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Abundance and survival of the hazel dormouse *Muscardinus avellanarius* in a temporary shrub habitat: a trapping study

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The knowledge of demography and abundance of the hazel dormouse *Muscardinus avellanarius* in Sweden in different habitats is poor. The hazel dormouse is classified as care-demanding on the national Red List in Sweden. In this study, dormice were live-trapped in a temporary mixed high shrub habitat in South-central Sweden, in order to estimate density and survival, and to evaluate a trap-based capture-mark-recapture method. Data on different trapping efforts suggested that 175 trap nights per ha were required for trapping most adults. The method seemed to be applicable for studies of dormice under natural conditions. The density of dormice was estimated at seven individuals per hectare. The average adult year-to-year survival rate was 56%–74%, which is higher than previously reported for this species. In our study, the trapping area should preferably be larger than 3.2 ha to avoid edge effects on density and survival estimates. To conclude, factors related to the survival of adult dormice might be important for the viability of populations.

1. Introduction

The hazel dormouse, *Muscardinus avellanarius*, occurs in deciduous woodlands with a well-developed understorey and shrubby habitats (Hurrell & McIntosh 1984, Berg 1990, Bright & Morris 1990, Gurnell *et al.* 1992). In addition to vegetation structure, a high diversity of deciduous shrub and tree species seem to be essential features of preferred habitats (Bright & Morris 1990, Berg & Berg 1997). In Sweden, the species has expanded its distribution in recent years (Berg 1990), possibly favored by the increased occurrence of deciduous vegetation on abandoned farmlands (e.g., Ahlén & Tjernberg 1996). Early successions of deciduous vegetation on clear-cuts have probably also provided temporary new habitats for the species (Berg 1990).

The hazel dormouse is classified as care-demanding on the national Red List (Ahlén & Tjernberg 1996). The knowledge of the basic biology of the species is limited (but *see* Hurrell 1980). It is a long-lived hibernating species, and survival rates of adults have been estimated at 40% (Catzeflis 1984). Females normally have only one litter per year, even though two litters were recorded (Gaisler *et al.* 1977). The juveniles do not breed until after their first hibernation (Gaisler *et al.* 1977). Newborn litters may be found throughout the season, but in Sweden most litters seem to be born in June–July (L. Berg unpubl.). The juveniles are independent at the age of 40–45 days (Wachtendorf 1951). To what extent the species is territorial is not sufficiently investigated (but *see* Bright & Morris 1991). Thus, additional knowledge of the abundance and demography, also in temporary habitats such as clearcuts and overgrowing pastures, is important for successful conservation of the species. At present, density data from temporarily occupied dormouse habitats are scarce, and data on survival rates are lacking in most parts of the distribution range (but *see* Catzeflis 1984). Generally, dormouse studies have been based on nest surveys (Hurrell & McIntosh 1984, Berg 1996, Berg & Berg 1997) and nestbox studies (e.g., Löhrl 1960, Pielowski 1960, Gaisler *et al.* 1977, Schulze 1970, 1986, Bäumler 1990, Morris, Bright & Woods 1990), while trapping methods, as in the present study, have been used more seldom (but *see* Bright & Morris 1990).

The aim of this study was to investigate whether or not a trap-based capture-mark-recapture method could be used to study densities and survival of the hazel dormouse, and to supply estimates of abundance and survival from a temporarily occupied habitat (a conifer planted pasture) at the northern edge of the species range.

2. Study site and methods

The study was conducted in 1988–1992, at Misterfall (57°58´N, 15°30´E), close to Kisa, in the southern part of the Östergötland county, in southern Sweden. On a large scale (> 100 km^2), the landscape was dominated by coniferous forests. The study site was a 5 ha old pasture, which was planted with spruce *Picea abies* about twenty years before this study was made. Young oaks *Quercus robur*, with an estimated coverage of 22%, birches *Betula spp.* (10%) and hazel *Corylus avellana* (16%) were abundant and, together with planted spruce, constituted a continuous dense shrub layer (2–3m) with only a few small clearings. Juniper *Juniperus communis* (9%) and aspens *Populus tremula* (3 %) were also relatively common.

