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Short communication

Predation of South American sea lions (*Otaria flavescens*) on artisanal fisheries in the Rio de la Plata estuary

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ABSTRACT

Interactions between pinnipeds and fisheries occur whenever there is spatial overlap between them. In Uruguay, the South American sea lion (*Otaria flavescens*) interacts frequently with artisanal fisheries by preying upon entangled fish. The objective of this study was to evaluate sea lion interactions with gillnets in three fishing ports of the Rio de la Plata estuary during an entire year. Data was collected on-board during 82 routine trips with artisanal fishermen. Minimum and maximum predation scenarios were estimated per fishing event. The number of pinnipeds interacting with artisanal fisheries was significantly higher in winter and spring, coinciding with the reproductive cycle of these animals. Catch per unit of effort did not differ significantly with presence or absence of interactions. Damage in all fishing ports was low, but significantly higher in autumn and spring, representing between 1.4 and 15.9% of potential catches, considering minimum and maximum scenarios. In addition to season, two factors may be influencing the magnitude of the interactions: distance to the closest colony and magnitude of fisheries landings. According to this study, sea lions did not cause a significant loss to artisanal gillnets. Further studies should consider this conflict as a component of socio-ecological systems using participative research to facilitate co-management.

1. Introduction

Competitive interactions between marine mammals and fisheries are a classical example of human–wildlife conflict. The wildlife component is highly valued by some sectors of society and the human component involves the livelihood of entire communities with few options for alternative employment (Matthiopoulos et al., 2008). Interactions occur whenever fishing activities overlap spatially with marine mammal feeding grounds or reproductive areas, and different effects can be observed (Wickens, 1995). Operational interactions include damage to gear and catches, and are frequently associated with pinnipeds (Harwood, 1987). The magnitude of such interactions depends on the pinnipeds' predatory behavior, resource abundance, distance to haul out sites and the fishing gear used (Northridge, 1985). Fish trapped in gillnets are an abundant and easy food source for pinnipeds that requires less energy than pursuing and catching prey (Hückstädt and Antezana, 2003). Similar to other pinnipeds, the South American sea lion (*Otaria flavescens*) (Shaw, 1800) has learned to follow fishing vessels and to interact frequently with coastal fisheries by preying upon entangled fish and damaging fishing gear (Hückstädt and Antezana, 2003; Szteren and Páez, 2002). The Uruguayan population of South American sea lions is approximately 12,000 animals and it is declining annually by 2% (Páez, 2006). Another resident pinniped species living on the Uruguayan coastline is *Arctocephalus australis*, which rarely interacts with artisanal fisheries (De María et al., 2012). Coastal fisheries in Uruguay are mostly artisanal in scale and important to human socio-economic development in coastal areas (Puig, 2006). Artisanal fishery is defined as an activity operating mainly in inshore coastal waters, for sale and/or subsistence, using small boats of less than 10 GT (Defeo et al., 2010). It is an unpredictable and highly variable activity, with difficult and irregular working conditions because of its dependence on climate and resource variability (Altez et al., 1988).

A total of 726 artisanal boats operate in the Uruguayan Coast of the Rio de la Plata and Atlantic Ocean (Puig et al., 2010). The last recorded catch of the entire Uruguayan artisanal fleet was 2835 tons in 2009 (Dirección Nacional de Recursos Acuáticos, 2010), of which approximately 60% consisted of *Micropogonias furnieri*, the main target species (Horta and Defeo, 2012). Artisanal fishermen complained about the damage to their catch and fishing gear caused by sea lions, and expressed their discomfort due to this problem. In this context, fishermen called on the local authorities to resume culling the sea lion population. Since this was a persistent problem, the objective of the present study was to evaluate pinniped predation on the catch of artisanal gillnet fisheries. This

