Selective consumption of rodents by the Variable hawk *Geranoaetus polyosoma* (Accipitriformes: Accipitridae) in the Atacama Desert, northern Chile

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ABSTRACT. *Geranoaetus polyosoma* (Quoy & Gaimard, 1824) is a diurnal raptor widely distributed in South America. Although the trophic ecology of this bird has been more studied in the southern extreme of its range, little information is available on its dietary response to prey supply in desert environments. In the present study, we report on the trophic ecology of *G. polyosoma* in a sub-urban desert zone in northern Chile, with the following objectives: (1) to quantitatively describe its diet and (2) to determine its dietary selectivity in response to prey supply in the study area. The diet of *G. polyosoma* consisted mainly of rodents (97.2%). A greater preference (p < 0.05) was observed for the following large prey items (> 19.5 g): two native rodent species, *Phyllotis xanthopygus* (Waterhouse, 1837) and *Eligmodontia puerulus* (Philippi, 1896); and two introduced rodent species: *Rattus rattus* (Linnaeus, 1769) and *R. norvegicus* (Berkenhout, 1769).

KEY WORDS. Diet, predation, Red-backed hawk, trophic ecology.

INTRODUCTION

The diurnal raptor Variable hawk, *Geranoaetus polyosoma* (Quoy & Gaimard, 1824), is widely distributed in South America, from the central Andes of Colombia to Patagonia and Tierra del Fuego, including the Falkland Islands (Thiollay 1994, Ferguson-Lees and Christie 2001). The common subspecies in mainland Chile is *Geranoaetus polyosoma polyosoma*, present in many environments (e.g. arid and sub-humid zones, low-lying land, mountain shrubland, temperate forests, meadow shrubland and agroecosystems), from sea level to 4500 m in elevation; it also frequents sub-urban zones, entering through mountain chains (Pavez 2004).

In Chile and Argentina, the diet of the Variable hawk has been studied for only a few eco-regions (sensu Dinerstein et al. 1995). Consequently, information on the trophic ecology of this raptor bird is scarce, especially in arid environments (Ponce et al. 2018). The information available in the literature documents a diet based mainly on rodents, birds, reptiles, amphibians and invertebrates (Schlatter et al. 1980, Jiménez 1995, Figueroa et al. 2003, Baladrón et al. 2006, Travaini et al. 2012, Baladron 2014, Valladares et al. 2015, Ponce et al. 2018). Its dietary selectivity is subjected to geographical variations; for example, it is a generalist in Argentinean Patagonia (Monserrat et al. 2005), and a specialist on the south-east coast of the Province of Buenos Aires (Baladrón et al. 2006). Its trophic ecology has been insufficiently studied in the central and northern part of its range (Travaini et al. 2012, Ponce et al. 2018), and its dietary response to prey supply is unknown.

The Atacama Desert is one of the largest hyperarid deserts in the world. Desertification of the region began 14,000 years ago during the aridification of the world’s climate. Sedimentological data from the Middle Miocene to the Upper Pliocene successions in the modern Atacama Desert indicate that a semi-arid climate persisted from 8 to 3 kyr, punctuated by a more arid phase around 6 kyr. Hyperaridity therefore began only in the Late Pliocene (Harley and Chong 2002). Climatic conditions in this desert are extreme and primary production is low, limiting the supply of prey for top predators like birds of prey (Polis 1991, Megías et al. 2011, Carevic et al. 2013). Under these conditions, subsidiary sources are important for maintaining predator populations.
(Megías et al. 2011, Kristan et al. 2004). Urban areas can offer a greater variety of food, independent of the natural supply in the area (Kristan et al. 2004), and this new supply and consumption may be important for human health if these allochthonous prey are health pests like rodents of the genera *Rattus* and *Mus* (Bordes et al. 2015).

In this study we report the trophic ecology of *G. polyosoma* in a sub-urban area of an oasis in the Atacama Desert, Chile, describing its diet quantitatively and determining its dietary selectivity in response to the supply of prey and the consumption of allochthonous prey species.

**MATERIAL AND METHODS**

Ojo Opache (22°29’S; 69°01’W) is a suburban oasis located by the Loa River, 5 km south-west of Calama (Fig. 1). It lies in the central valley of the Antofagasta Region of Chile. The Atacama Desert covers most of the Region, with a prevailing desert climate varying between coastal desert, normal desert and high-altitude marginal desert (Köppen 1948). The climate of the region is very arid, with scarce precipitation and almost no rivers. The desert climate is absolute, with relief formations and high soil salinity. The river Loa is the only important watercourse in the area. The vegetation belongs to the flash-flood desert type of the Andean desert sub-region (Gajardo 1994).