Dormice were live-trapped in commercial rat-traps from JÄRNIA (9 × 9 × 26 cm). The traps were baited with hazelnuts and small pieces of apple. The traps were placed at a height of 1.5–2.0 m above ground in forked branches and checked every morning. Initially, checks were made also in the evenings, but then the traps were always found empty. The trapping was conducted in squares (Fig. 1) with 25 traps in each (S1, S2, L1–L4), except for one rectangle (L5) with 20 traps. At the initial stage in 1988–1990 two small squares (S1, S2) enclosing an area of 1 600 m^2 each where the traps were set 10 m apart were used. Since dormice were found to move over larger areas, the distance between the traps was extended to 20 m in 1989 (L1 and L5). During 1989 and 1990, trapping was conducted in both small and large squares, while in 1991 and 1992 only large squares were used for trapping (*see* Table 1). The trapping was conducted for three consecutive nights, approximately once a month during the summer (May–September). When dormice were trapped in the large squares, they were trapped for three nights, and then the traps were moved to the other two squares. The traps in the four large squares enclosed an area of 32 400 m^2. However, when density was calculated (Table 2), the trapped area was considered as the area delimited by the traps, with half a home range added at the edges (Hansson 1981). A rough estimate of a home range size from our trapping data was 0.5 ha, (mean half ranging diameter was estimated to 40 m from trapping positions), if a circular home range shape is assumed. This estimate is in accordance with the results from radiotracked dormice by Bright & Morris (1992), who found the mean minimum convex polygon range area per tracking session to be 0.45 ha.

All captured dormice were sexed, weighed, and individually marked by ear clipping (Twigg 1978). The animals were classified as juveniles or adults. Animals weighing less than 15 g were classified as juveniles (i.e. born the same year), and animals weighing 15 g or more as adults, since marked juveniles had not reached this weight by the time of the last trapping session in early September, and no adults of known age had a weight below 15 g (own observation). Animals of uncertain age were excluded.

Furthermore, the reproductive status of females was determined, i.e. whether they were lactating or visibly pregnant. The proportion of reproducing females was calculated as the number of reproducing females divided by the total number of adult females per year.

3. Results

3.1. Density

In 1988–1992 a total of 719 captures were made during 4 058 trap-nights (mean = 0.177 captures

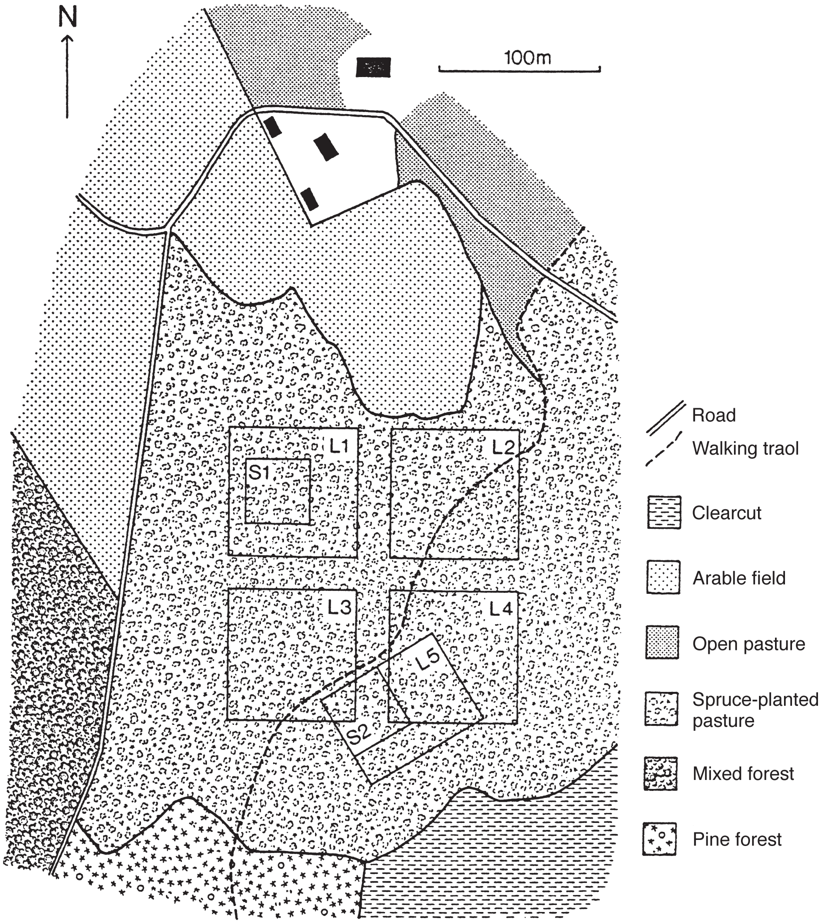

Fig. 1. Map of the study site. S1–S2 indicates small squares where trapping was done 1988–1990 and L1–L5 indicate large squares where trapping was done 1989–1992 (*see* Table 1).

