

Article

South American Sea Lions *Otaria flavescens*, a good indicator of relative spatial and temporal changes in the distribution and abundance of marine resources?

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ABSTRACT. Oceanographic fluctuations and changes in ocean productivity directly affect the abundance and distribution of prey species, which in turn, affect the population status of their predators. In order to have a better understanding of this predator-prey relationship, the aim of the present study was to analyze the diet of the South American Sea Lion *Otaria flavescens* (Shaw, 1800) in two rookeries of the San Matias Gulf, in northern Patagonia (Argentina). A total of 52 scat samples of *O. flavescens* were collected in the Promontorio Belén colony and 35 in Caleta de los Loros during the late spring of 2011. The analysis of the samples indicated that at both localities fish occurred in 100% of scats with prey remains, followed by cephalopods (32.3%) and crustaceans (21.4%). The fish *Raneya brasiliensis* (Kaup, 1856) constituted the main prey taxon, both in terms of occurrence and numerical abundance. The octopod *Octopus tehuelchus* (d'Orbigny, 1834) and squids of the genus *Doryteuthis* constituted the dominant cephalopod prey. It is concluded that sea lions focused their foraging activity on those species of demersal and benthic habits, associated with coastal and shelf waters. Furthermore, this study reports for the first time the feeding habits of the South American Sea Lion colony of Promontorio Belén, second in population size of Río Negro province.

KEYWORDS. Pinnipeds, trophic ecology, San Matias Gulf.

RESUMEN. Lobos marinos de un pelo sudamericanos *Otaria flavescens* ¿buenos indicadores de cambios espaciales y temporales relativos en la distribución y abundancia de los recursos marinos? Las fluctuaciones oceanográficas y los cambios en la productividad del océano afectan directamente a la abundancia y distribución de las especies presa, que a su vez afectan al estado de la población de sus predadores. Con el fin de tener una mejor comprensión de esta relación predator-presa, el objetivo del presente trabajo fue analizar la dieta del lobo marino de un pelo sudamericano *Otaria flavescens* (Shaw, 1800) en dos apostaderos del Golfo San Matias, en Patagonia norte (Argentina). Se colectaron un total de 52 muestras de fecas de *O. flavescens* en el apostadero de Promontorio Belén y 35 en Caleta de los Loros durante la primavera tardía de 2011. El análisis de las muestras indicó que en ambas localidades los peces ocurrieron en el 100% de las muestras con remanentes alimentarios, seguidos por cefalópodos (32.3%) y crustáceos (21.4%). El pez *Raneya brasiliensis* (Kaup, 1856) constituyó el principal taxón presa, tanto en términos de ocurrencia como de abundancia numérica. El octópodo *Octopus tehuelchus* (d'Orbigny, 1834) y los calamares del género *Doryteuthis* constituyeron los cefalópodos presa dominantes. Se concluye que los lobos marinos centraron su actividad forrajera en aquellas especies de hábitos demersales y bentónicos, asociado a aguas costeras y de plataforma. Además, este estudio analiza por primera vez los hábitos alimenticios de la colonia de lobos marinos de un pelo sudamericanos en el apostadero de Promontorio Belén, segunda en tamaño poblacional de la provincia de Río Negro.

PALABRAS-CLAVE. Pinnípedos, ecología trófica, Golfo San Matias.

Oceanographic fluctuations and changes in ocean productivity directly affect the abundance and distribution of prey species, which in turn affects the population status of their predators (GUINET *et al.*, 2001; MC MAHON *et al.*, 2005; MELIN *et al.*, 2012; LOEB & SANTORA, 2015; ABREU *et al.*, 2019). A better understanding of this predator-prey relationship would allow predators to be used as indicators of changes in the marine environment. Sea lions, as top predators, could be good indicators of relative spatial and temporal changes in the distribution and abundance of

marine resources. A comprehensive analysis of biological and oceanographic information has the potential to provide a better understanding of the dynamics of the marine ecosystem and its influence on shaping the life history of predators (SOTO *et al.*, 2006; CONSTABLE *et al.*, 2014).

