

OVERLAP BETWEEN PINNIPED SUMMER DIET AND ARTISANAL FISHERY CATCHES IN URUGUAY

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Abstract – The similarity of the trophic ecology of *Arctocephalus australis* and *Otaria flavescens* in Uruguay was studied to help understand a possible trophic competition between the two species and its relation with artisanal fisheries. Dietary data for both pinnipeds together with artisanal fisheries catch data were analyzed to estimate the overlap in prey species and sizes. Diet overlap was very high (Colwell and Futuyma overlap index, $C = 0.80$), with three fish species (*Anchoa mitchilli*, *Cynoscion guatucupa*, and *Trichiurus lepturus*) comprising more than 90% of the total number of individuals consumed by both species. In addition, the length of these three fish prey taken by fur seals and sea lions was similar, suggesting a large overlap not only in species but also in the size of prey ingested. The main difference between the two pinniped diets was that *O. flavescens* showed a more diverse diet than *A. australis*. Concerning pinniped-fisheries interactions, a low level of overlap was observed between the diet of each pinniped and artisanal fisheries catches ($C = 0.22$ for *O. flavescens*, and $C = 0.09$ for *A. australis*). Possibly, sea lion diet is broader than artisanal fisheries catches. Length comparisons for *C. guatucupa*, the only species well represented in both pinniped species diet and fisheries catches, indicated that individuals taken by the latter were larger than those consumed by the pinnipeds. However, the use of different age classes of the same resource, at different times or spatial locations do not imply less intensity of the interaction.

Resumen – Se estudió la similitud en la ecología trófica entre *Arctocephalus australis* y *Otaria flavescens* en Uruguay, para comprender la posible competencia trófica entre ellas y su relación con la pesca artesanal. Para ello, se analizaron datos de dieta de ambos pinnípedos junto con datos de capturas de la pesca artesanal, para estimar el solapamiento de especies y tamaños de presas. El solapamiento de dieta entre *O. flavescens* y *A. australis* fue muy alto (índice de solapamiento de Colwell and Futuyma, $C = 0.80$), y tres especies (*Anchoa mitchilli*, *Cynoscion guatucupa*, and *Trichiurus lepturus*) comprendieron más del 90% del total de presas consumidas. Además, la talla de estas tres especies fue similar para ambos Pinnípedos, por lo que se sostiene que existe un gran solapamiento, no solo de especies sino también de las tallas de presas ingeridas. La principal diferencia entre ambas dietas fue que *O. flavescens* presentó una dieta más diversa que *A. australis*. En referencia a las interacciones entre Pinnípedos y pesquerías, se observó bajo solapamiento entre la dieta de cada especie y las capturas de la pesca artesanal ($C = 0.22$ para *O. flavescens*, y $C = 0.09$ para *A. australis*). Posiblemente, la dieta de *O. flavescens* sea más amplia que las capturas pesqueras. Las comparaciones de tallas para *C. guatucupa*, la única especie bien representada en la dieta de ambos Pinnípedos y en las capturas pesqueras, indicó que los peces capturados eran mayores que las consumidas por los lobos marinos. Sin embargo, el uso de diferentes clases de edad de un mismo recurso, en diferente escala espacio temporal, no necesariamente implica menor intensidad de la interacción.

Keywords: *Otaria flavescens*, *Arctocephalus australis*, diet, artisanal fishery, dietary overlap.

Introduction

The extent of trophic interactions between marine mammals and fisheries is an increasingly important issue for conservation and fisheries management, and a cause of debate in different ambits. Conflicts between pinnipeds and fisheries occur worldwide, varying in extent and impact according to the pinniped species involved, the fishing gear used, the geographical area and season. Passive gear and the increase of fishing

activities in coastal areas have caused an increase in the interactions between fisheries and seals worldwide (Harwood, 1987). In this sense, interaction with fishing operations has been recorded for 36 of the 45 pinniped species and subspecies currently known (Wickens, 1995). In South America, there is some information about this topic for all the countries which share the distribution of southern sea lions, such as in Argentina (Crespo *et al.*, 1995; Fazio *et al.*, 2000⁵), Chile (Oporto *et al.*, 1991, Rodríguez and Stotz, 2002⁶, Hückstädt and Antezana,

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⁵ Fazio, A., Palmeiro, A., Mendez, M., Botta, S. and Bordino, P. (2000). Interacción entre lobos marinos de un pelo *Otaria flavescens* y la pesquería artesanal del Cabo San Antonio, Buenos Aires, Argentina. Page 44 in *Abstracts*, 9^a Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur y 3^o Congreso de la SOLAMAC, 30 October - 3 November 2000, Buenos Aires, Argentina.