per trap night). The density of the dormice superficially seemed to vary considerably between years (Table 2). However, the area and trapping effort also varied between the years (range 96.2–252.5 trap-nights ha^{-1}), and the estimated density of the dormice in different years was correlated with the trapping effort for both adults (linear regression, $r = 0.88$, df = 1, $p < 0.05$) and juveniles ($r = 0.94$, df = 1, $p < 0.05$). Plotting of a subset of data (S1 and S2 1990), in which the most intensive trapping was done, suggests that approximately 175 trap-nights per ha were required to trap most adults in an area (Fig. 2). Such a trapping effort was only reached in 1990, thus the densities in the other years (especially in 1992) were probably underestimated.

Furthermore, trapping efficiency (i.e. no. of captures of adults per trap-night, all traps and years included) was significantly lower early in the season (May–June 1990–1991) than late in the season (July–September 1990–1991, *see* Fig. 3), indicating that the required trapping effort may be lower than 175 trap nights per ha, when trapping is done only late in the season. The trapping frequency did not differ much between the large squares (19.5 trappings per 100 trap nights and hectare) and small squares (22.2 trappings per 100 trap nights and hectare). This suggests that the

Table 1. Number of trapnights included in the analyses in each of the seven squares, during the years 1988 to 1992.

Year	S1	S2	L1	L2	L3	L4	L5
1988	125	125	0	0	0	0	0
1989	300	150	75	0	0	0	60
1990	225	225	225	0	0	0	180
1991	0	0	225	225	225	225	180
1992	0	0	150	150	150	150	0

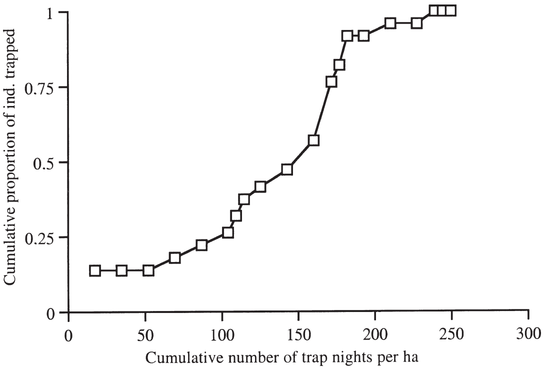

Fig. 2. Cumulative proportion of adult individuals trapped in relation to cumulative number of trap nights in S1 + S2 1990 (including traps from L1 and L5 situated within the small squares).

large squares with the lower density of traps (traps 20 m apart compared to 10 m apart in small squares) could be used without loss in trapping efficiency. The number of captured juveniles during the same period was zero in period 1 (25 May–5 June) and period 2 (25 June–5 July), three in period 3 (25 July–5 August) and 26 in period 4 (25 August–5 September). That is, late August and September is the most suitable period for trapping of juveniles. Thus, the real density of juveniles was probably higher than the figures presented here, since a large proportion of the trapping (ca. 60% of the trap nights) was done in late May–early August.

Adults were trapped on average 4.3 ± 0.3 (mean ± SE) times per year. Juveniles were trapped on average 1.9 ± 0.2 (mean ± SE) times during their first year. However, some adults (25.7%) were trapped only once during the study while others seemed to be attracted to the traps (e.g., one individual was trapped 45 times). There was a tendency for a higher proportion of males (57.3%) than females (42.7%) among the 75 trapped adults (*G*-test, $G = 3.2$, df =1, $p = 0.07$), while the proportion of females (52.2%) and males (47.8%) among 46 trapped juveniles was similar ($G = 0.2$, df = 1, $p = 0.68$).