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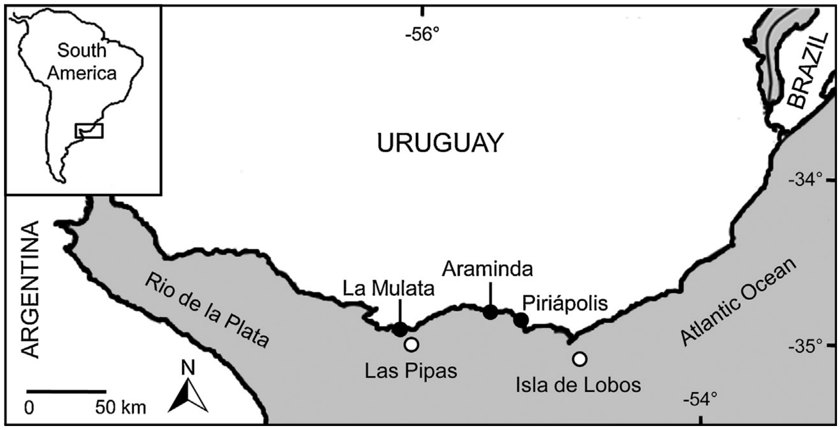

Fig. 1. Study area showing the 3 fishing ports where samplings were conducted (●) and pinniped rookeries (○).

study is the first to collect data over an entire year, in three fishing ports of the Uruguayan coast, in the Rio de la Plata estuary.

2. Materials and methods

2.1. Data collection

From January to November 2010 data were collected by on-board observers during routine fishing trips with artisanal fishermen. Damage was quantified during the entire fishing event by a neutral observer to minimize possible bias derived from fisherman records (Harwood, 1987; Wickens, 1995). The study was carried out in three fishing ports along the Rio de la Plata estuary on the west coast of the South Atlantic Ocean: La Mulata (34°53′56″ S–56°04′07″ W), Araminda (34°47′20″ S–55°33′19″ W) and Piriápolis (34°52′30″ S–55°16′53″ W) (Fig. 1). A "fishing event" was defined as a fishing activity in a specific area and effort during a fishing trip. Several fishing events could take place during the same fishing trip if gillnets were set in areas separated from each other by at least 15 min of navigation, or if the entire gear was taken out of the water and set again. Data were collected and recorded during the soak time and net retrieval of each fishing event: the number of pinnipeds, predation, damage to fish, the total catch per fish species, and the number and size of the gillnets, as well as the soak time itself. The number of pinnipeds interacting was determined by counting those individuals which were diving or feeding in the fishing gear or around the boat at any time during a fishing event.

2.2. Data analysis

The catch per unit of effort (*CPUE*) was calculated as: $CPUE = C/t{\cdot}s \times 1000$, where C is the total catch (kg), t is the time gillnets were in the water (h) and s is the net surface (m^2).

Interactions were considered to be taking place when pinnipeds were observed or predation was recorded (see details in Szteren and Lezama, 2006a). Pinniped-related damage was defined as fish consumed from the fishing gear or damaged fish or fish remains were found. Additionally, sea lion gillnet tugging was considered as an indirect clue of predation. This loss of catch registered on-board was considered the minimum predation (P_{min}). It was only registered in La Mulata and Piriápolis, but not in Araminda due to operational difficulties previously anticipated. To estimate the biomass of each fish ingested by the pinnipeds, the caught species' average weight was used; it was assumed that the predated fish followed the same weight distribution as those captured. When the consumed fish could not be identified, it was considered to be an individual of the most abundant species caught during the fishing event (Szteren and Páez, 2002). In addition, a maximum predation scenario was estimated (P_{max}) based on the assumption that each registered pinniped ate its total daily intake during that fishing event (see Szteren and Lezama, 2006a,b). When no pinniped was seen during a fishing event, but damage was registered, the worst possible situation was assumed (i.e. male adult sea lion daily intake = 9 kg). Both predation estimates were calculated per unit of effort ($PPUE_{min}$ and $PPUE_{max}$), as: $PPUE_{min} = P_{min}/t{\cdot}s \times 1000$, where the unit of P_{min} is kg, and t and s are the same as in *CPUE*.

