic loss = (total value in US dollars of all fish traded (during monitored onboard surveys) * % fish predation by sea lions)/100%

2.4. Interviews

In order to compare the economic losses estimated using data collected during onboard surveys with the perception of the fishermen based on their interviews, we conducted 100 face-to-face interviews with fishermen who work in medium-scale gillnet fishing boats in the community of Torres/Passo de Torres. Interviews were conducted by three different researchers (ACP, MTE and RM), and followed a strict protocol [33,45]. Interviewees were selected through random cluster sampling [45]. Interviews were conducted individually and lasted for approximately 20 min. Respondents were grouped into three sample categories: sailors, captains, and boat owners. Sailors represented the lowest hierarchical rank of fishermen in the boat. In terms of profitability shared among the crew, all sailors (five to six per boat) usually divide 25% of the daily profits, the captain receives 25% of all fishing profit, and the boat owner receives the remaining 50% (see Ref. [33] for details).

Interviews were based on a semi-structured questionnaire containing 14 items, of which 12 were closed-ended questions and two open-questions (Table 2). For the closed-ended questions (questions 1 to 12), the interviewee selected only one answer from a set of pre-defined alternatives. The questions were designed to assess the socio-economic characteristics of the fishing community (questions 1 to 5), the fishermen's knowledge about sea lions (questions 6 and 7), perceptions of human-sea lion conflict (questions 8 to 10), and perceptions of the fishing activity (questions 11 to 14; see Table 2).

2.4.1. Evaluation of economic losses caused by sea lions based on fishermen's knowledge and perceptions

We used descriptive statistics to evaluate socio-economic variables (age, fishing experience, education level, hierarchical level in the crew and amount of income source) and absolute frequency to summarize the results for knowledge and perceptions. Statistical analyses were performed in the Statistical Package for the Social Sciences (SPSS) software version 20.

3. Results

3.1. Onboard surveys

3.1.1. Interactions between South American sea lions and local fisheries

During the 161 fishing operations monitored, we observed 68 episodes of interactions with sea lions (42.2% of the operations). The interactions occurred from April 2011 to March 2012, mainly in spring (n = 30) and winter months (n = 28), with only one interaction observed during the summer (on March 13, 2012) and nine episodes in autumn. Similar to the interviews conducted with the fishermen, the interactions seemed to occur throughout the year in the study period. However, when it was taken into account the fishing operation effort monitored throughout the year (n = 161), the interactions with sea lions occurred with the highest frequency during autumn (52.9%; 9 of the 17

Table 2
Questionnaire applied to the fishing community of Torres/Passo de Torres, in southern Brazil (adapted from Ref. [33]).

Socio-economic variables	1) Age	<20, 21–30, 31–40, 41–50, >50
	2) Fishing experience (years)	<10, 11–20, 21–30, 31–40, >40
	3) Education level	Elementary school incomplete, E.S. complete, High school incomplete, H.S. complete
	4) Hierarchical level in the crew	Sailor, Captain, Boat owner
	5) Source of income	Fishing and other activity besides fishing, Fishing as the only source of income
Knowledge about South American sea lion	6) How many sea lions are on the island?	Less than 50, About 100, About 200, About 300, Do not know
	7) During which season do you see more sea lions?	Spring, Summer, Autumn, Winter, Do not know
Perception of human–sea lion conflict	8) How frequently do sea lions attack the fishing nets?	Never, Rarely, Regularly, Always, Do not know
	9) How many kilos of catch can a sea lion eat during each attack?	Up to 5 kg from, Up to 20 kg, 20 kg–50 kg, More than 100 kg, Do not know
	10) How big do you consider the damage caused by sea lions to the local fishing community?	Insignificant, Small, Medium, Large, Huge
Perception of the fishing situation	11) The profit from fishing ten years ago was?	Good, Median, Bad, Do not know
	12) How is the amount of fish caught currently?	Good, Median, Bad, Do not know
	13) What is your suggestion for improving fishing productivity in the region?	Free answer
	14) What is your suggestion to solve the human-sea lion conflict in this region?	Free answer

operations), followed by winter (48.3%; 28 of the 58 operations), spring (41.7%; 30 of the 72 operations), and summer (6.7%; 1 of the 15 operations).

Predatory behavior (sea lions consuming fish from the nets) was observed in 49 interaction events (72.1%), and search behavior (sea lions only searching the nets for fish) in 25 interaction events (36.7%). Both behaviors were observed in the same fishing operation in 10.3% of the interactions. During these interactions, 168 specimens were registered: 119 were preying on fish nets, and the remaining were only searching the nets. Most of the sea lions were young (n = 72; 42.9%) or subadult males (n = 56; 33.3%); 26 (15.5%) were adult males and 14 (8.3%) were classified as undetermined. The number of specimens interacting with the fishing per event varied from one to eight sea lions (mean = 2.47; sd = 1.69; median = 2; mode = 1).

3.1.2. Local productivity, estimation of fish predation and economic loss caused by sea lions

The total productivity (amount of fish caught) of the 10 monitored boats was 32,277 kg. In terms of fish caught it was equivalent to US$ 62,279.24. The daily food consumption of sea lions involved in the interactions according to their different age classes was estimated in 12 kg for adult males, 7.2 kg for subadult males, 2.0 kg for juveniles, and approximately 4% of its body weight from sea lions in captivity [44]. Taking into account these results, the minimum scenario for daily feeding capacity for a wild young male sea lion (n = 9) was a daily biomass intake of 2.17 kg, the mean scenario of 3.70 kg per day, and the maximum scenario of 5.23 kg per day. For wild subadult males (n = 5), the daily feeding capacity was 2.17 kg as a minimum scenario, the mean scenario of 5.07 kg per day, and 7.96 kg per day as a maximum scenario. On the other hand, wild adult males (n = 25) would consume from 2.66 kg, 10.66 kg, to 18.66 kg per day (minimum, mean and maximum daily feeding capacity scenarios, respectively). When it was not possible to determine the age category of the wild animal interacting with fisheries, a mean value of daily feeding capacity was used: minimum scenario as 2.33 kg, mean scenario of 6.48 kg and 10.62 kg per day as a maximum scenario.