In reference to the feeding ecology of the South American sea lions, *Otaria flavescens* (Shaw, 1800), its study is of utmost importance if we consider that one of the factors affecting the population fluctuations of marine mammals is the availability of food in the ocean (CRESPO & PEDRAZA,

1991; SOTO *et al.*, 2006). The information available on the diet of *O. flavescens* has increased in the last two decades in different areas of its distributional range (SOTO *et al.*, 2006; HÜCKSTÄDT *et al.*, 2007; BUSTOS *et al.*, 2014, 2019; CÁRDENAS-ALAYZA *et al.*, 2022). These studies suggest that *O. flavescens* has a generalistic and opportunistic trophic behaviour, with differences in the diet between males and females, probably associated with different feeding areas (KOEN ALONSO *et al.*, 2000; NAYA *et al.*, 2000; DRAGO *et al.*, 2009; CRESPO *et al.*, 2012; ZENTENO *et al.*, 2015). Up to date, dietary studies in the maritime coast of Río Negro province (North Patagonia) have been focused on the colonies of Punta Bermeja and Caleta de los Loros (BUSTOS *et al.*, 2012, 2014, 2019). These have indicated differences in the relative proportions of the dominant prey taxa between both rookeries.

In this regard, it is important to highlight that this study is the first to analyze the feeding habits of the sea lions' colony of Promontorio Belén, second in importance in terms of population size of Río Negro province. On the other hand, the colony of Caleta de los Loros, unlike that of Promontorio Belén, is smaller in size and located within the bounds of a Protected Natural Area which is administered by the Secretaría de Ambiente y Cambio Climático of Río Negro Province. Both colonies are permanent, with seasonal variation in number of individuals throughout the year and catalogued as "mixed colonies", *i.e.* important reservoirs of juveniles with small breeding areas in constant growth (DANS *et al.*, 2004). It is worth mentioning that the study season, late spring, constitutes a stage immediately prior to the beginning of the reproductive period of this otariid species. Therefore, it provides important information on the type and availability of prey in a key stage of the annual cycle of the species.

On the other hand, another factor that may influence the population status of pinnipeds is their interaction with fisheries. This overlap could exist in those areas where this group of marine mammals feed and fisheries activities occur (WICKENS *et al.*, 1992). The aims of the present study were to: a) examine for the first time the diet of *O. flavescens* from the Promontorio Belén rookery, b) assess whether or not there was geographical variation in the feeding habits of *O. flavescens* between the two rookeries analysed, c) evaluate the potential/actual overlap between sea lions and fishery activities in the use of marine resources within the study area.

MATERIALS AND METHODS

Field data collection.

During the first half of December 2011, a total of 87 fresh scats of *O. flavescens* were collected at the sea lion rookeries of Promontorio Belén (PB: 41°09'S, 63°48'W) (n=52) and Caleta de los Loros (CL: 41°02'S, 64°10'W) (n=35) (Fig. 1). The faecal samples were preserved in 70% ethanol and brought to the laboratory for further analysis.

