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Original Investigation

Trophic ecology of a top predator colonizing the southern extreme of South America: Feeding habits of invasive American mink (*Neovison vison*) in Tierra del Fuego

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ABSTRACT

The American mink (*Neovison vison*) is a semi-aquatic, generalist carnivore released onto Tierra del Fuego (TDF) Island in the 1940s, subsequently spreading to adjacent islands in the archipelago with potential effects on native prey populations. Knowledge of this new predator's trophic ecology is essential to identify threats, plan control strategies and conserve native fauna. We studied seasonal mink diet in TDF in different habitats. We identified undigested remains from 493 scats collected between May 2005 and March 2009 along marine coasts and freshwater shores (rivers and lakes). Small mammals and fish were the main mink prey in TDF (over 65% of diet items). Seasonal variations were not detected, but diet did vary significantly between marine and freshwater habitats, where more terrestrial items were consumed. Among mammals, mink consumed more small native rodents than exotic species. Native fish consumption was also important with greater representation of species from the families Nototheniidae and Galaxiidae in marine and freshwater habitats respectively. Birds were the third item in importance, but did not constitute a particularly large part of the mink's diet on TDF. Overall, differences found in mink diet between habitats reflected their generalist/opportunistic feeding behaviour and did not differ greatly from observations in its native range or in other areas where it has been introduced. Our results establish the interactions between this novel predator and its prey and also illustrate the need to continue research on native prey populations to quantify mink impact on them and understand the ecological context of this biotic assemblage.

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Introduction

Top predators are important species in ecosystems, influencing the distribution and abundances of their prey (Begon et al., 2006). Invasive exotic species also are influential in ecosystems, constituting a main cause of anthropogenic changes to global biodiversity (Vitousek et al., 1997). In particular, introduced carnivores on islands strongly affect native species through depredation, often severely reducing or even causing the extirpation of endemic species (Courchamp et al., 2003). Therefore, studying the diet of an exotic predator is essential to understand its effect on native species and the entire ecosystem (Melero et al., 2008), including islands, as well as being necessary to plan management strategies to control the novel predator and conserve the native ecosystem (Barun and Simberloff, 2011).

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American mink (*Neovison vison*) are semi-aquatic carnivores native to North America. This species was brought in captivity to the northern sector of Tierra del Fuego (TDF) Island in 1948 and 1953 to establish fur farms (Lizarralde and Escobar, 2000). Several animals were released into the Mitre Peninsula and in the area north of Fagnano Lake (Fig. 1), where small groups were reported by 1988 (Fabbro, 1989). From the mid- to late-1990s, mink were found along the Beagle Channel (BC) (Lizarralde and Escobar, 2000) and by 2000 had begun to gradually spread to other islands of the archipelago, including Navarino, Hoste and Lennox (Anderson et al., 2006; Davis et al., 2012). Mink are opportunistic and generalist predators, whose diet has been shown to reflect the availability and abundance of both aquatic and terrestrial prey (Dunstone, 1993). American mink consume mainly fish and mammals in both its native range (i.e. North America) (Melquist et al., 1981; Ben-David et al., 1997) and in Europe, where it was introduced around 1920 (Erlinge, 1969; Dunstone and Birks, 1987; Ferreras and Macdonald, 1999). Furthermore, as an exotic species, the mink has been shown to have negative effects on native prey populations such small rodents, crustaceans, ground-nesting birds, insects, amphibians, reptiles, and intertidal marine communities, usually in proportion

