



Short communication

New insights into the prey spectrum of Darwin's fox (*Pseudalopex fulvipes* Martin, 1837) on Chiloé Island, Chile

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The Pacific coastal range of Chiloé Island, southern Chile, is covered with dense old-growth Valdivian rainforests. These forests in pristine areas reach down to the shoreline, interrupted only by occasional sandy beaches, this represent part of the native habitat of Darwin's fox or Chilote fox *Pseudalopex fulvipes*, the only native canid present on Chiloé Island. This canid is endemic in Chile and until recently, thought to inhabit only on Chiloé Island (46°S) and in Nahuelbuta National Park (37°S) on the mainland 600 km further north, however, new indirect evidence suggests that a third population may exist on the mainland in coastal forests (39°21'S, 73°14'W) (Vilà et al. 2004). Darwin's fox is considered the second most endangered mammal in Chile (Cofré and Marquet 1999) and is classified as Critically Endangered, CR C2a (ii), in the Red List of the IUCN (Jiménez and McMahon 2004; Jiménez et al. 2004).

The studies on the ecology and feeding behaviour of this species, in forested areas (Medel et al. 1990; Jaksic et al. 1990; Jiménez et al. 1991; Yahnke et al. 1996) show the Darwin's fox has an omnivorous diet (small mammals, reptiles, insects, and fruits) (Jaksic et al. 1990; Jiménez et al. 1991), however, our

field observation records along the shore on Chiloé includes sightings of foraging behaviour (digging) in the intertidal of sandy beaches where the macrofauna consists of sand crabs, talidrid amphipods and isopods (Brown and McLachlan 1990; Jaramillo et al. 1993). There are no systematic studies about its diet in coastal areas (Rau and Jiménez 2002) and the aim of this study was to investigate the diet of Darwin's fox when foraging on sandy beaches on Chiloé Island during two different seasons.

The area searched for scats is part of the Ahuenco private reserve with 850 ha (42°06'S, 74°05'W—41°47'S, 73°53'W) located on the northwestern coast of island, adjacent to the Pacific Ocean and exposed to the westerly winds with annual rainfall over 2000 mm (Smith-Ramírez et al. 2005). Here, the temperate rainforest predominates and the human population is sparse, sandy beaches and wetlands represent a small proportion of the area (Subiabre and Rojas 1994). The shore flora is dominated by herbaceous plants, shrubs such as Myrtaceae and Bromeliaceae, some secondary forest with dense foliage of a moderate height containing *Drimys winteri* (Winteraceae), *Aextoxicon punctatum* (Aextoxicaceae), *Amo-*

myrtus luma and *Luma apiculata* (Myrta-ceae). Inland areas consist of North-patago-nian and Valdivian rainforest species: *Nothofagus* spp., *Podocarpus nubigena*, *Eucryphia cordifolia*, *Aextoxicon punctatum*, *Laureliopsis philippiana* and several Myrta-ceae (Veblen et al. 1983). There are no records of European lagomorphs in the area (in contrast to the mainland).

We collected Darwin's fox feces opportunistically during 13 sampling trips, 5 in winter and 8 in summer of 2001 and 2002. Each trip covered about 8–10 km of the coastal area taken in forest, sandy beaches and dunes close to the rainforest. Most of the feces were found in latrines at den sites typically 1–2.5 km apart. The data for each season was pooled for the food-habits analysis. Size, shape, colour and smell were used to recognize Darwin's fox feces (Jaksic et al. 1990), and the collected samples were oven dried at 40 °C. Remains (teeth, hair, feathers, scales, seeds, etc.) present in the feces were identified and counted. Small mammals were recognized by identification of teeth and bones using identification keys and micro-photographs, up to genus or even species level when possible (Tab. 1). Invertebrates were identified to the lowest taxonomic level possible, and quantified by counting legs, compound eyes and other exoskeletal pieces. The maxillaries, mandibles, back legs or compound eyes, when available, were counted to estimate the minimum number of individual prey consumed (Juárez and Marinho-Filho 2002). The amount of fruit eaten was estimated by counting the seeds (small seeds) present in each fecal sample and normalized using the known number of seeds per fruit. For the analysis of hair and feathers, the frequency of occurrence was used because it is not possible to assign their presence to any particular number of individuals (Rau et al. 1995). Each dietary item identified (species level mostly) was presented as percent frequency and as relative biomass (García and Kittlein 2005): for the former the total prey-items used was the sum of all individuals recorded for the all prey; for the latter we used weights of adult mammals from previously published tables (Atalah et al. 1980; Jaksic 1986; Jaksic et al. 1983;

