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Authors: Romero, Rafael, and Guitián, José

Source: *Folia Zoologica*, 66(2) : 117-125

Published By: Institute of Vertebrate Biology, Czech Academy of Sciences

URL: <https://doi.org/10.25225/fozo.v66.i2.a6.2017>

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Food and feeding habits of Eurasian otter, *Lutra lutra*, and American mink, *Neovison vison*, in an Atlantic island of northwest Spain

Rafael ROMERO^{1*} and José GUTIÁN²

¹ Rúa do Presidente Salvador Allende, nº 13 baixo A, 15705 Santiago de Compostela (A Coruña), Spain; e-mail: rromerosuances@gmail.com

² Departamento de Biología Celular e Ecoloxía, Facultade de Biología, Universidade de Santiago, 15782 Santiago de Compostela, Spain

Received 25 October 2016; Accepted 12 April 2017

Abstract. A small population of otter and mink coexist on the Isle of Sálvora, off the coast of Galicia, a region in northwest Spain. The aim of this study was to analyse the feeding habits of both species (taxa and type of prey) and their degree of trophic overlap. In order to analyse which habitat features best define otter and mink trophic preferences, fish preys were defined according to three criteria: substrate preference, position in the water column, and tidal zones. A total of 178 otter spraints and 158 mink scats were collected and analysed between May and October 2007. The relative frequency of occurrence and the biomass of each taxon were calculated. Mink consume mainly rabbits in spring, seagulls in summer, and rodents and shrews in autumn. The frequency of rabbits and gulls in mink diet was related to the abundance of both prey on the island. Otters were basically feeding upon fish throughout the study period. Their main prey was garfish (pelagic fish) during spring and summer, and Blenniidae and Gobiidae (benthic fish of rocky bottom pools) in autumn. These fishes are also consumed by mink during late summer, when the diet overlap between both species is higher (August diet overlap of 43.5 %, mean diet overlap of 16.4 %).

Key words: Mustelidae, sympatric species, invasive species, coastal habitat, diet overlap, monthly variation

Introduction

The American mink (*Neovison vison* Schreber, 1777) has spread throughout much of Europe and currently occupies an area stretching from Russia and Scandinavia to Britain and the Iberian Peninsula (Dunstone 1993, Larivière & Jennings 2009). The existence of wild populations in Europe is a consequence of their multiple escapes from mink farms (Bonesi & Palazón 2007). The species is linked to waterbodies, therefore their main habitats include rivers banks, wetlands, and coastline. As per their habitat requirements, the American mink frequently co-occur with the Eurasian otter (*Lutra lutra* Linnaeus, 1758).

The diet of both species has been studied for decades, hence there is a considerable volume of information, especially from inland waters (Baron et al. 1993, Macdonald & Strachan 1999, Jędrzejewska et al. 2001, Melero et al. 2008, 2014). Studies to date have shown that mink in Europe feed upon a variety of prey, but generally show a primary preference

for fish and a secondary preference for mammals (Macdonald & Strachan 1999, Jędrzejewska et al. 2001). Mink have also been seen to focus on crayfish when they are in abundance (Melero et al. 2008, 2014). However, other taxa may be important prey, so that the mink will traditionally be defined as typically generalist and exploiting both aquatic and terrestrial habitats (Sidorovich 2000, Jędrzejewska et al. 2001, Bartoszewicz & Zalewski 2003). The otter is a specialist predator whose diet is mostly composed of aquatic prey, preferably fish, and also amphibians, mammals and birds although to a lesser extent (Jędrzejewska et al. 2001, Kruuk 2006, Krawczyk et al. 2016).