All these estimates combined with the number of sea lions interacting during the onboard surveys were used to calculate the effects of fish predation by sea lions on the local fish productivity in four different scenarios. The results of the estimate of fish predation by the total sea lions were: 268.34 kg in the minimum scenario, 650.45 kg in the mean and 1032.55 kg in the maximum scenario, while 670 kg was estimated taking into account data from animals in captivity (Table 3). Taking into account the fish predation by sea lions and the price of the fish during the study, we estimate in US$ 513.50 as minimum scenario of economic loss caused during the interactions, which represented less than 1% (Table 3) of the productivity of the monitored boats. Even in the maximum scenario we estimate in US$ 1931.58 as economic losses, which corresponds only to 3% of the productivity (Table 3). When we compared the values estimated for wild animals with animals in captivity, we observed that the captive scenario (US$ 1266.49) was very similar to the mean scenario estimated for wild animals (US$ 1230.26).

The fishing catch (productivity in kg) estimated during the interactions with sea lions was not significantly different when compared with the catch with no interactions with sea lions (median CPUE without interactions = 0.00130, n = 112, median CPUE with interaction = 0.00120, n = 49 - U = 2383, p = 0.964).

3.2. Interviews

3.2.1. Socio-economic characteristics of the fishing community

Of a total of 350 fishermen in the community, 100 were interviewed. Of these fishermen, 77 were sailors (77%), 21 were captains (21%), and two were boat owners (2%). Their ages ranged from 16 to 70 years old (mean = 35), with fishing experience varying from one to 48 years (mean = 24 years). Only 8% of fishermen completed high school, and 85% of them had fishing activity as an exclusive income source (Fig. 2).

3.2.2. Fishermen's knowledge about South American sea lions

Fishermen's knowledge about the biology of sea lions was considered fair. Fifty-six percent of the answers were correct, 40% were incorrect, and about 4% answered "do not know" to the questions. When asked

Table 3
Estimate of the economic losses caused by the South American sea lions during the interactions monitored by an onboard researcher in the community of Torres/Passo de Torres, between April 2011 and March 2012. * estimated daily feeding capacity of 4% of body weight of South American sea lions in captivity [44].

	Biomass of prey consumed by local sea lions			
	Minimum scenario (kg)	Mean scenario (kg)	Maximum scenario (kg)	*Estimate from captivity animals [45] (kg)
Fish predation by sea lions (kg)	268.34	650.45	1032.55	670.00
Economic Loss (US$)	513.50	1230.26	1930.58	1266.49
% Economic Loss (US$)	0.80	1.94	3.01	2.03

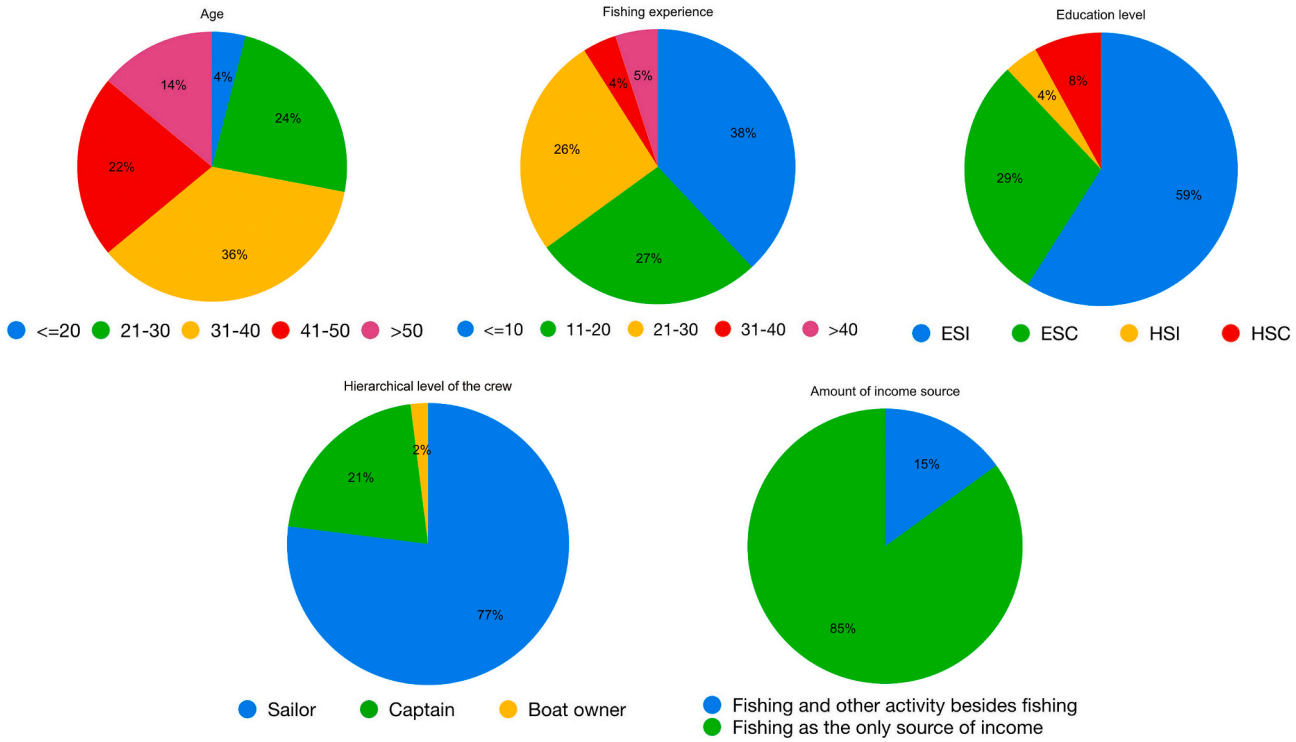

Fig. 2. Socioeconomic profile of the fishermen interviewed in the fishing community of Torres/Passo de Torres, southern Brazilian coast, during 2011–2012. Percentage of the fishermen by age (years), by fishing experience (years), by education level (ESI = Elementary school incomplete, ESC = elementary school complete, HIS = high school incomplete, HSC = high school complete), by hierarchical level of the crew (sailor, captain, boat owner) and amount of income source (fishing as the only source of income and fishing and other activity).

about the approximate number of animals that periodically visited the WRIL, 44% correctly answered that approximately 100 animals visited the island (Fig. 3A); 2% erroneously suggested that there were more than 300 individuals on the island. Regarding the seasonality of sea lions in the region, 69% correctly answered winter, and 7% autumn as the months were sea lions were present on the island (Fig. 3B).

