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Ecology of stoats *Mustela erminea* in a valley of the Cantabrian Mountains, northwestern Spain

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Abstract

There is very little information on the ecology of stoats *Mustela erminea* in the Iberian Peninsula, the southwestern limits of their Eurasian range. The aim of this study is to gain more knowledge of some ecological aspects of Iberian stoats, principally habitat and diet, by direct observation and scat collection in a valley in the Cantabrian Mountains, northwestern Spain. Stoats were observed in all the elevation range of the valley (820–1350 m a.s.l.) in different habitats including hedgerows-meadows, river and mountain meadows, normally close to woody vegetation. The body size of individuals killed on the road was larger than that reported for stoats in the Spanish Pyrenees, and winter whitening was complete. Stoats coexisted with common weasels *Mustela nivalis*, but in different habitats. According to scat analysis, stoats had a relatively varied diet of small mammals, insects, eggs/birds, fruit, reptiles and earthworms. In autumn-winter, small mammals and fruit were clearly the most abundant items in their diet, but in spring-summer it included more food categories. In the upper valley, most of the food items were fruits, and in the middle and lower valley, small mammals. Amongst the small mammals, mostly *Apodemus* mice were consumed, followed by *Microtus* voles, and to a lesser extent, *Arvicola* water voles, *Talpa* moles and *Crocidura* shrews. Stoats ate the fruits of at least five plant species and defecated the seeds intact, thus acting as potential dispersers via endozoochory. Presumably, this diverse diet was favoured by the biogeographical complexity of the study area, where the Eurosiberian and Mediterranean regions meet, its wide elevation range and heterogeneous landscape. However, the highest percentages of biomass ingested corresponded to small mammals in any season and at any elevation, although they were slightly lower in spring-summer and in the upper valley.

Resumen

La información sobre la ecología de los armiños *Mustela erminea* en la península Ibérica, límite suroeste de su distribución euroasiática, es muy reducida. El objetivo de este estudio es ampliar el conocimiento sobre algunos aspectos ecológicos, principalmente hábitat y dieta, de los armiños ibéricos, mediante observación directa y recogida de excrementos en un valle de la cordillera Cantábrica, noroeste de España. Se observaron armiños en todo el rango altitudinal del valle (820–1350 m s.n.m.) en hábitats diferentes como setos-prados, río y prados de montaña, habitualmente cerca de vegetación leñosa. El tamaño corporal de individuos recién atropellados fue mayor que el documentado para armiños del Pirineo español, y el blanqueamiento invernal del pelaje fue completo. Los armiños coexistieron con comadrejas *Mustela nivalis*, pero ocuparon hábitats distintos. Según el análisis de excrementos, los armiños tuvieron una dieta relativamente variada compuesta por micromamíferos, insectos, huevos/aves, frutos, reptiles y lombrices de tierra. En otoño-invierno, micromamíferos y frutos aportaron la mayoría de unidades alimentarias, pero en primavera-verano la aportación estuvo más repartida entre más categorías de comida. En el valle alto, la mayoría de unidades alimentarias fueron frutos, y en los valles medio y bajo micromamíferos. Entre los micromamíferos, destacó el consumo de ratones *Apodemus*, seguido de topillos *Microtus*, con menor importancia de ratas de agua *Arvicola*, topos *Talpa* y musarañas *Crocidura*. Los armiños comieron frutos de al menos cinco especies de plantas y defecaron semillas intactas, actuando así como dispersantes potenciales mediante endozoocoria. La complejidad biogeográfica del área de estudio, confluyendo las regiones eurosiberiana y mediterránea, su amplio rango altitudinal, y su heterogeneidad paisajística, presumiblemente favorecieron esta dieta diversa. Sin embargo, los porcentajes más altos de biomasa ingerida correspondieron a micromamíferos en cualquier estación y altitud, aunque fueron algo menores en primavera-verano y en el valle alto.

Key words

Coat colour, diet, frugivory, habitat, Iberian Peninsula, Mustelidae.

Introduction

The stoat *Mustela erminea* Linnaeus, 1758 is widely distributed throughout Eurasia and North America, and has also been introduced in New Zealand. Its biology and ecology are well-known in areas such as Britain, central Europe, Scandinavia, Russia, Canada, USA and New Zealand (King & Powell 2007, Larivière & Jennings 2009, Yom-Tov *et al.* 2010). However, few studies have been carried out on this mustelid species in the north of the Iberian Peninsula, the extreme southwest of its Eurasian range, which include some detailed information on its local distribution and habitat but very little regarding important aspects such as breeding and diet (Ruiz-Olmo *et al.* 1997, Gisbert & García-Perea 2007, Ruiz-Olmo 2010, Camps *et al.* 2011). In reviews by King & Powell (2007) and Larivière & Jennings (2009), no reference is made to the stoat in Iberia. Furthermore, although the diet of stoats can be diverse, they are normally specialist predators of small vertebrates, and consume little fleshy fruit (King & Powell 2007, Larivière & Jennings 2009). Fruits are an important part of the stoat diet only in some habitats such as subarctic or alpine, when their availability and profitability are high, but this is not necessarily associated with decreases in small rodent populations (Martinoli *et al.* 2001 and references therein).

The aim of this study is to further knowledge of Iberian stoats using data obtained in the Cantabrian valley of the Torío river in northwestern Spain, where this species has already been recorded (Hernández 1993, 2008a). Particular attention is paid to the altitudinal distribution in relation to habitat availability, and diet in relation to prey availability. Relative high variety of food is expected with regard to prey species in the study area as a whole, as it is composed of different habitats, and also some consumption of fruits as they are abundant in hedgerows and forest edges in summer and autumn, and can be found scattered in open areas. Information on activity, aggregation, space use, body size, winter whitening and interactions with other species is also given.

