Patterns of spatial overlap in a monogamous large rodent, the crested porcupine

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ABSTRACT

The crested porcupine *Hystrix cristata* is a large rodent which pairs for life. We studied the space use of 17 female and 9 male radio-tracked porcupines in an evergreen coastal woodland ("macchia", EW) and in an agricultural estate (AE), with special reference to the use of cultivations. Home range sizes of male porcupines (4.72–323.40) ranged around 114 ha (median) during the warm period (April–September) and 162 ha during the cold one (October–March). Home ranges of females (2.48–323.40) were *c.* 91 ha during the warm period and *c.* 143 ha during the cold one. Habitat composition and selection changed from the cold to the warm months, with porcupines being present in agricultural areas especially in the latter. Home range overlap between members of the same pair varied from 57% to 97% (median, 75%). Habitat selection was analyzed at the second (within study area) and at the third (within home range) order of selection. Within study areas, porcupines avoided cultivations and selected habitats with dense vegetation, providing cover and food. Within home ranges, in the warm period, porcupines selected agricultural areas in EW, where this habitat represented a minor portion of the study site. In that season, the Mediterranean "macchia" is a poor source of food, forcing porcupines to travel long distances to reach feeding sites. No significant difference of habitat selection within home ranges was detected between members of the same pair. Cultivations may play a key-role for porcupine survival, especially in poor habitats, as they provide abundant food resources in the warm period.

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1. Introduction

Mating systems are strongly influenced by key ecological factors, *e.g.* intensity of predation, distribution and quality of food resources and, in particular, parental care. Monogamy, in which neither sex may access more than one mate (Emlen and Oring, 1977), is a mating strategy occurring in less than 5% of mammalian species (Kleiman, 1977). This behaviour may occur when the participation of both parents is required for the survival of offspring (*i.e.* obligate monogamy) or when widely dispersed mates or other resources make polygyny or polyandry disadvantageous (*i.e.* facultative monogamy: Wolff and Sherman, 2007). In most small rodents, monogamy has been inferred by observations in captive

conditions, sometimes integrated by spatial behaviour studies, *i.e.* analysing home range overlap of males and females, whereas the picture is even less clear amongst large rodents (Wolff, 1985, 1989).

The crested porcupine *Hystrix cristata* L., 1758 is a large, non-territorial rodent with a discontinuous, wide distribution range, from Morocco to Libya, and from Senegal to Ethiopia and Central Tanzania, also occurring in Italy (Mori et al., 2013; Mori and Lovari, 2014). Bulbs, tubers, vegetables and fruits build up the staple of its diet (Bruno and Riccardi, 1995). Anecdotal information from captive individuals would suggest monogamy for this species (Mohr, 1965; Felicioli et al., 1997), although further confirmation of this issue is needed from free-ranging porcupines.

Lovari et al. (2013) monitored a total of 20 radio-tagged adult, paired crested porcupines in four areas of different habitat richness, defined as "a function of the number of habitat types (*i.e.* main vegetation cover) per ha, within each home range". For both sexes, home range size was influenced by habitat richness and distance from den

to food rich areas, with a significantly inverse exponential relationship. On the other hand, Sonnino (1998) reported that, at night, two crop feeding porcupines spent *c.* 42.% of active fixes in the ecotone, nearly 30% in woodland and as many in fields or fallows, while two individuals feeding on natural food resources stayed mostly in woodland and scrubwood (69%). Species select resources with the best trade-off between life requirements and potential threats (*e.g.* Johnson, 1980; Morris, 2003; Piper, 2011; Castillo et al., 2012). The determinants of animal movements (*e.g.* food and mate search: Lott, 1990) may be identified through studies of habitat selection (*e.g.* Mortelliti and Boitani, 2008; Wasko and Sasa, 2012; Lovari et al., 2013). Food and mate search and predator avoidance are the main determinants of animal ranging movements. Disentangling the effect of these factors may be difficult (Cody, 1981; Manly et al., 2002). Thus, habitat selection could best be understood by comparing it in different study sites, where only one of these variables changes.

Although crested porcupine is legally protected in Italy (National Law 503/1981, the transposition of the Convention of Berne 1979; National Law 157/1992; DPR 357/1997, the transposition of Habitat Directive 92/43/CEE), its conservation determines reimbursement costs for crop damages (*e.g.* Alkon and Saltz, 1985; Sharma and Prasad, 1992; Khan et al., 2000), *e.g.* a total of up to 19,500 euros/year claimed by farmers in Southern Tuscany (*c.* 8325 kmq), Italy, in recent years. Thus, some information on habitat selection by this rodent may help understand the importance of cultivations as determinants of its spatial behaviour.

Therefore, our study was aimed to assess the seasonal variation in home range size, range overlap and habitat selection in pair members of *H. cristata*, at study area and individual home range levels, in two areas characterized by contrasting habitat composition. We predicted that (i) movements of porcupines would change seasonally in relation to a spatially fixed factor (*i.e.* den location) and a spatially variable one (food-rich areas, *i.e.* cultivations); (ii) home range overlap would be extensive between partners of the same pair, if the species is monogamous; (iii) habitat selection would not differ between partners of the same pair.

