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EVIDENCE OF A LOCAL RANGE EXPANSION IN A FRAGMENTATION-SENSITIVE SPECIES: THE CASE OF RED SQUIRREL (*SCIURUS VULGARIS*) IN CENTRAL ITALY

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Sciurus vulgaris
central Italy
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colonization
extinction
woodland management

ABSTRACT. – The Red squirrel *Sciurus vulgaris* Linnaeus, 1758 is currently expanding its range in plains and hills of Central Italy, colonizing or re-colonizing areas where it was never or only irregularly recorded since the 1950s. Here we report some observations regarding this range expansion based on a relatively large data-set covering the period 1850-2011 (471 records: 72 published, 399 unpublished) in a large study area covering the hills and plains of Tyrrhenian Central Italy (Latium). After considering the temporal patterns of a more recent sub-set of presence data (1950-2009: i.e. six decades) we identified three geographic regions: (i) a large northern region with an area where the species occurred historically (at least since 1950: Volsini Mts) and an area where the species occurs more recently (after the1970s); (ii) a region with two areas, one where the species occurred irregularly between the 1970s and 2000s, and, a second one where it has occurred from the 2000s; (iii) a region where the species was locally extinct in the 1950s-1960s, where significant amounts of land reclamation and forest fragmentation and isolation occurred in the 20th century. These geographic and temporal patterns mirror (i) some recent changes in temporal and spatial regime of coppice management, (ii) abandonment of traditional farming and cultivation of mountainous areas, leading to an increase of forested area, (iii) implementation of conservation measures in nature reserves and in Special Areas of Conservation (from the second half of 1970s), and (iv) the ageing of planted coniferous forests (mostly from 1950s). These co-occurring factors may explain the range expansion of the species in recent times.

INTRODUCTION

The Red squirrel *Sciurus vulgaris* Linnaeus, 1758 is a Palearctic forest rodent, relatively widespread in broad-leaved, mixed and coniferous forests of Europe from the sea level up to the tree line (Gurnell & Wauters 1999). In Italy the species occurs in almost all mainland regions except for most of the Po plain, the Adriatic coastal plains (due to historical anthropogenic forest fragmentation), and a few southern regions (Campania, Basilicata and Calabria), while it is absent in Sicily, Sardinia and small islands (Wauters & Martinoli 2008).

S. vulgaris is sensitive to habitat loss and degradation (Celada *et al*. 1994, Delin & Andrén 1999, Rodrìguez & Andrén 1999, Hale *et al*. 2001, Koprowski 2005, Mortelliti *et al*. 2009, 2010, 2011, Spinozzi *et al*. 2012). Recent studies performed in Central Italy have shown that an increase in forest habitat in the landscape increases the probability of occurrence of the Red squirrel, while the role of structural connectivity (e.g., hedgerows) is less important (Mortelliti *et al*. 2011). In addition this species experiences high levels of mortality due to road accidents, due to its high colonization ability (Gurnell 1991, Capizzi & Santini 2007, Battisti *et al*. 2012). Nevertheless, when environmental constraints allow it (e.g., de-fragmentation among suitable patches, reduction of coppice management: Spinozzi *et al*. 2012), it may re-colonize areas (Santos-Reis & Mathias 1996, Bon *et al*. 2008). This phenomenon has been highlighted in Italy and evidences of a recent range re-expansion after apparent historical extinc-

tions have been recorded in central regions such as southern Tuscany and northern Latium (Contoli 1977, Contoli *et al*. 1980, Sforzi & Ragni 1997, Amori *et al*. 2007).

We here provide new data on the local distribution of this rodent in coastal and sub-coastal areas of the Tyrrhenian side of Central Italy. Following the observed spatial and temporal patterns of occurrence (by original data or grey literature; e.g., Battisti *et al*. 2011), we hypothesize possible explanations of this range expansion.

