CSIRO PUBLISHING

Wildlife Research, 2008, **35**, 434–440 www.publish.csiro.au/journals/wr

Monitoring the small-scale distribution of sympatric European pine martens (*Martes martes*) and stone martens (*Martes foina*): a multievidence approach using faecal DNA analysis and camera-traps

Stefano Rosellini[A,E], *Enrique Osorio*[B], *Aritz Ruiz-González*[C], *Ana Piñeiro*[A] *and Isabel Barja*[D]

[A]Departamento de Biología, Unidad Zoología, Facultad de Ciencias, Universidad Autónoma de Madrid, Campus de Cantoblanco, 28049 Madrid, Spain.
[B]Departamento de Zoología, Facultad de Biología, Universidad de León, Campus de Vegazana, 24271 León, Spain.
[C]Departamento de Zoología y Biología Celular Animal, Facultad de Farmacia, Universidad del País Vasco, C/Paseo de la Universidad 7, 01006 Vitoria, Spain.
[D]Departamento de Biología y Ciencias del Medio Ambiente, Facultad de Ciencias Experimentales, Universidad SEK, C/Cardenal Zúñiga 12, 40003 Segovia, Spain.
[E]Corresponding author. Email: stefano.rosellini@yahoo.es

Abstract. The European pine marten (*Martes martes*) and stone marten (*Martes foina*) are two closely related mustelids that live sympatrically over a large area of Europe. In the northern Iberian Peninsula, the distribution ranges of both species overlap extensively. The objectives of this study were (1) to verify whether, on a small scale, both species also live sympatrically and (2) to compare camera traps and scat DNA as methods for detecting marten species. The study was conducted in a protected area (province of Ourense, north-west Spain), which covers 6700 ha. To test the sympatry hypothesis, 90 fresh faecal samples, identified as faeces of genus *Martes* on the basis of their morphology, were collected from June 2004 to August 2006. The specific identification of faecal samples was conducted using polymerase chain reaction–restriction fragment length polymorphism (PCR-RFLP) techniques. In addition, 20 camera-traps (916 camera-trap-nights) were in operation during the study period. Of the faecal samples collected, 88.8% were attributed to the European pine marten, while the remaining 11.2% were not amplified by PCR and thus could not be assigned. The European pine marten was identified in 57.9% of the photos of carnivores and the stone marten was not detected in any. The faecal DNA analysis and camera-trap results supported previous conclusions about habitat preferences and the distribution of the two species obtained using other methods. The two non-invasive methods that were used in this study were shown to be reliable techniques that can be employed simultaneously, because each method has advantages and disadvantages that are influenced by the size of the area inventoried, sampling effort, and cost and efficiency of the method. The data gathered using these methods provided important information on the understanding of trophic and competitive interactions between the species.

Introduction

The European pine marten (*Martes martes* Linnaeus, 1758) and stone marten (*Martes foina* Erxleben, 1777), species similar in both morphology and feeding habits, are closely related mustelids that live broadly sympatrically over an extensive area of Europe. Limited knowledge of their ecological niches in sympatric areas, their extremely elusive behaviour and the high degree of difficulty in distinguishing their faeces on the basis of morphology alone, contributes to the difficulty of studying and monitoring their populations.

The European pine marten occupies most of Europe, from Mediterranean biotopes to Fennoscandia taiga, and western Siberia and Iran (Proulx *et al*. 2004). The stone marten is present throughout continental Europe, but it is absent from Great Britain and Ireland as well as most of the Mediterranean islands except Crete (Proulx *et al*. 2004). On the Iberian Peninsula, the European pine marten has a Eurosiberian distribution and is also present on the islands of Majorca and Minorca (Mitchell-Jones *et al*. 1999; Palomo and Gisbert 2002); the stone marten is present throughout the Iberian Peninsula (Fig. 1) (Palomo and Gisbert 2002).

The European pine marten is associated primarily with Eurosiberian deciduous and coniferous forests (Delibes 1983; Mitchell-Jones *et al*. 1999) and prefers mature forests and areas with permanent watercourses (Barja 2005*a*). In contrast, the stone marten can survive in a variety of habitats across its distribution range, including fragmented woodlands, villages and their periphery, and areas near farms (Waechter 1975; Delibes 1983; Sacchi and Meriggi 1995; Blanco 1998; Mitchell-Jones

 10.1071/WR07030 1035-3712/08/050434

et al. 1999; Virgós and Garcia 2002; Lanszki 2003). Libois and Waechter (1991) also observed that the stone marten tends to principally occupy deforested and altered areas when the European pine marten is present. In addition, its predilection for rocky habitats allows it to use buildings and other man-made structures (Delibes 1983). However, this species appears to be highly flexible as it is also found in typical forest habitats in Russia and is therefore not exclusively dependent on the presence of rocky terrain (Waechter 1975). The stone marten is also more thermophilic than the European pine marten, allowing it to occupy urban environments (Waechter 1975). The ecological requirements of both species can sometimes overlap; in these circumstances, the European pine marten stays in forested landscapes and the stone marten seems to be displaced to more urbanised areas (Delibes 1983).

