The diet of the southern water vole, *Arvicola sapidus* in southern Navarra (Spain)

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ABSTRACT

The trophic ecology of *Arvicola sapidus* Miller, 1908 was studied, based on the analysis of the stomach contents of 48 specimens collected in southern Navarra (Spain). Diet composition, trofic niche width and seasonal variations are described. The diet consisted entirely of herbaceous plants. Monocotyledoneae were the most important items, as determined by relative frequency (% N) and Simpson´s dominance index (D): Gramineae (% N= 51,6; D= 19,60), Typhaceae (% N= 17,5; D= 3,87) and Cyperaceae (% N= 16,8; D= 3,46). Although the diet was more varied in spring and summer, monocotyledons were the greatest source of food throughout the year. The values for dominance, cumulative diversity and population diversity indicate that the species has a stenophagous diet.

RESUMEN

Se ha estudiado la ecología trófica de la rata de agua *Arvicola sapidus* Miller, 1908, en función del análisis del contnido estomacal de 48 ejemplares capturados en el sur de Navarra (España). Se describe la composición de la dieta, la amplitud del nicho trófico así como las variaciones estacionales. La dieta ha consistido exclusivamente en plantas herbáceas. Las monocotiledoneas constituyen el item más importante tanto por su frecuencia relativa (% N) como por el índice de dominancia de Simpson (D): Gramíneas (% N= 51,6; D= 19,60), Typhaceas (% N= 17,5; D= 3,87) y Cyperaceas (% N= 16,8; D= 3,46). Aunque la dieta fue más variada en primavera y en verano las Monocotiledoneas fueron el mayor recurso todo el año. Los valores obtenidos para dominancia, diversidad acumulativa y diversidad poblacional indican que esta especie tiene una dieta estenófaga.

Key Words: Diet, estenophagous, *Arvicola sapidus*, Rodentia, Spain

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Introduction

The southern water vole, *Arvicola sapidus* Miller, 1908 (Rodentia, Arvicolidae), is tied closely continental waters with abundant shoreline vegetation and earthy substrates. A few studies give isolated information is given on the diet of *A. sapidus* (Z a b a l a 1983, F a u s 1984) and general descriptions can be found in various compendia and handbooks (C a b r e r a 1914, R o d e & D i d i e r 1946, S a i n t - G i r o n s 1973, R e i c h s t e i n 1982). In addition, a more detailed study was conducted by V e n t u r a et al. (1989) in the delta of the River Ebro (Spain).

The aim of this work was to analyse the diet of *A. sapidus* in southern Navarra (Spain) and its seasonal variation.

Study Area, Material and Methods

The study area lies in the lower basin of the River Aragon (a tributary of the R. Ebro) in southern Navarra (Spain). This region, with an annual mean temperature of 13.5 °C and approximately 450 mm of rainfall annually, has a semiarid and mesothermic climate (C r e u s 1986) and falls within the Mediterranean biogeographic region (B á s c o n e s & U r s ú a 1986). The area is traversed by various streams and irrigation and drainage canals, with associated hydrophilic communities develop; notably, reeds and rushes, and particularly the associations *Typho-Scirpetum tabernaemontani* and *Cirsio-Holoschoenetum* (U r s ú a 1986). The period of vegetative activity of these communities lasts from the end of March to the beginning of November. To study seasonal variation in water vole diet, the year was divided into three four-monthly periods, the first of which took in the months of November, December, January and February (NDJF), the second included March, April, May and June

(MAMJ) and the third, July, August, September and October (JASO). This division was chosen because it best fitted the phenology of the plants, thus allowing results to be interpreted more easily. The sample analysed consisted of 48 specimens of *A. sapidus* (24 males, 24 females) captured during 1986, and including four specimens for each month of the study.