We collected 201 pellets from a *G. polyosoma* nesting site in a ravine in Ojo Opache during August 2002. Considering the meal-to-pellet interval reported by Houston and Duke (2007), we estimate that 201 pellets correspond to pellets accumulated under nest during 41-55 days for two hawks. Pellets were measured with a caliper, accuracy 0.1 mm, and dry weight was obtained in a digital scale, accuracy 0.01 gr. Prey items were identified to species level in micro-mammals, and family and genus level in birds and insects when the species could not be identified. We used as identification guides Reise’s key (1973) and the insect guides of Peña (1986) and Arias (2000), as well as reference material from zoological collections. The contribution of each prey species to the biomass consumed was estimated following Marti (1987): \[ B_i = 100 \left( \frac{S_p N_i}{\sum S_p N_i} \right) \] , where \( S_p \) is the weight of species i, \( N_i \) is the number of individuals of species i consumed and \( B_i \) is the percentage of the total biomass contributed by species i. Mass values of mammals were obtained from the databases of the Chilean National History Museum and from the values documented by Muñoz-Pedreros (1992), Jaksic (2001) and Muñoz-Pedreros and Gil (2009). Mass values of birds were obtained from the literature (Morgado et al. 1987, Egli 1996).

To estimate the diversity and abundance of rodents at the same area we used Sherman traps with an effort of 1,077 trap/nights. The following trophic analysis were used to characterize diet: (a) diversity of prey consumed through the Shannon-Wie-
RESULTS

Morphometry of pellets and diet composition. The 201 compact, measurable pellets were subjected to morphometric analysis. Mean values recorded were length 26.6 mm (SD ± 7.94), breadth 19.5 mm (SD ± 5.68) and height 16.1 mm (SD ± 5.23). The number of prey remains recorded was 290, (1.44 per pellet), of which 287 were vertebrates and only three were invertebrates (Table 1).

Rodents made up most of the diet (97.2%) of *Geranoaetus polyosoma*, while marsupials (0.7%) and birds represented only a marginal contribution (1.0%). The most frequent prey species, in descending order, were *Mus musculus* Linnaeus, 1758, *Eligmodontia puerculus* (Philippi, 1896), *Phyllostis xanthopygus* (Waterhouse, 1837) and *Rattus ratti* (Linnaeus, 1769). The rodents which contributed most to the diet by biomass, in descending order, were: R. rattus, *Rattus* sp., *P. xanthopygus*, *Rattus norvegicus* (Berkhout, 1769) and *M. musculus*. Exotic rodent species (*Rattus* spp. and *M. musculus*) together contributed more than half the biomass (57.7%) of the diet of *G. polyosoma* in the Ojo Opache (Table 1). The equity was high (H’ = 0.82, Hmax = 0.954, J = 0.86), meaning that the prey frequency tends towards heterogeneity.

Trophic niche breadth and diet selectivity. During field sampling, 84 specimens collected were from four species (Table 2). The *χ²* test indicated that, for this location, *G. polyosoma* did not consume all the vertebrate prey species in the same propor-

| Prey item         | Mass (g) | N   | %F | %B |
|-------------------|----------|-----|----|----|
| Thylamys pallidior| 31.2     | 2   | 0.7| 0.4|
| Subtotal Marsupials| 2        | 0.7|    | 0.4|
| Phyllostis xanthopygus| 57.3    | 36  | 12.4| 12.1|
| Mus musculus      | 15.9     | 76  | 26.2| 7.1|
| Eligmodontia puerculus| 19.5 | 46  | 15.9| 5.3|
| Rattus rattus     | 158      | 31  | 10.7| 28.8|
| Rattus norvegicus | 93.3     | 17  | 5.9 | 9.3 |
| Rattus sp.        | 125.7    | 17  | 5.9 | 12.5|
| Indeterminate rodents| 68.8 | 59  | 20.3| 23.8|
| Subtotal Rodents  | 282      | 97.2| 98.9|
| Total Mammals     | 284      | 97.9| 99.3|
| Indeterminate birds| 41       | 3.0 | 1.0 | 0.7 |
| Total Birds       | 3        | 1.0 | 0.7 |
| Total vertebrates | 287      | 98.9| 99.9|
| Cratomeles armatus| 0.5      | 1   | 0.3 | 0.0 |
| Orthoptera indeterminate| 0.5 | 1   | 0.3 | 0.0 |
| Scarabaeidae indeterminate| 0.5 | 1   | 0.3 | 0.0 |
| Total invertebrates| 3       | 1.0 | 0.0 |
| Total preys/g     | 290      | 100 | 100|
| Pellets (N)       | 201      |     |    |
| B                 | 5.91     |     |    |
| Bsta s/invertebrates| 0.53    |     |    |
| Bsta c/invertebrates| 0.45    |     |    |
| H’                | 0.82     |     |    |
| J’                | 0.86     |     |    |