Material and methods

Study area

The study area is located in the valley floor of the Torío river in the Cantabrian Mountains (León province, northwestern Spain), from its source (43º1'8''N, 5º35'57''W, 1350 m a.s.l.) near Piedrafita la Mediana to close to where it runs into the Bernesga river (42º35'52''N, 5º32'56''W, 820 m a.s.l.) in the vicinity of the city of León. The Torío river can be considered wild, without dams or any other significant modifications. The valley descends 55 km from north to south. The landscape in the upper valley is mainly treeless, though there are some beech *Fagus sylvatica* and birch *Betula alba* groves on the slopes. It is composed of meadows, pastureland, broom plants and rock outcrops, and scattered shrubs and trees. In the middle and lower valley, the landscape is a mosaic of riparian woodland, meadows, orchards, hedgerows, and poplar *Populus x canadensis* plantations, with Pyrenean oak *Quercus pyrenaica* woodland, scrubland and pastureland on the slopes. From the source of the river to its mouth, the Eurosiberian biogeographic region gives way to the Mediterranean one, between the annual isohyets of 1700 mm and 400 mm, the annual isotherms of 5 ºC and 12 ºC, and the annual mean of 50 and 10 days of snow. More information on landscape, flora and climate in the Torío river valley can be found in Hernández (1988, 1993, 2009) and Hernández & Zaldívar (2013).

Stoat data collection: direct observation of individuals

With the exception of diet, data on the ecology of stoats were obtained by direct observation of individuals. As stoats can be active at any time of day or night (Debrot *et al.* 1985, King & Powell 2007, Larivière & Jennings 2009), they are sometimes seen during daylight. Throughout 1984–2007, stoat sightings in the study area were recorded on field trips organized to investigate the ecology of several vertebrate species (e.g. Eurasian red quirrel *Sciurus vulgaris*, Hernández 2014). During this time, numerous field trips with varying effort and in different parts of the valley were made by car, bicycle or on foot, along the main road running through the valley, and other secondary roads to small lateral valleys, dirt tracks or cross-country.

However, most of the field trips were conducted systematically during the 2001–2006 sub-period, in a sub-area of ca. 80 ha in the middle valley, in a habitat composed mainly of hedgerows that separate irrigated meadows grazed by livestock and cut for hay, with an estimated hedgerow density of 3.3 km per 10 ha. During this sub-period, 41 trips were made in winter, 96 in spring, 134 in summer and 84 in autumn. Winter was considered to be December–February, spring March–May, summer June–August and autumn September–November. On a given trip, half of the sub-area was explored by slowly walking around it, with frequent stopping intervals, mainly following the hedgerow edges and secondarily (≈ 10% sampling effort) the oak grove edge adjacent to the hedgerows. On the next trip, the other half was explored, and so on. More than 85% of field trips were conducted in the morning in all seasons, and the rest in the afternoon. To ensure good visibility conditions, morning trips lasted from one hour after sunrise to 12:00 h (solar time), and afternoon trips from 12:00 h (solar time) to one hour before sunset.

The following circumstances were recorded on each stoat sighting: date, solar time, weather, number of indi-

viduals, coat colour, predominant habitat in a 50 m radius, microhabitat used, and behaviour. Road-kills were sexed and, where possible, weighed and measured. Previous studies (e.g. Hernández 1993, 2008a), as well as direct sightings and indirect evidences (tracks, scats) of other carnivore species recorded in the area and study period, provided basic knowledge (species presence) of the composition of the carnivore community.

Stoat diet: scat analysis and small mammal community

Scats collected in the study area were analysed to study stoat diet. Scat analysis remains the primary tool used to assess carnivore diets in general (Klare *et al.* 2011, Wachter *et al.* 2012), and stoat diet in particular (e.g. Korpimäki *et al.* 1991, Martinoli *et al.* 2001). Throughout the study period, and with a greater sampling effort during 2001-2006, scats with a shape and size corresponding to stoat were collected in small plastic bags, in places where individuals had previously been spotted. A total of 33 stoat scats were collected, 18 of which during 2001-2006. This sample size is slightly lower than that considered statistically necessary to adequately describe a carnivore's diet (59 scats, according to Trites & Joy 2005), but it was considered sufficient as Eurasian stoats usually consume a smaller range of prey species than other carnivores. Five of the scats were collected in the upper valley in meadows-pastureland-rock outcrops, 22 in the middle mainly in hedgerows-meadows and six in the lower valley in oak grove edges. Five of the scats were collected in winter, two in spring, seven in summer and 19 in autumn. The months mentioned in the previous section were considered for each season. At least some scats were collected in both autumn-winter and spring-summer at all three elevations. The scats were located on the ground, at the foot of hedgerows and road and irrigation ditch edges, and in slightly raised parts of hedgerows, such as tree stumps and branches horizontally placed to act as a barrier. Although stoats coexist with common weasels *Mustela nivalis* in the study area, the latter have not been observed in the cool valley floor, predominated by hedgerows and meadows, but only, and on very few occasions, in drier zones of the margins of the valley, in oak grove edges, pine plantations and crops. Only scats measuring 4–6 cm long and 4–6 mm wide were considered to be exclusively stoat (in accordance with Blanco 1998a and Ballesteros 1999) (Fig. 1) as Iberian common weasel scats are generally less than 3 cm long (García & Mateos 2009). The European polecat *Mustela putorius* is also found in the study area, but their scats, which are usually > 6 cm long and > 6 mm wide (Blanco 1998a, Purroy & Varela 2005), are unlikely to be mistaken for stoat.

After collection, the stoat scats were air-dried at 22 ºC for two weeks. Prey remains were obtained from scats and identified using the usual procedures for carnivore scat analysis (Gade-Jørgensen & Stagegaard 2000, Zabala & Zuberogoitia 2003, Klare *et al.* 2011, Tambling *et al.* 2012). The dried scats were washed under running water through a metal sieve (mesh size 0.5 mm) to remove the unidentifiable micro-fraction. Remains from different food categories were separated for each scat, and then air-dried again for more precise identification.

Fig. 1. A stoat scat from the study area in March. Photo: Ángel Hernández.