The method used to prepare the stomach contents samples is described by V e n t u r a et al. (1989). The contents of each stomach were sub-divided into four equal parts. A sub-sample was then taken from each of these and spread out on a glass microscope slide. Each sample was rinsed with Hertwig's liquid and mounted in glycerin. All four preparations were examined within six different fields viewed at 100× magnification to determine the presence/absence of dietary components. Identification of plant remains was achieved by comparison with a reference collection of microscopic preparations of plant epidermis taken from the study area.

The identifiable fragments found in each area were scored as one plant taxon. The data obtained were ordered to form a matrix of trophic resources, in which the columns represented different plants and the rows the stomachs which the sample derived. From this matrix, various calculations were carried out: the frequency of appearance, or numerical frequency (N), the relative frequency or percentage occurrence (%N) and the percentage of stomachs with a particular item present (%P). We also calculated Dominance and Diversity. To calculate these measures, we set the same taxonomic level for all items identified (R u i z & J o v e r 1981). As the similarity of the epidermis of Gramineae makes them easily identifiable as a family, but hard to identify in terms of species (see M a r t í n e z 1988), we grouped all species by the taxonomic category of family.

The most widespread measure of dominance is Simpson's index (D) (K r e b s 1989, M a g u r r a n 1989), which is expressed as:

$$D = \sum p_i^2$$

where p_i is the probability that an item belongs to the category of item i ($1 < i < z$, z = total number of stomachs). However, to calculate the index correctly for a finite community, we used:

$$D = \sum \left[\frac{n_i(n_i-1)}{N(N-1)} \right]$$

where n_i is the number of items belonging to the category of item i and N is the total number of items.

In finite samples, the most appropriate measure of diversity (M a r g a l e f 1974) is Brillouin's index (HB):

$$HB = \frac{1}{N} * \mathrm{Ln} \left(\frac{N!}{n_1! n_2! n_3! ...} \right)$$

where N = total number of items in the collection, n_1 = number of diet components belonging to category of item *1*, n_2 = number of elements belonging to category of item *2*, etc. On the basis of this index, we calculated the total cumulative diversity (H_z) and the population diversity (H_p) (R u i z 1985, V e n t u r a et al. 1989, C a s t i é n & G o s á l b e z 1997). The cumulative diversity curve is drawn by placing the stomachs in increasing and decreasing order of diversity. The value of H_z corresponds to the final value of the function of cumulative diversity. Calculation of H_p is carried out as follows:

$$H_p = \frac{1}{z \text{-} t} \sum_{k=t+1}^{z} h_k$$

where h_k is obtained by the formula:

$$h_k = \frac{M_k * H_k - M_{k-1} * H_{k-1}}{M_k - M_{k-1}}$$

where M_k = cumulative number of items in the sample from the kth stomach; H_k = cumulative diversity of the sample from the kth stomach; z = total number of stomachs; t = point at which the H_k/k curve stabilises, that is, when the proportions of the different categories of prey are similar to those of point "z". G tests were used to compare these proportions (S o k a l & R o h l f 1986). On the basis of Brillouin's index, we also calculated the values of mean diversity ($\overline{HB}$):

$$\overline{HB} = \frac{1}{n} \sum_{i=1}^{i=48} HB_i$$

where HB_i = diversity in stomach i and n = number of stomachs and equitability (J):

$$J = \frac{HB}{\ln S}$$

where HB = estimated diversity and S = number of taxa.

The similarity between the diets of each seasonal period was estimated by Spearman's correlation coefficient.

Results

Diet composition

The results of numerical frequency (%N) (Table 1) indicate that Gramineae constitute the major component in the diet of *A. sapidus*. In this family, the only species identified with certainty was the giant reed, *Phragmites australis*, which accounted for 32.5 % of the total food consumed. Typhaceae (*Typha angustifolia* and *T. latifolia*), and Cyperaceae (*Scirpus*

Table 1. Numerical frequency (N), relative numerical frequency (%N) and percentage presence (%P) by year and by season, for the trophic matrix of *A. sapidus* in southern Navarra.