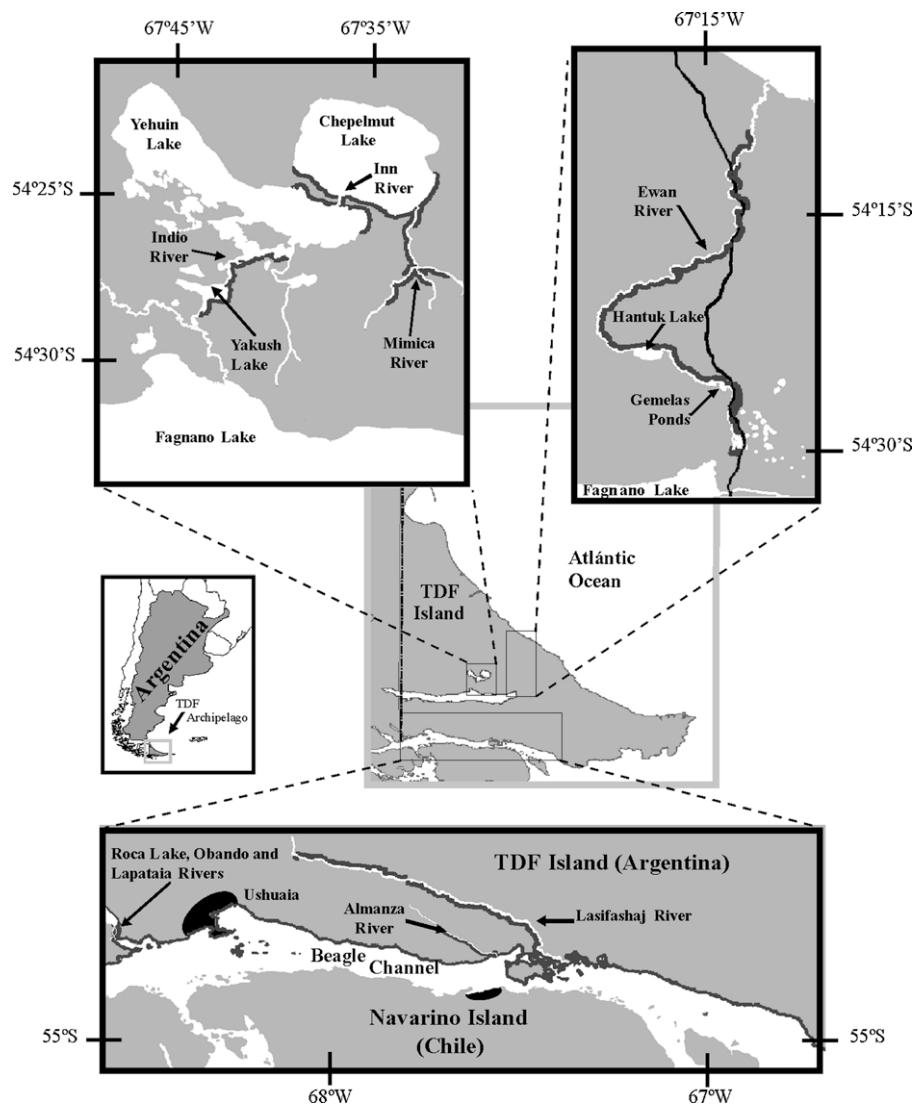


Fig. 1. Map of the study area. Sampling areas indicated as dark grey lines.

to their availability (Lode, 1993; Craik, 1995; Maran et al., 1998; Jedrzejewska et al., 2001; Delibes et al., 2004; Ahola et al., 2006).

In continental Patagonia, introduced mink feed mostly on freshwater crustaceans and small mammals (Medina, 1997; Previtali et al., 1998). Fasola et al. (2009, 2010) indicated that the consumption of crustaceans was correlated with the distribution and relative abundance of these prey species across the region. Within the TDF Archipelago, the mink invaded Navarino Island a little over a decade ago. As a recently arrived predator, it showed variations in spatial (marine and freshwater habitats) and seasonal (warm and cool seasons) diet, with its consumption along the coast mainly consisting of small mammals and birds followed by fish (Schüttler et al., 2008; Ibarra et al., 2009). However, seasonal comparisons were conducted only within one year and habitats were studied individually, rather simultaneously. A preliminary study on the north shore of the BC on TDF Island indicated that mink consumed a wide range of prey, including both terrestrial and marine vertebrates and invertebrates (Gómez et al., 2010), but a detailed understanding of the spatial and temporal dynamics of mink trophic ecology in the TDF Archipelago is still lacking.

The present study addresses part of this gap by describing the American mink's diet on TDF Island and analyzing its variation (i) between freshwater and marine habitats and (ii) between seasons.

These results allow us to better understand the mink's ecological role in this novel biotic assemblage and to help determine priorities for native prey conservation and management of this new top predator in the archipelago.

Material and methods

The TDF Archipelago comprises the group of islands at the southernmost tip of South America, characterized by a cold oceanic climate (Rabassa et al., 2000), is considered one of the world's last wilderness areas (Mittermeier et al., 2002). However, in fact, this entire biome has a high percentage of introduced taxa, particularly terrestrial vertebrates (Anderson et al., 2006, 2011).

