

Short note

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Diet of Culpeo fox (*Lycalopex culpaeus*, Molina 1782): the role of non-native prey in a strongly seasonal environment of south-central Chile

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Abstract: In this study, we establish the seasonal variation of the Culpeo fox's diet in a seasonal ecosystem of south-central Chile. By scat analyses, 21 prey taxa were identified, 16 were animal and five were plant species. Mammals (88.47%) were the main biomass contribution with small seasonal fluctuations. Plants contributed the most to the differences observed in all seasons since they showed very marked changes. We determined that the Culpeo fox inhabiting the Andes of south-central Chile feeds mainly on small non-native mammals all year round, and supplements its diet opportunistically from items whose abundance oscillates seasonally.

Keywords: Canidae; Carnivora; lagomorphs; scat analysis; trophic generalism.

The study of feeding habits of generalist predators inhabiting seasonal ecosystems allows us to understand the variations of the main ecological interactions under different climatic conditions. It allows synchronously to characterize the dynamics of the consumer and the annual abundance variations and availability of trophic resources (Iriarte and Jaksic 2017). The environmental scenario of the Andean region of south-central Chile is dominated by the Mediterranean climate, characterized by a marked seasonality (wet and cold winters and dry and hot summers; Mooney 1970; Myers et al. 2000). The main generalist

predator in this region is *Lycalopex culpaeus* (Molina 1782). The diet of *L. culpaeus* is composed of a broad spectrum of prey, from ungulates to insects and fruits (Jiménez and Novaro 2004). Nevertheless, the most common prey items are rodents and non-native mammals, with a substantial change in the use of resources when the abundance of these prey decrease (e. g., Guzmán-Sandoval et al. 2007; Martínez et al. 1993; Rubio et al. 2013). Thus, the relative abundance of the prey has a significant role in the temporal predominant trophic items of the predator's diet (Carlsson et al. 2009; Ignazi et al. 2020). The first studies of the culpeo fox's diet in south-central Chile concluded that the relatively low predation of non-native mammals (<5%) was a sign that native predators had not yet learned to hunt for this introduced species (Jaksic and Soriguer 1981). However, Rubio et al. (2013), for the first time, report a significantly higher occurrence of non-native mammals than of native small mammals pooled together (>80%). Specifically, this aspect of the Culpeo fox's trophic ecology is fundamental because Chile is the South American region where non-native mammals (mainly lagomorphs) exhibit their most invasive behavior, reaching their highest densities (Bonino et al. 2010; Buenavista and Palomares 2018; Simonetti 1986). Lagomorphs have adaptations that facilitate expansion through complex geographies such as the Mediterranean and Andean regions of southern South America. This include the ability to cross mountain barriers up to 1000 m high and vast waterways (Jaksic et al. 2002). However, despite their relevance, in previous works, the seasonal aspect of diet variation and seasonal differences in prey availability are not explicitly considered as part of the fieldwork protocol. Therefore, this study's main objective is to determine the seasonal variation pattern of the Culpeo fox's diet in a native Andean environment of central-southern Chile.

Fieldwork was conducted in private owner lands of the Andean valley of Santa Gertrudis River (36°40'0"S; 71°22'0" W; from 653 to 873 m. a. s.l.), Ñuble Region, Chile. This area corresponds to a native mixed ecosystem of temperate hygromorphic and Andean foothill forests with markedly seasonal climate (from dry and hot summers to snowy