Accurate species identification is a key step in conservation biology and a necessary component of wildlife management and conservation studies. However, determining presence and absence of elusive or cryptic species can be logistically difficult, particularly when relying solely on field signs such as faeces, hair or tracks (Piggott and Taylor 2003). Traditionally, this kind of information is subjected to a variety of morphological analyses for definitive species identification (Kohn and Wayne 1997). Nevertheless, there are situations in which such samples, deposited by sympatrically occurring carnivores of similar body size, cannot be assigned at the species level on the basis of morphology alone (Farrell *et al*. 2000; Davison *et al*. 2002; Birks *et al*. 2004; Kurose *et al*. 2005). Misidentification of species from faeces is probably common, and has been indicated for different sympatric carnivore species (Paxinos *et al*. 1997; Ernest *et al*. 2000; Farrell *et al*. 2000; Davison *et al*. 2002; Palomares *et al*. 2002; Dalén *et al*. 2004; Sugimoto *et al*. 2006; Pilot *et al*. 2007). Traditionally, the presence of martens has been determined from data obtained from road kills or hunting information, live-trapping surveys, sighting surveys (Messenger and Birks 2000), track plates and camera-traps (Zielinski and Kucera 1995), fur-snagging devices (Messenger and Birks 2000; Lynch *et al*. 2006) and scat-based surveys, which have several limitations for detecting and identifying different marten species (Birks *et al*. 2004). Each method has advantages and disadvantages that are influenced by the size of the area inventoried, sampling effort, and cost and efficiency of the method (Birks *et al*. 2004). Methods of non-invasive genetic sampling of animal populations and camera-trapping are becoming more common for identification of mammalian species (Karanth 1995; Zielinski and Kucera 1995; Paxinos *et al*. 1997; Murakami 2002; Palomares *et al*. 2002; Azlan and Sharma 2003; Gómez-Moliner *et al*. 2004; Swann *et al*. 2004; Kurose *et al*. 2005; Trolle and Kéry 2005). Because the faeces of the European pine and stone marten cannot be reliably separated on the basis of morphology alone (Marchesi *et al*. 1989; Pilot *et al*. 2007), the application of methods that will positively distinguish the two could be an invaluable tool for conducting non-invasive surveys to determine the presence and distribution, trophic and habitat requirements, niche overlap and competitive interactions of the mustelids in sympatric areas.

Although several studies on the distribution of mammals have been conducted on the Iberian Peninsula (Blanco *et al*. 1992; Rodriguez and Delibes 1992; Virgós 2001; Palomo and Gisbert 2002), there is a remarkable absence of information on the distribution of the European pine marten and the bio-ecological relationship between it and the stone marten. Consequently, the goal of this work was to apply a multi-evidence approach incorporating two different survey techniques (faecal DNA analysis and camera-traps) to monitor the small-scale distribution of the two marten species in the northern Iberian Peninsula. This study compared the effectiveness, logistics and monetary efficacy of both techniques for this type of research.

Materials and methods

Study area

The study was performed in the Montes do Invernadeiro Natural Park, a mountainous area located in the north-west Iberian Peninsula (Universal Transverse Mercator (UTM) coordinates: 29T 064633–643 and 467462–472) (Fig. 1). The study area, which covers 6700 ha, varies in altitude from 880 to 1707 m. The climate is continental, with hot summers and cold winters

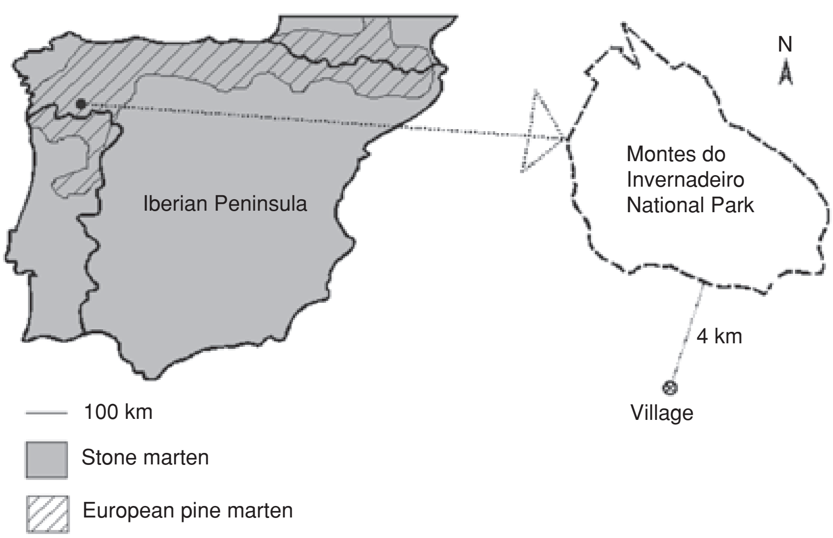

Fig. 1. Broad-scale distribution of the stone marten and the European pine marten over the Iberian Peninsula (modified from Mitchell-Jones *et al*. 1999; and Palomo and Gisbert 2002) and location of the study area.

(Barja 2001). The flora is diverse, including Mediterranean plant communities and Atlantic relic forests (Castroviejo 1977; Barja 2001). The plant community is scrubland, dominated by heather (*Erica australis*), prickled broom (*Pterospartum tridentatum*) and sandling (*Halimium lasianthum*). The original forests remain in valleys and along watercourses and are formed principally by associations of oak (*Quercus robur*), birch (*Betula celtiberica*), holly (*Ilex aquifolium*) and rowanberry (*Sorbus aucuparia*). Large tracts of extended forestlands are formed by Scot pine (*Pinus sylvestris*), which has repopulated deforested areas (Barja 2001). The park is occupied by carnivores such as the Iberian wolf (*Canis lupus*), badger (*Meles meles*), European polecat (*Mustela putorius*), stoat (*Mustela erminea*), European common weasel (*Mustela nivalis*), genet (*Genetta genetta*), wildcat (*Felis silvestris*), red fox (*Vulpes vulpes*) and otter (*Lutra lutra*). The study area appears to have suitable resources to support both the European pine marten and the stone marten. However, the presence of both species in the study area has not previously been examined. There are no human populations in the study area and the nearest village is 4 km from the park.