3.2.3. Fishermen's perception of human-sea lion conflict and on local fishing activity

In relation to the fishermen's perceptions of the conflict with sea lions, they were considered negative. The majority of fishermen (80%) believed sea lions were always present during fishing operations (Figs. 3C), and 88% of them believed that sea lions could consume 100 kg of fish or more in each interaction (Fig. 3D). In relation to that, 69% of the fishermen believed that sea lions caused considerable economic losses to the local fishing activity (Fig. 3E).

Fishermen's perceptions about the local fishing activity were also considered negative. Fifty-nine percent of the fishermen reported that fishing in the region in the early 2000s was much better than in 2011–2012 (period of the interviews). In addition, they believed that a decline in profitability occurred in the previous 10 years, from 2002/03 to 2012/13 (Fig. 4).

The fishermen who knew about the existence of other problems that affect the fishing in the region, such as a shallow channel that hinders the departure of the boats to the sea and weather conditions, suggested some actions to improve the activity. Seventy-four out of 100 fishermen interviewed provided suggestions. The most common suggestions were deepening the channel (25.4%), increasing law enforcement on fishing activities (20.3%), and an increase in financial compensation to the fisherman due to sea lions' damage (= amount of fish loss) (12.2%). In relation to financial income, they believed that there has been a decrease in the last 10 years, which were partially attributed to the presence of sea lions. They also recognized overfishing and difficulties in the fisheries and suggested ways to improve fishing in the region to make it more profitable.

When asked about the potential alternatives/ways to reduce conflicts with sea lions, only 27 of the 100 fishermen suggested alternatives to reduce the conflict. Of those, 14.5% suggested different ways to eradicate the sea lions in the region (e.g. translocation to another area, authorized hunting seasons), and only 15% (n = 4) were convinced that there is no solution to the conflict (Table 4). On the other hand, 18% (n = 5) suggested that fishermen must change their behavior (e.g. to fish in greater depth or do not fish near the island), and 15% (n = 4) suggested the development of non-lethal techniques to keep sea lions from approaching the boat.

4. Discussion

South American sea lions are commonly blamed for causing significant economic loss to fishing activity on the southern Brazilian coast, resulting in their persecution and killing. Our findings, however, show otherwise. Actual losses caused by sea lions to the local fishery, as assessed by onboard surveys, were smaller than what was perceived by the fishermen from Torres/Passo de Torres. The actual financial loss caused by sea lions was only about 3% of the productivity of the year, even in the worst-case scenario; which differs greatly from the "large" or "huge" damage perceived by most of the fishermen (Fig. 3E). This exaggerated view of economic loss in the fisheries caused by the sea lions as well as their overstated perception of sea lion daily intake (~100 kg per interaction) were probably magnified by their regular presence in the region, which was corroborated by our onboard surveys. Our results showed that sea lions inhabited the WRIL and interacted with fishermen throughout the study period, which is in accordance with the fishermen's complaints in the interviews, although it is slightly different from the marked seasonal observation of sea lions recorded in Brazil [20,32].