The few studies conducted in coastal areas suggest that in these habitats both species consume more aquatic prey than in inland waters (Macdonald & Strachan 1999, Jędrzejewska et al. 2001). Overall, otters in the marine environment behave like fish specialists (Kruuk 2006), while mink eat a wider variety of prey (Clode & Macdonald 1995, Schüttler et al. 2008, Fasola et

* Corresponding Author

al. 2009, Valenzuela et al. 2013). The existence of some overlap in their diet in coastal areas, especially in the consumption of benthic fish, suggests that there could be some competition between the two species (Clode & Macdonald 1995). However, mink tend to consume a greater amount of terrestrial prey (mainly mammals) when they are abundant, both on islands and in freshwater ecosystems (Clode & Macdonald 1995, Bueno 1996, Bonesi et al. 2004, Valenzuela et al. 2013). This situation minimises the overlap between the diets of both species and, therefore, facilitates their coexistence, at least in inland waters (Bonesi & Macdonald 2004). In addition, mink can change its activity patterns in the presence of otter (Harrington et al. 2009).

Otters and mink coexist in many areas of the north of the Iberian Peninsula such as on the coastline of Galicia, northwest Spain (Munilla et al. 1997, Palomo et al. 2007). The existence of wild mink populations in Galicia is a consequence of their escape from mink farms as well as instances of their deliberate release in the 1970s, which led them to occupy the coastal areas (Vidal & Delibes 1987). The little data that exist suggest that on the northwest coasts of the Iberian Peninsula, otters feed primarily on fish (Nores et al. 2000, Romero et al. 2012), while mink prefer crabs and fish (Delibes et al. 2004).

Here, we show the monthly variation of feeding habits of otters and mink on the Isle of Sálvora (Galicia, northwest Spain). The main goals of this study were: 1) the comparison of the diet of both species from a taxonomic point of view; 2) the comparison between feeding habits, taking into account the habitats of prey consumed by both species (position in the water column, tidal zone, and substrate); and 3) analyzing the variation in the overlap of the diet according to the availability of prey. Due to the abundance of mammals on the island, we predicted a minimal overlap between the diet of both species.

Material and Methods

Study area

The study was carried out on the Isle of Sálvora, which belongs to the National Park of the Atlantic Islands of Galicia (northwest Spain) (Fig. 1). It has an area of 215 ha, with a perimeter of approximately 10 km and a height of 70 m. It is located at the mouth of the Ría de Arousa (a saline estuary), which is approximately at 3 km distance from the nearest coast. There is an extensive intertidal zone of less than 10 m in depth around the island. Its coastline is formed by granite rock, where numerous rocky pools are formed, where

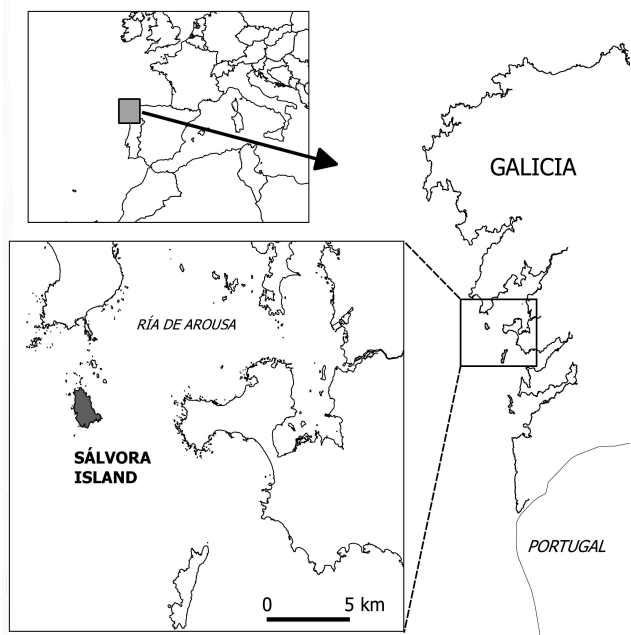


Fig. 1. Study area.