METHODS

Study area: The area under investigation is part of the hilly and plain sectors of the Tyrrhenian Central Italy that lies between the Fiora River (Northern border), and the Garigliano River (Southern border). The mid and lower stretch of Paglia, Tiber and Sacco rivers represent the eastern limits of the study district. This area is about 20,000 km^2 wide and includes parts of three administrative regions (from North to South: Tuscany, Umbria, Latium), encompassing mountain and hilly reliefs of volcanic origin (Tolfa, Cimini and Vicani Mts., Vulsini and Sabatini Mts., Alban Hills) as well as coastal and sub-coastal plains (the southern part of Maremma, Campagna Romana and Pontinia plain). In our historical analysis we considered also bibliographic data referring to some anti- and sub-Apennine mountainous sectors (Lepini, Ausoni, Aurunci Mts.). Geographic sectors analyzed are reported in Fig. 1. For details on geology, orography, phytoclimatology and vegetation, see: Landi Vittorj (1989), Blasi (1994), Blasi *et al*. (2010a, 2010b).

This study does not include the limestone groups of the western side of Central Apennines and the more internal Central Apennines limestone western ranges (Sabini, Prenestini, Simbruini, Ernici Mts.), corresponding to the historical known range of this species in peninsular Italy (Wauters & Martinoli 2008).

Data collection and analyses: The local historic range of the species has been assessed from a critical review of bibliographic data published between first half of the 19th Century and 2011. Records have been obtained from: i) historical literature (e.g., textbooks and papers in scientific periodicals published from the first half of the 19thCentury to 1960); ii) modern scientific literature (e.g., textbooks and papers published in peer reviewed journals from 1960); iii) "grey literature" (e. g., non peer-reviewed literature, mostly published from 1970, inclusive of technical reports and divulgative papers). The official mammal data-bank of the Province of Rome public Agency (Amori *et al*. 2009) has been also included.

Original data showing current range expansion of the species came from different sources: direct observations (i.e. sightings), identification of food remains, hair tubes data, and road kills. These records were mostly collected from 2000 to 2011 by the authors; records dating from 1980 to 1999 were also taken into account; personal communications from local experienced zoologists and naturalists were also selected.

Both datasets (i.e. literature records and observation data) have been arranged in a data-base and ordered geographically and chronologically, from North to South and from the oldest to the most recent one, respectively. Data reliability has been scored from 3 (max) to 1 (min), according to the authors evaluation (expert based Delphi approach; Linstone & Turoff 1975).

To assess the geographic similarity of the studied areas on a historical basis we organized data using only the six most recent and complete 10-years periods (i.e., decades: from 1950 to 2009). This analysis allowed us to infer a pattern of similarity among regions on a historical basis, so facilitating an analysis on the hypothesized range expansion at this spatial scale. The similarity among geographic areas based on the presence of the species in the 10-years periods was calculated using the Cluster method (Between Groups Linkage, Measure: squared Euclidean Distance) using SPSS 13.0 for Windows software.

RESULTS

Data set. Four-hundred-seventy-one records on the presence of *S. vulgaris* were collected from the study area between the first half of the19th to the first decade of the 21th Century, 72 published (from near 50 bibliographic sources) and 399 unpublished (389 data points from 2000 to 2011, 10 in 1981–1999). Among published data, 34 (47.2 %) were given a score of 3 (maximum reliability; see Methods), 37 (51.4 %) a score 2, 1 (1.4 %) a score 1 (minimum reliability). Among unpublished records, 377 (94.5 %) were given a score of 3 (maximum reliability), 15 (3.7 %) a score 2, 7 (1.7 %) a score 1 (minimum reliability). These data were used to rebuild historical and present local range and dynamic of the species in the study area.

Historical range. Historical range of this species in the Italian peninsula corresponds to a large part of Apennines and neighboring hilly contexts (Wauters & Martinoli 2008) and historical presence in Central Apennines is stated by several authors in the last decades (e.g., Angelici *et al*. 1988, Sarrocco 1988, Various Authors 1989, Regione Lazio 1998; see review in Amori *et al*. 2009). For Central Italy, first scientific documents date back to the first half of the the 19th Century, when Bonaparte (1838-1841) described the endemic subspecies *S. v. italicus* as present in the Central Apennines but without providing exact localities.