A particularly worrying member of this exotic assemblage is the mink, due to its potential impact on native biodiversity through predation and competition. Therefore, we studied American mink diet by analyzing scats collected between 2005 and 2009 from marine coasts of the BC and freshwater shorelines, including seven lakes (Chepelmut, Yehuín, Yakush, Roca, Gemelas 1, Gemelas 2, and Hantuk) and nine rivers (Almanza, Ewan, Indio, Inn, Lapataia, Lasifashaj, Mimica, Los Castores and Ovando) (Fig. 1). Each site was surveyed for mink scats within 50 m of the water line (Harrington and Macdonald, 2008) twice a year, during warm (spring-summer;

November to January) and cold (fall–winter; May–August) seasons. This sampling regime was determined due to weather conditions that create logistic limitations to access some survey sites in all seasons.

Fresh mink faeces, as per Dunstone (1993), were collected. Total scats collected and analyzed were 493; 268 from marine coasts (140 and 128 from warm and cold seasons, respectively) and 225 from freshwater habitats (90 and 135 from warm and cold seasons, respectively). This sample size met statistical requirements for diet assessment, which were determined for this study from results of Trites and Joy (2005). Faeces were stored in 70% ethanol to preserve samples and to keep some delicate remains (e.g., fish skull bones) wet to avoid damage by desiccation. Before analyses, each sample was washed with warm water through a sieve (0.3 mm mesh) to facilitate separation of remains. Undigested remains were identified to the lowest possible taxonomic level and sorted into seven main categories (mammals, fish, birds, crustaceans, insects, polychaetes, and chitons), using a dissecting scope (10 \times). All items were classified according to origin (native or exotic) and the habitat type where they were likely taken (aquatic or terrestrial). Identification was based on our own reference collection (Wildlife Ecology and Conservation Laboratory, CADIC) and supplemented with published descriptions and identification keys (Chehébar and Martín, 1989; Pearson, 1995; Gosztonyi and Kuba, 1996; López et al., 1996; Volpedo and Echeverría, 2000; Tapella and Lovrich, 2006). We identified mammal remains from teeth, jaws, and hairs. Digestion resulted in sufficient damage to feathers so as to prevent further identification. Fish species were identified from cranial bones, otoliths and scales. Crustaceans were classified on the basis appendages and exoskeletal fragments. Insects were identified from exoskeletons, polychaetes from setae and chitons from plates. Mink hairs in scats were considered to be the result of grooming and therefore were disregarded in analyses. Plant material and crustaceans less than 5 mm in length also were excluded from the analyses, as they were considered to be secondary prey, incidental intake or adhesion after defecation.

For each scat, we recorded the items present and the volume (V) of each main category, as its percentage of total sample volume. We estimated V visually by placing each scat per category uniformly in a Petri dish that was divided into eight portions (each portion corresponded to 12.5% of total volume). We calculated the following indexes for each prey category: (i) frequency of occurrence (FO: number of scats with the prey category/total number of scats), (ii) relative frequency of occurrence (RFO: number of occurrences of the prey item/sum of occurrences of all prey items), (iii) mean percentage of estimated volume (MV: average of V estimated in each sample for the prey category), and (iv) frequency of occurrence as a dominant item (DOM: number of occurrences of the prey item when is dominant in scats, considering as dominant item those with the largest V in each scat). Each index has benefits and disadvantages (see Fasola et al. 2010), and so it is necessary to use all indexes to describe a species' diet (Raya Rey and Schiavini, 2005). FO and RFO are the most used indexes in trophic ecology because they are easily calculated and compared (Carss and Parkinson, 1996) and detect those items that are highly digested, but they also overestimate small prey items. MV does not necessarily reflect the amount of prey consumed, as different prey types present differential digestion rates and different numbers of hard parts that remain in the digestive tract; it also underestimates highly digestible items (Zabala and Zuberogoitia, 2003). Finally, DOM compensates for overestimation of secondary prey intake and avoids overemphasizing occasional or less important categories, but also underestimates those items that are highly digested (Fasola et al., 2010). If all indexes are correlated, though, descriptions and comparisons could be continued relying on only one of them. Therefore, we used Spearman's rank correlations to compare