mink and otters can easily scavenge after high tides. Sandy beaches account for 10 % of the coast of the island. The coastal shores are accessible to mink and otters, thanks to its gentle slope. There are two small brooks and several fresh water springs, which can dry out in late summer during drought years. The small- and medium-size mammals present on the island are: the greater white-toothed shrew (*Crocidura russula*), the rabbit (*Oryctolagus cuniculus*), the brown rat (*Rattus norvegicus*), and the wood mouse (*Apodemus sylvaticus*). Rabbits, that were probably introduced to the island, reach high population densities in comparison with other mainland regions of the Iberian Peninsula (L. Latorre, pers. comm.). The colony of gulls (*Larus michahellis*) of the island (7800 couples) is able to produce more than 2000 chicks between early June and late July. The information collected during 2007 (culling campaigns) and successive years (using camera traps) suggests the existence of at least four otters and four mink living on the island.

Scat and spraint analysis

During year 2007, a monthly collection of mink scats and otter spraints was conducted from May to October along a sampling shore route. The route included the entire perimeter of the island, composed of a rocky strip of between 10 to 20 m in width. A total of 158 mink scats (monthly mean: 26.3 ± 4.72) and 178 otter spraints (monthly mean: 29.7 ± 5.05) were collected and analysed. Mammals, birds, and reptiles were identified by the presence of bones, hair, feathers and

scales with the aid of a comparative collection and a 10-22 × 50 mm binocular magnifying glass, using the descriptions of Teerink (1991) and Day (1965). Fish were identified using a comparative collection and descriptive guides of different structures, including otoliths (Leopold et al. 2001, Tuset et al. 2008) as well as vertebrae and pharyngeal teeth (Conroy et al. 1993, Watt et al. 1997). Any taxonomic categories used will be referred to hereinafter as taxon or taxa (Tables S1 and S2).

The following parameters were calculated: relative frequency of occurrence (RFO, percentage of occurrence of each taxon) and the biomass (BM, percentage of biomass of each taxon) (see Clavero et al. 2004). BM was estimated using several different methods depending on the case: a) for much of the fish species, regression equations were used. Fish size was estimated from the vertebrae or otolith length (Table S1); b) the average weight of the garfish was estimated to be approximately 120 g (comparative collection). Given that the head is not consumed, it was awarded a weight of 100 g for each garfish consumed by otters; c) weights estimated by other authors were used for the rest of the prey (Table S2).

Prey groups and habitats

Prey have been grouped according to their habitat preferences, in order to analyse the nature of the habitat characteristics that best define the food preferences of otters and mink. The prey were separated into terrestrial species (amphibians, reptiles, birds, and mammals) and marine species (fish, and crabs). The different fish taxa were grouped, based on their habitat preferences (see Corbera et al. 1996, Froese & Pauly 2015). Hence, each species of fish was defined according to three criteria: a) substrate preference (rocky bottom, sandy bottom, and water); b) position in the water column (benthic, nectobenthic, and pelagic); c) tidal zones (rocky pools, intertidal, and non-tidal).

For each criteria, the proportion of biomass of each group is expressed in ternary diagrams (http://serc.carleton.edu/NAGTWorkshops/petrology/plot_programs.html) that are predominantly used in the geosciences (Zahid & Barbeau 2011). Each one of the three vertex in the ternary diagram would indicate that 100 % of the detected fish belong to that group. The central point of the diagram would indicate that the three groups have been detected equally (33.3 %).

The relative abundance of rabbits (number of rabbits/km) was estimated by visual census. A total of 16 transects were made, of 4 m wide and 1100 m long, one hour after sunrise. Census trails were distributed

monthly as follows: two in June, four in August, five in September, and five in October.