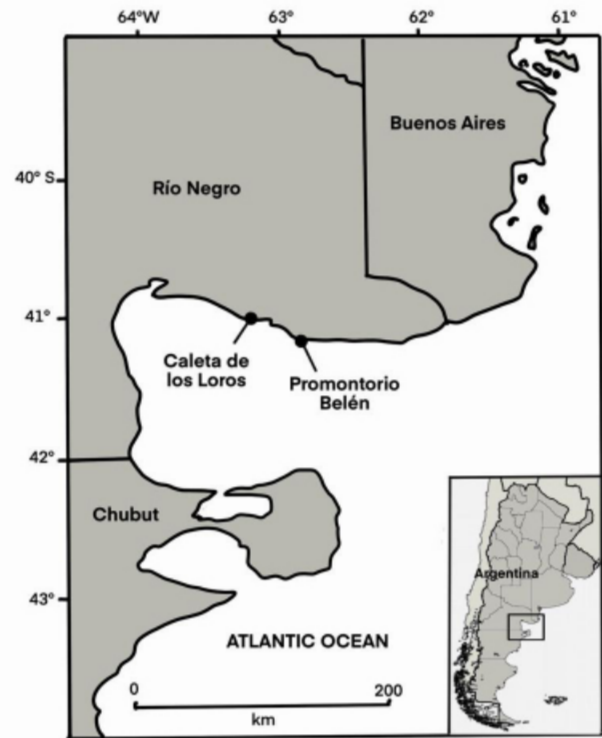


Fig. 1. Study area showing the location of the rookeries analysed at Río Negro Province, Argentina.

Additionally, in order to obtain a general picture of the population size and structure of each colony sampled, the total number of individuals were counted and catalogued in the following sex-age classes according to DANS *et al.* (2004).

Adult + subadult males (~>3 years old).

Adult females + unknown sex juveniles (including under yearlings).

Laboratory analysis.

Hard prey remains were recovered using sieves of different mesh size (2.5-0.5 mm) and rinsing water and, whenever possible, the different prey taxa were identified to the lowest possible taxonomical level. Fish were recognized from otoliths, bones, eye lenses and scales (teleost), teeth and dorsal plates (elasmobranchs); cephalopods from beaks, eye lenses and pens and crustaceans from exoskeleton remains. Fish otoliths and cephalopod beaks were identified by comparison with available catalogues (TORNO, 1976; CLARKE, 1986; VOLPEDO & ECHEVERRÍA, 2000; VOLPEDO *et al.*, 2017; XAVIER & CHEREL, 2021) and reference collections housed in the Laboratorio de Sistemática, Anatomía y Bioecología de Mamíferos Marinos, División Mastozoología of the Museo de Ciencias Naturales "Bernardino Rivadavia" (MACN-CONICET) and COLV in the Instituto de Investigaciones en Producción Animal (INPA/UBA-CONICET). The size and weight of the fish identified in the scats were estimated

using regression equations (TORNO, 1976; HECHT, 1987; BALDÁS *et al.*, 1997; KOEN ALONSO *et al.*, 2000; VOLPEDO & ECHEVERRÍA, 2000 and VOLPEDO *et al.*, 2017). In the case of otoliths, a correction factor was applied according to the degree of erosion following REID (1995). Those specimens highly eroded were not taken into account and excluded from further analysis following DANERI *et al.* (2008). In regard to cephalopods, allometric equations were used to determine dorsal mantle length (ML in mm) and wet mass (W in g) from their beak sizes (CLARKE, 1986; PINEDA *et al.*, 1996; KOEN ALONSO *et al.*, 2000; XAVIER & CHEREL, 2021). For the main prey taxa identified, the percentage frequency of occurrence (%FO), numerical abundance (%N), biomass (%W), prey importance index (IIMP) and a modified version of the Index of Relative Importance (IRI) were calculated (REID, 1995; GARCÍA-RODRÍGUEZ & DE LA CRUZ-AGÜERO, 2011; BUSTOS *et al.*, 2014). In order to make the interpretation of both indices easier, these were expressed on a percent basis (%IRI, %IIMP) following CORTES (1997).

Statistical analysis.

A nested ANOVA test was performed to detect geographical differences in the sizes of the dominant prey species consumed in common by sea lions from both colonies. This analysis allowed testing of the null hypothesis of no differences between localities. In addition, a chi-squared test was performed to assess geographical variation in the occurrence of the main prey taxa of *O. flavescens* as well as in the population composition (sex-age classes) of each sea lions colony.

RESULTS

Sea lion population composition.

During the sampling period the females-juveniles category made up the largest portion of the population at both rookeries, being the occurrence of males negligible (Tab. I).

Notwithstanding, there were significant differences between colonies in the relative proportions of the sex-age classes assigned (X² Yates: 17.4 P < 0.0001). In proportion, the contribution of males was much lower in Promontorio Belén than in Caleta de los Loros.