Table 2. Frequency and relative abundance of micromammals in Ojo Opache and *χ²* values for vertebrate prey consumed by *G. polyosoma* (*χ²* = 15.507, p = 0.05). In bold statistical significance p < 0.05.

| Species            | Frequency | Relative abundance | *χ²* |
|--------------------|-----------|--------------------|------|
| Abrothrix olivaceus| 4         | 4.8                | 0    |
| Phyllostis magister| 18        | 21.7               | 0    |
| Mus musculus       | 59        | 71.1               | 3.8  |
| Rattus rattus      | 2         | 2.4                | 27.1 |
| Thylamys pallidior | 0         | 0                  | 2.0  |
| Phyllostis xanthopygus| 0       | 0                  | 36.0 |
| Eligmodontia puerculus| 0       | 0                  | 46.0 |
| Rattus norvegicus  | 0         | 0                  | 17.0 |
| Rattus sp.         | 0         | 0                  | 17.0 |
| Total              | 83        | 100                |      |
tion as their presence in the area ($\chi^2 = 15.507$, p = 0.05); significant selectivity was detected in favor of R. rattus, P. xanthopygus, E. puerulus, R. norvegicus and Rattus sp. (Table 2). No statistically significant differences were detected for the consumption of M. musculus and the marsupial Thylamys pallidior Thomas, 1902 (Table 2). The trophic niche breadth value for G. polyosoma in Ojo Opache was 5.913 (maximum 10).

**DISCUSSION**

The general composition of the diet of G. polyosoma in the study area agrees with reports for different eco-regions (Schlatter et al. 1980, Fuentes et al. 1993, Jiménez 1995, Figueroa et al. 2003, Baladrón et al. 2006, 2014, Travaini et al. 2012, Ponce et al. 2018), in the sense that rodents are the most important prey item. However, our findings in the oasis of Ojo Opache, Calama, in the Atacama Desert, differ from those of Valladares et al. (2015), also an arid environment, who reported a high consumption of lizards (Liolaeus and Callopistes) (57.1%) and a low consumption of rodents (19.8%). The same finding is reported in Pampa del Tamarugal, where the lizard Microlophus theresioides (Donoso-Barros, 1966) was the most frequent species (45.3%) in the diet, followed by the native rodent Phyllotis darwini (Waterhouse, 1837) (40.4%, Ponce et al. 2018). The low consumption of invertebrates also differs from findings in another semi-arid environment (Las Chinchilllas National Reserve) by Jiménez (1995), who documented a high consumption of insects (27.6%). The equity and trophic niche breadth are greater than Jiménez (1995), who documented a high consumption of insects in the Chilean matorral eco-region (e.g. La Dehesa, Metropolitan Region) (H’ = 0.82 versus H’ = 0.6; Bsta = 0.532 versus Bsta = 0.187).

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**LITERATURE CITED**

Arias E (2000) Coleópteros de Chile. Fototeknika, Santiago, 209 pp.
Baladrón AV, Bó MS, Malizia AI (2006) Winter diet and time-activity budgets of the Red-backed Hawk (*Buteo polyosoma*) in the coastal grasslands of Buenos Aires province, Argentina. Journal of Raptor Research 40: 65–70. https://doi.org/10.3356/0892-1016(2006)40[65:WDATBO]2.0.CO;2

Baladrón AV, Cavalli M, Martinez G (2014) Dieta del aguilucho común (*Geranoaetus polyosoma*) en pastizales costeros y zonas periurbanas de la región pampeana. Nótulas Faunísticas 143 (2014): 1–5.

Bordes F, Blasdel K, Morand S (2015) Transmission ecology of rodent-borne diseases: new frontiers. Integrative Zoology 10(5): 424–435. https://doi.org/10.1111/1749-4877.12149

Carevic F, Carmona SR, Muñoz-Pedreros A (2013) Seasonal diet of the Burrowing Owl *Athene cunicularia* Molina, 1782 (Strigidae) in a hyperarid ecosystem of the Atacama Desert in northern Chile. Journal of Arid Environments 97: 237–241. https://doi.org/10.1016/j.jaridenv.2013.07.008

Dinerstein E, Olson DM, Webster AL, Primm SA, Brookbinder MP, Ledec G (1995) A Conservation Assessment of the Terrestrial Ecoregions of Latin America and the Caribbean. The World Bank, Washington, DC, 129 pp.