Data analysis

The diets of both species were compared with the overlap index (Schoener 1970) $C_{jk} = 100 - (0.5 * \sum |P_{ij} - P_{ik}|)$, using a range from zero (no overlap) to 100 (complete overlap): C_{jk} = Percentage overlap between species j (otter) and species k (mink), P_{ij} = Proportion taxa i related to the total taxa used by species j (otter), P_{ik} = Proportion taxa i related to the total taxa used by species k (mink). Differences in the

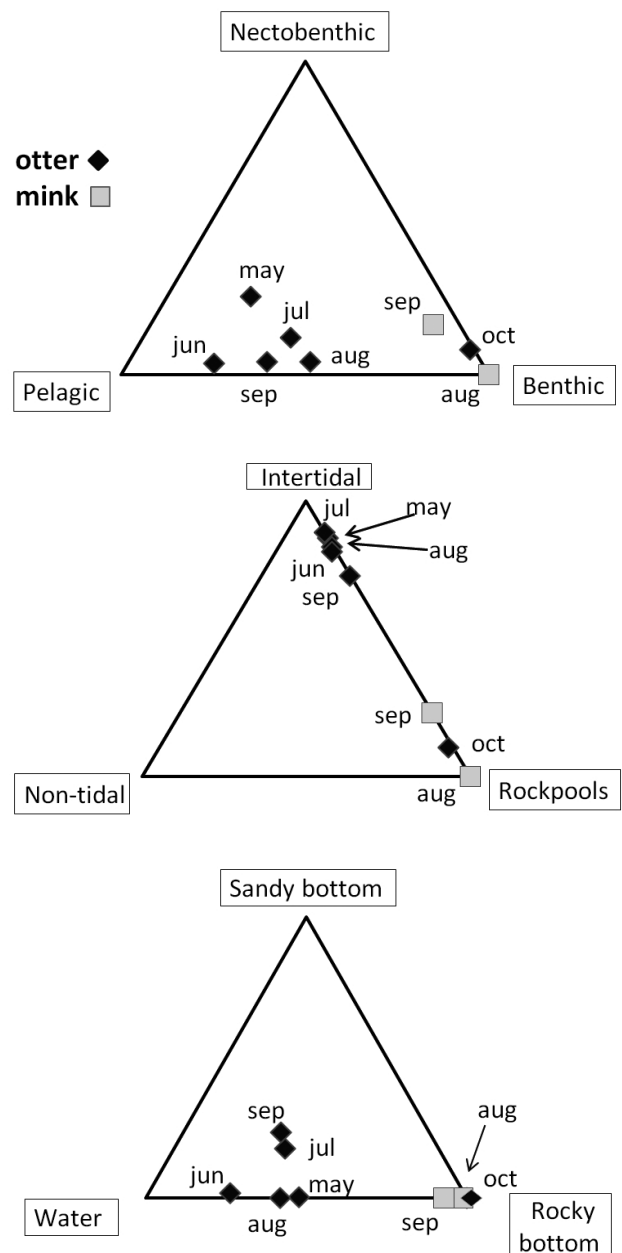


Fig. 2. Monthly percentage of fish biomass consumed by otters (black diamond) and mink (grey quadrates) according to their position in the water column (above), tidal influence (middle) and substrate (below).

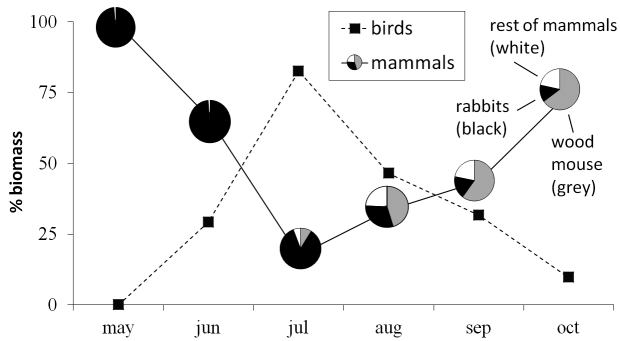


Fig. 3. Monthly variation of biomass (%) of the main prey of mink. The relative percentage of the most important mammals in the mink diet are indicated in pie plots.

frequency of occurrence of each taxon in the diets of otters and mink were tested by contingency tables (χ^2 test). The t-test was used to compare sizes of different prey. The relationship between the availability of rabbits and their presence in the diet of mink was tested using a Spearman correlation coefficient. SPSS 15.0 statistical software was used for all the tests.