⁶ Rodríguez, A.L. and Stotz, W. (2002). Descripción de la interacción del lobo marino común, *Otaria flavescens* (Shaw, 1800) en la actividad de los pescadores artesanales de las caletas de Coquimbo y Peñuelas, IV Región, Chile. Page 46 in *Abstracts*, 10^a Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur y 4^o Congreso de la SOLAMAC, 14-19 October 2002, Valdivia, Chile.

2003), Peru (Arias Schreiber, 1993), and Brazil (Carvalho *et al.*, 1996⁷; Ott *et al.*, 1996⁸; Soto *et al.*, 2000⁹).

Two types of interactions between marine mammals and fisheries may be studied. Operational interactions, which include damage to fishing gear or catches, disturbance to the fishing activity and marine mammal incidental catch, and biological interactions which involves predation or competition for resources between both predators (Wickens, 1995). In Uruguay, only one study focused on operational interactions between southern sea lions and artisanal fisheries quantifying damages caused by the animals to the fishing catches (Szteren and Páez, 2002). However, no studies have considered ecological interactions.

Two otariid species breed in some coastal islands off Uruguay, the South American fur seal (*Arctocephalus australis*) and the southern sea lion (*Otaria flavescens*). The Uruguayan fur seal population is the largest of this species worldwide, reaching about 300000 individuals (Páez, 2000). On the other hand, the population of *O. flavescens* was estimated in approximately 12000 animals in 1996, with a decreasing trend of 5-7% yearly (Páez, 1996¹⁰). One of the proposed causes of this population decline is the illegal killing by artisanal fishermen (Vaz-Ferreira *et al.*, 1994¹¹). Unlike the off-shelf foraging of *A. australis*, southern sea lions forage in coastal waters and frequently interact with artisanal fishing activities (Vaz-Ferreira, 1976). Another possible cause, not previously mentioned, could be the interaction between both pinniped species for trophic resources.

Competition between species implies a reduction in some population attributes, such as growth, survival or fecundity rates, with the condition of a limited resources supply (Begon *et al.*, 1996). The relationship between population rates and other biological variables like species abundance, resources availability and potential competitors is not straightforward. The use of dietary overlap indexes gives information on the similarity of the trophic biology of the species involved. Therefore, these indexes are a valuable approach to assess the existence of potential interactions among species through exploitative competition. The aim of the present study is to analyse the overlap in prey species and sizes between

both pinniped species, and between each species and artisanal fishery catches in Uruguay.

Methods

A total of 137 scats of *A. australis* and 57 of *O. flavescens* were collected in January 1998, at 'Isla de Lobos' rookery (35°01'50"S - 54°53'00"W) on the Atlantic coast of Uruguay. The methodology concerning scat collection is described in detail in Naya *et al.* (2000; 2002). Sagittal otoliths were recovered and then identified using reference material and published identification guides. Percent minimum number of individuals (%MN) was calculated as:

$$\%MN = \frac{ni}{ntotal} * 100$$

where, *ni* is the number of individuals of an item, and *ntotal* is the total number of individuals (Naya *et al.*, 2000). This index measures the minimum number of individual prey taxa, and it uses the maximum count of otoliths (right or left) or cephalopod beaks (upper or lower) (Lowry *et al.*, 1990). To estimate prey size only otoliths with low or no erosion were measured, using a correction factor of 15% to otoliths with little erosion. Fish lengths were estimated from regressions (Naya *et al.*, 2002).