Collection of faecal samples

The European pine marten, the stone marten and other carnivores use forest roads and frequently defaecate on them as a way of visual-scent marking (Robinson and Delibes 1988; Barja *et al*. 2004; Barja 2005*b*; Barja *et al*. 2005). Initially, two scat-based surveys were conducted to estimate the distribution range of the genus *Martes* in the study area. The study area comprised 67 cells (UTM) of 1 km^2 each. In the initial survey, two 400-m transects in each cell were examined and 26 yielded *Martes* scats. Later, in order to collect fresh *Martes* faecal samples, transects 300 m long were surveyed on foot along forest roads monthly from June 2004 to August 2006 in these 26 cells alone. These surveys were conducted only in the 26 cells where signs of the presence of *Martes* species (scats, footprints, sightings) had previously been detected. We found fresh faeces in 17 of the 26 cells and old faeces in the remaining nine cells. Fresh faeces were characterised by their strong smell, presence of a mucus layer and lack of any sign of dehydration. Morphological characteristics, such as size and shape, were used to distinguish faeces of the genus *Martes* from those of medium-sized carnivores such as red fox and wildcat. The territory of the European pine marten is 1.3 km^2 for males and 1.0 km^2 for females (O. Berdión, Department of Zoology and Animal Cell Biology, Universidad País Vasco, Spain, pers. comm.). The mean territory size of the stone marten is similar to that of the European pine marten, being about 0.96 km^2 (López-Martín 2003). Thus, in order to increase the likelihood of obtaining faecal samples from separate individuals, the transects were placed 700 m apart. The transects were uniformly distributed throughout the study area and 218.7 km were surveyed. When fresh faeces of the genus *Martes* were detected, the date, time and UTM cell were recorded. A sample was collected from the fresh scat using a gloved hand. A new glove was used for each sample to avoid cross-contamination. All collected faecal samples were stored in hermetic and sterilised tubes, preserved with ethanol (96%) and maintained at –20°C until assayed (Piggott and Taylor 2003; Gómez-Moliner *et al*. 2004).

Genetic analysis of faecal samples

The specific identification of faecal samples was accomplished by the polymerase chain reaction–restriction fragment length polymorphism (PCR-RFLP). The faecal DNA extraction procedure was based on the protocol described in Gómez-Moliner *et al*. (2004). Extraction blanks were included to monitor for contamination and were processed as separate samples in the subsequent amplifications. A small fragment (276 bp) of mitochondrial DNA (mtDNA), D-loop region, was amplified with specific primers developed for *Martes* and *Mustela* by PCR. The primers were designed to amplify small fragments to maximise the probability of amplification of degraded DNA. Following DNA amplification, PCR products were digested with the restriction enzymes *Hae*III and *Rsa*I. The combined use of both enzymes produced a species-specific banding pattern allowing the scats of *M. martes* and *M. foina* to be discriminated. This method was recently developed and provides a reliable and effective molecular technique for unequivocal genetic identification of sympatric marten species through the use of species-specific differential haplotypes (Ruiz-González *et al*. 2008).

Camera trapping

Every three months, from June 2004 to October 2006, 10–20 automatic line-triggered cameras (models: Moultrie, Canon Prima AF 9s, Stealth Cam) were set in place and baited with chicken placed 70 cm from the ground and 2 m from the cameras. The cameras were equipped with different activation systems. Sixteen used passive and active infrared activation and four employed a plate system triggered by the pressure of the animal's weight. The cameras were placed in those cells where *Martes* faeces had been detected during the surveys and in optimal areas for both marten species even if signs of the animals were not detected. The optimal areas were selected on the basis of the known habitat preferences of both marten species (Delibes 1983; Sacchi and Meriggi 1995; Virgós and Garcia 2002; Barja 2005*a*). The cameras remained in the field for 3–12 days (916 camera-trap-nights). The cameras were placed in a total of 22 UTM cells (32.8% of cells had cameras in them). Each camera was revisited every third day.

The European pine marten and the stone marten are similar morphologically. Both species have a spot on the neck called a 'bib', which is yellow in the European pine marten and white in the stone marten (Cabrera 1914). Therefore, bib colour was used to distinguish between the two species. Spot patterns, size and symmetry of the bibs differ between individuals of the same species (Cabrera 1914). In the present study, the differences in the bib morphology and distance between cameras allowed us to identify individuals. To increase the probability of photographing the bibs, the cameras were baited with chicken placed 70 cm from the ground and 2 m from the cameras. The morphology of the bibs was analysed in the photographs obtained and when the spot pattern, size and symmetry coincided, the photographs were assigned to a single individual. Also, when the distance between cameras was greater than 1.3 km, we considered that the photographs obtained were of different individuals of the same species. This assumption was supported by the morphological differences of the bibs in the photographs.