Overall diet.

The analysis of faecal samples containing prey remains (n=75) indicated that, for both rookeries, 100% of scats contained fish, followed by cephalopods and crustaceans with a frequency of occurrence of 32.3% and 21.4% respectively. There were significant differences between rookeries in the frequencies of occurrence of these three prey taxa (X² = 8.02; p < 0.05) with crustaceans being more frequent in Caleta de los Loros (PB 15.2% vs. CL 27.6%) and cephalopods more representative in Promontorio Belén (PB 54.3% vs. CL 10.3%) (Fig. 2).

Tab. I. Sea lion population composition during the spring of 2011 at the rookeries of Promontorio Belén and Caleta de los Loros, Río Negro province, Argentina.

	Promontorio Belén	Caleta de los Loros
Females + unknown sex juveniles	1194	785
Adult + subadult males	15	35
Total	1209	820

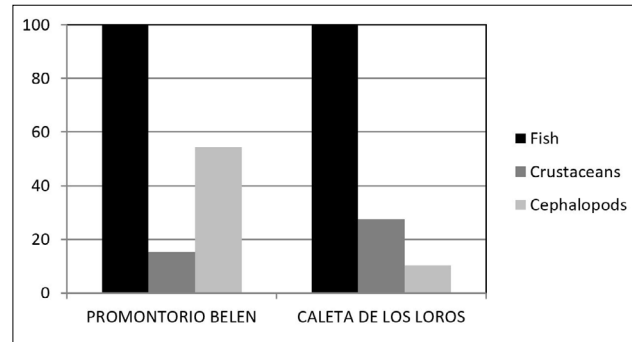


Fig. 2. Frequency of occurrence of the main prey taxa in the diet of *Otaria flavescens* (Shaw, 1800) from the San Matías Gulf, Argentina.

Regarding both colonies combined, fish were represented by a total of 335 otoliths. Their identification indicated that the most frequent and dominant fish species was *Raneya brasiliensis* (Kaup, 1856), with a mean frequency of occurrence of 82.4% and contributing 95.6% to the IRI and 60.8% to the IIMP. Of lesser importance were *Porichthys porosissimus* (Cuvier, 1829) (%IRI = 1.3, %IIMP = 12.3) and *Acanthistius brasilianus* (Cuvier, 1828) (%IRI = 1.2, %IIMP = 7.6). The diversity of fish prey species identified differed between both sites (PB: 11 vs. CL: 4) (Tab. II). There were no significant differences between rookeries in the sizes (standard length) of *R. brasiliensis* preyed upon by *O. flavescens* (Nested ANOVA F = 2.29, p = 0.15), with greater mean lengths in Caleta de los Loros (18.5 ± 3.2 mm) than in Promontorio Belén (16.3 ± 3.4 mm). Regarding cephalopods, beaks belonging to different teuthoid species (mainly *Doryteuthis* spp.) were found only at Promontorio Belén, while the octopod *Octopus tehuelchus* (d'Orbigny, 1834) was the only species found in common at both sampling areas.

Promontorio Belén.

A total of 52 scats were collected at this colony. The analysis of the samples with hard remnants (n= 46) indicated that 100% of them contained fish remains. The identification of the sagittal otoliths (n = 275) indicated that the most frequent (%FO = 81.5) and dominant fish species was *R. brasiliensis*, which, alone, constituted 75.6% in numbers and 71.3% in biomass of the total fish preyed on by sea lions. *Acanthistius brasilianus* was second in terms of frequency of occurrence (%FO = 22.2) and biomass

Tab. II. Taxonomic composition of teleost fish prey remains recovered from scats of *Otaria flavescens* (Shaw, 1800) during the spring of 2011 at Rio Negro province, Argentina, expressed as percentage of frequency of occurrence (FO%), total number (N%), wet weight (W%), prey importance index (IIMP%) and index of relative importance (IRI%).