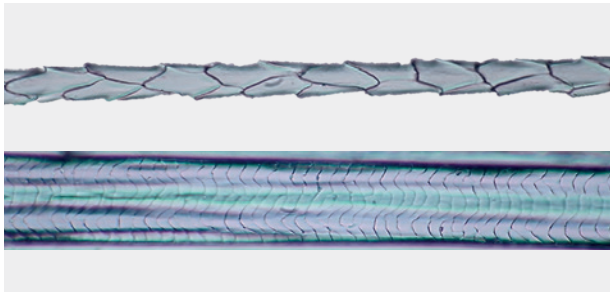

Fig. 2. Cuticular impressions of guard hairs were used to identify small mammal prey. Illustrative example: shaft (above) and shield (below) scale patterns for *Apodemus*. Photos: Pilar Zaldívar.

Teeth and hairs found in the scats were used to identify mammal prey with the help of reference material from the study area and available literature. Teeth were identified by comparing them with reference skulls from known species and using the keys by Blanco (1998a, b) and Purroy & Varela (2005). Guard hairs were extracted from every scat taking care to select GH1 and GH2 hairs, since they provide the most information (Teerink 1991). An average of 10 selected hairs per scat were cleaned in tepid water with detergent, rinsed in distilled water and air-dried. Cuticular scale patterns were obtained using clear nail polish, following De Marinis & Agnelli (1993), and examined under a compound microscope at 100× and 400× magnifications (Fig. 2). Identification was by comparison with reference cuticular impressions of known species and using the keys by Faliu *et al.* (1980) and Teerink (1991), to genus level.

Feathers and remains of hard eggshell indicated the presence of birds. Scales indicated that reptiles had been consumed. Hard parts of the body such as mandibles, elytra and legs, indicated the presence of insects and helped to identify them. Fleshy fruit seeds were identified by comparison with reference material collected in the study area and available literature (Torroba *et al.* 2013). Earthworm consumption was detected by the ma-

trix of the scat being gritty and microscopic visualization of chaetae. Plant remains such as small pieces of stalk or leaves were dismissed as part of the stoat diet, as very few appeared in the scats, and were probably not associated with intentional consumption but with the herbivorous diet of some prey (i.e. caterpillars) or accidental ingestion when eating fruits.

Repetition of certain remains, such as teeth in small mammals or mandibles and other pair structures in insects were taken into account to estimate the number of prey. If remains enabled the prey to be identified but not the number, then it was considered a single prey. The mean values of seeds per fruit given by Torroba *et al.* (2013) were used to convert number of seeds into number of fruits. Earthworms were seen in only one scat, accounting for approximately 15% volume, so the number of individuals consumed was considered to be the equivalent of the fresh mass of a very small mammal, that is, a shrew. Nevertheless, stoats have very small stomach capacity, hence a single scat usually contains the remains of only one principal prey in terms of biomass (King & Powell 2007).

To estimate the biomass ingested (fresh mass), a mean body weight was assigned to each individual prey, which corresponded to the identified species or to one similar taxonomically and in size, preferably present in the study area, obtained by consulting the bibliography (small mammals: Purroy & Varela 2005; birds and bird eggs: Cramp 1985, 1988, Cramp & Perrins 1993; reptiles: Galán 1984; insects: Arnaldos & Presa 1993, Weber & Heimbach 2001, Holzer *et al.* 2003, Tammaru & Esperk 2007, Zalewski & Ulrich 2008; earthworms: Dittbrenner *et al.* 2010; fleshy fruits: Herrera 1987).

The results are presented as: frequency of occurrence per scat (percentage of scats containing a particular food item), frequency of occurrence per food item (percentage of the number of occurrences of one food item of the total number of occurrences of all food items), and percent estimated biomass ingested (fresh mass) of each food category.

According to numerous studies (review by King & Powell 2007), in Eurasia stoats feed mainly on small mammals, and also in Spain, according to the few data available in this country on their diet (review by Ruiz-Olmo 2010). Information on the small mammal community in the Torío river valley was obtained from studies carried out using trapping and analyses of the diet of predatory species (Alegre & Hernández 1990, Hernández 1995, 2008b), as well as unpublished sightings (Ángel Hernández pers. obs.). Additional information came from the analysis of common barn owl *Tyto alba* pellets collected during 1985-1989 in five sites in the middle valley, where the landscape is formed mainly by hedgerows and meadows and some oak grove edges, scrubland and pastureland, the small mammals eaten being identified by skull keys (Blanco 1998a, b, Purroy & Varela 2005). The diet of the common barn owl is a good indication of the composition of the small mammal community in the areas it inhabits (e.g. Yom-Tov & Wool 1997, Torre *et al.* 2004, Avenat 2005, Thiam *et al.* 2008). Luque *et al.* (2013) were consulted to establish years when demographic explosions of the common vole *Microtus arvalis* occurred in the region where the study area is located (Castile and León), and personal observations were also considered. Although lagomorphs can be important prey items for stoats, in the study area rabbits and hares are very scarce.

Statistical analysis

The chi-square test (χ^2), with Yates correction for one degree of freedom, was used to compare series of absolute frequencies (Fowler *et al.* 1998). Standard deviation (SD) was estimated as a measurement of dispersion. $P < 0.05$ was considered statistically significant.

Results

Sighting rates

Stoat sightings were recorded in nine (37.5%) of the total 24 years considered, including the first and last year (1984 and 2007, respectively). Considering sightings and scats together, the presence of stoats was recorded in 12 (50.0%) of the 24 years. Of a total of 15 sightings, including both living and dead individuals, eight (53.3%) were made in the 2001–2006 sub-period. Most of the sightings occurred in spring-summer (12 sightings, 80.0%) and very few in autumn-winter (three sightings, 20.0%). During the 2001–2006 sub-period, the number of sightings per season was proportional to the seasonal sampling effort (number of field trips per season) ($\chi^2_3 = 2.26$, $p > 0.05$). At the time of the sightings, the weather was very variable, with a wide range of temperatures.