Egli G (1996) Biomorfología de algunas aves de Chile Central. Boletín Chileno de Ornitología 3: 2–9.

Ferguson-Lees J, Christie DA (2001) Raptors of the world. Christopher Helm, London, 320 pp.

Figueroa RA, Corales SE, Alvarado S (2003) Diet of the Red-backed Hawk (*Buteo polyosoma*) in a forested area of the Chilean Patagonia and its relation to the abundance of rodent prey. El Hornero 18(1): 43–52.

Fuentes MA, Simonetti JA, Acevedo PA (1993) Diet of the Red-backed Buzzard (*Buteo polyosoma exsul*) and the Short-eared Owl (*Asio flammeus suindu*) in the Juan Fernández Archipelago of Chile. Journal of Raptor Research 27: 167–169.

Gajardo R (1994) La Vegetación Natural de Chile. Clasificación y Distribución Geográfica. Editorial Universitaria, Santiago, 165 pp.

Hartley AJ, Chong G (2002) A late Pliocene age for the Atacama Desert: implications for the desertification of western South America. Geology 30: 43–46.

Hiraldo F, Donázar JA, Ceballos O, Travaini A, Bustamante J, Monserrat AL, Funes MC (2005) Respuesta dietaria de tres rapaces frente a una presa introducida en Patagonia. Revista Chilena de Historia Natural 78: 425–439. https://doi.org/10.4067/S0716-078X2005000300006

Hirold F, Donázar JA, Ceballos O, Travaini A, Bustamante J, Funes MC (1995) Breeding biology of the grey eagle-buzzard (*Buteo polyosoma*) in the Atacama Desert. Boletín Chileno de Ornitología 3: 2–9.

Hirold F, Donázar JA, Ceballos O, Travaini A, Bustamante J, Funes MC (1995) Breeding biology of the grey eagle-buzzard (*Buteo polyosoma*) in the Atacama Desert. Boletín Chileno de Ornitología 3: 2–9.

Hirold F, Donázar JA, Ceballos O, Travaini A, Bustamante J, Funes MC (1995) Breeding biology of the grey eagle-buzzard (*Buteo polyosoma*) in the Atacama Desert. Boletín Chileno de Ornitología 3: 2–9.

Hirold F, Donázar JA, Ceballos O, Travaini A, Bustamante J, Funes MC (1995) Breeding biology of the grey eagle-buzzard (*Buteo polyosoma*) in the Atacama Desert. Boletín Chileno de Ornitología 3: 2–9.

Hirold F, Donázar JA, Ceballos O, Travaini A, Bustamante J, Funes MC (1995) Breeding biology of the grey eagle-buzzard (*Buteo polyosoma*) in the Atacama Desert. Boletín Chileno de Ornitología 3: 2–9.

Hirold F, Donázar JA, Ceballos O, Travaini A, Bustamante J, Funes MC (1995) Breeding biology of the grey eagle-buzzard (*Buteo polyosoma*) in the Atacama Desert. Boletín Chileno de Ornitología 3: 2–9.

Jaksic FM (2001) Ecología de comunidades. Ediciones Universidad Católica de Chile, Santiago, 233 pp.

Jaksic FM, Jiménez JE, Castro SA, Feinsinger P (1992) Numerical and functional response of predators to a long-term decline in mammalian prey at semi-arid Neotropical site. Oecologia 89: 90–101. https://doi.org/10.1007/BF00319020

Jiménez JE (1995) Historia natural del aguilucho común (*Buteo polyosoma*): una revisión. El Hornero 14: 1–8.

Köppen W (1948) Climatología: con un estudio de los climas de la tierra. Fondo de Cultura Económica, México, 478 pp.

Korpimäki E, Norrdahl K (1989) Predation of Tengmalm’s owls: numerical responses, functional responses and dampening impact on population fluctuations of microtines. Oikos 54: 154–164. https://doi.org/10.2307/3565261

Kosoy M, Khylap L, Cosson JE, Morand S (2015) Aboriginal and invasive rats of genus *Rattus* as hosts of infectious agents. Vector-Borne and Zoonotic Diseases 15(1): 3–12. https://doi.org/10.1089/vbz.2014.1629

Kristan WB III, Boarman WI, Crayon JJ (2004) Diet composition of common ravens across the urban-wildland interface of the West Mojave Desert. Wildlife Society Bulletin 32: 244–253.

Levins R (1968) Evolution in changing environments: some theoretical explorations. Princeton University Press, New Jersey, 132 pp.

Magurran AE (1998) Ecological diversity and its measurement. Princeton University Press, New Jersey, 179 pp.