Some records have been published between the end of the 19th and the beginning of the 20th Century concerning hilly and plain sectors of Tyrrhenian Central Italy (e.g., Carruccio 1898, Lepri 1911). According to these records, the Red squirrel was more or less common in the coastal and sub-coastal low-plains (e.g., Campagna Romana, Pontinia plain; respectively sectors 2 and 9 in Fig. 1), as well as in the more inland anti-Apenninic or Apenninic volcanic mountains (Vicani Mts.) and calcareous mountain systems (Ernici, Lepini Mts. and neighboring areas). One historical record from the southern sector of Tuscan

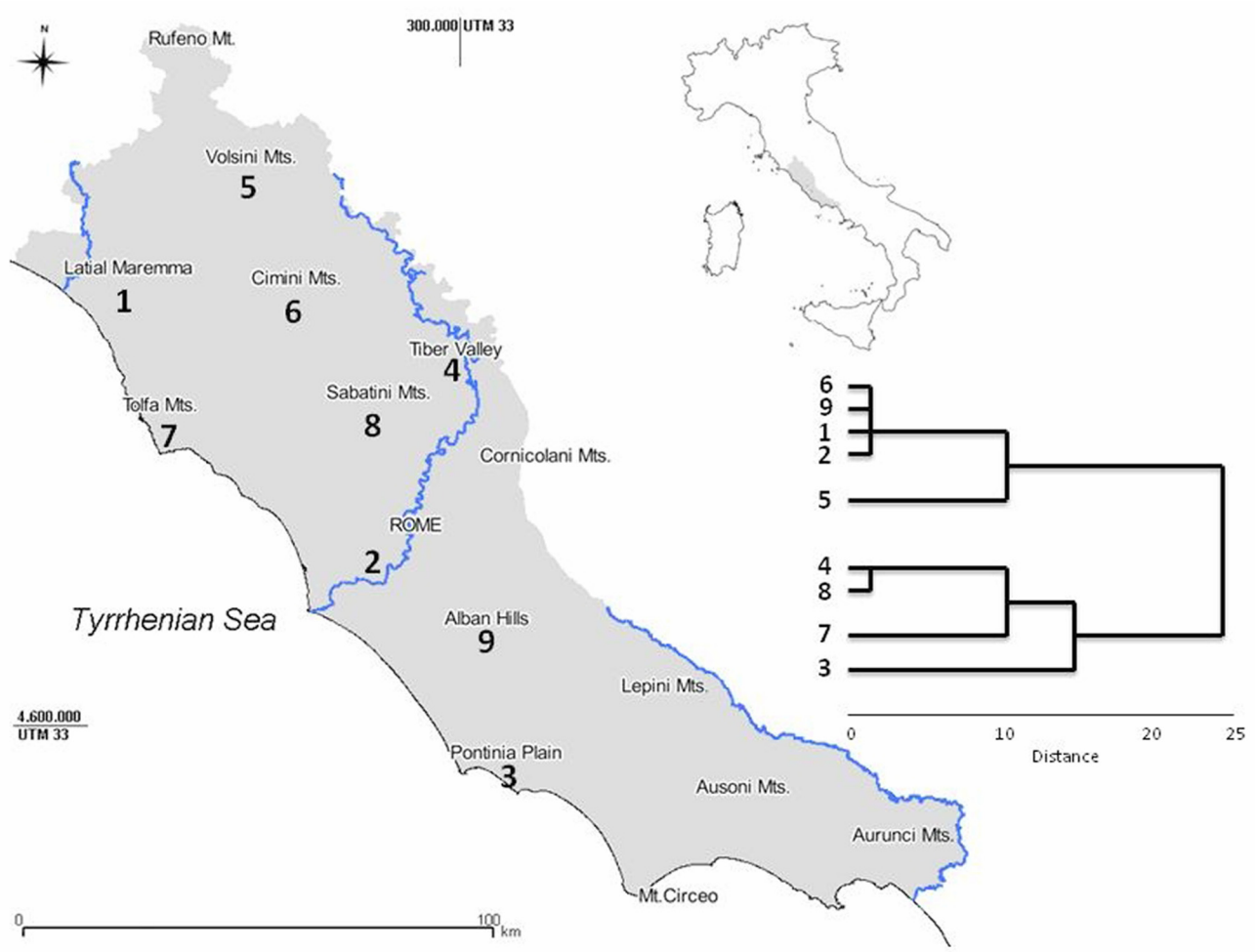

Fig. 1 – Study area and similarity among geographic sectors (presence/absence matrix by only original data; cluster method: Between Groups Linkage; measure: Squared Euclidean Distance). First group: 1, Latial Maremma; 2, Campagna Romana; 5, Volsini Mts ; 6, Cimini Mts.; 9, Alban Hills; Second group: 4, Mid Tiber River Valley; 7, Tolfa Mts.; 8, Sabatini Mts.; Third group: 3, Pontinia plain (see text for details).