During the same month, a quantification of artisanal fisheries catch was recorded directly onboard fishing boats at three localities on the Uruguayan coast (Szteren and Páez, 2002). These three localities, named 'Piriápolis', 'La Paloma' and 'Cabo Polonio', are situated within a maximum distance of 100km from 'Isla de Lobos' (Figure 1). Data were collected during 14 trips onboard artisanal fishing boats: eight on bottom gillnetters and six on longliners. These data were pooled for the analyses in this study. Fishing boats are between 4 and 9m long, with outboard engines and operate within 5 to 7 nautical miles from the coast. During the fishing trips observers recorded each fish species caught, and the total weight per species. Prey diversity was analyzed by a rarefaction procedure (Heck *et al.*, 1975; Naya *et al.*, 2002). This method allows comparing

⁷Carvalho, R.V., Silva, K.G. and Messias, L.T. (1996). Os pinípedes e a pesca no litoral do Rio Grande do Sul, Brasil. Abstract. Addendum, in *Abstracts 7ª Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur*. (SOLAMAC), 22-25 October 1996, Viña del Mar, Chile.

⁸Ott, P.H., Moreno, I.B., Danilewicz, D. and Olivera, L.R. (1996). Leões marinhos (*Otaria flavescens*) e a pesca costeira no sul do Brasil: uma análise preliminar das competições e conflitos. Page 62 in *Abstracts 7ª Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur*. SOLAMAC. 22-25 October 1996, Viña del Mar, Chile.

⁹Soto, J.M., Souza Filho, M.B. and Mincarone, M.M. (2000). Interação do leão-marinho, *Otaria flavescens* (Shaw, 1800), com a pesca de emalhe na costa do Rio Grande do Sul, Brasil. Pages 733-735 in *Abstracts Anais da XIII Semana Nacional de Oceanografia*. 29 October-03 November 2000, Itajaí, SC, Brasil.

¹⁰Páez, E. (1996). Simulaciones estocásticas en la población de *Otaria flavescens* en Uruguay. Page 116 in *Abstracts, 7ª Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur*, 22-25 October 1996, Viña del Mar, Chile.

¹¹Vaz-Ferreira R., Páez, E., Ponce de León, A., Bianco, J., Rios, C. and Stagi, A. (1994). Relaciones entre el león marino de Sudamérica, *Otaria flavescens* y el lobo de dos pelos de Sudamérica, *Arctocephalus australis* en Uruguay. Page 11 in *Abstracts, Primer Encuentro Nacional sobre Fauna Acuática*. Sociedad Zoológica del Uruguay and Instituto Nacional de Pesca. October, 1994, Montevideo, Uruguay.

different samples of prey species found in several predators, because it calculates the expected richness of species in each sample if all samples were of a standard size. This is the only diversity measure sensitive to rare species and unbiased by sample size (Magurran, 1988). The overlap between pinniped diets and each of the species diet with fisheries catches was calculated by the Colwell and Futuyma (1971) index,

$$C = 1 - 1/2 * \sum_{j=1}^n |p_{1j} - p_{2j}|$$

where p_{1j} and p_{2j} are the proportions of the j th prey item in pinnipeds diet or in the fishery catch. Overlap was calculated from prey numeric composition, discarding unidentified prey in the estimation.

Differences in prey mean lengths between pinnipeds and between each species and fishery catches was tested. The homogeneity of variances was verified through Levene test. This test is powerful for population distributions and is less sensitive to normality in the data (Sahai and Ageel, 2000), minimizing the necessity to transform the data or using a low power non-parametric test. According to the Levene test the null hypothesis (homogeneity of variances) could not be rejected and the Student t-test was applied.

Results

Fur seal-sea lion dietary overlap

A total of eight prey taxa were found in the scats of each pinniped species. However, despite the same value for the observed

richness, the rarefaction curves showed that the diet diversity was greater in *O. flavescens* than in *A. australis* (Figure 2).