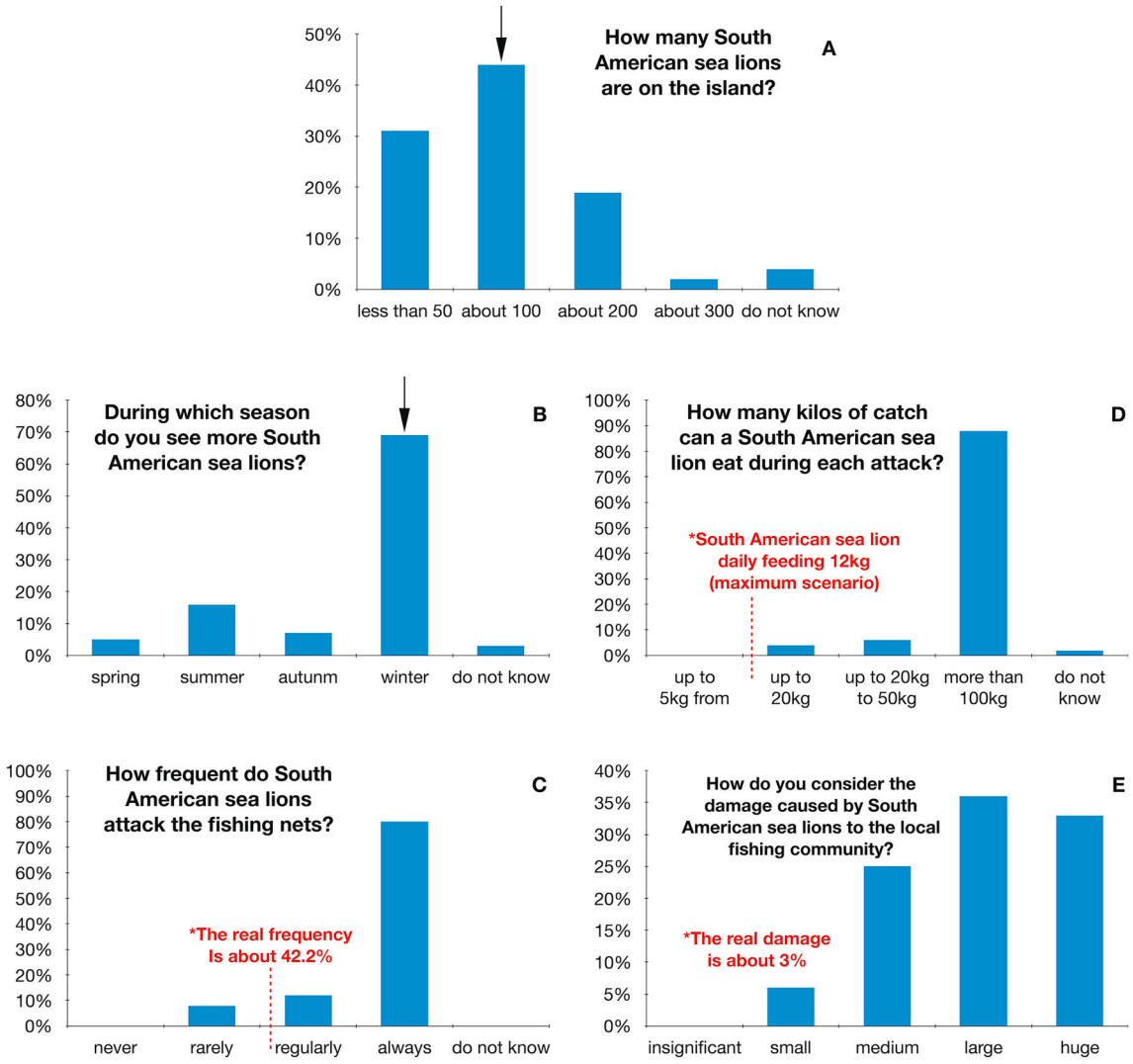

Fig. 3. Frequency of answers to the questions about fishermen's knowledge on South American sea lions and fishermen's perceptions of human-sea lion conflict applied to the fishing community of Torres/Passo de Torres, southern Brazilian coast. The arrow in the graphics A and B indicates the correct answer on sea lions' biology according to the scientific literature. In the graphics C, D, E the red phrase indicates the actual scenario observed by onboard researcher.

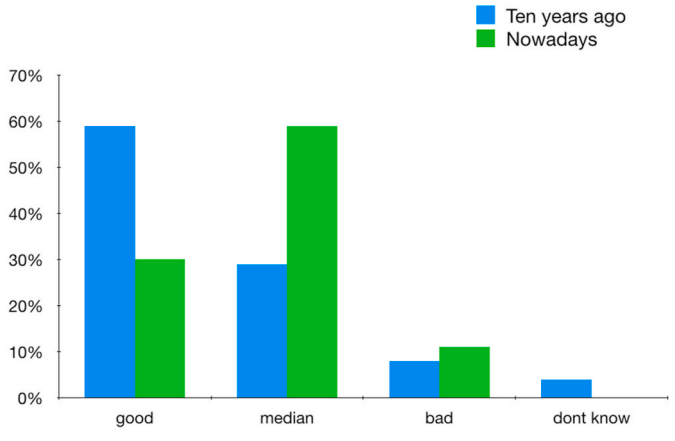

Fig. 4. Frequency of answers of the fishing community of Torres/Passo de Torres, southern Brazilian coast to the questions: How was the fishing profit ten years ago? How is the fishing profit nowadays?

The investigation using both interviews with fishermen and onboard observers to assess simultaneously the perceived and the actual economic loss caused by sea lions, respectively, is a novel way to examine interactions between fishermen and marine mammals. Despite the time-lapse since this study was conducted, this is still a timely finding as no similar research addressing sea lions in the southwestern Atlantic Ocean has been carried out due to economic, logistical, and even local legal constraints. Although the economic losses have not been systematically monitored since this study was conducted, anecdotal reports suggest that the negative perceptions and attitudes of the local fishermen towards sea lions still remain. Moreover, the information presented here corresponds to a unique baseline data for future comparative studies on the economic impact of sea lions on southern Brazilian fishery.

Despite the importance of our findings, some factors that may influence the negative perceptions of the sea lions among fishermen could not be assessed in this study. Firstly, the sea lions occasionally consume only part of the fish caught in the net [20], and they are known not only to feed upon the catch but also to damage the gillnet gear, which also should be considered in the economic loss analysis. Secondly, weather conditions, untrained crew, silting up of the channel of the estuary, and the high operational costs of the local fishing were previously reported to the region [33,46]. It is likely that all these factors influence more

Table 4
Open questions and answers about fishermen's perceptions about the conflict with South American sea lion and the status of current local fishing activity.

Open question	Answers	Absolute Frequency[a]
What is your suggestion to improve fishing in the region?	- Increase the depth of the channel	25
	- Improve monitoring of fishing activity	20
	- Distribute fishing equipment	6
	- Prohibit trawling fishing	6
	- Let the fishermen work without regulation	5
	- Financial compensation to the fisherman	12
What is your suggestion to solve the human-sea lion conflict in the region?	- Translocation of the South American sea lions	6
	- Authorize hunting	6
	- Find a way to keep sea lion from approaching the boat	4
	- There is nothing to be done	4
	- Catch fish in greater depth	3
	- Set aside a place for sea lions only	2
	- Ban fishing near the island	2

[a] **Some fishermen did not answer all of them**.

negatively the economic loss of the local fishery than the sea lions' interactions [33,46], but they were never considered in this analysis.

About 56% of the answers to the questions assessing knowledge about the biology of sea lions were correct, and around 80% of the fishermen had a negative perception of human-sea lion interaction. According to the fishermen, sea lions were seen throughout the year and were interfering with the fishing, mostly around the WRIL during winter months. The onboard surveys revealed a similar situation, with animals interacting throughout the year, but mainly from autumn to spring months. According to Silva et al. [47], sea lions are prevalent throughout the year in the WRIL, varying in the number of individuals according to the season, with August being the month with the highest occupancy of sea lions in WRIL. On the other hand, Procksch et al. [40] suggested that usually September is the month with the highest pinniped abundance on the island.

Most of the fishermen (80%) were convinced that sea lions currently interact with the local fishing. This finding is not in agreement with what was recorded by the onboard observer, who reported these episodes in less than 50% of the fishing operations and less than 36% of fishing trips resulted in predatory behavior. The observer also reported that in 72% of these interactions, sea lions were displaying a predatory behavior on the gillnets. Although the fishermen were aware of the number of animals in the region, and of the season when most interactions happened, these fishermen believed that despite the small number of sea lions in the region, they still caused great damage to the fishing. These results may be negatively influenced by the fishermen's perceptions, mainly in the case of economic damage caused by sea lions [33]. This perception is also highlighted by the belief that sea lions can eat hundreds of kilograms of fish over the course of one interaction. Moreover, most of the fishermen believed that sea lions caused considerable economic loss to the local fishing activity.

The onboard surveys, however, revealed that the economic loss ranged from only 0.80%–3%; these estimates were only possible based on the different scenarios calculated. It is important to mention that this economic loss could be underestimated since the onboard observer only reported the interactions with sea lions when the fishermen were removing the nets from the water, not covering the putative interactions that occur during the entire soak time of the nets, which can be around 24 h for fixed bottom gillnets. This is a really important but logistically difficult task, perhaps only accomplished using technological devices, such as waterproof cameras with long time duration batteries. Since we did not apply such technology in the present study, we have to assume that we are underestimating the economic losses caused by sea lions.