Maremma (Grosseto Province) is known in the 1920s (Sforzi & Ragni 1997). The species was also recorded in the Pontinia plain (sector 3 in Fig. 1) in the 1930s (Lepri 1935) and records from this area are known until the 1950s although the autochthonous status of the local population should be demonstrated (Zerunian & Reichegger 1997). Surprisingly, there is no other evidence for the presence of this species in the study area until the first half of the 1980s, despite intensive research carried out for many years in Central Italy and the ease of identifying the species on the field (Gippoliti 2009).

Bruno (1973) reported *S. vulgaris* in the Tolfa hilly area, where it was considered present but low in abundance. Contoli *et al*. (1980), Pavan & Mazzoldi (1983) and Calò & Verucci (1993) considered the species almost extinct in this area, although presumably occurring in the surroundings. During this period no samples of Red squirrel have been reported in natural history museums and local or private collections (L. Contoli pers comm). The species was reported occasionally in the Sabatini Mts. (sector 8 in Fig. 1; Pavan & Mazzoldi 1983), and Angelici (1989) does not report it in the Cimini Mts (sector 6 in Fig. 1). Few records were collected in the 1970s from the NW of Latium (Rufeno Mt.: Cagnolaro 1981, Pavan & Mazzoldi, 1983). Between the 1990s and the beginning of the 21th Century, no records are known from the Tolfa hilly system (Angelici & Boitani 1994, Angelici 2005, Various Authors 2006), the anti-Apennine ranges of Lepini Mts. and Ausoni-Aurunci Mts. (Pavan & Mazzoldi 1983, Corsetti 2002), the Castelporziano Presidential Estate (Fanfani *et al*. 2006) and the Circeo National Park (Amori *et al*. 2005). A patchy and irregular distribution is nevertheless known in the north and in central sectors of the Latium region (Pavan & Mazzoldi 1983, Cobolli & Vigna Taglianti 1992, Sforzi & Ragni 1997, Capizzi 2009, Verucci 2011).

Reliable historical records are available for the Lepini Mts. until the immediate post-II War period, when the

Table I. – Red squirrel presence in the hills and plains of Tyrrhenian Central Italy. Data are grouped following 8 (uneven) time-intervals. The first time-interval includes unpublished records from 1900 to 1949. The following six 10-year time intervals spanned from 1950 to 2009: grey, not recorded; dark grey, recorded. Data from the last two years are also reported (2010-2011). Symbols: [+] = literature records (* = data only from Pavan & Mazzoldi, 1983); + = unpublished (original) records (1950-2009). The number of recent records (n) is given for each geographic sector. White columns: data considered in descriptive discussion but not in statistical cluster analysis.

			Clusterized decades						
Geographic sector/periods	1900-1949		1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2011
1. Latial Maremma (n = 15)	[+]		-	-	[+]	[+]	[+]	+	+
2. Campagna Romana (n = 19)	-		-	-	[+]*	[+]	[+]	+	+
3. Pontinia plain (n = 0)	[+]		-	-	[+]*	-	-	-	-
4. Mid Tiber River Valley (n = 2)	-		-	-	[+]*	-	-	+	+
5. Volsini Mts. (n = 179)	-		[+]	-	[+]	[+]	[+]	+	+
6. Cimini and Vicani Mts. (n = 65)	[+]		-	-	[+]*	+	+	+	+
7. Tolfa Mts. (n = 19)	-		-	-	-	-	-	+	+
8. Sabatini Mts. (n = 86)	[+]		-	-	[+]*	-	-	+	+
9. Alban Hills (n = 5)	-		-	-	[+]*	[+]	[+]	+	-

species was still caught for food in the mature woods of the area (Amori *et al*. 2002, Corsetti 2006). Municipalities of the area where the species was believed to be present were mapped in Cagnolaro (1981) and listed in Pavan & Mazzoldi (1983); these records were considered doubtful and none were mapped in Amori & Aloise (2006).

A number of records is known from some large urban parks of Rome (sector 2 in Fig. 1; Pavan & Mazzoldi 1983, Calò & Verucci 1993, Amori *et al*. 1997, Zapparoli *et al*. 2004), but the autochthonous status of the local population is questionable (Zapparoli *et al*. 2004).