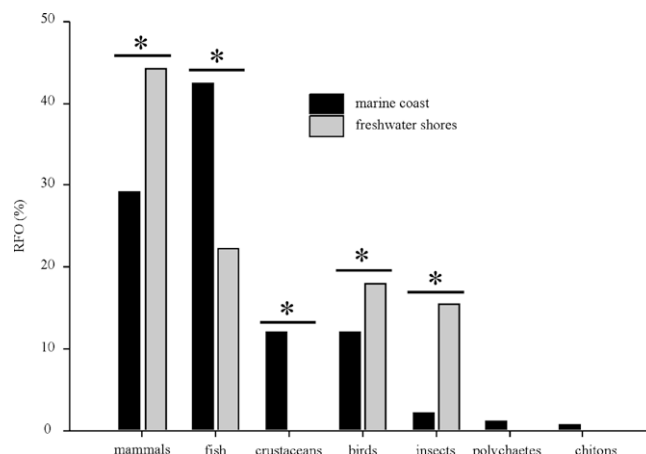


Fig. 2. Overall diet of the American mink on Tierra del Fuego Island (expressed as relative frequency of occurrence – RFO), differentiating by habitat type. * indicates significant differences ($p < 0.05$).

between them and found that all indexes were significantly correlated to one another ($n = 493$): FO vs. RFO $r_s = 1$, $p = 0.003$; FO vs. MV $r_s = 0.94$, $p = 0.017$; FO vs. DOM $r_s = 0.94$, $p = 0.017$; RFO vs. MV $r_s = 0.96$, $p = 0.009$; RFO vs. DOM $r_s = 0.96$, $p = 0.009$; MV vs. DOM $r_s = 1$, $p = 0.003$. Subsequent comparisons were done with RFO, as it is the most frequently used in the literature (Carss and Elston, 1996). Those diet categories with RFO less than 5% were considered inconsequential and therefore excluded as per Kamler et al. (2007).

Mink diet was evaluated between habitats (marine and freshwater) and seasons (warm and cold) within each habitat type. RFO index differences were assessed using chi-square test and Fisher's exact test, when 20% or more of the expected frequencies were below five (Zar, 1984). Furthermore, to better understand mink trophic ecology, the Shannon and Weiner (1963) diversity index (H') was calculated for each habitat based on the minimum prey categories identified. To assess differences in diversity of diet items between marine and freshwater habitats, a Kruskal–Wallis test was used with seasonal values as replicates. All statistical analyses were conducted in R version 2.9.1 (R Development Core Team, 2009), and statistical significance was accepted at $p < 0.05$.

Results

The American mink's diet on TDF Island was significantly different between marine and freshwater habitats ($\chi^2 = 129.41$, $df = 5$, $p < 0.001$); mammals and fish together represented more than 65% of total consumption (Table 1 and Fig. 2). In freshwater habitats, mink preyed on more terrestrial prey than in marine habitats ($\chi^2 = 90.70$, $df = 2$, $p < 0.001$). Also, the mink's diet was less diverse (Kruskal–Wallis rank sum test, $K = 6.82$, $df = 1$, $p < 0.01$) in freshwater ($H' = 1.99$) than in marine ($H' = 2.54$) habitats. Mammal consumption was higher in freshwater than in marine habitats ($\chi^2 = 8.59$, $df = 1$, $p < 0.005$) with small native rodents being more heavily consumed than exotic mammal species (Table 1). Mink fed more upon fish in marine habitats than in freshwater ones ($\chi^2 = 17.96$, $df = 1$, $p < 0.001$). Birds constituted the third category in importance in both environments, but were more consumed in freshwater habitats than marine areas ($\chi^2 = 3.98$, $df = 1$, $p < 0.05$). While we were not able to identify avifauna to the species level, Passeriformes claws were found in a few scats from both marine and freshwater habitats, and upland goose (*Chloephaga picta*), kelp goose (*C. hybrida*) and flightless steamer duck (*Tachyeres pteneres*) remains were discovered inside mink dens on the BC coast. Crustaceans were only in scats from marine coast sites, being consumed

Table 1

American mink (*Neovison vison*) diet composition in marine and freshwater habitats on Tierra del Fuego Island between 2005 and 2009, expressed as relative frequency of occurrence – RFO ($n=493$).