Results

Comparison of the diets according to taxa

A significant difference was found in the frequency of occurrence (RFO) of prey consumed by mink and otters ($\chi^2 = 446.76$, $df = 4$, $p < 0.001$). The mammals accounted for 60.2 % of the prey of mink, which represented more than 50 % of the biomass consumed; followed by birds and fish (Table 1). The most important prey in the mink diet was the rabbit, followed by gulls and the wood mouse. The most consumed fish were blennies and gobies (Table 1).

The diet of otters was dominated by fish (RFO = 97.1 %), and it presented a larger number of fish taxa than in the diet of mink (16 taxa vs. 4 taxa, respectively). The most frequent prey in the diet of otter was the garfish, followed by blenny, long-spined bullhead, and wrasse (Table 1).

The average weight (biomass) of all fish consumed by both species was different ($t = 4.696$, $df = 38.75$, $p < 0.001$): the fish consumed by otters were larger (47.55 ± 46.06 g) than those consumed by mink (21.94 ± 21.25 g). However, when the sizes of two families of fish (blennies and gobies) consumed by both species are compared, no differences were found (Bleniidae: $t = 1.164$, $df = 174$, $p > 0.05$; Gobiidae: $t = 2.039$, $df = 24$, $p > 0.05$).

Comparison of diets as prey groups

For the whole period of study, much of the prey consumed by otters were marine taxa (fish and crabs),

while mink consumed more terrestrial prey (Table 1). The most important marine prey for both carnivores consisted of fish (RFO: 98.7 % for otter, and 96.9 % for mink). Otters consumed a greater variety of fish groups according to their habitat, while mink consumed almost exclusively benthic fish of rocky bottom and rocky pools (approximately 75 % of the total fish biomass) (Table 1, Fig. 2). Fish of rocky bottom was the group most frequently consumed by otters, but accounted for a similar proportion of total BM than open-water fish (Table 1). With respect to the tidal situation, almost 100 % of the fish preyed upon by otters are characteristic of the intertidal zone.

Monthly variations and diet overlap

The diets of both species showed a monthly variation, which was especially apparent in mink (Figs. 2 and 3). Rabbits were consumed by mink mainly in the spring (May and June) (Fig. 3). The appearance of rabbit in the mink diet was correlated with its abundance ($r = 0.617$, $p < 0.05$, $n = 16$). The frequency of rabbits in the mink diet decreased from 89 % in May to 4 % in October, according to rabbit abundance (ranged from 15 individuals/km to 0.5 individuals/km in the same period). Birds and fishes were consumed mostly during summer (July), and rodents were consumed mostly during early autumn (October) (Table 1, Fig. 3).

The diet of otters also showed monthly variations: pelagic fish (predominantly the garfish) were consumed continuously between May and September, while benthic fish was little consumed throughout the year, but increased greatly in October (Fig. 2). Nectobenthic fish (Labridae) were consumed predominantly in May, while sandy bottom fishes (flatfish) appear only during summer (Fig. 2).

Mink and otters showed a diet overlap of 16.4 %. The maximum value of niche overlap index (43.5 %) occurs during August, varying between 2.7 % and 0 % in May and June, and 16.4 % to 11.8 % in September and October. The high consumption of blennies and gobies by otters and mink in August is responsible for the high values of overlap.