	N	%N				%P			
	Annual	Annual	NDJF	MAMJ	JASO	Annual	NDJF	MAMJ	JASO
Gramineae	840	51.6	57.8	50.4	46.6	93.7	100	87.5	93.7
Typhaceae	285	17.5	13.4	22.3	17.1	43.7	37.5	50.0	43.7
Cyperaceae	273	16.8	25.9	12.8	11.4	41.7	62.5	25.0	37.5
Compositae	74	4.5	0.0	5.1	8.6	20.8	0.0	18.7	43.7
Leguminosae	65	4.0	2.9	4.9	4.2	14.5	12.5	12.5	18.7
Onagraceae	32	2.0	0.0	0.0	5.8	8.3	0.0	0.0	25.0
Juncaceae	32	2.0	0.0	0.0	5.8	4.2	0.0	0.0	12.5
Malvaceae	27	1.6	0.0	4.5	0.5	4.2	0.0	6.2	6.2
Total	1628								

lacustris and *S. holoschoenus*) also made up substantial portions, while Juncaceae (*Juncus* sp.) provided a small component of the diet. Altogether, monocotyledons accounted for 87.9 % of the total food consumed. The other taxa identified were dicotyledons, and constituted unimportant fractions of the diet: Compositeae (*Sonchus maritimus* and *Pulicaria dysenterica*), Leguminosae (*Trifolium* sp.), Onagraceae (*Epilobium* sp.) and Malvaceae (*Althaea officinalis*). We ascertained that the water vole's diet was exclusively vegetable.

Analysis of the frequency of the presence (%P) of each type of food (Table 1), confirms the results from numerical frequencies: Gramineae, Typhaceae and Cyperaceae families were consumed by a high proportion of animals. The presence of *P. australis* (72.9 %) was conspicuous, which indicates the importance of this species in the diet of water voles in southern Navarra. The other taxa (Compositae, Leguminosae, Onagraceae, Malvaceae and Juncaceae) are present in smaller quantities, the last two being eaten occasionally.

Trophic niche amplitude

Simpson's index indicates the predominance of Gramineae over the other plant families consumed (Table 2). Typhaceae and Cyperaceae represented more moderate, though still substantial, values for dominance, whilst the other taxa had much lower values. The relatively low values for cumulative trophic diversity, mean trophic diversity and equitability (Table 2) suggest a diet which specialises in the use of few resources.

Calculation of population diversity was carried out using the method set out above. Once the individual diversities in each stomach had been calculated and placed in ascending and descending order, we estimated the cumulative trophic (HB_k/k) for both orders and to draw graphs to show these (Fig. 1). As expected, both functions came together in the last value, which corresponds to the cumulative diversity in all stomachs examined, H_z. However, from stomach 42 onwards, the proportion of different categories of food was not significantly different from the final frequency (G = 12.49859ns; d.f. = 7): for these reasons this value was taken as point "t". Once the population diversity had been calculated ($H_p = 0.705334$) from the upper curve – the one in general use – a value markedly lower than that for cumulative diversity was obtained ($H_z = 1.424511$).

Table 2. Values for the Simpson's indices of dominance (D), mean diversity (HB), cumulative diversity (H_z) and equitability (J) obtained for the trophic matrix of A. sapidus in southern Navarra (the entire year and in individual seasons).