Conversely, another important parameter that could corroborate our assumption of low economic losses caused by sea lions was the fishing catch per unit of effort (CPUE). The onboard results indicated that the CPUE estimated during the interactions with sea lions was not significantly different when compared with the catch with no interactions with sea lions. In other words, the onboard results suggested that the presence of sea lions did not affect the CPUE and did not cause significant damage (probably less than 3% of the total income) to the fisheries of the region. In addition, we cannot forget that sea lions forage naturally into the sea, and the interactions with the fisheries must be considered as only one possible source to fulfill their dietary energy requirements, that is likely to be reinforced by overexploitation of marine resources and habitat degradation [12,20,26].

Similarly, Szteren and Páez [10] did not find differences in the CPUE in the presence or absence of sea lion interactions in artisanal fishermen in Uruguay. No significant relation was found between the number of sea lions interacting during the fishing trip and the CPUE in artisanal fishermen in Chile [9]. Based on these similar results observed in Uruguay and Chile, we can suggest that the low damage caused by sea lions to the fishing operations possibly occurs because they primarily forage into the sea, which is their natural behavior.

In the early 1990s, however, Oporto et al. [43] estimated that sea lions caused annual losses of US$ 120,000 in artisanal small-scale fishery in southern Chile (between 29°S and 42°S). Due to the conflicts with sea lions, the authors estimated a loss between US$ 7000.00 and US$ 40,000.00 per year for salmon farmers. For the salmon industry, Sepúlveda and Oliva [22] estimated an economic loss in the south of Chile, between US$ 6.7 and 8.3 million per year due to the mortality of fish related to the South American sea lions' attacks on rearing tanks.

It is important to mention that the present study evaluated interactions between sea lions and medium-scale fishing activities. Medium-scale fishing has greater autonomy and potential fishing than artisanal fisheries [24]. In this context, artisanal fisheries would undoubtedly have a greater economic impact, as the boats are small, have lower autonomy and a limited fishing area when compared to the boats monitored in the present study. For artisanal fishery on the coast of Uruguay, Szteren [48] estimated an economic loss of 19% of the financial gain. Variable economic impact on fisheries has been reported for other pinniped species. In California's salmon fishery for instance the Californian sea lions *Zalophus californianus* (Lesson, 1828) destroyed the equivalent of 16% of the production in the commercial troll fishery [49], and in the coast of Massachusetts the Harbor seal, *Phoca vitulina* (Linnaeus, 1758), was responsible for the loss of about 0.4% of the region's fishing productivity [50].

4.1. Management implications

Respondents recognized that, besides the conflict with sea lions, there was a problem of overfishing and economic difficulties in the previous 10 years (i.e., the early 2000s) in the local fishery. They also suggested ways to improve fishing activity in the region to make it more profitable. A fourth of the fishermen (n = 25) suggested practical and possible actions such as improving the channel depth. Dredging of the river would already be a solution that would help the fishermen to pass through the sandbank that currently provoke beaching and tipping of the fishing boats, resulting in financial and material damages (Delfino pers. comm., president of the local fishing community). In addition, the improvement of the channel depth probably will also increase the number of fishing days per year.

The second most frequent suggestion was to increase law enforcement on fishing activities (n = 20). Fishermen stated that even with the existence of some important laws to assist fishing in the region, such as the no-take zones, periods of fishing closures, and the indication of

adequate mesh to each fish species, some fishermen did not follow the Brazilian fishing regulations. However, there were many conflicting opinions within the fishing community about improving fishery regulations. Some fishermen suggested that fishing laws in the region must be withdrawn or relaxed by removing certain aspects of the laws in order to make fishing easier in spite of overfishing [26,51]. Therefore, working to create/adapt laws will only have a practical result if we have better oversight, as well as a better acceptance by the fishermen of the reasons and potential benefits resulting from the protective regulations.

Regarding measures that could be used to decrease interactions or to solve the human-sea lion conflict, most of the respondents suggested ways to eradicate the sea lions in the region (e.g. culling [52]). Few fishermen were convinced that there is no solution to the conflict, and only very few suggested changing their own behavior. There are only a few studies on selective removing or reallocating pinnipeds as a management strategy [53–55]. In Brazil, culling sea lions is not an option, since all marine mammals are protected under national law since 1986 (SUDEPE no. 11, February 21, 1986).

Acoustic deterrent devices against phocids, *P. vitulina* and *Halichoerus grypus* Fabricius, 1791, were also used by fishermen in marine salmon *Salmo salar* farms on the west coast of Scotland [55]. As a result, authors found that sound exposure led to a 93% reduction in the number of fish lost due to seal damage. Although no specific acoustic study was designed to prevent sea lions' depredation, the use of acoustic deterrent devices applied to diminish the incidental capture of franciscana dolphins, *Pontoporia blainvillei* (Gervais & d'Orbigny, 1844) in Argentine waters was counterproductive because they attracted sea lions to the gillnets [56]. Alternatively, fishermen could increase the frequency in which they change the position of their nets. However, the conflict would still remain with local fishermen, since sea lions keep following the boats and finding the new position of the nets [33]. Therefore, applying this alternative could not prevent the killing of sea lions. This situation is confirmed by the 25% of carcasses of sea lions collected between 1991 and 2012 had interactions marks [46].

Another measure pointed out by the fishermen was compensation. The discussion about the compensation for damage caused by wildlife to production raises some reflections: 1) fishermen should not bear the cost of sea lion conservation: this "cost" could be shared by the entire society, which could, for example, pay for the alleged economic loss of 3% in the final price of the fish, and 2) without adequate compensation, measures would not be supported for very long, once it negatively impacted the development of local fisheries [57]. On the other hand, no significant damage caused by sea lions was observed in this community, but the existence of the conflict is evident. The financial compensation for the damage caused by the sea lions to this fishing community is not seen as an effective management measure for the current scenario. In order for compensation schemes to work out, further evaluation and an indication of economic losses to the community are required. In this context, it will be important to investigate if a potential reduction of the sea lion damage could be translated into higher economic benefits for the fishermen.