Furthermore, the potential catch from each fishing event (*CPUE* + *PPUE*) was defined for each scenario as the catch fishermen would have had, if there had been no interaction with pinnipeds. In order to determine what percentage of the catches were predated upon in relation to the potential catches, the predation percentage (*%PPUE*), as calculated in Szteren and Lezama (2006a) was used: $\%PPUE = [PPUE/(CPUE + PPUE)] \times 100$.

2.3. Statistical analysis

To deal with the high proportion of records in which the catch was zero, the effect of pinnipeds on the *CPUE* of artisanal fisheries was tested through a two step delta approach (Maunder and Punt, 2004). Firstly, *CPUE* was considered as a binary response variable and modeled using a Generalized Linear Model (GLM) with a binomial distribution and logit link function (Shono, 2008). In this model, the season (summer, autumn, winter and spring), the fishing port (La Mulata, Araminda and Piriápolis), and the interaction with pinnipeds (presence/absence of interaction) were treated as factors and considered explanatory variables. Secondly, non-zero *CPUE*s were modeled using a GLM with gamma distribution and log link function (Punt et al., 2000). Once again, the season, the fishing port and the interaction with pinnipeds were the explanatory variables in the model. The R step function (R Development Core Team, 2011), based on the Akaike's Information Criterion, was used to simplify the models. $PPUE_{min}$ was analyzed in the same way as *CPUE*, with season and fishing port as explanatory variables. Changes in the number of pinnipeds between fishing ports and seasons were analyzed using GLM with a negative binomial distribution with log link function.

3. Results

3.1. Fishing catches

A total of 82 fishing events were monitored: 22 in La Mulata, 23 in Araminda and 37 in Piriápolis. The model obtained for binary

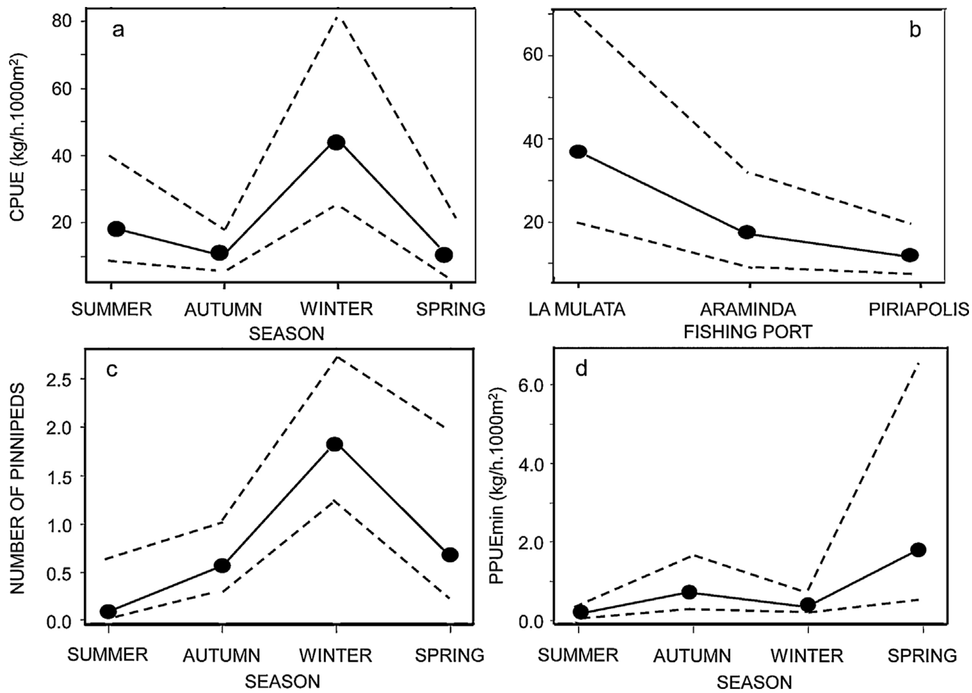

Fig. 2. Partial effects of the seasons (a) and fishing ports (b) on *CPUE*. (c) Mean number of pinnipeds in each season. (d) Effect of the season in minimum predation per unit of effort ($PPUE_{min}$). Mean (●) and 95% confidence interval (-·-) are shown.