The patchy distribution of Red squirrel in the study area is also represented in the maps appearing in the most authoritative textbook and check-list on the Italian mammals published between 1981 and 2006 (e.g., Cagnolaro 1981, Amori 2002, Amori & Aloise 2006). The most updated maps are in Wauters & Martinoli (2008) and Capizzi (2009).

Present range in hilly and plain areas. According to the temporal pattern of data occurrence (1950-2009), three geographic areas can be identified: 1) a group of source areas where the species has known to be present historically (before 1950s: Volsini Mts.) and more recently (after 1970s: Maremma, Cimini, Alban Hills, Campagna Romana); 2) a large (re) colonized context with two sub-areas (where the species occurs irregularly in 1970s and in 2000s: Mid Tiber River Valley, Sabatini, and where it occurs only from 2000s: Tolfa Mts.); 3) a southern area where the species was locally extinct in the 1950s-1960s (Pontinia plain), probably due to extensive land use changes (land reclamation, forest fragmentation) occurred here (Amori *et al*. 2005, Zerunian & Reichegger 1997).

DISCUSSION

Our data corroborate the evidence of a recent range expansion of Red squirrel in hilly and plain sectors of Tyrrhenian Central Italy, confirming what was recorded in neighboring Mediterranean areas (e.g., Southern Tuscany: Sforzi & Ragni 1997). A progressive recolonization of hilly and plain sectors with a high number of sightings from the end of 1990s of the 20th Century and with an increase from 2005 to present, most of them in areas up to 600 m a.s.l. Clustering of the time-scaled similarity among the areas (Fig. 1) suggests a recolonization presumably moving away from Northern Latium (Volsini Mts., Cimini Mts., Maremma, respectively sectors 5, 6 and 1 in Fig. 1) towards some hilly areas near Rome (e.g., Sabatini Mts., Tiber River Valley; and from 2000s, Tolfa Mts., respectively sectors 8, 4 and 7 in Fig. 1).

The Red squirrel is known as a fragmentation-sensitive species (e.g., Celada *et al*. 1994, Delin & Andrén 1999, Amici & Battisti 2009, Mortelliti *et al*. 2009, 2010, 2011, Spinozzi *et al*. 2012), sensitive to habitat loss and degradation (e.g., due to intense coppice management), although its re-colonization ability has been highlighted by Wauters & Dhondt (1992). The role of ecological barriers has also been emphasized by genetic studies from Italy (Trizio *et al*. 2005). Furthermore, it has been demonstrated that it is vulnerable to competition with *Sciurus carolinensis* where these two species occur syntopically, and an extensive literature speculating on the ecological reasons why the Grey squirrel outcompetes the Red one does exist (e.g. see Bertolino & Genovesi 2003, Gurnell *et al*. 2004, 2006, Wauters & Martinoli 2008).

In this regard, a serious potential threat to the conservation of the Red squirrel in Central Italy may be posed by the spread of the Grey squirrel from Umbria region, where a viable, free-ranging population does exist near Perugia, at about 50 km from the Latium region (Paoloni *et al*. 2012).

Probably, the suitability of a large set of forest patches in hilly and plain areas favouring the colonization of this species is increased in the study area, where large extensions of deciduous and artificial conifer forests occur (28.6 % of the regional surface: Regione Lazio 2000). We suggest that these geographic and temporal patterns mirror some recent changes in (i) temporal and spatial regime

of coppice management (from 1960s, mainly consisting in an increase of rotation cycle and in the number of standards utilized, thus causing an aging of many forest stands) (Bernetti 1995), (ii) abandonment of traditional farming and cultivation of mountainous areas, leading to an increase of forested area (Piussi & Pettenella 2000), (iii) implementation of conservation measures in nature reserves and in Special Areas of Conservation (from the second half of 1970s; e.g., Regione Lazio 1998), (iv) the aging of coniferous afforestations (mostly from 1950s: Romano 1986, Mercurio 2004), (v) changes in its behavior, at least in urbanized and suburbanized areas where this species lives in proximity with man (Amori *et al*. 2009). With regard to point (i), we have to note that the presence of several standards is a key factor in determining the quality of coppice for the species, as pointed out also in studies carried out in the UK (Gurnell *et al*. 1992).

We identify the above points as co-occurring factors supporting range expansion of the species in last decades. These causal factors may explain range expansion of this rodent occurring also in other Mediterranean landscapes (e.g., Bon *et al*. 2008).

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