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winters; Cid and Loyola 2017; Quintanilla 1983). During each season between June of 2016 and February of 2017, and following a transect of 7.5 km, we identified and stored 69 scats, following the protocols described in field guides (Iriarte and Jaksic 2017; Muñoz-Pedreras 2008). A total of 22 prey taxa were identified and pooled in five large groups: reptile, birds, insects, mammals and plants (Table 1). Prey remains were identified to species when possible, according to keys (Pearson 1995; Reise 1973) and reference collections (MZUCCC – Herbarium CONC). We determined the importance of trophic items based on frequency of occurrence per item, per scat and biomass contribution (Klare et al. 2011; Marti 2007). Body mass data was obtained from Smith et al. (2003) for mammals, Figueroa et al. (2006) for birds and insects, Fredes et al. (2014), Perea et al. (2013),

and Usenik et al. (2007) for plants. Levins index (B) was used to calculate the amplitude of the trophic niche for each season (Krebs 1989). We evaluated significant changes to evidence the seasonal change in diet using bootstrapped empirical distribution and Mann-Whitney's U -test (Wilcoxon 1992). We correct the effect of multiple comparisons using Bonferroni corrections to each p values obtained.

Our results are agreeing with several studies showing that Culpeo fox has an omnivorous nature (Fuentes and Jaksic 1979; Medel and Jaksic 1988; Zúñiga and Fuenzalida 2016). However, the use of biomass estimates allowed us to establish that, during the study period, more than 80% of the diet of the Culpeo fox was carnivorous, with most biomass contribution by *Lepus europaeus* (73.21%) and

Table 1: Seasons and scat numbers.

Levins index	Autumn (10)			Winter (22)			Spring (21)			Summer (16)		
	1.46 (0.121)			4.801 (1)			2.242 (0.327)			1.625 (0.164)		
Trophic item	%ST	%IT	%BM	%ST	%IT	%BM	%ST	%IT	%BM	%ST	%IT	%BM
Insects	40.00	3.17	0.00	54.55	24.21	0.13	71.43	4.08	0.09	18.75	0.17	0.04
<i>A. cumingii</i>	0.00	0.00	0.00	9.09	1.05	0.01	4.76	0.24	0.01	6.25	0.06	0.04
Coleoptera	0.00	0.00	0.00	18.18	12.63	0.12	33.33	1.92	0.06	0.00	0.00	0.00
Orthoptera	0.00	0.00	0.00	4.55	0.53	0.00	9.52	0.48	0.02	0.00	0.00	0.00
Undetermined	40.00	3.17	0.00	22.73	10.00	0.00	23.81	1.44	0.00	12.50	0.11	0.00
Plants	70.00	84.92	12.44	31.82	59.47	0.18	76.19	90.17	18.94	131.25	98.98	16.72
<i>Rubus</i> sp.	10.00	1.59	0.02	13.64	26.84	0.18	0.00	0.00	0.00	12.50	1.13	0.07
<i>Greigia</i> sp.	0.00	0.00	0.00	0.00	0.00	0.00	47.62	30.22	2.06	25.00	1.02	0.18
<i>Prunus</i> sp.	50.00	82.54	12.42	0.00	0.00	0.00	23.81	59.47	16.88	50.00	21.15	15.70
<i>A. chilensis</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.50	75.52	0.77
Undetermined	10.00	0.79	0.00	18.18	32.63	0.00	4.76	0.48	0.00	6.25	0.17	0.00
Mammals*	140.00	11.11	87.05	113.64	13.16	99.68	90.48	4.56	80.09	81.25	0.73	83.28
<i>L. culpaeus**</i>	0.00	0.00	0.00	0.00	0.00	0.00	4.76	0.24	0.00	0.00	0.00	0.00
<i>L. europeus</i>	10.00	0.79	51.04	22.73	2.63	92.47	9.52	0.48	58.19	25.00	0.23	71.58
<i>O. bridgesii</i>	0.00	0.00	0.00	0.00	0.00	0.00	4.76	0.24	1.17	0.00	0.00	0.00
<i>O. cuniculus</i>	10.00	0.79	26.72	0.00	0.00	0.00	4.76	0.24	15.23	6.25	0.06	9.37
<i>O. longicaudatus</i>	20.00	1.59	0.74	13.64	1.58	0.40	14.29	0.72	0.63	0.00	0.00	0.00
<i>R. auritus</i>	0.00	0.00	0.00	4.55	0.53	0.35	0.00	0.00	0.00	0.00	0.00	0.00
<i>Rattus</i> sp.	30.00	2.38	7.30	27.27	3.16	5.29	14.29	0.72	4.16	12.50	0.11	1.71
<i>A. olivaceus</i>	20.00	1.59	0.74	27.27	3.16	0.80	9.52	0.48	0.42	12.50	0.11	0.26
<i>A. longipilis</i>	10.00	0.79	0.51	9.09	1.05	0.37	4.76	0.24	0.29	12.50	0.11	0.36
Undetermined	40.00	3.17	0.00	9.09	1.05	0.00	23.81	1.20	0.00	12.50	0.11	0.00
Birds	10.00	0.79	0.52	13.64	1.58	0.00	14.29	0.72	0.89	12.50	0.11	0.00
<i>G. gallus</i>	10.00	0.79	0.52	0.00	0.00	0.00	14.29	0.72	0.89	0.00	0.00	0.00
Undetermined	0.00	0.00	0	13.64	1.58	0.00	0.00	0.00	0.00	12.50	0.11	0.00
Reptiles	0.00	0.00	0.00	13.64	1.58	0.00	9.52	0.48	0.00	0.00	0.00	0.00
Undetermined	0.00	0.00	0.00	13.64	1.58	0.00	9.52	0.48	0.00	0.00	0.00	0.00