Discussion

Comparison of the diet according to taxa

According to the obtained results, the diets of mink and otters on the Isle of Sálvora differ. Mink select preferably mammals and birds, while otters feed almost exclusively on fish. Only four fish taxa were detected in the diet of mink, while otters consumed a total of 16 fish taxa. Most of those fish (mainly rocklings, blennies, gobies, and wrasses) has been

Table 1. Results of scat and spraint analysis. Abbreviations: RFO – relative frequency of occurrence, BM – percentage of total estimated weight, m – marine taxon, t – terrestrial taxon. Fish habitat: Sub – substrate (R – Rocky bottom, S – Sandy bottom, W – Water), Wa – Water column (B – Benthic, N – Nectobenthic, P – Pelagic), and Ti – tidal zones (RP – Rocky pools, I – Intertidal, M – Marine).

	Latin name	Comon name	Fish habitat				Otter		Mink	
			m/t	Sub	Wa	Ti	RFO	BM	RFO	BM
Fish	<i>Anguilla anguilla</i>	eel	m	R	B	I	1.1	0.2		
	<i>Conger conger</i>	conger	m	R	B	I	1.6	3.4		
	Gadidae	rocklings	m	R	B	I	3.6	3.7		
	<i>Trisopterus</i> sp.	poor cod	m	W	P	M	0.4	0.1		
	<i>Belone belone</i>	garfish	m	W	P	I	17.6	42.0		
	<i>Taurulus bubalus</i>	longspined bullhead	m	R	B	RP	8.3	10.1		
	<i>Trachurus trachurus</i>	Atlantic horse mackerel	m	W	P	M	0.2	0.2		
	Labridae	wrasse	m	R	N	I	7.3	8.3	0.5	0.6
	<i>Scomber</i> sp.	Atlantic mackerel	m	W	P	M	0.2	0.2		
	Gobiidae	goby	m	R	B	RP	3.8	0.9	5.4	4.3
	Blenniidae	blenny	m	R	B	RP	44.5	13.3	7.0	1.9
	<i>Tripterygion delaisi</i>	black-faced blenny	m	R	B	RP	0.2	0.1		
	Mugilidae	mullet	m	W	P	I	0.2	0.1	1.1	0.3
	Pleuronectiforme	flatfish	m	S	B	I	0.2	0.1		
	Pleuronectidae	sole	m	S	B	I	1.4	5.8		
	<i>Solea</i> sp.	sole	m	S	B	I	0.2	0.2		
	Not identified fish		m				6.3	8.1	2.7	1.4
	Total fish						97.1	96.6	16.7	8.4
Amphibians	<i>Discoglossus galganoi</i>	painted frog	t				0.2	0.1	0.5	0.1
	Total amphibians						0.2	0.1	0.5	0.1
Reptils	<i>Coronella austriaca</i>		t						2.2	2.2
	Total reptils								2.2	2.2
Birds	<i>Larus michaellis</i>	gull	t						18.8	31.6
	Not identified bird								1.1	1.6
	Total birds						0.8	1.3	19.9	33.3
Mammals	<i>Crocidura</i> sp.	greater white-toothed shrew	t						9.1	4.3
	<i>Apodemus sylvaticus</i>	wood mouse	t						17.7	14.7
	<i>Rattus</i> sp.	brown rat	t						0.5	1.6
	<i>Oryctolagus cuniculus</i>	rabbit	t				0.2	1.2	30.6	33.9
	Not identif. mammal		t				0.4	0.4	2.2	1.3
	Total mammals						0.6	1.6	60.2	55.8
Crustaceans	Total crustaceans						1.2	0.4	0.5	0.2
	Total						100	100	100	100

reported in other European coastal localities as prey of otters (Murphy & Fairley 1985, Heggberget 1993, Beja 1997, Kingston et al. 1999, Clavero et al. 2004) and mink (Dunstone & Birks 1987, Clode & Macdonald 1995, Delibes et al. 2004). However, the importance of each of these fish in the diet of both carnivores on the Isle of Sálvora varied with respect

to these coastal areas, probably due to the existence of a different fish fauna in this geographical area. In the case of the otters, it is important to note that the garfish has only been found as their main prey on the coast of Galicia (Romero et al. 2012).