Dietary overlap between the two pinniped species was high, reaching a Colwell and Futuyma overlap index of 0.80. For both otariid species, the anchovy (*Anchoa marmorata*), the weakfish (*Cynoscion guatucupa*) and the cutlassfish (*Trichiurus lepturus*) were the most consumed fish species (Table 1, Figure 3). Cephalopods were an important prey item for *A. australis* but not for *O. flavescens*. In addition, the estimated length of these prey (Table 2) did not differ between both otariid species (*A. marmorata*: $t_{185} = 1.23$, $p = 0.22$; *C. guatucupa*: $t_{15} = 1.94$, $p = 0.07$; *T. lepturus*: $t_{21} = 1.79$, $p = 0.09$).

Pinnipeds-fishery overlap

The Brazilian codling (*Urophycis brasiliensis*) constituted the greatest proportion of artisanal fisheries catches; however, it was only found in scats of *O. flavescens* in a low proportion (Table 1, Figure 3). Other important fish in the catches were *C. guatucupa* and the narrownose smoothhound (*Mustelus schmitti*). Overlap between these catches and pinniped diets at 'Isla de Lobos' was low for both species, being higher for *O. flavescens* ($C = 0.28$) than for *A. australis* ($C = 0.09$) (Figure 3). Comparison of fish lengths between pinniped species and fisheries was done only for *C. guatucupa* (Table 2) because it was the only species taken by both pinniped species and fisheries. Individuals caught by fisheries were larger (> 3 years) than those consumed by the pinnipeds (1-2 years) ($t_{85} = 8.27$, $p < 0.001$ for *A. australis*, and $t_{90} = 9.21$, $p < 0.001$ for *O. flavescens*) (ages according to Ehrhardt *et al.*, 1977).

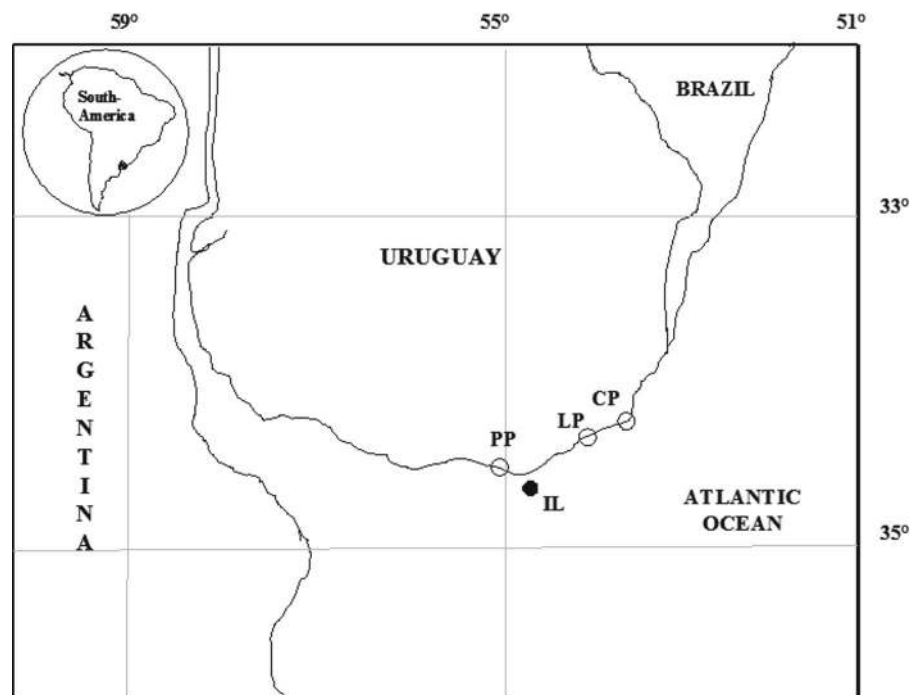


Figure 1. Study area, showing the location of the seal colony 'Isla de Lobos' (IL), and the three fishing localities: Piriápolis (PP), La Paloma (LP), and Cabo Polonio (CP).