Prey	Marine coast	Freshwater shores
Mammals	29.2	44.2
Native	17.6	28.5
Cricetidae (<i>Oligoryzomys longicaudatus</i> ; <i>Abrothrix longipilis</i> ; <i>A. olivaceus</i>)		
Exotic	11.6	15.7
Muskrat (<i>Ondatra zibethicus</i>); European rabbit (<i>Oryctolagus cuniculus</i>); rats (<i>Rattus rattus</i> ; <i>R. norvegicus</i>); North American beaver (<i>Castor canadensis</i>)		
Fish	42.5	22.3
Nototheniidae	18.8	–
<i>Patagonotothem sima</i> ; <i>P. tesellata</i> ; <i>P. cornucola</i> ; <i>P. magellanica</i> ; <i>Eleginops maclovinus</i>		
<i>Harpagifer bispinis</i>	7.9	–
<i>Galaxia maculatus</i> ; <i>G. platei</i>	–	12.8
Exotic trout	–	9.5
<i>Salmo trutta</i> ; <i>Oncorhynchus mikiss</i> ; <i>Salvelinus fontinalis</i>		
Unidentified	15.8	0.0
Birds	12.1	18.0
Crustaceans	12.1	–
<i>Munida subrugosa</i> ; <i>M. gregaria</i>	7.2	–
Amphipods	1.7	–
Isopods	1.5	–
Unidentified	1.7	–
Insects	2.2	15.5
Beetles (Coleoptera)	2.2	9.9
Dragonfly (<i>Rhionaeshna variegata</i>)	–	5.6
Polychaetes	1.2	–
Chitons	0.7	–
Terrestrial	43.5	71.7
Aquatic	56.5	28.3

at same level as birds. Insect representation was significantly higher in freshwater environments than marine sites ($\chi^2 = 36.57$, $df=1$, $p < 0.001$).

Diet of coastal American mink

Native fish were the main prey of mink on the marine coast, followed by mammals, and then by both birds and crustaceans (Table 1). Occasional consumption of beetles, polychaetes and chitons was found as well (Fig. 2). No significant differences were observed between the amount of terrestrial and aquatic prey items in the coastal mink's diet. The significant seasonal differences observed for diets in the coastal zone ($\chi^2 = 11.61$, $df=5$, $p < 0.05$) were driven by a significant increase in the consumption of crustaceans ($\chi^2 = 7.35$, $df=2$, $p < 0.01$) during the cold season, while the other main prey categories did not vary between seasons (Fig. 3a). While total and exotic mammal representation in the diet remained unchanged throughout the year, the consumption of native rodents increased during the warm season ($\chi^2 = 11.59$, $df=2$, $p < 0.005$; Fig. 3a). Regarding fish, while the family Nototheniidae was the most consumed as a group, the single most consumed species was *Harpagifer bispinis* (Table 1).

Diet of freshwater American mink

Mink inhabiting freshwater environments fed mainly on small mammals, with fish in second place and then birds and insects (Table 1). The consumption of terrestrial prey was significantly higher than aquatic ones ($\chi^2 = 22.54$, $df=2$, $p < 0.001$). No differences were found between seasons for mink diets in freshwater habitats ($\chi^2 = 8.10$, $df=4$, $p = 0.088$). Mink did prey more on native mammals during the cold season rather than the warm period ($\chi^2 = 16.27$, $df=2$, $p < 0.001$; Fig. 3b). Exotic mammal consumption did not show seasonal differences. No differences were found