Westerberg [52] proposed that a way to manage conflicts involving seals is to separate the competitors - fishermen and phocids - through the implementation of MPAs. Since the WRIL has been an MPA since 1983, it is vital that the local fishing regulations in the no-take zone are respected by local fishermen. However, the WRIL still lacks a management plan as well as clear rules for the sustainable use of marine resources. Moreover, sea lions usually interact with the fishing boats out of the limits of the WRIL [12], making useless to solve this conflict any no-take zone legislation of fishing only in the very small area of this MPA (*i.e.* 1 km^2).

Another potential measure to improve the situation in the medium to long terms is environmental education. According to Pont et al. [33], the fishermen in Torres/Passo de Torres are not interested in the research about the sea lions, nor have an interest in knowing the ecology of the species, creating a barrier between the researcher and the fishermen. Therefore, community engagement and social marketing strategies should be implemented to overcome this barrier. It is also important to properly provide feedback of the research results to the fishermen, to correct their impact perceptions, and to make it clear to them that there are other factors affecting fishing [33]. In this context, a local workshop focused on discussing fisheries and sea lions could be a promising strategy. Since 2016, there are meetings of the Consulting Council of WRIL, which is composed of fishermen, scientists and local authorities; these events could be the best moments to facilitate this discussion. Participatory management may be a way forward for promoting the coexistence between sea lions and the local fisheries, where the perception and conservation interests of fishermen are taken into account, as well as sustainable use of the WRIL, simultaneously with the protection of the sea lions. The Consulting Council of WRIL plays an important role in this management strategy. For instance, it regularly discusses the problems of the MPA, which include fishermen's current complaints against the sea lions, the no-take zone legislation of fishing in the WRIL, as well as the most controversial actions involving changing fishing practice to culling, explaining the importance of this species as a predator and its ecological influence on local biodiversity. Identifying and acknowledging the differences and commonalities among the stakeholders is a starting point for finding solutions and must be the main responsibility of this Council.

It would also be important to explore the potential of sea lions as a tourism attraction in the region since the WRIL is the only natural area of Brazil where pinnipeds can be observed in their natural habitat [33]. Sea lions could bring economic gains or increase local profits [57]. Local regulations for this activity are under construction and should be implemented in the coming year. The involvement of the fishing community in this specific touristic activity could contribute to increasing tolerance to sea lions.

Acknowledgments

The authors would like to thank all the fishermen from Torres and Passo de Torres, especially to Z18 association and Adriano Delfino Joaquim, for their collaboration. We are also grateful to Cádiz Sustainable Ideas Awards, Amnéville Zoo and Fundação Grupo O Boticário de Proteção à Natureza, for the financial support. To *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)* - Finance Code 001) that provided a Master's grant (PROSUP) to ACP and RM, and post-doctoral grant (PNPD) for RM in PPGDS/UNESC. To *Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)* that provide the Research Productivity grants No. 303813/2011-3, 308650/2014-0 and 310621/2017-8 to LRO. To Fernando Lopes, who kindly create the map of the study area. The research group "Observa Litoral" (UERGS/CNPq) also contributed to this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpol.2020.104193.

Author statement

All authors (Larissa Rosa de Oliveira – LRO; Ana Carolina Pont - ACP; Rodrigo Machado - RM; Mônica Tais Engel - MTE; Paulo Henrique Ott - PHO, Enrique A. Crespo - EAC and Silvio Marchini - SM) declare they had no conflict of interest whatsoever.

L.R.O. developed the conceptualization of the study. L.R.O., A.C.P. and R.M. designed the experiments. A.C.P. and M.T.E. performed the interviews, R.M. conducted the onboard surveys. A.C.P. and R.M. performed the formal analysis. L.R.O., E.A.C., P.H.O. and S.M. conducted the validation of the data. L.R.O. and E.A.C. were responsible for funding acquisition and project administration. A.C.P., L.R.O., R.M., P.H.O., S.M. and E.A.C. wrote the original draft. L.R.O., P.H.O. and S.M. reviewed

and edited the final version of the manuscript.

References

[1] S.P. Northridge, World Review of Interactions between Marine Mammals and Fisheries, FAO Fisheries Technical Paper, 1984, 251-190.

[2] D. Pauly, D. Zeller, Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining, Nat. Compunction 7 (2016) 10244.

[3] D. Pauly, D. Zeller, The global fisheries crisis as a rationale for improving the FAO's database of sheries statistics, Fish. Cent. Res. Rep. 11 (2003) 1–9.

[4] P.A. Wickens, A Review of Operational Interactions between Pinnipeds and Fisheries, vol. 346, FAO Fisheries Technical Paper, 1995, p. 86.

[5] D.M. Lavigne, Marine mammals and fisheries: the role of science in the culling debate, in: N. Gales, M. Hindell, R. Kirkwood (Eds.), Marine Mammals: Fisheries Tourism and Management Issues, CSIRO Publishing, Victoria, 2003, pp. 31–47.

[6] E.A. Crespo, S.N. Pedraza, S.L. Dans, M. Koen-Alonso, L.M. Reyes, N. García, M. Coscarella, Direct and indirect effects of the high seas fisheries on the marine mammal populations in the northern and central Patagonian coast, J. Northwest Atl. Fish. Sci. 22 (1997) 189–207.

[7] E.A. Crespo, D. Oliva, S.L. Dans, M. Sepúlveda, Current Status of the South American Sea Lion along the Distribution Range, University of Valparaíso, Valparaíso, 2012.

[8] M. Arias-Schreiber, Interacciones entre lobos marinos *Otaria byronia* y la pesquería artesanal en el puerto San Juan de Marcona, Perú, Thesis, Univesidad Nacional Agraria La Molina, Lima, 1993.

[9] M. Sepúlveda, M.J. Pérez, W. Sielfeld, D. Oliva, L.R. Durán, L. Rodríguez, V. Araos, M. Buscaglia, Operational interactions between South American sea lions *Otaria flavescens* and artisanal (small-scale) fishing in Chile: results from interview surveys and on-board observations, Fish. Res. 83 (2007) 332–340.

[10] D. Szteren, E. Páez, Predation by southern sea lions (*Otaria flavescens*) on artisanal fishing catches in Uruguay, Mar. Freshw. Res. 53 (2002) 1161–1167.

[11] M. De María, F.R. Barboza, D. Szteren, Predation of South American sea lion (*Otaria flavescens*) on artisanal fisheries in Rio de la Plata estuary, Fish. Res. 149 (2013) 69–73.