A total of 19 individuals were seen, 16 alive (1.3 ± 0.9 individuals per sighting, $n = 12$ sightings) and three killed on the road (three sightings). The only two sightings of more than one individual occurred in the middle of summer. During one of these sightings, two individuals appeared to be hunting on the banks of an irrigation ditch, entering vole burrows on a number of occasions. During the other, four individuals were seen climbing up and down a hedge several times until they moved with great agility along the hedgerow, one after the other, amongst the branches of the shrubs and trees, at a height of 1–2 m. The three indivuals killed on the road were males and were found at the end of March, end of June and mid August. The male found in March showed enlarged testicles, with a small quantity of sperma outside the penis.

Habitat and space use

Stoats were seen from the highest part of the study area, at almost 1400 m, to the lowest part, at almost 800 m,

Fig. 3. Stoat habitats in the study area. Above: hedgerows and meadows in winter and spring. Below: the river in spring and mountain meadows with scattered shrubs and low stone walls in spring. Photos: Ángel Hernández.

though the majority of sightings (14 of 15, 93.3%) occurred in the middle-lower valley. Most of the sightings (86.7%) were recorded in habitats with predominant hedgerows-meadows, but also on the riverbank (6.7%) and in mountain meadows with scattered shrubs and low stone walls (6.7%) (Fig. 3). Individuals seen in hedgerows-meadows were normally in the hedgerows or nearby (for example in wood piles), though some were seen crossing meadows on more open land and then hiding in hedgerows or crossing the road (including the three road- kills). The individual in the mountain meadow zone was seen at the foot of a stone wall. The climbing ability of stoats was verified on two occasions: in the case of the previously-mentioned group of four, and one individual which, in mid July, climbed from the ground to approximately 5 m up a common ash *Fraxinus excelsior*, climbed back down to a height of 2 m and then jumped off.

Body size and winter whitening

Two of the three male stoats killed on the road were measured and weighed. One weighed 286 g, with a head-body length of 26.3 cm, tail length 11.2 cm (not including tuft), ear length 21.1 mm and hind foot length 42.4 mm (not including claws), and the other 241 g, 26.8 cm, 10.9 cm, 21.4 mm and 43.3 mm, respectively. Individuals with a winter coat (apparently completely white except for the black tip of the tail) were observed in January, with a summer coat (brown back and yellowish belly) between mid March and mid September, in the transition to summer coat (most of the body white with dark spots on the back) at the beginning of March, and in the transition to winter coat (white front and tail, except for the black tip, and the rest of the body brown-coloured) in mid November. No stoat sightings were recorded in February, October and December.

Interactions with other species

Apart from prey species found in scats, other interspecific interactions involving stoats were observed. The individual that climbed up and down the common ash was mobbed whilst doing so by three common blackbirds *Turdus merula* and one song thrush *Turdus philomelos*, which followed it closely constantly emitting alarm calls. The road-kill found at the end of March had ticks of varying size on the anterior part of its back and also on its ears; before it was handled, two Eurasian magpies *Pica pica* were seen trying to fly down from the trees at the road

Fig. 4. Most of the stoat scats contained small mammal remains, followed by insects, eggs/birds and fruit, and to a smaller extent, reptiles and earthworms. Top left: water vole *Arvicola terrestris* hills (this species lives in meadows in the study area). Remaining photographs: female field cricket *Gryllus campestris*, common blue tit *Cyanistes caeruleus*, *Rubus* blackberries, young Schreiber's green lizard *Lacerta schreiberi*, and unidentified earthworm. All of the photographs were taken in the study area. Photos: Ángel Hernández.

edge on several occasions to feed off it, but were prevented from doing so by passing cars. Besides stoats, the community of wild carnivores in the study area, considering the whole valley, was composed of Iberian wolves *Canis lupus signatus* (indirect evidences -IE-), red foxes *Vulpes vulpes* (direct sightings -DS-), common weasels *Mustela nivalis* (DS), European polecats *Mustela putorius* (IE), pine martens *Martes martes* (IE), beech martens *Martes foina* (DS), European otters *Lutra lutra* (IE), European badgers *Meles meles* (IE), common genets *Genetta genetta* (DS) and wildcats *Felis silvestris* (DS). Two common weasels, the carnivore species that most resembles the stoat in appearance and habits, were seen, one at the end of March and the other at the beginning of July, amongst shrubs in the vicinity of oak groves, and a third individual at the end of August, amongst the bricks of a fallen wall in a zone of crops and pine plantations; this individual was mobbed by a cirl bunting *Emberiza cirlus*.

Stoat diet: scat analysis and small mammal community

Eighty-four food items were identified in the 33 scats. Small mammal remains appeared in most of the scats (93.9%), followed by insects (24.2%, reaching 44.4% in spring-summer), eggs/birds (12.1%) and fruit (9.3%), and to a lesser extent, reptiles and earthworms (3.0% each) (Fig. 4). In autumn-winter, small mammals and fruit constituted most of the food items (≈ 50% and 40%, respectively), whereas in spring-summer there were more food categories, none of which exceeded 30%, resulting in significant seasonal differences ($\chi^2_5 = 14.77$, $p < 0.05$) (Fig. 5). We found high percentages of fruits in the upper valley (≈ 75% food items) and small mammals in the middle and lower parts (≈ 55% and 75%, respectively), resulting in significant elevational differences ($\chi^2_{10} = 57.68$, $p < 0.001$) (Fig. 6). Numbers of insects were moderate in spring-summer and in the middle and lower valley (20–25% food items) (Figs. 5 and 6). As for ingested biomass, percentages of small mammals were the highest in all seasons and at all elevations, generally > 90%, though they were slightly lower in spring-summer and in the upper valley (≈ 80–85%) (Figs. 5 and 6).