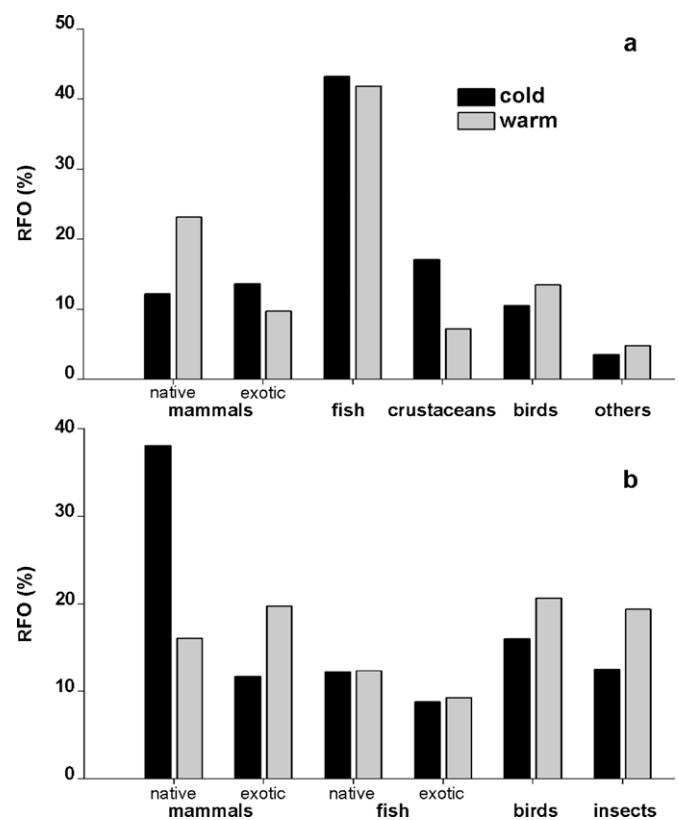


Fig. 3. Prey items found in American mink diet along (a) the marine coast of the Beagle Channel and (b) freshwater habitats, compared between cold (black) and warm (grey) seasons on Tierra del Fuego Island. Data expressed as relative frequency of occurrence – RFO %. * indicates significant differences ($p < 0.05$).

between native (*Galaxias maculatus* and *G. platei*) and exotic (various trout species) fish consumption ($\chi^2 = 0.92$, $df = 2$, $p = 0.82$). Mink also fed regularly on beetles and larval stages of *Rhionaeshna variegata* along freshwater shorelines (Table 1).

Discussion

Same patron, different restaurant

The American mink's trophic ecology in the TDF Archipelago is not substantially different from that observed in its native range or in other places where it is exotic, such as Europe and continental Patagonia (Table 2). This study represents the first report in the TDF Archipelago that compares overall American mink diet between marine and freshwater habitats during different seasons spanning several years. In general, mink ate all main prey categories available on TDF Island and showed a more "terrestrial" diet in freshwater habitats and more "aquatic" diet along the marine coast. The differences observed between these habitat types apparently responded to the differential prey offering of each habitat, reflecting the opportunistic trophic behaviour previously described by Dunstone (1993) for this predator. Also, the mink's marine diet was more diverse than the freshwater one, which is consistent with the results obtained within its native range as well (Ben-David et al., 1997). These last authors suggested that marine coasts offered greater quantity and variability of both feeding sites and prey availability than lakes and riparian shores. On the other hand, freshwater bodies in the TDF Archipelago are typically ultra-oligotrophic, unproductive, and low in prey diversity for carnivorous species (Sielfeld, 1989). Our findings support these assertions.

Furthermore, we did not find seasonal variations for the main categories in the mink's diet, except for significantly higher crustacean consumption during the cold season on the marine shores. However, this result was driven by a single, exceptional beach stranding event of *Munida* spp. that occurred in May 2007 along the BC (Lovrich et al., 2007). This type of occasional event could mask more subtle dietary differences between seasons. These data also showed that mink diet responded quickly to such sporadic increases in the availability of some prey, reinforcing the description of this species as opportunistic. Future studies seeking to better link the trophic behaviour of mink to occasional events in the TDF region might focus on occasional rodent population explosions, as well, since these are known to occur as a function of seed masting by *Nothofagus pumilio* (personal observation; Dr. Martínez Pastur, pers. commun.).

Two sides of the same coin

American mink on TDF preyed more upon native prey than on exotic taxa, demonstrating their real threat to native biodiversity, effects which may be even more acute for native species that are already rare. Despite the fact that extensive data on native prey population dynamics in the TDF Archipelago currently do not exist, our finding that native rodents were the most consumed mammalian prey could be expected to have further food web implications for the archipelago's native predators, such as raptors and the Fuegian culpeo fox. Furthermore, habitat and seasonal differences in rodent availability could explain the fluctuations of these native prey in the mink's diet, as suggested by Schüttler et al. (2008). Among the mink's exotic mammal diet, the muskrat (*Ondatra zibethicus*) was the most consumed species in both coastal and freshwater habitats, which coincides with findings for Navarino Island (Schüttler et al., 2008; Ibarra et al., 2009) and North America (Dunstone, 1993), where both mink and muskrats are native.