Iriarte et al. 1989; Johnson et al. 1992) and unpublished laboratory data (crustaceans, lizards and fruits) gathered by the authors. Dietary niche width for each season was calculated using Shannon's index (H') and its variance (Zar 1974) using DIVERS software. We also computed Hill's $N(1)$ diversity index as the antilog₁₀ of H' (Hill 1973). This index is proportional to prey item richness when there is an even consumption of the prey-items (see Tab. 1). We compared Shannon's indexes from each season with the Hutcheson test ("t", Brower et al. 1990).

A total of 66 feces (42 in summer and 24 in winter) were collected during the study. Remains of 33 vertebrate and 18 invertebrate taxa were identified (Tab. 1), among the former, rodents of the genus *Akodon*, *Oligoryzomys*, *Loxodontomys* and *Rattus* were represented as well as the marsupial *Dromiciops gliroides*. Bird remains were found in seven samples, three of them contained Passeriformes: one green-backed firecrown hummingbird (*Sephanoides sephaniodes*), another Emberezidae, and two samples with undetermined species. Reptile remains appeared in three samples, all of them corresponding to *Liolaemus* sp., the only genus inhabiting the island. Sixteen insect taxa and one arachnid were recognized in the remains (for some monospecific genera it was possible to arrive at the species level for some insects). Among them *Cratomelus armata*, a big Gryllidae that lives under logs on the rainforest floor, was the main insect captured by *P. fulvipes* during the first summer. In the second summer, two marine crustaceans, the anomuran crab *Emerita analoga* (16–32 mm) and the talitrid amphipod *Orchestoidea tuberculata* (2–18 mm) constituted a large part of the diet. At adult stage, these two crustaceans are typical of the low-intertidal zone and supralittoral, respectively, of sandy beach environments (Jaramillo et al. 1993). The seeds identified belonged to the sweet pulpy fruit (locally called chupón) of the big perennial bromeliacea *Greigia sphacelata*. According to the number of seeds per fruit (unpublished data) the total number of fruit consumed was at least 73 units (27 in 2001 and 46 in 2002) meaning that four inflorescences were consumed (we report that a

single inflorescence contains approximately 21 fruits).

During the 2001 summer, the vertebrates comprised 32.7% of the diet increasing to 42.3% in winter, in the summer of 2002, however, vertebrates contributed only 13% numerical frequency, coinciding with the highest frequency of the marine crustaceans (74%) and 25% of total biomass consumed (Tab. 1). The food-niche width in the summer of 2001 indicates the highest diversity of prey in our samples ($H' = 2.975$, $\text{var} = 0.008$), which can be explained by an increase of fruit, insects and birds consumed over that period (114 prey-items). For the 2001 winter, the invertebrates were substituted by a higher consumption of small mammals (34.6%) showing a food-niche width of $H' = 2.54$ ($\text{var} = 0.014$) indicating a generalist miscellaneous diet in both seasons compared. Whereas in the second summer it was more specific to marine crustaceans, with $H' = 1.669$ ($\text{var} = 0.019$) and Hill's diversity index of 47 prey-species. This specific diet behaviour for the 2001 summer contrasts with others already published and also with our own data collected during the previous year. Comparing both summer diets with a Hutcheson test confirms the differences between them ($t = 7.963$, $P < 0.05$).