Moreover, although the diet of mink on the Isle of Sálvora is similar to other European localities, where

the species feeds largely on rabbits (Jenkins & Harper 1980, Wise et al. 1981, Dunstone & Birks 1987, Ferreras & Macdonald 1999) or seabirds (e.g. Craik 1997, Nordström et al. 2003, Schüttler et al. 2009), it shows certain peculiarities that are not expected on a coastal island, as is the low consumption of fish. Generally, fish are an important prey in the diet of mink (e.g. Macdonald & Strachan 1999). In coastal areas, the proportion of fish usually exceeds 30 %, even reaching 70 % (Clode & Macdonald 1995, Jędrzejewska et al. 2001, Delibes et al. 2004, Salo et al. 2010), which contrasts sharply with the Isle of Sálvora where, surprisingly, fish do not reach 17 %. It is noteworthy that this study was focused on a very small area and, thus, is based upon a reduced number of animals. Therefore, conclusions could be partially biased towards individual preferences.

Comparison of diets according prey groups

On the Isle of Sálvora, otter consumed almost exclusively marine prey, in accordance with other European coastal localities (Jędrzejewska et al. 2001), while mink fed on terrestrial prey, which contrasts strongly with other European and American areas, where mink consume both aquatic and terrestrial taxa (Dunstone 1993, Macdonald & Strachan 1999, Schüttler et al. 2008, Fasola et al. 2009, Valenzuela et al. 2013). Studies conducted on islands and other seashore zones reported a significant consumption of marine prey (fish and crabs) (Clode & Macdonald 1995, Delibes et al. 2004, Schüttler et al. 2008, Valenzuela et al. 2013). However, it is necessary to consider that winter months are not included in this study and this may influence the obtained results, since fish in coastal areas are usually consumed by mink during winter (Dunstone & Birks 1987, Macdonald & Strachan 1999).

According to some studies performed on the coasts of Europe, the fish caught by otters, and especially by mink, are mainly benthic species that inhabit the intertidal zones, preferably on rocky substrate (see Fig. S1 supplementary material). However, on the Isle of Sálvora some of the prey of otters, such as flatfish or garfish, are not consumed by mink. These kinds of fish, living in areas of sandy substrates on exposed beaches (flatfish), or relatively distant from the shore (garfish), are generally avoided by mink (Ben-David et al. 1996, Bonesi et al. 2000). The strip of water that is accessible to mink is very narrow and is usually limited to certain areas of the intertidal zone (Bonesi et al. 2000). This means that on the Isle of Sálvora (and elsewhere), mink would be limited to capturing

fish in the intertidal zone, mainly rocky benthic fish of rocky pools such as, for example, Gobiidae and Bleniidae. Therefore, the different abilities to access the various fishing areas could explain differences in the fish consumed by otters and by mink on the Isle of Sálvora.

Monthly variations, diet overlap and availability of prey

Monthly variations in food habits that were observed in this study, suggest that both carnivores adapt their diet according to the availability of their respective prey. This seems evident for mink, as the consumption of rabbits and gulls is related to their monthly abundance. Sampling transects made on the Isle of Sálvora for estimating rabbit abundance, confirmed that rabbits were consumed when they were more abundant (spring and early summer), as has been reported in the coast of Scotland (Dunstone & Birks 1987), for example. Similarly, the predominance of gulls in the diet of mink from June to August also seems to respond to an increase in the availability of gulls during their breeding season. On the Isle of Sálvora, the density of gull chicks in some areas may reach more than 200/ha (Munilla 1997). Overall, mink that are inhabiting islands mainly feed on birds during their breeding period (Craik 1997, Nordström & Korpimäki 2004, Schüttler et al. 2008, Ibarra et al. 2009).