[12] R. Machado, P.H. Ott, I.B. Moreno, D. Danilewicz, M. Tavares, H.A. Crespo, S. Siciliano, L.R. Oliveira, Operational interactions between South American sea lions and gillnet fishing in southern Brazil, Aquat. Conserv. Mar. Freshw. Ecosyst. 26 (2016) 108–120.

[13] L.A. Hückstädt, T. Antezana, Behavior of the southern sea lion (*Otaria flavescens*) and consumption of the catch during purse-seining for jack mackerel (*Trachurus symmetricus*) off central Chile, ICES (Int. Counc. Explor. Sea) J. Mar. Sci. 60 (2013) 1003–1011.

[14] S. Goetz, M. Wolff, W. Stotz, M.J. Villegas, Interactions between the South American sea lion (*Otaria flavescens*) and the artisanal fishery off Coquimbo, northern Chile, ICES (Int. Counc. Explor. Sea) J. Mar. Sci. 65 (2008) 1739–1746.

[15] A. González, R. Vega, E. Yáñez, Operational interactions between the South American sea lion *Otaria flavescens* and purse seine fishing activities in northern Chile, Rev. Biol. Mar. Oceanogr. 50 (2015) 479–489.

[16] P. SecoPon, G. García, S. Copello, A. Moretinni, H.P. Lértora, J. Pedrana, L. Mauco, M. Favero, Seabird and marine mammal attendance in the Chub mackerel *Scomber japonicus* semi-industrial Argentinian purse seine fishery, Ocean Coast Manag. 64 (2012) 56–66.

[17] P. Reyes, R. Hucke-Gaete, J.P. Torres-Florez, First observation of operational interactions between bottom-trawling fisheries and South American sea lion, *Otaria flavescens* in south-central Chile, J. Mar. Biol. Assoc. U. K. 93 (2013) 1–6.

[18] S.L. Dans, M. Koen-Alonso, E.A. Crespo, S.N. Pedraza, N. García, Interactions between marine mammals and high seas fisheries in Patagonia: an integrated approach, in: N. Gales, M. Hindell, R. Kirkwood (Eds.), Marine Mammals: Fisheries Tourism and Management Issues, CSIRO Publications, Melbourne, 2003, pp. 88–103.

[19] A.M. Segura, A.D. Delgado, A. Carranza, La pesquería de langostino en Punta Del Diablo (Uruguay): un primer acercamiento, Pan Am. J. Aquat. Sci. 3 (2008) 232–236.

[20] R. Machado, L.R. Oliveira, S. Montealegre-Quijano, Incidental catch of South American sea lion in a pair trawl off southern Brazil, Neotropical Biol. Conserv. 10 (2015) 43–47.

[21] A. Torriente, R.A. Quiñones, D.A. Miranda-Urbina, F. Echevarría, South American sea lion and spiny dogfish predation on artisanal catches of southern hake in fjords of Chilean Patagonia, ICES (Int. Counc. Explor. Sea) J. Mar. Sci. 67/2 (2010) 294–303.

[22] M. Sepúlveda, D. Oliva, Interactions between South American sea lions *Otaria flavescens* (Shaw) and salmon farms in Southern Chile, Aquacult. Res. 36 (2005) 1062–1068.

[23] J. Vilata, M. Sepúlveda, D. Oliva, The predation of farmed salmon by South American sea lions (*Otaria flavescens*) in southern Chile, ICES (Int. Counc. Explor. Sea) J. Mar. Sci. 67/3 (2010) 475–482.

[24] I.B. Moreno, M. Tavares, D. Danilewicz, P.H. Ott, R. Machado, Descrição da pesca costeira de média escala no litoral norte do Rio Grande do Sul: comunidades pesqueiras de Imbé/Tramandaí e Passo de Torres/Torres, Boletim do Instituto de Pesca 35 (2009) 129–140.

[25] L.G. Cardoso, M. Haimovici, Caracterização tecnológica, social, econômica e ecológica da atividade pesqueira sediada em Passo de Torres, vol. 37, Boletim do Instituto de Pesca, Santa Catarina, Brasil, 2011, pp. 275–288.

[26] M. Machado, L.R. Oliveira, P.H. Ott, P. Denuncio, M. Haimovici, L.G. Cardoso, D. Danilewicz, I.B. Moreno, M. Borges-Martins, Changes in the feeding ecology of South American sea lions on the southern Brazilian coast over the last two decades of excessive fishing exploration, Hydrobiologia 819 (2018) 17–37, https://doi.org/10.1007/s10750-018-3618-8.

[27] M. Haimovici, J.P. Castello, P.R. Abdallah, Desenvolvimento da pesca industrial sediada em Rio Grande: uma visão histórica sob a ótica de atores privilegiados, in: M. Haimovici, J.M. Andriguetto, P.S. Sunye (Eds.), A Pesca Marinha e Estuarina no Brasil: Estudos de Caso, Editora da FURG, Rio Grande, 2014, pp. 17–28.

[28] M.S. Boffo, E.G. Reis, Atividade pesqueira da frota de média escala no extremo sul do Brasil, Atlantica 25 (2003) 171–178.

[29] M. Haimovici, L.V. Miranda, Pesca da pescada olhuda no sul do Brasil, in: C.L. W. Rossi, M.C. Cergole, A.O. Ávila-da-Silva (Eds.), Análise das Principais Pescarias Comerciais da Região Sudeste-Sul do Brasil: Dinâmica Populacional das Espécies em Exploracão, Série Documentos Revizee-Score Sul, IOUSP, 2005, pp. 40–45.

[30] M. Haimovici, J.M. Ignácio, Pesca da corvina no sul do Brasil, in: C.L.W. Rossi, M. C. Cergole, A.O. Ávila-da-Silva (Eds.), Análise das principais pescarias comerciais da região sudeste-sul do Brasil: dinâmica populacional das espécies em exploração. Série documentos Revizee-Score sul, IOUSP, 2005, 2005, pp. 101–107.

[31] L.G. M. Haimovici, L.G. Cardoso, Long-term changes in the fisheries in the Patos Lagoon estuary and adjacent coastal waters in Southern Brazil Mar. Biol. Res. 13 (2017) 135–150.

[32] F.C.W. Rosas, M.C. Pinedo, M. Marmotel, M. Haimovici, Seasonal movements of the south American sea lion (*Otaria flavescens* Shaw, 1800) of the Rio Grande do sul coast, Brazil, Mammalia 58 (1994) 51–59.