The consumption of insects and fruit instead small mammals during summer and autumn had been also described for the three *Pseudalopex* species in Chile in line with the natural decrease of rodent density from spring–summer in Valdivian forest (Murúa et al. 1986; Meserve et al. 1991). Even in previous study in Chiloé during summer the feces composition of *P. fulvipes* reached 74% of insects (Jiménez et al. 1991), while in autumn, terrestrial invertebrates were substituted by fruit (seeds were present in 49% of the feces). In our case of the consumption of Bromeliaceae inflorescences could represent an adaptative and opportunistic behaviour because the fruits are surrounded by hard and spiny leaves in a rosette, but previous root feeding by coypus (*Myocastor coypus*) would leave their fruit accessible to other animals, including Darwin's foxes (Valenzuela, unpublished data).

With respect to marine food items previous publications have recorded, for the same

region, non-native (*Rattus* sp.) as well native rodents (Cricetids) consuming intertidal organisms on rocky shores (Martínez et al. 1986; Zamorano 1986, Navarrete and Castilla 1993) but it seems that there is no published evidence of canids feeding on crustaceans on sandy beaches. Only few sightings of Darwin's foxes on shore have included observations of feeding on shellfish, shorebirds or seaweed (Jiménez and McMahon 2004), however in a study performed in an area with abundant sand dunes (end of fall), no crustaceans were recorded in the fox's diet (Rau and Jiménez 2002).

The records for Pampa's foxes *Pseudalopex gymnocercus* studied in sand dunes, grassland and scrubland habitat on the Argentinian coast show a high consumption of fruit (*Apodanthera saggitifolia*) during summer as opportunistic feeding in the sand dune habitat (García and Kittlein 2005), but no consumption of intertidal crustaceans. For mammals in general our finding of *E. analoga* in Darwin's fox feces constitutes the first report on the occurrence of this crustacean on the diet of a terrestrial mammal. By contrast Talitridae species have been described as food items for other mammals on coastlines in other parts of the world (Brown and McLachan 1990).

In this case even though Darwin's fox has been described as a rainforest fox (Jaksic et al. 1990; Jiménez et al. 1991; Vilà et al. 2004; Yahnke et al. 1996;) and as it has been suggested in a radio-telemetry study that it is present in old-growth forest 70% of the time (Jiménez and McMahon 2004), our observations on diet prove that foxes living in the coastal area of the island will also use sandy beaches to search for marine food items. The low value of the Shannon's index for the second summer shows a specialist diet towards higher energy food more than just opportunistic behaviour, at least in our study area, where the dense rainforest is much more extensive than sandy beach areas. Also two sightings of Darwin's fox using the sandy beach habitats confirm this. This field records correspond to a diurnal sighting of one individual digging in the sand along the shore, and we assume looking for *E. analoga*, because, according to Jaramillo et al. (1993),

Table 1. Number of individuals (*n*), percentage numerical frequency (PF%) and relative biomass (BM) of each prey-item in diet of Darwin's fox in Chiloé coast, southern Chile. The parenthesis show subtotals.