CPUE did not show significant effects of the interactions with pinnipeds on the probability of obtaining catches. In addition, no differences between different seasons or fishing ports were found. In the non-zero *CPUE* model, the interactions with pinnipeds did not help to explain catch levels. However, when catches were registered, the model exhibited significant differences between seasons and fishing ports (percentage of explained deviance = 20%). During the winter, the highest values for landings were obtained with significant differences to autumn ($p = 0.00042$) and spring ($p = 0.0034$). However, no other significant differences were found between seasons (Fig. 2a). With respect to fishing ports, La Mulata had significantly higher landings than Piriápolis ($p = 0.0055$). The former port did not show significant differences to Araminda. Moreover, no significant differences were observed between Araminda and Piriápolis (Fig. 2b)

3.2. Interactions with pinnipeds

O. flavescens was the species that interacted with artisanal fisheries. Only 2 individuals of *A. australis* were observed (one predating upon gillnet catches at La Mulata and one caught as bycatch in Piriápolis). The maximum number of interacting pinnipeds per event was observed at Araminda (7 individuals), followed by La Mulata (5 individuals) and Piriápolis (4 individuals). In all cases the mean did not reach 1.5 individuals (Table 1). The GLM for the number of pinnipeds did not show significant differences between fishing ports. This model only revealed a significant increase in the number of pinnipeds from summer to winter, while remaining constant in spring (summer–autumn $p = 0.037$, summer–winter $p < 0.001$, summer–spring $p < 0.001$, percentage of explained deviance = 31%). No significant differences were found between winter and spring (Fig. 2c). Overall, the fishing port with the highest percentage of fishing events with interactions (63.4%) was La Mulata; the lowest was Piriápolis (40.54%) (Table 1).

Table 1
Mean number of pinnipeds, percentage of fishing events with interactions (% of interactions), mean *CPUE*, mean of minimum and maximum predation per unit of effort ($PPUE_{min}$ and $PPUE_{max}$) and the respective percentages of pinniped predation (%$PPUE_{min}$, %$PPUE_{max}$) at each fishing port, when corresponds standard deviations are shown between brackets.

	Fishing ports		
	La Mulata	Araminda	Piriápolis
# of pinnipeds	1.27 (1.32)	1.43 (1.99)	0.59 (1.07)
% of interactions	63.44	60.87	40.54
CPUE (kg/h × 1000 m²)	27.74 (34.32)	35.22 (73.51)	10.80 (22.87)
$PPUE_{min}$ (kg/h × 1000 m²)	0.24 (0.56)	–	0.22 (0.65)
%$PPUE_{min}$	1.37 (2.99)	–	13.61 (48.66)
$PPUE_{max}$	3.42 (5.62)	1.55 (3.26)	1.09 (2.70)
%$PPUE_{max}$	15.9 (16.50)	6.52 (10.60)	15.3 (27.4)

3.3. Damage

The model for binary $PPUE_{min}$ did not show spatial or temporal variations in the probability of observing predation on landings. However, when analyzing non-zero $PPUE_{min}$ (i.e. only when predation on catches was observed) a seasonal variation was found (percentage of explained deviance = 34%). Damage was significantly higher in autumn and spring (summer–autumn $p = 0.023$, summer-spring $p = 0.0052$ and winter–spring $p = 0.027$) (Fig. 2d). No differences in non-zero $PPUE_{min}$ were observed between fishing ports. Low values of $PPUE_{min}$ were found in La Mulata and Piriápolis (0.24 and 0.22 kg/h × 1000 m² respectively) (Table 1). Minimum pinniped predation represented at least 1.37% and 13.61% of potential catches in La Mulata and Piriápolis, respectively (Table 1). The mean values of $PPUE_{max}$, were higher in La Mulata (3.42 kg/h × 1000 m²) and lower in Piriápolis (1.09 kg/h × 1000 m²) (Table 1). Maximum pinniped predation represented between 6.52% and 15.9% of potential catches in Araminda and La Mulata, respectively (Table 1).