Prey taxon	Promontorio Belén						Caleta de los Loros						Total		
	%F	%N	%M	%IIMP	%IRI	%F	%N	%M	%IIMP	%IRI	%F	%N	%M	%IIMP	%IRI
Ophidiidae															
<i>Raneya brasiliensis</i>	81,5	75,6	71,3	64,3	94,7	85,7	83,3	72	73,4	94,6	82,4	77	72,9	60,8	95,6
<i>Genypterus blacodes</i>	3,7	1,5	0,2	1,2	0						2,9	1,2	0,2	1,1	0
Batrachoididae															
<i>Porichthys porosissimus</i>	14,8	3,6	4,5	7,7	1	28,6	3,3	10	20,7	2,7	17,6	3,6	5,8	12,3	1,3
<i>Triathalassothia argentina</i>	3,7	0,7	2,1	0,6	0,1						2,9	0,6	1,7	0,5	0,1
Merlucciidae															
<i>Merluccius hubbsi</i>	11,1	4,4	4	6,5	0,7						8,8	3,6	3,2	5,9	0,5
Serranidae															
<i>Acanthistius brasilianus</i>	22,2	2,5	7,9	8,3	1,8						17,6	2,1	6,4	7,6	1,2
Macrouridae															
<i>Coelorrhinus fasciatus</i>	14,8	2,2	1,4	1,5	0,4						11,8	1,8	1,1	1,4	0,3
Macruroniidae															
<i>Macrurus magellanicus</i>						14,3	5	14,5	5,2	2	2,9	0,9	3,1	4,4	0,1
Paralichthyidae															
<i>Paralichthys</i> sp.	14,8	4	2	7,7	0,7	14,3	3,3	3,4	0,8	0,7	14,7	3,9	2,4	3,8	0,7
Pinguipedidae															
<i>Pseudoperca semifasciata</i>	3,7	0,7	0,5	0,6	0						2,9	0,6	0,4	0,5	0
Stromateidae															
<i>Stromateus brasiliensis</i>	3,7	0,7	3,4	0,8	0,1						2,9	0,6	2,8	0,7	0,1
Triglidae															
<i>Prionotus nidigula</i>	11,1	1,1	2,6	0,9	0,3						8,8	0,9	2,1	0,9	0,2
Unidentified	14,8	2,9				28,6	5				17,6	3,3			

(%M= 7.9), while *Merluccius hubbsi* (Marini, 1933) did so in numbers (%N = 4.4) (Tab. II). In regard to cephalopods, these were found in 54.3% of the samples and were mainly represented in numbers by *O. tehueltchus* (%N=56), followed by the teuthoid *Doryteuthis gahi* (d'Orbigny, 1835) which represented 28% of cephalopods consumed. Measurement of lower hood/rostral length (LHL/LRL) of beaks represented specimens of a range of 23.7 – 67.9 mm ML and 4.5 - 81 g wet mass for *O. tehueltchus* and 112.3 –209.8 mm ML and 28.2 – 140.7 g wet mass for *D. gahi*. Crustaceans were of minor relevance, occurring in 15.2 % of samples.

Caleta de los Loros.

A total of 35 samples were collected, of which 29 contained prey remains. Of these, 100% present teleost species and 17.2% elasmobranchs. A total of 60 otoliths from four different species were retrieved from samples containing fish remains, with a dominance of *R. brasiliensis* in terms of frequency, number and biomass (85.7%, 83.3% and 72% respectively). Of lesser importance was *P. porosissimus*, with a frequency of occurrence of 28.6% and *Macruronus magellanicus* (Lönnerberg, 1907) in terms of number and biomass (5% and 14.5% respectively) (Tab. II). Cephalopods were represented uniquely by three beaks (upper n = 1 and lower n = 2) and one eye lens of the octopod *O. tehueltchus*.

Measurement of lower hood length (LHL) of both lower beaks represented specimens of 36.6 – 82.6 mm ML and 14.8 - 139.1 g wet mass. In regard to crustaceans, these were mainly represented by decapods and occurred in 27.6% of scats.