[33] A.C. Pont, S. Marchini, M.T. Engel, R. Machado, P.H. Ott, E.A. Crespo, M. Coscarella, M.S. Dalzochio, L.R. Oliveira, The human dimension of the conflict between fishermen and South American sea lions in southern Brazil, Hydrobiologia 770 (2016) 89–104.

[34] P.G. Kinas, K.G. Silva, S.G. Estima, D. Monteiro, Generalized linear models applied to stranding data of South American sea lions (*Otaria flavescens*) and South American fur seals (*Arctocephalus australis*) in southern Brazil, Lat. Am. J. Aquatic Mamm. 4 (2005) 7–14.

[35] K.G. Silva, C.V.L. Crivellaro, T.G. Araújo, R.B. Menezes, Os Mamíferos Marinhos no litoral do Rio Grande do Sul, Nema, Rio Grande, 2014.

[36] M.T. Engel, S. Marchini, A.C. Pont, R. Machado, R.L. Oliveira, Perceptions and attitudes of stakeholders towards the wildlife refuge of Ilha dos Lobos, a marine protected area in Brazil, Mar. Pol. 45 (2014) 45–51.

[37] D. Sanfelice, V.C. Vasques, E.A. Crespo, Ocupação sazonal por duas espécies de Otariidae (Mammalia, Carnivora) da Reserva Ecológica Ilha dos Lobos, Rio Grande do Sul, Brasil, Iheringia, Série Zoologia. 87 (1999) 101–110.

[38] M. Haimovici, Present state and perspectives for the southern Brazil shelf demersal fisheries, Fish. Manag. Ecol. 5 (1998) 277–290.

[39] M. Silva, O programa brasileiro de unidades de conservação, Megadiversidade 1 (2005) 22–25.

[40] N. Procksch, F. Grandi, K.R. Groch, P.A. Flores, M.Z. Oliveira, M.R. Veronez, E. Crespo, P.H. Ott, R. Machado, L.R. Oliveira, Abundância e ocupaçãoespacial de pinípedes no Refúgio de Vida Silvestre Ilha dos Lobos, Torres, Brasil, in: Anais do XII Congreso de la Sociedade Latinoamericana de especialistas en mamíferos acuáticos. Lima, Peru, 2018.

[41] E.A. Crespo, Dinámica poblacional del lobo marino del sur *Otaria flavescens* (Shaw, 1800), en el norte del litoral patagónico, Thesis, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina, 1988.

[42] M.F. Grandi, S.L. Dans, N.A. Gracia, E.A. Crespo, Growth and age at sexual maturity of South American sea lions, Mamm. Biol. 75 (2010) 427–436.

[43] J. Oporto, C.L. Mercado, L. Brieva, Conflicting Interactions between Coastal Fisheries and Pinnipeds in Southern Chile, Report on the Benguela Ecology Programme Workshop on Seal-Fishery Biological Interactions, University of Cape Town, South África, 1991.

[44] R. Kastelein, J. Kershaw, E. Berghout, P. Wiepkema, The food consumption of South American sea lions (*Otaria flavescens*), Aquat. Mamm. 21 (1995) 43–53.

[45] H. Newing, Conducting Research in Conservation: A Social Science Perspective, Routledge, New York, 2011.

[46] R. Machado, Conflito entre o leão-marinho sul-americano (*Otaria flavescens*) e a pesca costeira comercial no sul do Brasil: uma análise ecológica e econômica, Master thesis, Universidade do Vale do Rio dos Sinos, São Leopoldo, 2013.

[47] K.G. Silva, C.V.L. Crivellaro, T.G. Araújo, R.B. Menezes, Os Mamíferos Marinhos no litoral do Rio Grande do Sul, Nema, Rio Grande, 2014.

[48] D. Szteren, Impacto económico del león marino Sudamericano (*Otaria flavescens*) en la pesca artesanal en Uruguay, Thesis, Universidad Nacional de Córdoba, Córdoba, 1999.

[49] M.J. Weise, T.J. Harvey, Impact of the California sea lion (*Zalophus californianus*) on salmon fisheries in Monterey Bay, California, Fish. Bull. 103 (2005) 685–696.

[50] A.R. Rafferty, E.O. Brazer JR, R.D. Reina, Depredation by harbor seal and spiny dogfish in a Georges Bank gillnet fishery, Fish. Manag. Ecol. 19 (2012) 264–272.

[51] M. Machado, L.R. Oliveira, P.H. Ott, P. Denuncio, M. Haimovici, L.G. Cardoso, L. Milmann, M.A. Romero, R.A. Santos, M. Borges-Martins, Trophic overlap between marine mammals and fisheries in subtropical waters in the western South Atlantic, Mar. Ecol. Prog. Ser. 639 (2020) 215–232, https://doi.org/10.3354/meps13284.

[52] H. Westerberg, Policy Department B: Structural and Cohesion Policies: Potential Solutions to the Seals-Fisheries Conflict, 2010. http://www.europarl.europa.eu/studies. (Accessed 24 December 2018).

[53] S.M. Oksanen, M.P. Ahola, E. Lehtonen, M. Kunnasranta, Using movement data of Baltic grey seals to examine foraging-site fidelity: implications for seal-fishery conflict mitigation, Mar. Ecol. Prog. Ser. 507 (2014) 297–308.

[54] S. Robinson, A. Terauds, R. Gales, M. Greenwood, Mitigating fur seal interactions: relocation from Tasmanian aquaculture farms, Aquat. Conserv. Mar. Freshw. Ecosyst. 18 (2008) 1180–1188.
[55] T. Götz, V.M. Janik, Non-lethal management of carnivore predation: long-term tests with a startle reflex-based deterrence system on a fish farm, Anim. Conserv. 19 (2016) 212–221.
[56] P. Bordino, S. Kraus, D. Albareda, A. Fazio, A. Palmerio, M. Mendez, S. Botta, Reducing incidental mortality of Franciscana dolphin *Pontoporia blainvillei* with acoustic warning devices attached to fishing nets, Mar. Mamm. Sci. 18 (2002) 833–842.
[57] N. Gales, M. Hindell, R. Kirkwood, Marine Mammals, Fisheries, Tourism and Management Issues, CSIRO publishing, 2003.