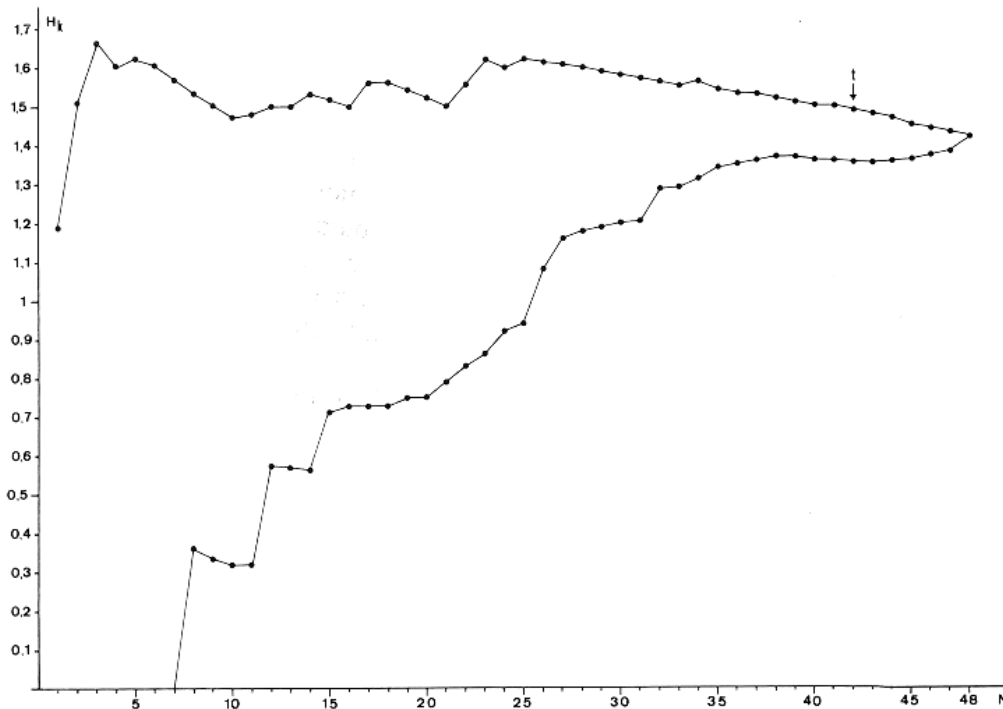|		Annual	NDJF	MAMJ	JASO
	Gramineae	19.6	7.3	7.2	5.1
	Typhaceae	3.9	1.1	1.2	1.6
	Cyperaceae	3.5	1.4	1.3	0.7
D	Compositae	0.6	0.0	0.3	0.3
	Leguminosae	0.7	0.2	0.4	0.1
	Onagraceae	0.2	0.0	0.0	0.2
	Juncaceae	0.3	0.0	0.0	0.3
	Malvaceae	0.3	0.0	0.3	0.0
HB		0.5			
H_z		1.4	1.0	1.3	1.6
J		0.68	0.74	0.76	0.76

Fig. 1. Cumulative trophic diversity: stomachs arranged are according to their diversity in increasing (lower curve) and decreasing order (upper curve). The point "t" represents the stomach at which the curve is considered stable (n = 42).

Seasonal variation in the diet

The numerical frequency of the different plant families in the diet underwent certain seasonal variations (Table 1). In the first period (NDJF), which was the coldest, three categories of items – Gramineae, Cyperaceae and Typhaceae – accounted for 96 % of the total intake, whilst the other taxa represented frequencies that were very low or zero. In the second period (MAMJ), which was warmer, and particularly in the third (JASO), the hottest of the three, the proportion of the three items mentioned above fell, although it was still high (85–75 %). During these periods, the consumption of other taxa increased as the diet diversified.

Seasonal variation in values for presence in the diet (%N) (Table 1) and the index of dominance (D) (Table 2) show changes similar to those seen in numerical frequencies. However, cumulative diversity (H_z) (Table 2) increased by season, in accordance with the more varied use of trophic resources in the warmer seasons. Nevertheless, the similarities of the values for equitability (Table 2) in the three periods suggest a certain balance in the consumption of the various items during these periods. This similarity is confirmed by the good correlations shown in the diet amongst seasonal periods: NDJF-MAMJ ($r_s = 0.8625$; $p < 0.01$), NDJF-JASO ($r_s = 0.7875$; $p < 0.01$) and MAMJ-JASO ($r_s = 0.8333$; $p < 0.01$).