In the case of the otters, we do not have information on the availability of prey on the Isle of Sálvora. However, the diet of otters on the Isle of Sálvora shows a similar seasonal pattern to other rocky coastal areas of Galicia, especially in the consumption of their main prey such as wrasses, blennies and garfish (Romero et al. 2012). The presence of garfish in the diet of otters is probably related to the arrival of this fish to the coast for the purpose of spawning during that period (Dorman 1989). This suggests that the monthly variation in the diet of otters Isle of Sálvora is effectively determined by a very different prey availability throughout the year, such as along other coastal areas of Europe (see Beja 1997, Kruuk 2006). Other factors, such as biomass intake or interspecific competition, can induce changes in diet. Especially interesting, is the increased consumption of blennies and gobies by otters in summer/autumn and not in spring/summer when these fish are more abundant (Beja 1997). According to Beja (1997), consumption of these fish may be related to the lack of other prey that might be preferred for their greater biomass and energy intake, as would be the case for garfish (fish that are much larger than blennies and gobies).

It is noteworthy that in October, when otters start feeding on blenny and goby, mink stop eating this fish. As some studies suggest, mink avoid fishing areas that are preferred by otters (Bonesi et al. 2000), at least on a temporary basis (Harrington et al. 2009). This would mean that the diet of mink on the Isle of Sálvora could be determined, at least in part, by the presence of otters on the island. This hypothesis is raised by some authors, who suggest that in a sympatric situation the mink change their prey, and feed on a greater proportion of terrestrial prey (Bueno 1996, Bonesi et al. 2004, Valenzuela et al. 2013). In this sense, some studies suggest that mink behave as generalists when otters are present (Bonesi & Macdonald 2004, Fasola et al. 2009, Gómez et al. 2010), avoiding competition by shifting their diet to other types of prey, that are less consumed by otters (Harrington et al. 2009), or feeding on types of prey that are particularly available and abundant, such as crabs and crayfish (Melero et al. 2008, 2014, Cassini et al. 2009). Notwithstanding,

the coexistence of mink and otters on the Isle of Sálvora would probably benefit from the abundance of terrestrial resources (rabbits, small mammals and seagulls) (Bonesi & MacDonald 2004). Moreover, the island, located in a coastal area with a high primary production of resources (Bode & Varela 1998), has a large intertidal area which provides very diverse and rich fauna, a feature that may also promote the coexistence of mink and otters (Melquist et al. 1981, Bonesi et al. 2000, Gómez et al. 2010).

Acknowledgements

Thanks go to A. Gómez, M. Pódra, C. Docampo, and P. Guitián for their assistance in the collection of scats and spraints. We are grateful to the staff of the Atlantic Islands of Galicia National Park, and lighthouse keepers on the Isle of Sálvora (P. Pertejo, J. Vilches and C. Carracedo) for the logistic support during all of the study period. We also thank J.A. Fernández, director of the National Park, for promoting the achievement of this study and for his general support. Matt Copley reviewed of the English. Two anonymous reviewers contributed to the improvement of the paper.

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Supplementary online material

Fig. S1. Percentage of fish biomass consumed by the otter (diamonds) and mink (quadrates) according to their position in the water column (above), tidal zones (middle) and substrate (below) in Sálvora (grey symbols) and in other European coastal localities (black symbols). Mink references: 1) Delibes et al. 2004, 2) Clode & Macdonald 1995, 3) Dunstone & Birks 1987. Otter references: A) Clavero et al. 2004, B) Kingston et al. 1999, C) Heggberget 1993, D) Murphy & Fairley 1985, E) Beja 1997, F) Mason & Macdonald 1980, G) Kruuk 2006, H) Clode & Macdonald 1995.

Table S1. Regressions equations for length and biomass calculation. Abbreviations: Lot – otolith length, Lp – fish length, LVt – vertebrae length, Pp – fish weigh.

Table S2. Prey weights from literature (http://www.ivb.cz/folia_zoologica/supplementarymaterials/romero_and_guitian_fig._s1,_table_s1,_s2.docx).