Results

The faecal DNA analysis allowed us to detect the European pine marten in 17 UTM cells and the camera-trapping in 9 cells (in 6 cells the species was detected by both methods). Therefore, the presence of the European pine marten was confirmed in 20 cells (29.9% of cells) (Fig. 2). However, neither method detected the stone marten. Of 90 analysed faecal samples from throughout the study area, after applying the PCR-RFLP method, we successfully identified 80 as being from the European pine marten and none from the stone marten. Consequently, 88.8% of the collected samples could be assigned to a species; in the remaining 11.2% the DNA extracted was not amplified by the primers used. The mean number of fresh faecal samples analysed per cell was 5.3; the mean number of scats detected was 1.97 per month per kilometre surveyed. In 65.4% of the study cells (17 of 26), fresh scats were collected. The faecal DNA analysis confirmed the presence of the European pine marten in 100% of the cells in which fresh faeces were collected.

The camera-traps captured 126 photographs of four different terrestrial carnivores (Fig. 3). The European pine marten was the most photographed species (57.9%), followed by red fox (33.3%), wildcat (5.6%) and Iberian wolf (3.2%). This sampling method confirmed the presence of the European pine marten in 40.9% of camera-equipped cells, red fox in 36.4% of the cells, wildcat in 27.3% and Iberian wolf in only 18.2%. The inter-camera distance (>1.3 km) allowed for the identification of nine different individuals of European pine marten. Also, seven different individuals were identified according to the morphology of the bibs. The cells where the presence of the European pine marten was confirmed (using faecal DNA analysis and camera-trapping) included a high percentage of tree cover (coniferous and deciduous forests), permanent watercourses and a high percentage of rocky substrate and outcroppings. In contrast, the cells in which pine martens were not detected were dominated by scrubland.

Discussion

In this study, both research methods indicated that, while the European pine marten was present in the study area, the stone marten was not. The PCR-RFLP technique allowed us to achieve a high rate of species identification (88.8%). These genetic analyses open the possibility for studying population genetics of the species, recognising that nuclear marker genotyping from scats is more difficult than mtDNA amplification. The remaining 11.2% of samples did not amplify. The possibility that some scat samples had been incorrectly identified in the

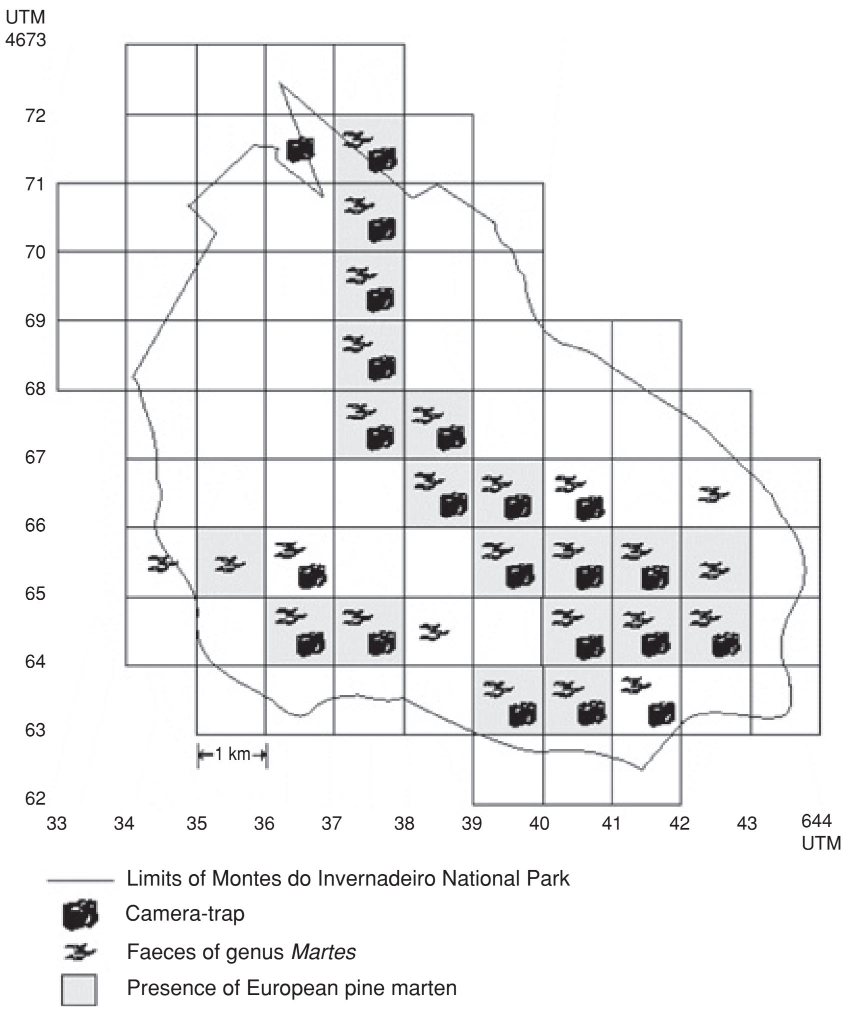

Fig. 2. Placement of the camera-traps, location of the faeces of the genus *Martes* and distribution of the European pine marten obtained from two different methods (faecal DNA analysis and camera-traps).

field as belonging to the marten would mean an even higher amplification success. Misidentifying fox scat as marten scat is a particularly common error (Davison *et al*. 2002). However, the primers developed for *Martes* and *Mustela* by PCR did not amplify in fox scats.