2. Materials and methods

2.1. Study area

Our study area included two sites of different habitat/food richness located in Southern Tuscany (Figs. 1 and 2), about 70 km far each other, and was characterized by different habitat types. Habitat types were classified in ten exclusive categories, as defined from both satellite images (Google Earth. Accessed on 10th July 2013) and ground confirmations: deciduous wood, pinewood, tall fallow, short fallow, agricultural area, wetland, shrubwood, Mediterranean "macchia" (*i.e.* a scrub type), abandoned olive grove and coastal dune.

One study site (about 400 ha, 140–250 m a.s.l.) was an agricultural estate, "Le Malandrine" (hereafter, AE) located in the municipality of Buonconvento–Siena (43°10′N, 11°30′E), in a fragmented rural area interspersed with fallows and small woods (Fig. 1-AE). This site was characterized by a Mediterranean climate, with warm, dry summers and relatively mild temperatures throughout the year. Average monthly temperatures were always below 25 °C in summer and above 0 °C in winter. Monthly average rainfall was about 61 mm, with a peak during the autumn (October and November). Snowfall was a very rare (1–2 days per year) event (Lovari et al., 2013). About 67% of the area was characterized by cereals, sunflowers, lucerne, and 4% abandoned fields. Deciduous wood (*Quercus cerris*, *Q. pubescens*, *Ostrya carpinifolia* and *Fraxinus ornus*) and shrubland (*Spartium junceum*, *Prunus spinosa*, *Ligustrum*

vulgare, *Crataegus monogina*, *Cornus sanguinea*, *Rosa canina* and *Rubus* sp.) covered, respectively, 10.5% and 6.2% of the territory (Fig. 1-AE).

The other study site (about 620 ha, 0–229 m a.s.l.) was mainly an evergreen Mediterranean "macchia" woodland (hereafter, EW), in a protected area (Maremma Regional Park) along the Tyrrhenian coast (Province of Grosseto: 42°39′N, 11°05′E). The climate was meso-Mediterranean; monthly average rainfall was about 58 mm (mean temperature of 6 °C in January/February and average temperatures of 23 °C in July/August; Lovari et al., 2013). The study area was characterized by pinewood (*Pinus pinea* and *P. pinaster*: 25.9%), with a coastal dense belt of shrubs (*Juniperus oxycedrus*, *J. macrocarpa*, *Smilax aspera*, *Calycotome spinosa*: 3.0%). Mediterranean "macchia" (sclerophyllic scrubwood with *Quercus ilex*, *Phyllirea* sp., *Cystus* sp., *Rosmarinus officinalis*, *Erica multiflora*, *Pistacia lentiscus*) covered the 25.6% of the territory. Main cultivations (24.0%) were sunflower, corn, wheat and oilseed rape. About 15% of the site was covered by meadows, uncultivated fields (tall fallow), and abandoned olive groves. The remaining 6.3% was constituted by wetland vegetation (*Salicornia glauca*, *Juncus* ssp.) and coastal dunes (*Ammophila arenaria*, *Anthemis maritimum*, *Pancratium maritimum* and *Medicago marina*, Fig. 1).

2.2. Radio-tracking and habitat selection analysis

Individuals were trapped in home-made metal box traps (55 × 75 × 100 cm), baited with fruits, vegetables, corn and peanut butter, and activated for a minimum of seven nights per month (Lovari et al., 2013). Captured crested porcupines were sedated according to a standard protocol (*cf.* Massolo et al., 2003). If captured individuals were adult (permanent premolars erupted: Van Aarde, 1985), they were equipped with a radio-collar (VHF radio-collars: AVM, USA; Biotrack, UK; Televilt, Sweden).

Each crested porcupine was radio-tracked for one night every 4 days and one full day every 15 days, for a minimum of 6 months and a maximum of 12 months. All porcupines (8 females and 4 males in AE; 9 females and 5 males in EW) were monitored (median n fixes/individual/period, 264.5; range, 136–548) for 14–20 h/week/individual (Appendix 1). Two periods were recognized according to ambient temperature: a warm one (April–September) and a cold one (October–March). In the first week from radio-tagging, porcupines were monitored on a 24 h cycle. Later on, fixes were collected mainly in dark hours, because of the consistent nocturnal habits of *H. cristata* (Corsini et al., 1995; Mori et al., 2014a). For the aims of our study we did not look for statistical independence of fixes between successive locations (Swihart and Slade, 1985), but for their biological independence (*e.g.* Lair, 1987), using a minimum time interval between successive locations long enough to allow any radio-tagged porcupine to cross entirely its home range.

The mean location error was determined by positioning several radio-tags in *c.* 150 known locations, at ground level, and by calculating the difference (in metres) between actual and estimated locations. Comparable radio-tracking procedures were used in both study sites: a mixture of distance (1 fix/120 min, in EW; 2 fix/120 min, in AE. Mean location error = 62 m, in EW; 28.7 m, in AE) and homing-in locations (1 fix/15 min. Mean location error = 14.28 m), for a mean value of 35 fixes/month/individual, in EW; 27 fixes/month/individual, in AE. Boundaries of each study area were defined by a total 100% Minimum Convex Polygon (MCP) encompassing all the radiolocations, with a 150 m wide buffer-area (*cf.* Castillo et al., 2012). Seasonal home range sizes were estimated through the MCP 95% and the 95% fixed kernel (Ker 95%: Lovari et al., 2013). MCP 95% and Ker 95% estimates were calculated through the statistical software R 2.13.1, packages *ade4* (Dray and Dufour, 2007) and *adehabitat* (Calenge, 2006). The software RANGES V (Kenward