Prey item	Year								
	2001			2002					
	Summer		Winter	Summer		Mass			
<i>n</i>	PF%	BM	<i>n</i>	PF%	BM%	<i>n</i>	PF% [%]	BM	Mass
Vertebrates		(32.7)			(42.3)			(12.9)	
Rodents		(23.6)			(34.6)			(6.9)	
<i>Akodon olivaceus</i>	2	3.6	70.0	1	1.9	35.0			35.0
<i>Akodon</i> sf. <i>longipilis-sanbornii</i> ¹	1	1.8	47.0	5	9.6	235.0	2	2.0	47.0
<i>Akodon</i> sp.	2	3.6	94.0	1	1.9	47.0	1	1.0	47.0
<i>Oligoryzomys longicaudatus</i>	3	5.5	93.0	8	15.4	248.0	2	2.0	31.0
<i>Loxodontomys micropus</i>							1	1.0	47.0
<i>Rattus</i> sp.				1	1.9	158.0			158.0
Undetermined cricetids	4	7.3	120.0	1	1.9	30.0	1	1.0	30
Undetermined rodent	1	1.8		1	1.9				
Marsupials									
<i>Dromiciops gliroides</i>				1	1.9		1	1.0	23.0
Undetermined mammal	1	1.8		1	1.9		1	1.0	
Birds		(3.6)			(3.8)			(3.0)	
<i>Sephanoides galeritus</i>				1	1.9	10.5	1	1.0	4.5
Emberizidae							2	2.0	10.5
Undetermined Passeriform	1	1.8							
Undetermined bird	1	1.8		1	1.9				
Reptiles		(3.6)						(1.0)	
<i>Liolaemus</i> sp.	2	3.6	16.0				1	1.0	8.0
Fishes					(1.9)				
Undetermined fish				1	1.9				
Invertebrates		(67.3)			(57.7)			(87.1)	
Arthropods		(54.5)			(26.9)			(12.9)	1.7

<i>Cratomelus armatus</i>	6	10.9	0.1	7	13.5	0.4	7	6.9	0.08
<i>Blatta</i> sp.	1	1.8	0.1						0.1
<i>Crossonichus viridis</i>	1	1.8	0.5						0.5
<i>Brachysternus angustus</i>	1	1.8	0.8					1.6	0.8
<i>Apterodorus bacchus</i>	1	1.8	2.4				2	2.0	0.6
<i>Zizzix chilensis</i>	4	7.3	0.4			0.4			0.4
<i>Nycterinus</i> sp.	1	1.8		1	1.9	1.0			0.5
<i>Aulacopalpus</i> sp.	2	3.8	1.2	2	3.8	1.2	1	1.0	1.2
<i>Megabombus dahlbomi</i>	1	1.8	0.2	1	1.9	0.2			0.2
<i>Carabidae</i>	1	1.8	0.1	1	1.9				
<i>Elateridae</i>	8	14.5	0.2						
<i>Scarabaeidae</i>	1	1.8	0.1			0.1			0.2
<i>Acrididae</i>	1	1.8		1	1.9				0.1
<i>Cerambycidae</i>			0.4				1	1.0	0.3
<i>Coleoptera</i>	1	1.8		1	1.9	0.1	1	1.0	0.4
<i>Lucanidae</i>			1.4	1	1.9				0.1
<i>Arachnidae</i>	2	3.6					1	1.0	0.7
Crustaceans		(12.7)			(30.8)			(74.3)	
<i>Orchestoidea tuberculata</i>	5	9.1	1	10	19.2	2.0	22	21.8	4.4
<i>Emerita analoga</i>	2	3.6	3.6	6	11.5	10.8	53	52.5	95.4
Number of fruits			29.7				46		50.6
<i>Greigia sphacelata</i>	27								1.1
Total items (no fruits)	26			20			18		
Total prey-items	55			52			101		
No. total feces	20			24			22		
% scats with plant material	35						20		
Shannon index	2.975	var 0.008		2.538	var 0.0141		1.669	var 0.019	
<i>M</i> (1) diversity index	944	prey-species		345	species-prey		47	species-prey	

¹The difficulty in identifying teeth of *A. longipilis* from *A. sanbornii* did not allow their discrimination.

it is the principal crustacean on these kind of beaches. In the 2002 summer another individual was seen eating *O. tuberculata* during the night, when the adults of this species emerge from deep in the sand in the supralittoral zone.

Carlton and Hodder (2003) introduce the “maritime mammals” concept, which makes reference to quite similar observations: a terrestrial mammal going into intertidal areas searching for live food and not detritus. As Darwin’s fox is not a territorial animal, with overlapping home-ranges (Jiménez and McMahon 2004), and considering the species known home-range of between 150 and 160 ha (Jiménez and McMahon 2004) we

assume that the study area (over 300 ha) contains more than one individual, but it is important to confirm whether these results represent a common behaviour throughout the island, or whether this is isolated behaviour.

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