Discussion

The results indicate that, in southern Navarra, the southern water vole has an exclusively herbivorous diet, and should be regarded as a primary consumer within the humid ecosystems of the region. This confirms the findings by V e n t u r a et al. (1989) in the Ebro Delta, and

contrasts with the findings of S a i n t - G i r o n s (1973) and R e i c h s t e i n (1982), who record the presence of animal prey in the diet of this rodent.

All the indices studied – numerical frequency, presence, dominance – show that Gramineae are the mainstay of the diet of the water vole, both annually and in different seasons. Within this family, *P. australis* is the species which is consumed most, possibly because of its abundance in the area and its presence throughout the year (it has powerful rhizomes). In any case, the high level of consumption of Gramineae might not be due exclusively to their abundance. Their high fibre content, which makes them indigestible, acts as a cofactor which increases the efficiency of protein assimilation (S o r i g u e r 1988); for this reason, their presence in the diet is fundamental. In fact, V e n t u r a et al. (1989) also found that Gramineae – *Arundo* sp., *Phragmites* sp. and *Agrostis* sp. – account for over 40 % of the diet of the water vole in the Ebro Delta.

Typhaceae (*Typha* sp.) and Cyperaceae (*Scirpus* sp.) are the other two plant types which are consistently eaten by water voles in substantial quantities, although to a lesser extent than Gramineae. Both, like *P. australis*, are perennials, which explains their presence in the diet throughout the year. Lower consumption of these plants in comparison with Gramineae and, particularly, the reeds, may be due to their lower abundance in the area. In fact, in the Ebro Delta (V e n t u r a et al. 1989), *Typha* sp. is the plant which is eaten most (46.1 % of relative frequency).

Various plant taxa complete the diet of *A. sapidus* (Compositae, Leguminosae, Onagraceae, Juncaceae and Malvaceae), representing a small part of the diet and with a markedly seasonal character: maximum variation and representation in JASO, minimum in NDJF. If their low consumption can be explained by their limited availability in the environment, the same is not true for the seasonal differences, as most of these plants are perennials. The indices of dominance, cumulative trophic diversity and population diversity indicate considerable stenophagy in the diet of the water vole. The greatest value for cumulative diversity as against population diversity suggests the presence of a single model of aggregation – there is no trophic segregation within the population – caused by the dominance of one or a few main resources. On the other hand, if we look at the area between the two curves in Fig. 1, we can see that there is a certain breadth, which indicates a clear variety in the intake of secondary resources: the indices of dominance confirm this. The diet consists basically of Gramineae, and to a lesser extent, of Typhaceae and Cyperaceae, which are the dominant taxa. Leguminosae and Compositae are the main complementary foodstuffs, while Malvaceae, Juncaceae and Onagraceae are consumed only occasionally.

The dietary model described for *A. sapidus* in southern Navarra corresponds to that reported by V e n t u r a et al. (1989) from the Ebro Delta. In the case of the delta population, the mainstay of the diet consisted of three dominant items – *Arundo* sp., *Phragmites* sp. and, particularly, *Typha* sp. – with other complementary and/or occasional items. B o o r m a n & F u l l e r (1981) note that, in England, *Phragmites* sp. and *Typha* sp. were eaten extensively by coypu, *Myocastor coypus*, another semi-aquatic rodent.

Trophic niche breadth undergoes variations over the course of the year, and cumulative diversity increases in the hotter seasons, when dominance decreases. A similar tendency has been shown by other authors (O b r t e l & H o l i š o v á 1979). All these factors indicate a more varied use of the trophic resources available in the warm and hot seasons, which is linked to plant phenology.

The literature contains various references to water voles causing damage in market gardens (C a b r e r a 1914), tree plantations (Z a b a l a 1983) and rice fields (F a u s 1984).

In the stomach contents analysed, we found no remains of cultivated vegetable species. It is true that crop damage has been observed to effect the fleshy roots of beetroot and maize (fallen heads of maize), however, the damage was very minor, and restricted to the areas closest to *A. sapidus* habitats.

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