The Levins index (in parentheses the standardized value) for each sampling window (all season have significant differences, except autumn versus spring) and seasonal change of Culpeo fox's diet from Andean Central Chile. Sampling was made during the years 2016–2017. Values indicate the percentage of occurrence of each item in the total of scats (%ST), the percentage of appearance of each item in the total of occurrences of all items (%IT), and the contribution of biomass supplied by each item (%BM). Values next to the column name signify the number of samples collected per season. *OCCST values are higher than 100% due to the appearance of each item on more than one scat. **Grooming. This item was not considered in any index.

Oryctolagus cuniculus (9.58%) (Table 1). Interestingly, our results show that it is very unlikely that this fox population could be facing critical seasons from a nutritional perspective because preys with higher biomass, while varying temporarily with small fluctuations, never fall below 74% in contribution per season (Table 1). Also, Culpeo fox opportunistically supplements this animal biomass with seasonal items. The major changes were in the occurrence and biomass measurements of winter, where plant species (e. g. *Prunus* sp. and *Aristotelia chilensis*) that dominated summer frequencies, were not recorded. In the same way, seasonal presence of native common prey like *Oligoryzomys longicaudatus* and *Agyneta olivacea*, seems to be related to their population dynamics, becoming very abundant during the winter season, but disappear almost completely in the summer (González and Murúa 1985; Meserve et al. 1999). Levins index comparisons showed that all season have significant differences (Table 1; $p < 0.001$), except autumn versus spring ($p = 1$). Seasonal variation of B has firmly subordinated to those items that show great seasonal variation, specifically *A. chilensis* and *Prunus* (Table 1). However, the biomass contribution made by these items during the sampling period is 17%. Additionally, during winter, trophic amplitude was higher ($B = 4.801$; Table 1), when there is no rabbit feeding and an increase in the use of *Rattus* and native rodents (including all the species detected in this work) showing a fast prey switch. Interestingly, the lagomorphs are quite successful in these native Neotropical environments. In this sense, the early development structure of Mediterranean landscapes may favor lagomorphs offering refuge from predators, though this effect may become negative once forests mature (Calvete et al. 2004; Hulbert et al. 1996). Moreover, in this particular case, these species of lagomorphs are extremely abundant in the native Andean forest with little human activity. No doubt, this requires future research efforts.

Finally, the study of predation interaction allows the detection of species that are difficult to detect by other methods within the study area, such as the appearance of cranial and dental remains of the native rodent *O. bridgesii* and *R. auritus*. In front of this results, we proposed that the Culpeo fox population that inhabits the Andes of south-central Chile feeds mainly on small non-native mammals, and supplements its diet opportunistically from items whose abundance oscillates seasonally.

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