Camera-traps detected martens in only 40.9% of the cells (9 of 22), whereas faecal DNA detected them in 100% of the cells in which fresh faeces were collected (17 of 17). However, both methods have advantages and disadvantages that are influenced by the size of the area inventoried, sampling effort, detectability and cost and efficiency of the method. Although a large number of faecal samples can be collected, the faecal DNA is highly degraded (Taberlet *et al*. 1999) and the faeces collected can be from other carnivore species for which the primers used do not amplify, implying important economic costs. Also, the collection of fresh faeces requires a high field effort. However, this method is advantageous for both large- and small-scale investigations. An advantage of camera-trapping is the possibility of obtaining a broad range of significant information regarding the carnivore's community. The absence of specific attractants does not allow the species of interest to be selectively photographed. Also, the greater effort required for instrument placement, physical monitoring of the cameras and revisits to the study area are a disadvantage for large-scale research efforts. In the current study, camera-traps detected the European pine marten in cells in which the faecal DNA analysis did not detect its presence. Also, the use of camera-traps allowed us to visually detect the European pine marten (and identify individuals) and other carnivores (red fox, wildcat and Iberian wolf), which are difficult to study due to their elusive and nocturnal habits. Camera-trapping allows the collection of valuable information about multiple species, including herbivores and carnivores, within any given community (Karanth 1995; Peterson and Thomas 1998; Azlan and Sharma 2003; Swann *et al*. 2004; Trolle and Kéry 2005). Nevertheless, the simultaneous use of both methods in a small-scale marten survey can enhance the accuracy of data and result in a more ecologically relevant study.

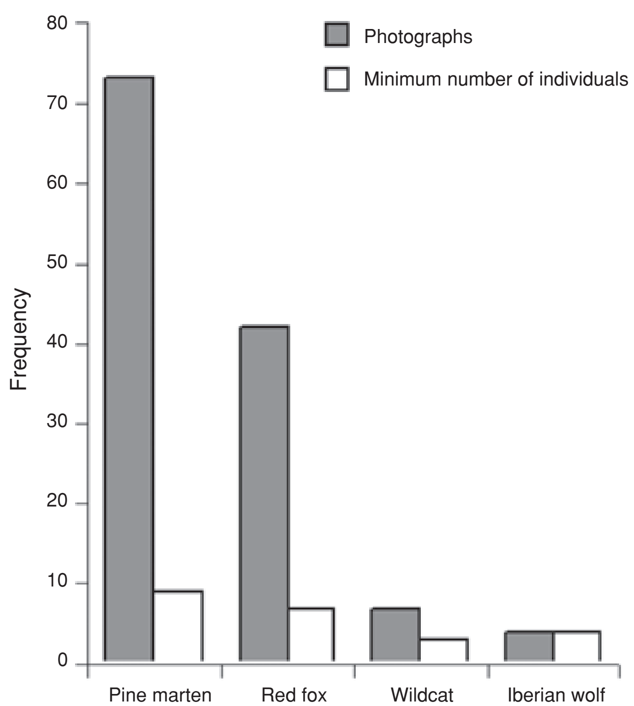

Fig. 3. Photographs of carnivores obtained using camera-traps, and an estimate of the minimum number of individuals present.

Small mammals are relatively abundant in the study area (64.4 animals ha^{-1}) (I. Barja, S. Rosellini and A. Piñeiro, unpubl. data) and are the primary prey of the European pine marten all year round (Rosellini *et al*. 2007). In some areas of the northern Iberian Peninsula small mammals have also been found to constitute the largest proportion of the stone marten diet (Delibes 1978). Nevertheless, despite the apparent presence of adequate food resources for the survival of both species within the study area, only the European pine marten is present. The ecological displacement that occurs when both species overlap in the same area is likely related to their relative densities and to the availability of trophic resources, even though prey items appear to be abundant. Competition for these resources can play a fundamental role in the interactions between individuals and species (Schoener 1983; Begon *et al*. 1986; Keddy 1989). Interspecific and intraspecific competition can cause a decrease in individual fitness (Begon *et al*. 1986). Since reduced fitness has significant negative consequences from an evolutionary standpoint, some kind of differentiation in the utilisation of trophic resources and habitat must occur in order for both species to coexist (Schoener 1974). Such differentiation can allow both species and individuals to avoid depressed fitness, that is, a decrease in fecundity and/or survival (Schoener 1974; Barrientos and Virgós 2006). In sympatric carnivores, there is ample evidence that ecological competition determines size and stability of populations (Palomares *et al*. 1996; Barrientos and Virgós 2006). Similar carnivores that coexist in the same area, therefore, normally differ in their trophic strategies (Schoener 1974; Clevenger 1994; Barrientos and Virgós 2006). In mustelids, the sympatry among species has been explained by differences in body size, which reduces interspecific competition (Erlinge 1986). While the high degree of trophic overlap between the two martens studied here has been reported by some authors (Marchesi *et al*. 1989; Clevenger 1994), the mechanisms of coexistence have been proposed only by Clevenger (1994).

The results of this work suggest a functional ecological mechanism for competition between the two studied species. On the Iberian Peninsula, the distribution ranges of the European pine marten and the stone marten overlap within the study area, providing a situation for ecological competition, and species segregation, on both a large and small scale. The exclusive detection of the European pine marten within the study area is likely associated with its preference for uniform and well conserved forests (Barja 2005*a*), resulting in the displacement of the stone marten to disturbed, deforested and urban areas (Delibes 1983; Libois and Waechter 1991).