The insects consumed were large, about 1.5–3.0 cm long, Lepidoptera larvae in spring, and Orthoptera (mainly grasshoppers, but also crickets) and Coleoptera in summer-autumn. Reptile remains found belonged to a lizard. Birds consumed were small passerines, and the remains of shell found corresponded to small- or medium-sized eggs. With the exception of one *Talpa* mole and one *Crocidura* shrew, small mammals eaten were rodents (94.1%) (Table 1). Just over half of them (56.2%) were *Apodemus* mice, with an even higher percentage in the lower valley, and the rest voles and *Arvicola* water voles. Bearing in mind overall and local distribution, as well as habitat, prey species were probably Iberian mole *Talpa occidentalis*, greater white-toothed shrew *Crocidura russula*, water vole *Arvicola terrestris* (in the study area *A. terrestris* is not aquatic and lives in meadows) and wood mouse *Apodemus sylvaticus*. In the case of voles, there are several possible prey species: most probably Lusitanian pine vole *Microtus lusitanicus* and common vole *M. arvalis*, because of their abundance, but also field vole *M. agrestis* and, in the upper valley, snow vole *Chionomys nivalis* syn. *Microtus nivalis*. Cherries (*Pru-*

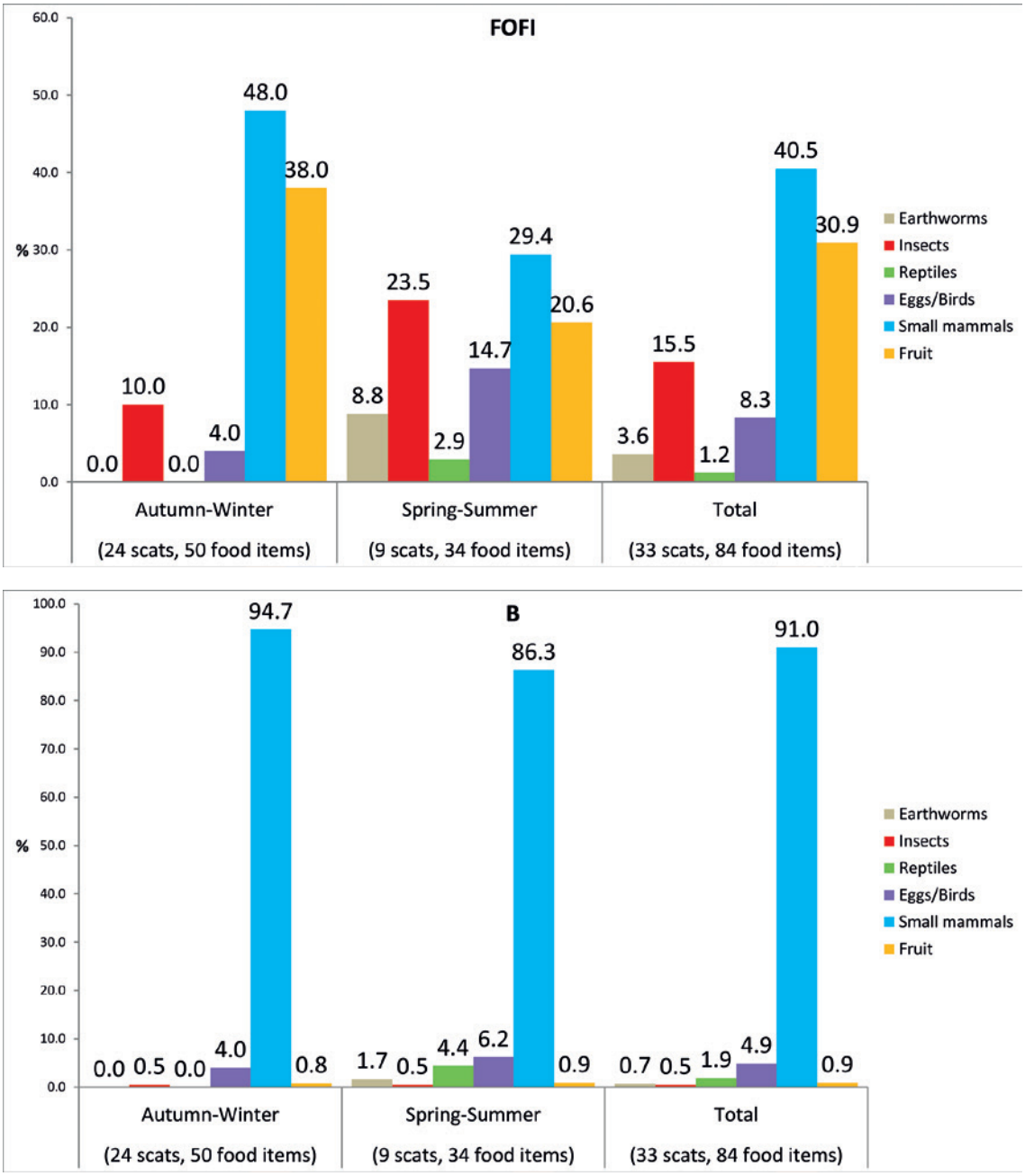

Fig. 5. Seasonal diet of stoats *Mustela erminea* in the study valley. FOFI: frequency of occurrence per food item (percentage of the number of occurrences of one food item of the total number of occurrences of all food items). B: percent biomass ingested (fresh mass) of each food category.

nus mahaleb and *P. avium*) were consumed in summer, and bilberries *Vaccinium myrtillus*, *Rubus* blackberries and Alpine buckthorn *Rhamnus alpina* fruits in autumn. The seeds found in the scats were apparently intact, i.e. viable for germination.