Marti C (1987) Raptor food habits studies. In: Pendleton BA, Millsap BA, Cline KW, Bird DM (Eds) Raptor management techniques manual. National Wildlife Federation, Washington, DC, 67–79.

Mclean N, Gage JDG, Lambsheds BJ, Paterson GLJ (1998) BioDiversity professional statistics analysis software V2. The Natural History Museum and Scottish Association for Marine Science, London.

Megías AG, Sánchez-Piñero F, Hódar JA (2011) Trophic interactions in an arid ecosystem: from decomposers to top-predators. Journal of Arid Environments 75: 1333–1341. https://doi.org/10.1016/j.jaridenv.2011.01.010

Monserrat AL, Funes MC, Novaro AJ (2005) Respuesta dietaria de tres rapaces frente a una presa introducida en Patagonia. Revista Chilena de Historia Natural 78: 425–439. https://doi.org/10.4067/S0716-078X2005000300006

Morgado E, Gunther B, González U (1987) On the allometry of rodent-borne diseases: new frontiers. Integrative Zoology 143 (2014): 1–5.

Muñoz-Pedreros A, Gil C, Váñez J, Rau R (2010) Raptor habitat management and its implication on the biological control...
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ZOOLOGIA 37: e55615 | https://doi.org/10.3897/zoologia.37.e55615 | December 7, 2020

of the Hantavirus. European Journal of Wildlife Research. European Journal of Wildlife Research 56(5): 703–715. https://doi.org/10.1007/s10344-010-0364-2

Nordahl K, Korpimäki E (2000) Do predators limit the abundance of alternative prey? Experiments with vole-eating avian and mammalian predators. Oikos 91: 528–540. https://doi.org/10.1034/j.1600-0706.2000.910315.x

Ostfeld RS, Holt RD (2004) Are predators good for your health? evaluating evidence for top-down regulation of zoonotic disease reservoirs. Frontiers in Ecology and the Environment 2(1): 13–20. https://doi.org/10.1890/1540-9295(2004 )002[0013:APGFYH]2.0.CO;2

Pavez E (2004) Descripción de las rapaces chilenas. In: Muñoz-Pedreros A, Rau J, Yáñez J (Eds) Aves Rapaces de Chile. CEA Ediciones, Valdivia, 29–106.

Pavez E, González CA, Jiménez JE (1992) Diet shifts of Black-chested Eagles (Geranoaetus melanoleucus) from native prey to European Rabbits in Chile. Journal of Raptor Research 26: 27–32.

Peña L (1986) Introducción al estudio de los insectos de Chile. Editorial Universitaria Santiago, Santiago, 4th ed., 253 pp.

Polis GA (1991) Complex trophic interactions in deserts: an empirical critique of food-web theory. The American Naturalist 138(1): 123–155.

Ponce C, Carevic FS, Carmona ER (2018) Seasonal diet by a generalist raptor: the case of the variable hawk (Geranoaetus polyosoma) at Atacama Desert, northern Chile. New Zealand Journal of Zoology 45: 171–179. https://doi.org/10.1080/03014223.2017.1395750

Reise D (1973) Clave para la determinación de los cráneos de marsupiales y roedores chilenos. Gayana, Zoología 27: 1–20.

Salamolard M, Butet A, Leroux A, Bretagnolle V (2000) Responses of an avian predator to variations in prey density at a temperate latitude. Ecology 81: 2428–2441. https://doi. org/10.1890/0012-9658(2000)081[2428:ROAAPT]2.0.CO;2

Schlatter R, Yáñez J, Jaksic F (1980) Food-niche relationships between Chilean Eagles and Red-backed Buzzard in Central Chile. Auk 97: 897–898. https://doi.org/10.1093/auk/97.4.897

Simpson EH (1949) Measurement of diversity. Nature 163: 688.

Thiollay JM (1994) Family Accipitridae (Hawks and Eagles). In: del Hoyo J, Elliott A, Sargatal J (Eds) Handbook of the birds of the world. Lynx Edicions, Barcelona, 52–205.

Travaini A, Santillán MA, Zapata SC (2012) Diet of the Red-backed Hawk (Buteo polyosoma) in two environmentally contrasting areas of Patagonia. Studies on Neotropical Fauna and Environment 47(1): 25–32. https://doi.org/10.1080/01650521.2011.649948

Valladares P, Álvarez-Henríquez N, Urrutia N, Olivares F, Alvarado S (2015) Dieta del aguilucho común Geranoaetus polyosoma (Quoy & Gaimard 1824) en la Región de Atacama, Chile. Gayana 79(2): 121–127.