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RECORD LITTER SIZE IN THE EURASIAN RED SQUIRREL (*SCIURUS VULGARIS*)

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ABSTRACT - In the literature, litter size in red squirrels *Sciurus vulgaris* ranges between 1-6 offspring. Here we report a record litter size, in Europe, of 7 young (6 males, 1 female), marked in the nest when 10-14 days old, in a high-elevation mountain pine habitat, Lombardy Alps (Northern Italy). We discuss implications of extreme winter conditions for life-history strategies and possible trade-offs between high reproductive investment and short life-span.

Key words: *Sciurus vulgaris*, litter size, life-history tactics, marginal habitat, mountain pine forest

RIASSUNTO - ***Dimensione eccezionale della cucciolata di scoiattolo comune* (Sciurus vulgaris)**. Dai dati di letteratura, il numero di esemplari per cucciolata nello scoiattolo comune *Sciurus vulgaris* varia generalmente da 1 a 6. Nel presente lavoro viene riportata per la prima volta in Europa la segnalazione di una cucciolata di 7 esemplari (6 maschi e 1 femmina), che sono stati marcati nel nido all'età di 10-14 giorni. Il nido è stato individuato in un habitat forestale dominato da pino mugo nel Parco Nazionale dello Stelvio, in Lombardia. Vengono prese in esame le implicazioni che le condizioni estreme, nel periodo invernale, possono avere sulle strategie riproduttive dello scoiattolo comune.

Parole chiave: *Sciurus vulgaris*, dimensione cucciolata, strategia riproduttiva, habitat marginale, foresta montana di conifere

INTRODUCTION

In food-limited habitats, the energy transferred by a lactating female to her offspring is limited by her ability to locate and ingest sufficient amounts of food prior to (capital breeders) or during (income breeders) lactation (Reznick, 1992; Weiner, 1992; Humphries and Boutin, 2000). Under constraints of food availability, physiological energetic ceilings and life-history trade-offs (e.g. smaller litters have higher individual survival than larger ones), a breeding female should produce the number and size of offspring, each breeding season, that maximises its lifetime reproductive success (Williams, 1966; Clutton-Brock, 1988; Humphries and Boutin, 2000).

Red squirrels (*Sciurus vulgaris*) can be considered income breeders since seasonal reproductive success depends on the amount of (high-quality) food to which a breeding female has access (Wauters and Dhondt, 1989, 1995; Wauters and Lens, 1995). Variation in lifetime reproductive success among females is mainly determined by variation in breeding lifespan (thus age of first reproduction, lifespan), but also by differences in litter size (measured in most cases around weaning-age, 8-12 weeks, Wauters *et al*., 1993; Wauters and Dhondt, 1995; Wauters and Lens, 1995), and the probability of juveniles/subadults to settle success-sfully (Wauters and Dhondt, 1993, 1995; Wauters *et al*., 1993). The latter depends on body mass differences, with heavier young being more likely to settle than those of lower body mass, which is partly affected by the mother's mass at the onset of breeding (Wauters and Dhondt, 1993; Wauters *et al*., 1993). Average litter sizes, at weaning, also differ between years in relation to seed-crop size of the major feeding trees (Wauters and Lens, 1995; Boutin *et al*., 2006).

Here we report an exceptionally large litter size, never recorded in any field study on free-ranging red squirrels in Europe.

STUDY AREA

Squirrels were studied in the central Italian Alps in a dwarf mountain pine (*Pinus mugo*) woodland with trees with both prostrate (3%) and arboreal habit (96%), nearby the artificial Cancano lakes (46°32' N, 10°16' E) in the Stelvio National Park. The study area covers 54 ha at a mean elevation of 1950 m. a.s.l. The area is almost entirely composed of a dense mountain pine forest (average tree density 3308 trees/ha) with few dead trees (1%). Average diameter at breast height is 14 cm. The undergrowth is composed of heather (*Erica carnea*), juniper (*Juniperus com-munis*), blueberry (*Vaccinium myrtillus*) and lingonberry (*Vaccinium vitis - idea*). The mountain pine habitat is at the upper-limit of the squirrel's distribution and is character-rised by long and cold winters (e.g. winter November 2005-April 2006: mean monthly minimum temperature from -11.7°C in January to -2.7°C in April; mean monthly maximum temperature from -2.6°C in December to 6.7°C in April), with permanent, but patchy snow cover between December and mid to late April, with marked annual variation in snow depth.

METHODS

Squirrels were live-trapped in three separate sessions per year, starting March-April, June-July and September-October. A trapping session involved the use of 20 to 30 ground-placed Tomahawk traps (models 201 and 202, Tomahawk Live Trap Co., Wisconsin, USA). Traps were placed on a grid, with distances of 100-150 m between traps and average trap density of 0.6-0.7 traps ha^{-1}. Traps were pre-baited with sunflower seeds and hazelnuts four to six times over a 30-day period, and then baited and set for eight to 12 days, until no new, unmarked squirrels were trapped for at least two consecutive days. Traps were partly covered by dark plastic to give shelter from rain or cold, and checked two-three times per day. Each trapped squirrel was flushed into a light cotton handling bag with a zipper (Wauters *et al*., 2007), or a wire-mesh 'handling cone' to minimise stress during handling, and individually marked using numbered metal ear-tags (type 1003 S, 10 by 2 mm, National Band and Tag Co, Newport, Kentucky, USA). It was weighed to the nearest 5 g using a Pesola spring-balance (Pesola AG, Baar, Switzerland),