In the study area, 22 small mammal species were detected, including hedgehogs, shrews, water shrews, moles, desmans, squirrels, mice, rats, water voles, voles and dormice, but not bats. Some species were associated with very specific habitats or elevation ranges, for example the Miller's water shrew *Neomys anomalus*, Iberian desman *Galemys pyrenaicus* and southern water vole *Arvicola sapidus* with the river as they are aquatic, *Rattus* rats and the house mouse *Mus domesticus* with villages, the bank vole *Myodes glareolus* and yellow-necked mouse *Apodemus flavicollis* with mountain forests (a scarce habitat in the valley), and the snow vole with mountain rocks. According to bibliographic information, the most abundant shrew and rodent species in the hedgerows and fields in the middle-upper valley were the greater white-toothed shrew, Lusitanian pine vole, common vole and wood mouse. In the analysis of the common barn owl pellets collected in this part of the valley, 1246 individuals were identified, the majority of which belonged to six small mammal species, with greater white-toothed shrews and wood mice being pre-

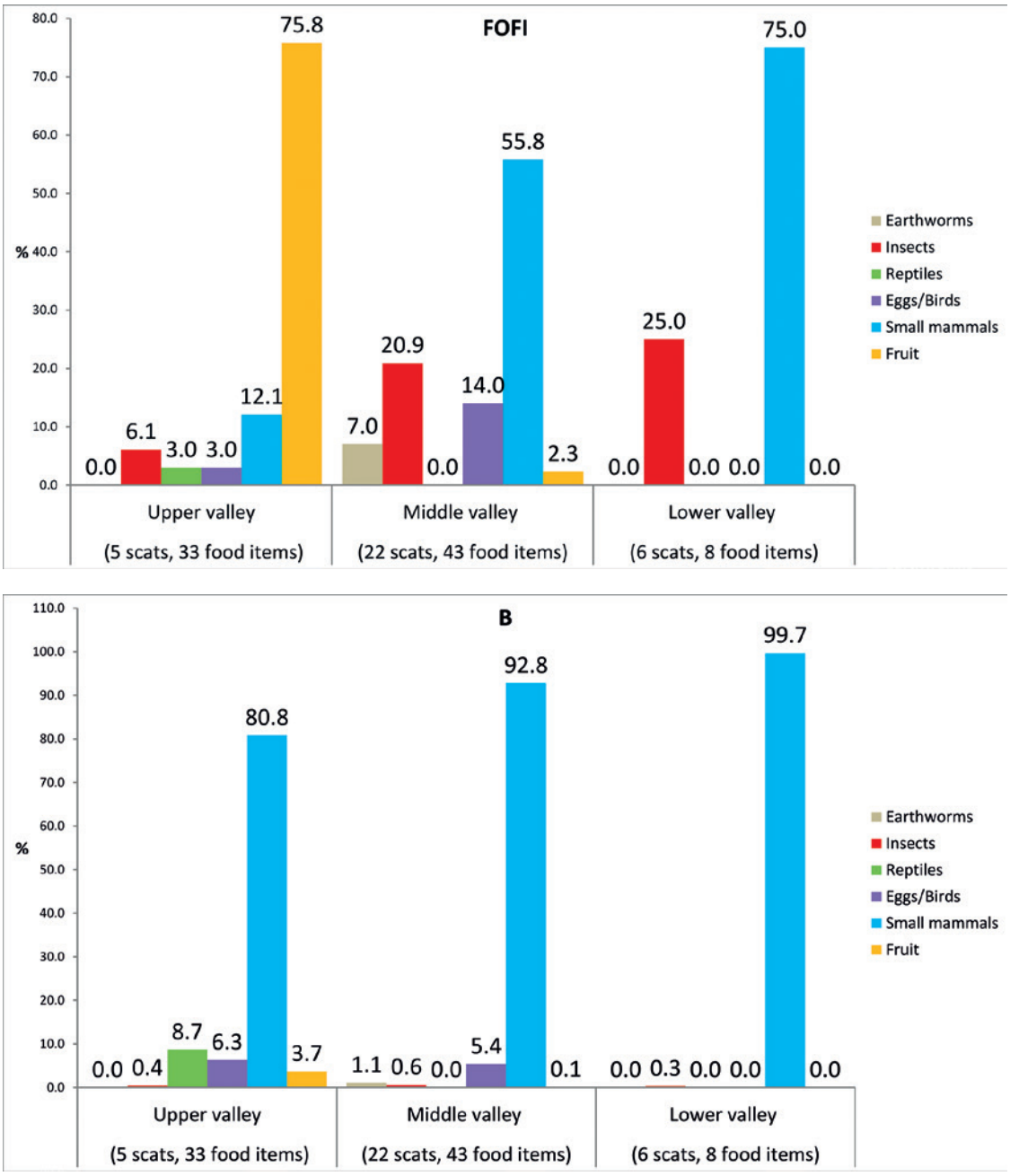

Fig. 6. Diet of stoats *Mustela erminea* in the study valley at different elevations. FOFI: frequency of occurrence per food item (percentage of the number of occurrences of one food item of the total number of occurrences of all food items). B: percent biomass ingested (fresh mass) of each food category.

dominant in oak woodland and scrubland, and greater white-toothed shrews and voles (Lusitanian pine voles and common voles) in hedgerows-meadows (Table 2).

Demographic explosions of common voles in the region where the study area is located occurred, during the 1984–2007 period, in 1983, 1988, 1989, 1993, 1997 and 2007. The number of years with/without a vole outbreak was 6/18 and the number of stoat sightings in years with/without a vole outbreak was 4/11, resulting in no association between vole outbreaks and stoat sightings ($\chi^2_1 = 0.07$, $p > 0.05$). Considering that the effect of common vole outbreaks on stoat numbers could be more noticeable the following year, i.e. 1984, 1989, 1990, 1994 and 1998 (2008 is outside the study period), carrying out the analysis in this way produced no significant differences either (5/19 years, 3/12 sightings) ($\chi^2_1 = 0.12$, $p > 0.05$).

Discussion

Sighting rates

Stoats were detected fairly regularly throughout the entire study, and more efficiently by more intensive sampling

Table 1. Small mammals in stoat *Mustela erminea* scats in the study valley at different elevations, to genus level. Percentages relating to the number of small mammal prey (%*n*) are given.