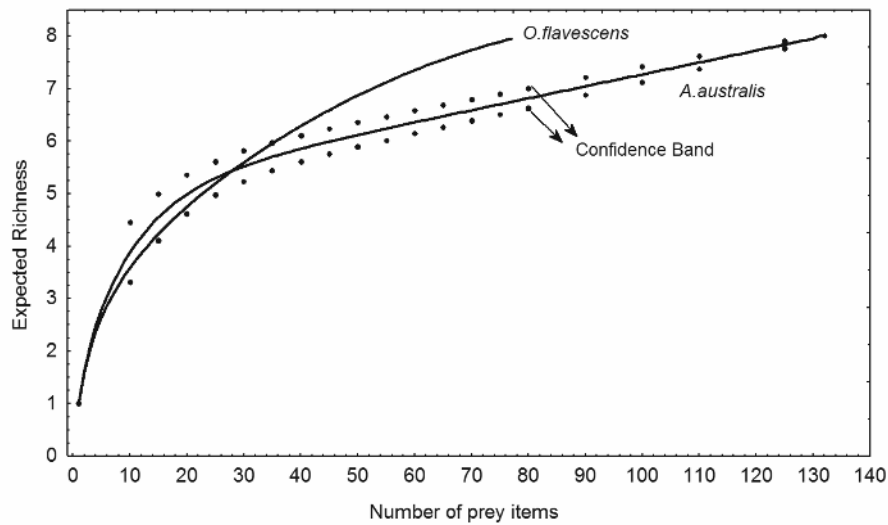


Figure 2. Rarefaction curves of *A. australis* and *O. flavescens* diets, at 'Isla de Lobos', Uruguay. Dot lines represent 95% confidence intervals for *A. australis*.

Table 1. Percent number of individuals (%NI) of each item consumed by *A. australis*, *O. flavescens* and number of individuals caught by artisanal fisheries.

PREY ITEMS	%NI	%NI	NI FISHERIES (1371kg)
	<i>A. australis</i>	<i>O. flavescens</i>	
<i>Cynoscion guatucupa</i>	8.33	22.78	28.42
<i>Engraulis anchoita</i>	6.82	2.53	0
<i>Anchoa maringii</i>	56.06	56.96	0
<i>Trichiurus lepturus</i>	14.39	10.12	0
<i>Urophycis brasiliensis</i>	0	1.27	36.75
<i>Micropogonias furnieri</i>	0.76	1.27	9.09
<i>Mustelus schmittii</i>	0	0	22.54
<i>Conger japonicus</i>	0	2.53	1.86
<i>Trachurus lathami</i>	0.76	0	0
<i>Merluccius hubbsi</i>	0.76	0	0
<i>Umbrina canosai</i>	0	0	0.35
<i>Parona signata</i>	0	0	0.87
Cephalopods	12.12	2.53	0
n	137	57	36
No. ind.	132	80	1718

(n) number of scats analysed or number of fishing trips observed, (No. ind.) number of individuals.

Table 2. Mean length (L, in mm), standard deviation (sd), and number of individuals (n) measured for the three main fish prey of *A. australis* and *O. flavescens* at "Isla de Lobos", and caught by artisanal fisheries.

	<i>A. australis</i>			<i>O. flavescens</i>			FISHERIES		
	L	sd	n	L	sd	n	L	sd	n
<i>C. guatucupa</i>	204.6	34.5	5	242.5	46.3	10	394.8	50.6	82
<i>A. maringii</i>	78.7	8.3	112	80.2	7.7	75	-	-	-
<i>T. lepturus</i>	681.7	97.9	18	761.7	14.8	5	-	-	-

Discussion

The diet of *A. australis* and *O. flavescens* was dominated by a few prey species, in agreement with other otariid dietary studies (e.g. Majluf, 1989; Goldsworthy *et al.*, 1997; Dellinger and Trillmich, 1999; Koen Alonso *et al.*, 2000). The greatest difference between both otariids diet was that *O. flavescens* presented a slightly more diverse diet than *A. australis*. The ability of *O. flavescens* to exploit a wide range of prey has been previously mentioned for Argentina (Crespo *et al.*, 1995; Koen Alonso *et al.*, 2000), and Chile (George-Nascimento *et al.*, 1985), the same being true for other sea lion species in other geographic areas (e.g. Lowry *et al.*, 1990 for *Zalophus californianus*; Lallas, 1997 for *Phocarctos hookeri*). Camacho Rios (2004) also compared the diet of a sea lion (*Z. californianus*) and a fur seal (*Arctocephalus townsendi*) in sympatry, and concluded that the sea lion's diet was richer and more diverse than that of fur seals.