and the length of the right hind foot (without nail) was measured (0.5 mm) with a thin ruler (Wauters *et al*., 2007). Sex, age, and reproductive condition were recorded following Wauters and Dhondt (1995). At first capture a skin sample was taken for DNA analysis using a biopsy punch of 3 mm diameter (Stiefel laboratories Milano, Italy). All squirrels first caught as juveniles (6 - 15 weeks old, body mass below 250g, Wauters *et al*., 2007) were defined as locally born offspring (see also Wauters and Dhondt, 1995). Moreover, by radio-tracking adult females in 2007 (Wauters and Dhondt, 1995; Wauters and Lens, 1995; Wauters *et al*., 2005), we were able to locate the nursing nest of two lactating females and tag their offspring (Wauters *et al*., 1993; Wauters and Dhondt, 1995). These juveniles were taken by hand from the nest when the female was absent (as revealed by radio-transmitter signal), handled, sexed and marked on the ground, and delicately put back in the nest. To minimise stress and handling time we did not weigh them. The total operation of climbing the tree, taking and handling the young, and returning them to the nest took less than 20 minutes.

The next day, we checked whether the mother still nursed the young in the same nest or whether she had moved them to a new nest. None of the litters was abandonned by the female (Wauters *et al*., 1993; Wauters and Dhondt 1995; Wauters and Lens 1995; Humphries and Boutin 2000; Boutin *et al*., 2006).

RESULTS AND DISCUSSION

Female F2340 was radio-tagged on 9 March 2007, weighing 295g, when in pre-oestrus conditions. She was recaptured pregnant on 24 April (body mass 330g) when palpation of the abdomen revealed the presence of three embryos. The nursing nest was found on 16 May and the three young (1 male, 2 females) were marked on 31 May 2007. Young were still blind, had already a dense coat and their lower incisors just started to erupt. Based on these characteristics their age was estimated at 20-25 days (Eibl-Eibesfeldt, 1951; Tittensor, 1977). On 26 June, when offspring was about 7 weeks old, the female was recaptured and still lactating, indicating that she successfully raised her litter. Body mass was 325g.

On 22 June 2007, F2167 was marked and radio-collared. She was pregnant and weighed 350g. The nursing nest was found on 27 July and seven young (6 males, 1 female) were marked. Offspring was blind and had only a downy fur cover emerging, typical for 10-14 day-old squirrels (Eibl-Eibe-sfeldt, 1951; Tittensor, 1977). A litter of seven was the largest one ever recorded for red squirrels (but see Ognev, 1940). In the UK, average litter size between birth and first weeks of life was 3.2 young (N = 81, Tittensor, 1977), and reviews reported litter sizes ranging from 2-5 (Lange *et al*., 1994) and 1-4, max. 6 young (Tittensor, 1977; Lurz *et al*., 2005). We only found a single citation from the (translated) Russian literature on “10 squirrels found in a nest” (in Ognev, 1940), but it is not clear whether this refers to a single litter. Detailed capture-mark-recapture studies in Western Europe reported maximum litter size (between birth and 1-week old) of four and average litter size of 3.0 ± 0.9 (N = 9, Wauters and Lens, 1995). Finally, even in a pine wood with supplementary feeding, average litter size was not higher than in natural populations (mean ± S.D. = 3.17 ± 0.47 and 2.40 ± 0.31 young in

two consecutive years, Shuttleworth, 1996 cited in Lurz *et al.*, 2005). Offspring losses during lactation can be high, and even complete litters can be lost due to predation or when body condition of the mother is reduced (loss of body mass between birth and weaning, Wauters and Dhondt, 1989, 1995; Wauters and Lens, 1995; Lurz *et al.*, 2005). In the case of the litter of seven, two juveniles were observed at less than 50m from the nest tree on August 31st and September 1st (ca. 6-7 weeks old), foraging on pine cones. One of them, a male, was recaptured at the end of October (ca. 3.5 months old), when also a male of the litter of three was trapped (nearly 6 months old).

Finally, trapping revealed that the other two resident adult females (F2359, body mass 295g, and F2429, body mass 395g) also produced a litter (caught in lactation on August 31st and September 2nd , respectively) and three juveniles were caught and marked on 1 and 2 September 2007 when about 10-12 weeks old (200 – 230g). One of the females probably had two litters in 2007, since we also captured a small juvenile (100g, ca. 6-7 weeks old) on 25 June 2007. This will be tested using parent assignment tests on DNA samples. Overall offspring sex-ratio (10 males, 4 females) was not different from even ($\chi^2_1 = 2.57$; P = 0.11). Body mass differed strongly among breeding females (range 295 – 395g), but two of them had a high lactation mass for female squirrels in populations throughout the Alps (Wauters *et al.*, 2007).

How can we explain this extremely high reproductive rate (14 offspring from 4 adult females = 3.5 juv./reproducing female)? We suggest that in this extreme habitat, with strong annual fluctuations in seed-crop size and thus food availability and long and cold winters with deep snow-cover, winter mortality can be very high. This was confirmed by our preliminary data (winter survival September 2006 - March 2007 = 0.25). Hence, the probability that squirrels only have one or two years to reproduce is high and females should adopt a trade-off between high reproductive investments when food abundance is high, against reduced survival (Williams, 1966; Clutton-Brock, 1988). We therefore predict that in mountain pine forests, red squirrels are selected to reproduce as yearlings and to invest heavily in reproduction in the first year after birth they have access to a rich seed-crop. To test this hypothesis, we will continue to monitor annual seed-crop production, squirrel numbers, reproductive success of all resident females and offspring survival/recruitment over the following years.

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