Small mammal genera	Upper valley	Middle valley	Lower valley	TOTAL
Moles				
Talpa	0.0	4.2	0.0	2.9
Shrews				
Crocidura	0.0	4.2	0.0	2.9
Voles and water voles				
Microtus	25.0	45.8	0.0	35.3
Arvicola	25.0	4.2	0.0	5.9
Mice				
Apodemus	50.0	41.6	100.0	52.9
Number of small mammal prey (*n*)	4	24	6	34

Table 2. Small mammals in the pellets of common barn owls *Tyto alba* collected in five sites in the middle part of the study valley. Percentages relating to the number of small animal prey (%*n*) are given for the five most consumed species, which account for over 93% in all sites. Habitat in site 1: oak woodland, scrubland and pastureland. Habitat in sites 2, 3 and 4: hedgerows-meadows. Habitat in site 5: scrubland, pastureland and hedgerows-meadows.

Small mammal species	Site 1	Site 2	Site 3	Site 4	Site 5
Shrews					
Sorex coronatus			5.3		8.5
Crocidura russula	46.8	41.4	36.1	45.9	27.2
Voles					
Microtus lusitanicus	7.3	28.2	32.3	20.4	22.4
Microtus arvalis	5.1	5.7		15.3	22.8
Microtus agrestis	2.2	7.8	4.5	6.1	
Mice					
Apodemus sylvaticus	36.0	11.9	16.5	11.2	12.2
Number of small mammal prey (*n*)	314	193	133	98	508

during the 2001–2006 sub-period. There are no data on stoat density in the Cantabrian Mountains, and in the Spanish Pyrenees, their tracks in the snow accounted for less than 5% of the total carnivore tracks, even in optimal habitats (Ruiz-Olmo *et al.* 1991, Ruiz-Olmo & Aguilar 1995, Ruiz-Olmo 2010). The lowest sighting rate in autumn-winter was apparently due to a lower sampling effort and not to a decrease in the activity and/or abundance of stoats. In a typical year, the highest number of stoat sightings is in mid-late summer, at the end of the breeding season, but there may also be notable variations in density amongst years linked to those of their prey (Bounous *et al.* 1995, King & Powell 2007). Nevertheless, in heterogenous environments with a wide diversity of prey, stoat density is generally more stable in time (King & Powell 2007), which perhaps occurs in most of the study area covered in a dense network of hedgerows between meadows very close to the river and oak woodland.

Individuals were normally spotted alone, keeping in line with the territorial nature of the species (Murphy & Dowding 1994, Martinoli *et al.* 2001, King & Powell 2007, Larivière & Jennings 2009). When several individuals were spotted together, this was presumably related to mating and the movement of family groups, which are both common in stoats in spring-summer (King & Powell 2007, Larivière & Jennings 2009). The fact that road-kills were males and not females, found in spring and summer, coincides with the tendency documented by other authors (northern Spain: Ceña & Ceña 2005 for La Rioja, Martínez de Lecea & Echegaray 2006 for Álava, José Luis Robles pers. comm. for the Porma river valley, León province; New Zealand: Murphy & Dowding 1994). This appears to be determined by the fact that male stoats have a larger home range and greater mobility than females (Samson & Raymond 1998, Martinoli *et al.* 2001, King & Powell 2007, Larivière & Jennings 2009).

Habitat and space use

According to the recorded sightings, stoats occupied different habitats in the entire study area. The highest number of sightings in the lower-middle valley in hedgerows-meadows coincides with a greater sampling effort in these zones, so stratified sampling with larger sample sizes is necessary to properly assess habitat selection. In the Spanish Pyrenees and other areas in northern Iberia, stoats also occupy different habitats, with a preference for countryside with hedgerows and stone walls, riparian forest, other not too dense forests, meadows, rocky ground and peat bogs, generally close to water and away from dense forest, from sea level to the alpine zone (Purroy & Varela 2005, Ruiz-Olmo 2010). Worldwide, this species occupies a wide range of habitats from sea level to 3000 m a.s.l.

(Larivière & Jennings 2009). Some individuals climbed shrubs and trees to considerable heights. Although the climbing capacity of stoats was already known through the presence of birds and/or eggs in their diet (King & Powell 2007, Larivière & Jennings 2009), no direct sightings had previously been reported in the literature.

Body size and winter whitening

Even though sound conclusions cannot be reached due to the small sample size, male stoats in the study area were considerably heavier and larger than in northeastern Iberia, well above ranges known for the Spanish Pyrenees (weight: 120–140 g, head-body length: 20–24 cm, Ruiz-Olmo 2010), with a similar weight and size to males from other places in northern Iberia (Valverde 1966, Ceña & Ceña 2005, Ruiz-Olmo 2010). The values obtained were similar to or slightly higher than those documented for central and northern Europe; in Eurasia, stoats increase in size from NE to SW, and from high-lying mountains to the lowest regions, hence do not follow Bergmann's Rule due to the influence of other factors besides avoidance of body heat loss, e.g. foraging efficiency, so that northern and high mountain stoats evolved their long, thin shape more markedly in response to the opportunity to hunt small rodents in their burrows and under snow (reviews by Reichstein 1993, McDonald & Harris 1998, King & Powell 2007).

The coat of the stoats in the study area was completely white in mid winter, with the transition to summer coat starting at the end of winter and to winter coat starting mid autumn. In other places in León province and northwestern Iberia, from high mountain areas to low regions, it is apparently normal for stoats to have a completely white coat between December and February (Valverde 1966, Ceña 1997, José Luis Robles pers. comm., Ángel Hernández pers. obs.). In the Spanish Pyrenees, where stoats are associated to higher elevations, the transition to summer coat usually starts later, when spring has already commenced, and the transition to winter coat earlier, from the onset of autumn, so completely white individuals can be seen for a longer period of time (November-April) (Ruiz-Olmo 2010). For stoats in general, the winter molt is faster and the winter coat longer-lasting where temperatures are lower, and winter whitening is probably a strategy to camouflage themselves in the snow and escape predation (King & Powell 2007). In the study area, it usually snows in winter, and more intensively at higher elevations.