4. Discussion

Our results show conclusively that pinnipeds are not responsible for low landings in any of the studied artisanal fishing ports. The present study supports previous studies in the region, which show that the species which interacts with artisanal fisheries in the vast majority of the cases is *O. flavescens*. The mean number of sea lions interacting with artisanal fisheries was low and similar to the number recorded in Piriápolis by Szteren and Páez (2002) and Szteren and Lezama (2006b), and in other areas in the southern cone region (Sepúlveda et al., 2007; de la Torriente et al., 2009).

A seasonal variation in the mean number of pinnipeds was observed, with minimum values recorded during the summer, and, increasing over the following months until spring. This pattern may be explained by the reproductive cycle of these animals; during the breeding season (summer), animals are attached to their rookeries while in winter their foraging activity increases (de la Torriente et al., 2009). This is because after the breeding season, males must recover their body condition and females are able to perform longer foraging trips (Rodríguez et al., 2013), as their pups become more independent. The reproductive cycle could also explain the two increases in damage by pinnipeds before and after the breeding season.

The percentage of fishing events with interactions is similar to previously reported values: from 40 to 63% in Uruguay and the region (Szteren and Lezama, 2006a,b; Szteren and Páez, 2002), from 4.2 to 71.4% in Chile (Sepúlveda et al., 2007) and 32% in Argentina (Fazio et al., 2000). This indicates that, in Uruguay, the percentage of fishing events with interactions has remained relatively stable for the last 15 years.

Based on these results, we hypothesize that there may be 2 factors determining the magnitude of interactions with sea lions in different fishing ports: distance to the closest colony and the presence of fish schools. Araminda and La Mulata showed higher and similar magnitudes of frequency of interaction, and mean number of sea lions. Even though Araminda is a fishing port located relatively far from a colony (~70 km), the presence of large schools of fish is most likely what attracted the sea lions. Moreover, fishing ports close to Araminda had the highest landings on the Uruguayan coast for several years (Horta and Defeo, 2012). Similarly, in Chile more interactions were recorded in areas with large fish schools and not in those close to the colonies (Goetz et al., 2008). La Mulata, in Montevideo, showed intermediate landings, but has a small haul out site in the artisanal fishing area, "Las Pipas" (Fig. 1).

The percentage of sea lion predation was low, even when considering the maximum predation scenario. The magnitude of sea lion predation was in the same range as in other sites of its distribution (see de la Torriente et al., 2009; Sepúlveda et al., 2007) as in previous studies in Uruguay (Szteren and Lezama, 2006a,b; Szteren and Páez, 2002). Possibly, the real magnitude of sea lion predation is between the minimum and maximum estimation (Szteren and Páez, 2002). Further research is needed to obtain a more precise estimation of the magnitude of this predation. Nevertheless, if predation levels were high, we would expect to see differences between fishing trips with and without interactions. This was not observed in any of the fishing ports studied.

Damage should be analyzed in the context in which it occurs; for example, in Piriápolis just 1.0 kg of predation would represent a greater percentage of the total catches than in Araminda and Piriápolis was the fishing port with the lowest interaction. In addition, this problem intensifies during autumn when sea lions predation increases and landings of the main species (*M. furnieri*) are at their lowest (Horta and Defeo, 2012). This aspect was not detected in previous studies because samples had never been collected in autumn. In further studies such human–wildlife conflicts should be considered a component of a socio-ecological system in which economic and governance aspects are also included (Ostrom, 2009).

The practice of culling marine mammal populations to increase fisheries yields in a direct and lineal proportion is no longer supported (Yodzis, 2001). According to this study, sea lions did not cause a significant loss to artisanal gillnets. Furthermore, the South American sea lion is the most influential species in determining the trophic structure of the Rio de la Plata's ecosystem (Bergamino et al., 2012). There is not enough evidence to justify culling this decreasing population. We suggest that strategies for effectively reducing conflicts should involve participative research with an integrative approach to facilitate co-management (Trimble and Berkes, 2013).

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