On a smaller scale, habitat fragmentation can allow for sympatric distribution of very similar species (Pilot *et al*. 2007). The observed spatial segregation of the two mustelids is probably due to both physical size, the European pine marten being the larger of the two (Delibes 1983; Barea and Ballesteros 1999; Barja 2005*a*), and the more general and flexible habits of the stone marten (Waechter 1975; Delibes 1983; Sacchi and Meriggi 1995; Mitchell-Jones *et al*. 1999; Virgós and Garcia 2002; Lanszki 2003). Interspecific competition is, therefore, avoided and the stone marten, due to its more generalist habits, shows a higher level of adaptability to human-altered environments, which may have implications for long-term viability of the species (Clevenger 1994).

The genetic analysis of four faecal samples collected in the periphery of the closest village to the study area, and the location of several dead mustelids, indicated that the European pine marten was also present there. This information and the other results obtained during this study seem to indicate that the scarce human-caused environmental alterations might influence in the absence of stone marten. In the study area and surrounding areas the density of humans is very low and the forest habitats are well conserved, with a progressive abandonment of agricultural activities, including crops and animal husbandry. We suggest, therefore, that further studies are needed to analyse the sympatry hypothesis on a small scale, considering different degrees of urbanisation and environmental disturbance. The possible competition and habitat segregation between the two marten species in the forests of the northern Iberian Peninsula is a basis for future studies regarding the animal community of forest habitats. These investigations provide fundamental information relative to habitat management directed principally at the conservation of the European pine marten since it apparently depends a great deal, if not exclusively, on unimpacted forest resources.

Acknowledgements

We thank the Nature Conservation Service of Ourense (Regional Government of Galicia) for providing the permits required to conduct this study in the Montes do Invernadeiro Natural Park. Thanks are due to Dr Benjamín Gómez-Moliner for supervising the molecular work. We are grateful to gamekeepers Tomás Pérez, Ricardo Prieto and Paco Barja for their help with fieldwork, and to Toni Gago for assistance during the collection of field data. A. Ruiz-González was supported by a Ph.D. grant from the Department of Education, Universities and Research (Basque Government) and S. Rosellini was supported by a postgraduate scholarship from the Universidad Autónoma de Madrid. This study has been supported by the Project USEK, n° 7-2004-05, Universidad SEK de Segovia.

References

Azlan, J. M., and Sharma, D. S. K. (2003). Camera trapping the Indochinese tiger, *Panthera tigris corbetti*, in a secondary forest in peninsula Malaysia. *The Raffles Bulletin of Zoology* **51**, 421–427.

Barea, J. M., and Ballesteros, E. (Eds.) (1999). 'Carnívoros Ibéricos, Serie de Estudios y Proyectos de Biología N°2.' (Colegio Oficial de Biólogos de Andalucía: Granada.)

Barja, I. (2001). La señalización en el lobo ibérico (*Canis lupus signatus*). Comparación con dos especies de Hienas (*Crocuta crocuta* y *Hyaena hyaena*). Ph.D. Thesis, Universidad Autónoma de Madrid, Madrid.

Barja, I. (2005*a*). Winter distribution of European pine marten *Martes martes* scats in a protected area of Galicia, Spain. *Mammalia* **69**, 435–438. doi:10.1515/mamm.2005.037

Barja, I. (2005*b*). Patrones de marcaje con heces por la marta europea (*Martes martes*) en el noroeste de España: importancia para su estudio. *Galemys* **17**, 123–134.

Barja, I., de Miguel, F. J., and Bárcena, F. (2004). The importance of crossroads in faecal marking behaviour of the wolves (*Canis lupus*). *Naturwissenschaften* **91**, 489–492. doi:10.1007/s00114-004-0557-1

Barja, I., de Miguel, F. J., and Bárcena, F. (2005). Faecal marking behaviour of Iberian wolf in different zones of their territory. *Folia Zoologica* **54**, 21–29.

Barrientos, R., and Virgós, E. (2006). Reduction of potential food interference in two sympatric carnivores by sequential use of shared resources. *Acta Oecologica* **30**, 107–116. doi:10.1016/j.actao.2006.02.006

Begon, M., Harper, J. L., and Townsend, C. R. (Eds) (1986). 'Ecology. Individuals, Populations and Communities.' (Blackwell Scientific Publications: Oxford.)

Birks, J. D. S., Messenger, J. E., Braithwaite, T. C., Davison, A., Brookes, R. C., and Strachan, C. (2004). Are scat surveys a reliable method for assessing distribution and population status of pine martens? In 'Martens and Fishers (*Martes*) in Human-altered Environments: an International Perspective'. (Eds D. J. Harrison, A. K. Fuller and G. Proulx.) pp. 235–252. (Springer-Verlag: New York.)

Blanco, J. C. (Ed.) (1998). 'Mamíferos de España.' (Geoplaneta: Madrid.)

Blanco, J. C., Reig, S., and Cuesta, L. (1992). Distribution, status and conservation problems of the wolf *Canis lupus* in Spain. *Biological Conservation* **60**, 73–80. doi:10.1016/0006-3207(92)91157-N

Cabrera, A. (Ed.) (1914). 'Fauna Ibérica. Mamíferos.' (Museo Nacional de Ciencias Naturales: Madrid.)

Castroviejo, S. (Ed.) (1977). 'Estudio sobre la Vegetación de la Sierra del Invernadeiro (Ourense).' (ICONA: Madrid.)

Clevenger, A. P. (1994). Feeding ecology of Eurasian pine martens and stone martens in Europe. In 'Martens, Sables and Fishers'. (Eds S. W. Duskirk, A. S. Arestad, M. G. Raphael and R. A. Powell.) pp. 326–340. (Cornell University Press: Ithaca.)