However, muskrat consumption was very low throughout the TDF Archipelago (less than 9% RFO on both TDF and Navarino Islands). Predation on European rabbit (*Oryctolagus cuniculus*) was nearly equal to that of muskrat on TDF Island, but rabbits are only found in and around TDF National Park and Ushuaia. Overall, the low consumption of muskrats and rabbits in the archipelago contrasts with the findings for mink diet in North American and Europe, where they constitute the principle prey items (Dunstone, 1993). Similarly, introduced rats (*Rattus rattus* and *R. norvegicus*) occupied a similar role as rabbits, being consumed mainly near human settlements. Even fewer remains from exotic North American beaver (*Castor canadensis*) were recorded in the mink's diet (1.3% RFO, 10 scats), which perhaps came from scavenging dead animals, as this behaviour was observed several times during field trips, or potentially being from direct predation of kits. Therefore, as reported here and in the previously cited works from the archipelago, no strong evidence was found of any exotic mammal species providing a significant subsidy to facilitate mink establishment and invasion, based on the low representation of these species in the diet of the introduced predator and/or their restricted geographic ranges. On the other hand, marine subsidies seem to be very important for mink, whereby fish are more consumed in marine habitats (where they are more abundant; Sielfeld, 1989) than freshwater sites. Specifically, the most consumed fish species (*Harpagifer bispinis* and *Patagonotothem* spp.) are usually associated with intertidal or shallow areas (López et al., 1996; Vanella et al., 2007), the same sites where mink also forage in their native distribution (Ben-David et al., 1997).

Bird consumption was within the ranges described previously for both its native and exotic ranges, showing the same pattern of increase in freshwater habitats (Table 2). However, the consumption of birds on Navarino Island has been reported as much higher than those described in this study (Schüttler et al., 2008; Ibarra et al., 2009). These authors agreed with Banks et al. (2004) that some island birds lack of defensive behaviour towards terrestrial predators was responsible for its high consumption, since Navarino Island has no native terrestrial predators (Maley et al., 2011). A different scenario can be observed on TDF Island, where a larger assemblage of native and exotic terrestrial predators can be found (Anderson et al., 2011), including the southern river otter (*Lontra provocax*), Fuegian culpeo fox (*Lycalopex culpaeus lycoides*), South America grey fox (*Pseudalopex griseus*), and feral dogs (*Canis lupus familiaris*) and cats (*Felis silvestres catus*), which could already have decreased bird populations even before this invasion. Additionally, during the last years we found a decrease of water bird nests along the northern coast of BC, based on census conducted during the avian breeding season (unpublished results) and potentially indicating a lower availability of this prey type, compared to Navarino Island and to interior freshwater environments. Therefore, differences in water bird consumption between both coasts of the BC (TDF and Navarino Islands) might reflect differential availability. Moreover, this finding highlights the idea that different ecosystems respond differently to the introduction based on intrinsic ecological factors of the site, rather than the invasive species per se (Anderson et al., 2009).

Only native marine crustaceans were consumed by American mink, coinciding with findings from its native Alaska, where freshwater ecosystems as in TDF do not have macro-crustaceans (Ben-David et al., 1997). The genus *Munida*, the main crustacean consumed, is considered the base of the BC food web and constitutes approximately 50% of the benthic community (Romero et al., 2004). Taking this into account, as well as the overall low crustacean representation in the mink's diet and the exceptional consumption described during stranding events of large schools of marine organisms, we consider that mink do not substantially affect *Munida* spp. populations.

Table 2

American mink diet (RFO) reported for marine coast (MC) and freshwater (FW) habitats (H) in both the mink's native and exotic ranges.