DISCUSSION

The diet of pinnipeds can be analyzed throughout different methods, *i.e.* scats, stomach contents, stable isotopes, among others (CROXALL, 1993). In Otariids, particularly, scat analysis has been used for several decades around the world, due to the high fidelity of its results (REID & ARNOULD, 1996; DANERI *et al.*, 2008; PÁEZ-ROSAS & AURIOLES-GAMBOA, 2010; HARRINGTON *et al.*, 2017). One of the main advantages of this method is that large numbers of scats can be easily collected, without the need to manipulate the animals or alter the colonies. However, this methodology presents some biases, such as the underestimation of those prey taxa that lack hard remains (crustaceans, elasmobranchs), due to their total or partial digestion (TOLLIT *et al.*, 1997; BOWEN, 2000). Notwithstanding, DELLINGER & TRILLMICH, 1988 stated that the numerical proportion of the different prey species can be correctly estimated from large samples of scats.

The results of the present study showed that, although sea lions consumed a wide variety of prey, a few species predominate in their diet. Fish were the most frequent and abundant prey at both sampling locations. This is in line with previous dietary studies of *O. flavescens* at other localities of the Southwest Atlantic which have reported the dominance of this prey taxon in its diet (THOMPSON *et*

al., 1998; KOEN ALONSO *et al.*, 2000; SUÁREZ *et al.*, 2005; ROMERO *et al.*, 2011; BUSTOS *et al.*, 2012, 2014; JARMA *et al.*, 2019). Furthermore, *R. brasiliensis* was the most important fish prey species at both rookeries, both in terms of %IRI (more than 95%) and IIMP (0.61%). It is remarkable that this demersal fish has also been reported to be an important prey item in the diet of *O. flavescens* in other seasons and localities from northern Patagonia and Buenos Aires province (KOEN ALONSO *et al.*, 2000; SUÁREZ *et al.*, 2005; ROMERO *et al.*, 2011; BUSTOS *et al.*, 2012, 2014). Moreover, for the sea lions colony of Punta Bermeja, the biggest of Río Negro province and the closest to the sampling areas in this study, BUSTOS *et al.* (2012, 2014) reported that *R. brasiliensis* was the predominant fish prey species consumed by sea lions in terms of frequency of occurrence and numerical abundance.

According to GOSZTONYI *et al.* (2007), this ophidiid constitutes a key species in the food web of the South Atlantic marine ecosystem, being an important prey item in the diet of marine mammals, marine birds and fishes. The fact that there were no significant differences in the estimated sizes of *R. brasiliensis* between rookeries, might indicate that sea lions preyed upon similar components (*i.e.* age classes) of this fish population during spring. It is interesting to mention that the less relevant fish species found in the present study, such as *A. brasiliensis*, *P. porosissimus*, *Paralichthys* sp. and *M. hubbsi*, among others, also present demersal-benthic habits and a general distribution in the southwest Atlantic Ocean, from southern Brazil to northern Patagonia in Argentina (COUSSEAU & PERROTTA, 2004).

Octopods dominated the cephalopod portion of the diet of *O. flavescens* at Promontorio Belén, while teuthoids were of lesser importance. Moreover, at Caleta de los Loros, only octopods occurred as cephalopod prey of sea lions, and in low numbers.

Different dietary studies carried out at northern Patagonia have shown that, in relation to the cephalopod prey of sea lions, there seems to be an alternation in the dominance of either octopods or teuthoids which varies according to the season, year and location of sampling. This, in turn, should reflect the opportunistic behavior of *O. flavescens*, whose pattern of predation probably depends on the prey availability at a given time and place (Tab. III).

In the present study, we found different contribution of crustaceans to the diet of sea lions between localities; while in Promontorio Belén they occurred in low proportions (15.2%), in Caleta de los Loros they represented the second most important prey item (27.6%). In this sense, some authors have mentioned that this taxon constitutes an important food item of sea lions (HAMILTON, 1934; THOMPSON *et al.*, 1998; SOTO *et al.*, 2006), while others have suggested that crustaceans might not be as important as previously considered but could represent prey of prey (secondary items), regarding that fish and cephalopods are partially carcinophagous (BUSTOS *et al.*, 2014).