Dalén, L., Götherström, A., and Angerbjörn, A. (2004). Identifying species from pieces of faeces. *Conservation Genetics* **5**, 109–111. doi:10.1023/B:COGE.0000014060.54070.45

Davison, A., Birks, J. D. S., Brookes, R. C., Braithwaite, T. C., and Messenger, J. E. (2002). On the origin of faeces: morphological versus molecular methods for surveying rare carnivores from their scats. *Journal of Zoology* **257**, 141–143. doi:10.1017/S0952836902000730

Delibes, M. (1978). Feeding habits of the stone marten, *Martes foina* (Erxleben, 1777), in northern Burgos, Spain. *Zeitschrift für Saugetierkunde* **43**, 282–288.

Delibes, M. (1983). Interspecific competition and the habitat of the stone marten *Martes foina* (Erxleben 1777) in Europe. *Acta Zoologica Fennica* **174**, 229–231.

Erlinge, S. (1986). Specialists and generalists among the mustelids. *Lutra* **29**, 5–11.

Ernest, H. B., Penedo, M. C. T., May, B. P., Syvanen, M., and Boyce, W. M. (2000). Molecular tracking of mountain lions in the Yosemite Valley region in California: genetic analysis using microsatellites and faecal DNA. *Molecular Ecology* **9**, 433–441. doi:10.1046/j.1365-294x.2000.00890.x

Farrell, L. E., Romant, J., and Sunquist, M. E. (2000). Dietary separation of sympatric carnivores identified by molecular analysis of scats. *Molecular Ecology* **9**, 1583–1590. doi:10.1046/j.1365-294x.2000.01037.x

Gómez-Moliner, B. J., Cabria, M. T., Rubines, J., Garin, I., Madeira, M. J., Elejalde, A., Aihartza, J., Fournier, P., and Palazón, S. (2004). PCR-RFLP identification of mustelid species: European mink (*Mustela lutreola*), American mink (*M. vison*) and polecat (*Mustela putorius*) by analysis of excremental DNA. *Journal of Zoology* **262**, 311–316. doi:10.1017/S0952836903004667

Karanth, K. U. (1995). Estimating tiger *Panthera tigris* populations from camera-trap data using capture–recapture models. *Biological Conservation* **71**, 333–338. doi:10.1016/0006-3207(94)00057-W

Keddy, P. A. (Ed.) (1989). 'Competition.' (Chapman and Hall: London.)

Kohn, M. H., and Wayne, R. K. (1997). Facts from feces revisited. *Trends in Ecology & Evolution* **12**, 223–227. doi:10.1016/S0169-5347(97)01050-1

Kurose, N., Masuda, R., and Tatara, M. (2005). Fecal DNA analysis for identifying species and sex of sympatric carnivores: a noninvasive method for conservation on the Tsushima Islands, Japan. *The Journal of Heredity* **96**, 688–697. doi:10.1093/jhered/esi124

Lanszki, J. (2003). Feeding habits of stone martens in a Hungarian village and its surroundings. *Folia Zoologica* **52**, 367–377.

Libois, R., and Waechter, A. (1991). La fouine (*Martes foina*). In 'Encyclopédie des Carnivores de France, Vol. 10'. (Eds M. Artois, and P. Delattre.) pp. 1–53. (Societé Française pour l'Étude et Protection des Mammifères, Bohallard: Puceul.)

López-Martín, J. M. (2003). Aspectos de la ecología de la marta (*Martes martes* L. 1758) y la garduña (*M. foina* Erx.1777) en los ambientes mediterráneos: interacciones con la gineta (*Genetta genetta* L. 1758). Ph.D. Thesis, Universidad de Barcelona, Barcelona.

Lynch, Á. B., Brown, M. J. F., and Rochford, J. M. (2006). Fur snagging as a method of evaluating the presence and abundance of a small carnivore, the pine marten (*Martes martes*). *Journal of Zoology* **270**, 330–339. doi:10.1111/j.1469-7998.2006.00143.x

Marchesi, P., Lachat, N., Leinhard, R., Debieve, P., and Mermod, C. (1989). Comparaison des régimes alimentaires de la fouine (*Martes foina* Erxl.) et de la martre (*Martes martes* L.) dans une région du Jura suisse. *Revue Suisse de Zoologie* **96**, 281–296.

Messenger, J. E., and Birks, J. D. S. (2000). Monitoring the very rare: pine marten populations in England and Wales. In 'Mustelids in a Modern World. Management and Conservation Aspects of Small Carnivore: Human Interactions'. (Ed. H. I. Griffiths.) pp. 153–162. (Backhuys Publishers: Leiden.)

Mitchell-Jones, A. J., Amori, G., Bogdanowicz, W., Krystufek, B., Reijnders, P. J. H., Spitzemberg, F., Stubbe, M., Thissen, J. B. M., Vohralik, V., and Zima, J. (1999). 'The Atlas of European Mammals.' (Academic Press: London.)

Murakami, T. (2002). Species identification of mustelids by comparing partial sequences on mitochondrial DNA from fecal samples. *The Journal of Veterinary Medical Science* **64**, 321–323. doi:10.1292/jvms.64.321

Palomares, F., Ferreras, P., Fedriani, J. M., and Delibes, M. (1996). Spatial relationships between Iberian lynx and other carnivores in an area of south-west Spain. *Journal of Applied Ecology* **33**, 5–13. doi:10.2307/2405010

Palomares, F., Godoy, J. A., Piriz, A., O'Brien, J., and Johnson, W. E. (2002). Faecal genetic analysis to determine the presence and distribution of elusive carnivores: design and feasibility for the Iberian lynx. *Molecular Ecology* **11**, 2171–2182. doi:10.1046/j.1365-294X.2002.01608.x

Palomo, L. J., and Gisbert, J. (Eds.) (2002). 'Atlas de los Mamíferos Terrestres de España'. (Dirección General de Conservación de la Naturaleza-SECEM-SECEMU: Madrid.)