Although there is considerable information about otariid diets, there are few publications comparing the diet of otariid species in sympatry. Among the studies that have been conducted, the observed relationship between diet overlap and foraging area distribution has shown contrasting results. For example, Dellinger and Trillmich (1999) also used the Colwell and Futuyma's index to analyze the overlap between *Z. californianus* and *Arctocephalus galapagoensis*, and concluded that they both use the same foraging areas but have a very low diet overlap. Apparently both species avoided competition by feeding at different times of the day. Using radio-transmitters and scat analysis, Antonelis *et al.* (1990) studied the foraging behaviour and diet of *Callorhinus ursinus* and *Z. californianus* in California. Both pinnipeds fed on similar prey but used different foraging areas (Antonelis *et al.*, 1990). *Arctocephalus gazella* and *A. tropicalis* had similar diets and foraging areas at Macquarie island (Goldsworthy *et al.*, 1997). Camacho Rios (2004) analysed scats from *Z.*

californianus and *A. townsendi* in Mexico, and found that the dietary overlap was minimal. An ecologic segregation in the use of habitat was proposed, where *A. townsendi* would feed farther from the coast than *Z. californianus*. For the pinnipeds studied herein, previous reports also suggest a spatial segregation with *A. australis* foraging mainly outside the continental shelf and *O. flavescens* foraging near the coast, both using similar prey species (Vaz-Ferreira, 1976).

A high overlap index can be evidence for or against the existence of competition, because despite competition may be operating, exclusion or displacement may be incomplete or impossible (Colwell and Futuyma, 1971). The extensive diet overlap between the two otariid species at 'Isla de Lobos' rookery indicated that the segregation of foraging areas was not associated with a marked resource differentiation. According to Antonelis *et al.* (1990), the greater overlap occurs when prey are most abundant, and the maximum segregation when prey are scarce. If this is true, in our example the low overlap between *A. australis* and *O. flavescens*, and the high overlap between the latter and artisanal fisheries, would be reflecting scarcity of resources in our study time.

Since the diets were analyzed during summer when both pinniped species are mainly restricted to land, the observed overlap could be overestimated as a result of an overrepresentation of prey caught close to 'Isla de Lobos', similarly to what was observed for New Zealand fur seals (see Fea and Harcourt, 1997). The analysis developed in this study is based on information taken in one month (January 1998), which constrains the generality of the obtained results. Nevertheless, we assume high diet diversity in this month (as found by Naya *et al.* (2002) for *A. australis*, and Camacho Rios (2004) for *Z. californianus*). In the case of *A. australis*, the breeding season is over by early January, so all age classes may be feeding at sea. As a result, the scats likely represent the first post-breeding foraging trips. Sea lions are in their breeding season so