Nevertheless, and considering the opportunistic feeding behaviour of this otariid species, it is interesting to

Tab. III. Dominant cephalopod prey taxon (at the order level) in the diet of *Otaria flavescens* (Shaw, 1800) according to season, year, locality, area and methodology.

Source	Present study		DANERI & HARRINGTON (unpublished data)	BUSTOS <i>et al.</i> (2019)	
Season-year	Spring 2011		Summer 2012–2015	May 2005 – Feb. 2008	
Locality – area	Promontorio Belen	Caleta de los Loros	Caleta de los Loros	Punta Bermeja	Caleta de los Loros
Methodology	Scats		Scats	Scats	
% N	Octopods (56%)	Octopods (100%)	Octopods (75%)	Octopods (69.5%)	Teuthoids (54.3%)

mention a particular situation observed with the argentine red shrimp *Pleoticus muelleri* (Bate, 1888), at the San Matías Gulf. This crustacean species experienced an exceptional increase in population numbers in the mid 2010's, generating an intense commercial fishing activity on this resource (DE CARLI *et al.*, 2012; BOSCHI *et al.*, 2016).

Coincidentally, during this period, *P. muelleri* unusually contributed in high proportions to the diet of *O. flavescens* from Caleta de los Loros during the summer of 2015 (A. Harrington and G. A. Daneri, unpubl. data).

The knowledge on the degree of interaction between pinnipeds and fisheries is an important tool for the management of this otariid species. In the San Matías Gulf, the Argentine Hake *M. hubbsi* constitutes the main target of fisheries (IRUSTA *et al.*, 2003). Despite that some dietary studies, based on the analysis of stomach contents, have reported that *M. hubbsi* is an important prey item of *O. flavescens* (KOEN ALONSO *et al.*, 2000; ROMERO *et al.*, 2011), other approaches based on scat analysis indicated that this fish was absent or poorly represented. In the present study, this fish species was absent in the sea lion scats from Caleta de los Loros, while in those from Promontorio Belén its presence was of minor relevance both in terms of %FO = 11.1 and %IIMP = 6.46. In regard to *R. brasiliensis*, this is not targeted by fisheries, hence overlapping with *O. flavescens* is negligible. Regarding *O. tehuelchus*, although not commercially important, it is an important target of the artisanal fisheries of the San Matías Gulf during spring and summer. Two fishing arts are used by fishermen: pot-longline in the subtidal zone and hand gathering in the intertidal areas (STORERO *et al.*, 2010). Therefore, the use of this resource can generate some degree of overlap between sea lions and artisanal fisheries.

Regionally, the species of *Doryteuthis* support local fisheries; both *D. sanpaulensis* (Brakoniecki, 1984) and *D. gahi* are target species of the argentine fishing fleet. The former is caught from southern Brazil to the San Jorge Gulf with trawls, as by catch in the shrimp and prawn fishery. On the other hand, *D. gahi* is captured in the southeast of the Malvinas Islands in two annual seasons, one from February to May and the other between August and October. In addition, it is caught incidentally by the freezer fishing fleet and factory ships (BRUNETTI *et al.*, 1999). From this information, one should expect a low degree of overlap between *O. flavescens* and fisheries in the consumption of these species.

In brief, the results obtained in the present study corroborate the opportunistic and generalist nature of *O. flavescens* as top predator of the San Matías Gulf. The diversity of prey species found in its diet, especially in Promontorio Belén, reflects the high availability of prey resources for the sea lion colonies in the study area. An interseasonal/interannual long term monitoring program of the diet of *O. flavescens* is strongly recommended in order to better understand the feeding ecology of this species. This, in turn, will aid to detect possible changes in local prey availability and thus in the food chains of the North Patagonian marine ecosystem.

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