Paxinos, E., Mcintosh, C., Ralls, K., and Fleischer, R. (1997). A non-invasive method for distinguishing among canid species: amplification and enzyme restriction of DNA. *Molecular Ecology* **6**, 483–486. doi:10.1046/j.1365-294X.1997.00206.x

Peterson, L. M., and Thomas, J. A. (1998). Performance of Trailmaster infrared sensors in monitoring captive coyotes. *Wildlife Society Bulletin* **26**, 592–596.

Piggott, M. P., and Taylor, A. C. (2003). Remote collection of animal DNA and its applications in conservation management and understanding the population biology of rare and cryptic species. *Wildlife Research* **30**, 1–13. doi:10.1071/WR02077

Pilot, M., Gralak, B., Goszczyński, J., and Posluszny, M. (2007). A method of genetic identification of pine marten (*Martes martes*) and stone marten (*Martes foina*) and its application to faecal samples. *Journal of Zoology* **271**(2), 140–147. doi:10.1111/j.1469-7998.2006. 00179.x

Proulx, G., Aubry, K. B., Birks, J., Buskirk, S. W., Fortin, C., *et al.* (2004). World distribution and status of the genus *Martes* in 2000. In 'Martens and Fishers (*Martes*) in Human Altered Environments: an International Perspective'. (Eds D. J. Harrison, A. K. Fuller, and G. Proulx.) pp. 21–76. (Springer-Verlag: New York.)

Robinson, I. H., and Delibes, M. (1988). The distribution of faeces by the Spanish lynx (*Felis pardina*). *Journal of Zoology* **216**, 577–582.

Rodriguez, A., and Delibes, M. (1992). Current range and status of the Iberian lynx (*Felis pardina* Temminck, 1824) in Spain. *Biological Conservation* **61**, 189–196. doi:10.1016/0006-3207(92)91115-9

Rosellini, S., Barja, I., and Piñeiro, A. (2007). Distribución y hábitos alimenticios de la marta (*Martes martes*) en el Parque Natural Os Montes do Invernadeiro (Galicia, NO de España). *Galemys* **19**, 99–114.

Ruiz-González, A., Rubines, J., Berdión, O., and Gómez-Moliner, B. J. (2008). A non-invasive genetic method to identify the sympatric mustelids pine marten (*Martes martes*) and stone marten (*Martes foina*): preliminary distribution survey on the N Iberian Peninsula. *European Journal of Wildlife Research* **54**, 253–261. doi:10.1007/s10344-007-0138-7

Sacchi, O., and Meriggi, A. (1995). Habitat requirements of the stone marten (*Martes foina*) on the Tyrrhenian slopes of the northern Apennines. *Hystrix* **7**, 99–104.

Schoener, T. W. (1974). Resource partitioning in ecological communities. *Science* **185**, 27–39. doi:10.1126/science.185.4145.27

Schoener, T. W. (1983). Field experiments on interspecific competition. *American Naturalist* **122**, 240–285. doi:10.1086/284133

Sugimoto, T., Nagata, J., Aramilev, V. V., Belozor, A., Higashi, S., and McCullough, D. R. (2006). Species and sex identification from faecal samples of sympatric carnivores, Amur leopard and Siberian tiger, in the Russian Far East. *Conservation Genetics* **7**, 799–802. doi:10.1007/s10592-005-9071-z

Swann, D. E., Hass, C. C., Dalton, D. C., and Wolf, S. A. (2004). Infrared-triggered cameras for detecting wildlife: an evaluation and review. *Wildlife Society Bulletin* **32**, 357–365. doi:10.2193/0091-7648(2004)32[357:ICFDWA]2.0.CO;2

Taberlet, P., Waits, L. P., and Luikart, G. (1999). Noninvasive genetic sampling: look before you leap. *Trends in Ecology & Evolution* **14**, 323–327. doi:10.1016/S0169-5347(99)01637-7

Trolle, M., and Kéry, M. (2005). Camera-trap study of ocelot and other secretive mammals in the northern Pantanal. *Mammalia* **69**, 409–416. doi:10.1515/mamm.2005.032

Virgós, E. (2001). Distribución y estatus del turón (*Mustela putorius*) en España: un análisis basado en encuestas. *Galemys* **13**, 39–61.

Virgós, E., and Garcia, F. J. (2002). Patch occupancy by stone martens *Martes foina* in fragmented landscapes of central Spain: the role of fragment size, isolation and habitat structure. *Acta Oecologica* **23**, 231–237. doi:10.1016/S1146-609X(02)01142-6

Waechter, A. (1975). Ecologie de la fouine en Alsace. *Terre et Vie* **29**, 399–457.

Zielinski, W. J., and Kucera, T. E. (Eds.) (1995). 'American Marten, Fisher, Lynx, and Wolverine: Survey Methods for their Detection.' (US Department of Agriculture Forest Service, Pacific Southwest Research Station: Berkeley.)

Manuscript received 7 March 2007, accepted 13 May 2008