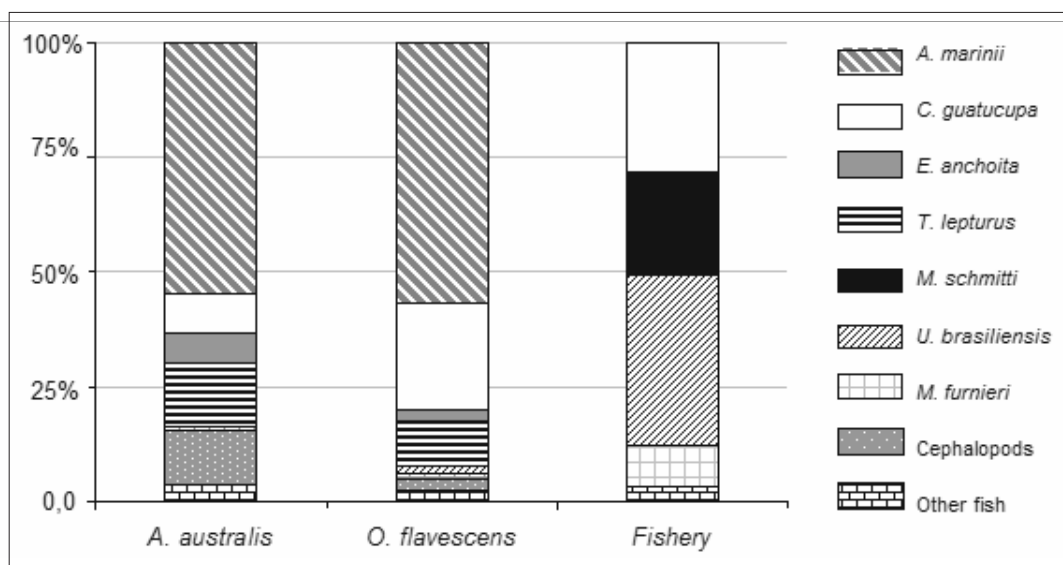


Figure 3. Consumption by *A. australis* and *O. flavescens* (in percentage number of individuals) of each prey species at 'Isla de Lobos', and artisanal fisheries catches.

the majority of the age classes are restricted to land. Scats would represent short foraging trips near the island for lactating females, normal diet of juveniles, or a rich diet prior to the fasting period in males.

The overlap between the diet of both pinniped species and fisheries catches seems low, and only *C. guatucupa* was an important resource for the three (Figure 3). However, the size classes of the prey species consumed by pinnipeds were smaller than those caught by the artisanal fisheries. This non-overlapping consumption is in agreement with previous findings in other geographic areas. For example, in the Falklands islands, Thompson *et al.* (1998) found no overlap between fish items in *O. flavescens* diet and the landed catch. Sea lions were taking smaller sizes than the fishery. The same was reported by Swartzman and Haar (1983) between *Callorhinus ursinus* and commercial fisheries at the Bering sea. In Patagonia (Argentina) commercial as well as non-commercial fish sizes were consumed by *O. flavescens* (Crespo *et al.*, 1997; Koen Alonso *et al.*, 2000). However, it should be noted that the consumption of different fish size-classes by pinnipeds and fisheries should not be equated with a lower intensity of competition (Harwood, 1987; Koen Alonso *et al.*, 2000). This is because the existence and extent of competition will depend on the effect of the fish removal by otariids and fisheries on fish population dynamics (Yodzis, 2001). The use of the same resource of different age classes or at different times or spatial locations does not necessarily mitigate the intensity of the interaction (Harwood, 1987).

It is important to highlight that artisanal fisheries are only catching a range of fish species and sizes, depending on the mesh size and type. Thus, our results help to confirm that the diet of sea lions can be broader than artisanal fisheries catches, allowing to a better understanding of the extent of the interaction between this fishery and pinnipeds.

The population of *O. flavescens* in Uruguay is declining; however, the causes are unknown. They could be related to the diet as has been found for Steller sea lions. For that species, Merrick *et al.* (1997) found that the lower the diet diversity, the greater the rates of decline in different populations in the Gulf of Alaska and the Aleutian Islands. In California (U.S.A.) sea lions exhibited more diverse diets during adverse environmental conditions (*e.g.* El Niño), because the preferred prey would be absent or less available to the animals (Lowry *et al.*, 1991). The greater the prey diversity in sea lions diet, the lower the interaction with fisheries might be, if these prey species have commercial importance.

Collection of fur seal and sea lion scats in Uruguay show some difficulties, particularly for the latter. First, the risk of high pup mortality due to crushing by adults during herd disturbances restricts the number of faeces that can be assembled. Second, the population decline of *O. flavescens* implies that, in the last years fewer areas on the rookery were occupied only by this species. In addition, most of these areas

are of difficult access to humans, making it a challenge to find zones where scats can be collected with confidence about pinniped species identity.

Although limited in time, the present research represents the first attempt to understand seal and sea lion-fisheries resource interaction on the Uruguayan coast. Further studies should investigate the dynamic of this and other fisheries-interactions over time and space to better understand the potential interactions among pinnipeds and fisheries.

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