Interactions with other species

Like in the study area, birds sometimes mob stoats and common weasels, even sporadically involving physical contact, to alert other possible prey in the vicinity and defend their nests (Hosey & Jacques 1998, King & Powell 2007). The ticks observed on one male stoat were not identified but several *Ixodes* species have been found on Irish stoats (Sleeman 1989). The wild carnivore community in the study area was rich in species due to the variety of habitats. Stoats coexisted with common weasels, although apparently segregated spatially in different habitats. Several authors have stated that the two species can be present in the same area, particularly in patchy environments, but common weasels avoid stoats as the latter usually dominate in territorial disputes; also, stoats have access to a comparatively wider range of food as they are not as dependent on small rodents as common weasels (King & Moors 1979, Erlinge & Sandell 1988, King & Powell 2007).

Stoat diet

In the study area, the stoat diet was composed of very different food categories on the whole, and although small mammals always constituted the largest fresh mass contributions, other food categories reached moderate values at specific elevations and in certain seasons. The analysis of a small sample of summer scats from the same area ($n=5$, July, middle valley), containing almost exclusively bird remains (Hernández 2008a), supports a certain degree of trophic plasticity of the species in the Torío river valley. Also, when a sample of spring scats collected in four localities in the west and northeast of León province were considered together ($n=10$, March–May, Compludo, Ocejo de la Peña, Santa Olaja de la Varga, Riaño), small mammals were predominant in the percentage of biomass ingested, but remains of earthworms, insects, reptiles and fruit were also found (Ángel Hernández pers. obs.). The remaining information available on the diet of stoats in Spain comes from populations in the Pyrenees, linked to high elevations, where almost all prey found are small mammals, though they have been seen attempting to capture passerines, or helping themselves to the food of ramblers in mountain huts (Ruiz-Olmo & Aguilar 1995, Ruiz-Olmo 2010). In a supraforestal ecosystem in the French Pyrenees, stoats also depended almost exclusively on small mammals, mostly voles, but also consumed a small number of insects and unspecified plants (Leconte 1984).

Therefore, Iberian stoats probably supplement their main diet of small mammals with other seasonally abundant and accessible food. However, further studies are necessary to determine the intensity of these interrelations and their causes. It is already known that stoats are capable of consuming a wide variety of food throughout their distribution range, and more so in temperate climates (Murphy & Dowding 1994, White & King 2006, King & Powell 2007, Larivière & Jennings 2009). Two common weasel scats (one in winter and another in summer) found in the middle valley only contained small mammal remains (Ángel Hernández pers. obs.), coinciding with the aforementioned greater specialization of this mustelid species, while it is true that the sample size is not significant.

Fig. 7. Female stoat killed on the road in the study valley in late July 2015. Photo: Ángel Hernández.

Fruit was consumed in the middle-upper valley in summer and autumn, when availability and profitability were greater. Some fresh scats collected in late March in the north-east of León province contained dog rose *Rosa canina* and blackthorn *Prunus spinosa* seeds, whose fruits can remain edible beyond the winter (Ángel Hernández pers. obs.). Frugivory therefore appears to be a profitable strategy for stoats in terms of optimal foraging, as proposed by Martinoli *et al.* (2001). They defecated the seeds entire, thus acting as potential dispersers of fleshy fruit plants.

The great importance of mice in the diet of stoats in the study area, and of voles to a lesser extent, suggests that stoats frequently hunted close to woody vegetation rather than open meadows and pastureland. The fact that most stoats spotted in a hedgerow-meadow habitat were sheltered by the hedgerows reinforces this suggestion. According to McDonald & Harris (1998), hedgerows and uncultivated field margins provide quality habitat for stoats in heterogeneous landscapes, and they rarely venture more than a few metres out into open fields. Also, water voles accounted for less than 6% of the total small mammal prey of stoats, and less than 3% of the small mammal prey of barn owls in all sites in the middle valley. Thus, in the study area, there was no evidence of the close link suggested by several authors between stoats and water voles (including southern water voles) in Spain, which could affect the distribution of the former due to supposed trophic specialization (Blanco 1998a, Gisbert & García-Perea 2007). In the Iberian Peninsula, latitudinal and altitudinal variations in the structure of small mammal communities are very marked, even more so in the north (e.g. Alegre *et al.* 1989, Sans-Fuentes & Ventura 2000, Soriguer *et al.* 2003). Both transitions occur in the study area, with a high zone of Eurosiberian affiliation and a lower one of Mediterranean affiliation, the result of which is a very varied small mammal community. Further research is needed concerning the biological and physical factors determining the distribution of Iberian stoats. The availability of different types of food in a mixture of habitats and noticeable consumption of mice probably contributed to the fact that common vole outbreaks, particularly noted in pastureland, had no effect on the number of stoat sightings, in contrast to more northerly latitudes where stoat density fluctuates in response to vole abundance (e.g. Korpimäki *et al.* 1991, Hellstedt *et al.* 2006).

Conclusions, stoat conservation and current scenario

According to the data obtained, stoats occupied various types of habitats at all elevations in the Torío river valley, were larger than individuals in the Spanish Pyrenees, showed complete winter whitening despite their southern location, coexisted with common weasels but in segregated habitats, had a relatively varied diet, with general prevalence of the small mammals, particularly *Apodemus* mice, in terms of biomass ingested, and were partly frugivorous and potential dispersers via endozoochory. For their conservation, it is essential to maintain the network of hedgerows found in most of the valley. The number of road-kills recorded could be reduced by lowering the speed of vehicles and installing small wildlife underpasses (see Vuurde and Grift 2005).

Currently, almost 10 years after the last sightings and indirect evidences included in this study, the general landscape has not changed and stoats continue to be established in the valley, but our visits have been very sporadic and brief since then. The most recent sighting was that of an adult female killed on the road in the middle valley in late July 2015 (Fig. 7). The carcass was still very fresh and weighed 201 g, with a head-body length of 24.0 cm, tail length 9.5 cm (not including tuft), ear length 19.5 mm and hind foot length 41.0 mm (not including claws), i.e. this female stoat was, as expected, smaller than the males in the area. It had only one visible, very protruding nipple, a sign that it had nursed a very small litter.

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