Region	H	n	Reference	M	F	C	B	I	A	R	O
<i>Native range – North America</i>											
USA – Alaska	FW	–	Ben-David et al. (1997)	9.7	89.9	–	–	–	–	–	0.4
USA – Alaska	MC	–		3.7	39.7	39.6	6.0	–	–	–	11.0
USA	FW	657	Melquist et al. (1981)	29.1	40.2	–	13.2	16.1	–	1.4	–
Canada	FW	1321	Racey and Euler (1983)	33.0	23.0	16.0	1.0	9.0	17.0	–	1.0
<i>Exotic range</i>											
<i>Europe</i>											
England	FW	42	Bonesi et al. (2004)	33.0	33.0	–	9.0	22.0	2.0	–	1.0
Scotland	MC	2043	Dunstone and Birks (1987)	40.9	29.1	18.7	11.2	–	–	–	0.1
Sweden	FW	122	Erlinge (1969)	8.9	62.5	–	22.9	3.8	1.9	–	–
England	FW	115	Ferreras and Macdonald (1999)	52.3	17.7	4.0	22.7	2.3	–	–	1.0
Poland	FW	200	Jedrzejewska et al. (2001)	40.0	28.0	–	6.0	–	26.0	–	–
France	FW	84	Lode (1993)	41.3	31.5	–	21.7	–	4.3	–	1.2
Estonia	FW	207	Maran et al. (1998)	18.9	18.2	1.6	5.1	10.9	43.3	1.4	0.6
Spain	FW	444	Melero et al. (2008)	9.0	9.9	73.3	5.3	1.7	–	–	0.8
<i>Continental Patagonia – South America</i>											
Chile	FW	109	Medina (1997)	40.4	8.3	47.4	2.6	1.3	–	–	–
Argentina	FW	60	Previtali et al. (1998)	15.2	13.4	36.0	11.0	23.2	–	1.2	–
Argentina	FW	197	Fasola et al. (2010)	37.8	13.9	37.8	15.8	5.7	–	2.0	–
<i>Tierra del Fuego (TDF) Archipelago</i>											
TDF Is.	MC	11	Fasola et al. (2010)	42.1	42.1	–	15.8	–	–	–	–
Navarino Is.	FW	414	Ibarra et al. (2009)	42.7	6.3	1.4	31.7	17.9	–	–	–
Navarino Is.	MC	193	Schüttler et al. (2008)	29.2	15.5	10.9	30.7	10.7	–	–	3.0
TDF Is.	FW	225	Present work	44.2	22.3	–	18.0	15.5	–	–	–
TDF Is.	MC	268		29.2	42.5	12.1	12.1	2.2	–	–	1.9

M: mammals; F: fish; C: crustaceans; B: birds; I: insects; A: amphibians; R: reptiles; O: others.

Concluding remarks

The approach used in this study allowed us to describe the diet of American mink in greater detail than has previously been attempted by simultaneously including multiple habitats and years. Nevertheless, it is not sensitive to highly digestible prey. Stable isotopes studies or the use of tracers, such as essential fatty acids, could help solve the bias associated with classic trophic ecology studies that rely on stomach or scat contents. Our findings, however, illustrate how this invasive species could be impacting these ecosystems and biotic communities, but there is very little or no information about ecosystem and community responses, regarding the abundance, availability and conservation status of native prey species (mainly rodents, fish of families Nototheniidae and Galaxiidae, and waterbirds and passerines). We strongly recommend that further research place greater emphasis on the ecosystem context of the prey populations, which will be indispensable to assess the full impact of this exotic predation on native fauna.

Additionally, as the coastal zones along the BC have been prioritized as a significant biodiversity conservation zone for sub-Antarctic birds (Pizarro et al., in press), simultaneous studies on mink predation effects on water bird populations, reproductive success and survival rates on both coasts of the BC are important to understand the differential response of these native prey to mink invasion with and without a history of native terrestrial predators. In the context of potential integrated conservation and management strategies in the TDF Archipelago, our results establish the baseline knowledge of the mink's diet and its interactions with native prey. Zavaleta et al. (2001) pointed out that it is also important to evaluate side effects of an invasive species introduction and management, such as different trophic levels. In the case of TDF Island, it is not only crucial to assess mink introduction and its potential control effects on prey population (to avoid increase of exotic prey, such muskrats and common rabbits), but also on meso-predator populations related to those prey to avoid an increase of exotic predator populations (South American grey foxes, dogs and cats) or to promote increases in native predator populations (southern river otter and Fuegian culpeo fox). At the same time,

invasional meltdown as a mechanism for facilitating the establishment and spread of subsequent exotic species (Simberloff and Von Holle, 1999) has not been confirmed for the TDF Archipelago, based on the trophic ecology of mink. In closing, we suggest that future management plans to remove American mink in the TDF Archipelago prioritize an initial strategy of trapping in areas where prey species and competitors are either high priority or vulnerable to protect the native prey and predator assemblage, which may reduce the success of the introduced predator and limit its effects on local species (Juliano et al. 2010).

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