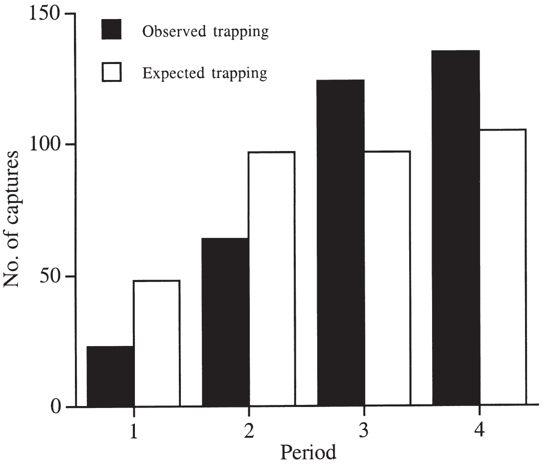

Fig. 3. Number of captures during different time periods in 1990 and 1991 (all traps included) in relation to expected number of captures, assuming equal trappability (corrected for number of trap nights). 1 = 25 May–5 Jun., 2 = 25 Jun.–5 Jul., 3 = 25 Jul.–5 Aug., 4 = 25 Aug.–5 Sep. Differences between time periods were significant (Chi-square test $\chi^2 = 40.9$, df = 3, $p < 0.001$).

3.2. Survival rates

The overall recapture rate between years was 56.4% for adult males (n = 43), 46.2% for adult females (n = 32), 54.8% for juvenile males (n =

Table 2. Number of dormice individuals and estimated density (no. of individuals per ha) of different age and sex captured during different years. M = males and F = females.

Year	Adults		Juveniles		Total	Area (ha)	Total density	Density	
	M	F	M	F				Adults	Juveniles
1988	7	4	3	4	18	2.9	6.3	3.8	2.4
1989	9	13	6	7	35	4.8	7.3	4.6	2.7
1990	19	13	6	11	49	4.8	10.2	6.7	3.5
1991	22	14	9	11	56	7.1	7.9	5.1	2.8
1992	14	6	1	1	22	6.8	3.3	3.0	0.3

22) and 34.5% for juvenile females ($n = 24$). However, our estimates of survival were complicated by edge effects (i.e. individuals trapped close to edges might move outside the area), and differences in the trapping effort between years. An analysis of the edge effects showed that 84 individuals (both juveniles and adults) trapped within 20 m from the edge (mean from all traps where an individual was captured) had a lower recapture rate in the following year (38.1%) than 92 individuals trapped more than 20 m from the edge of the area (53.3%, *G*-test, $G = 4.08$, df = 1, $p < 0.05$). Furthermore, recapture rates varied between years and seemed to be correlated with the trapping effort (Table 3), although the small sample size makes it difficult to test this hypothesis. At least the low trapping effort in 1992 seemed to be too low for estimating survival rates. Therefore, the figures presented here are minimum values, and the actual survival rates may be even higher. A subset of data, excluding individuals trapped within 20 m from the edge of the trapping area and excluding data from 1992, suggest that the overall survival between years for adult males ($n = 39$) was 74.4%, for adult females ($n = 23$) 56.5%, while sample sizes for juveniles were too small for calculating "corrected" survival rates. When the juveniles and adults were combined, there was a tendency (including the entire area and all the years) for a higher survival rate between years of the males as compared with the females ($G = 3.6$, df = 1, $p = 0.057$), whereas there was no difference between adults and juveniles, when combining the females and males ($G = 0.8$ df = 1, $p > 0.3$).

In general, surviving dormice were found in the same area as in the preceding year (mean ± S.E. distance between home range centres = 51 ± 6 m). However when ages were combined, the females (mean = 37.4 ± 7.4 m) were more philopatric than the males (mean = 61.0 ± 7.6 m, *t*-test, $t = 2.2$, $p < 0.05$). Furthermore, the adults (mean = 41.8 ± 6.3 m) were more philopatric than the juveniles (mean = 68.2 ± 9.8 m), when the males and females were combined ($t = -2.3$, $p < 0.05$).

The proportion of the non-reproducing adult females was estimated at 61%. Year-to-year survival of the non-reproducing adult females (48%) was somewhat higher than that of the reproducing adult females (35.5%), although this difference was not significant ($G = 0.9$, $p > 0.3$).

4. Discussion

Earlier studies (Bright & Morris 1990) suggested that dormice are unlikely to be recaptured without very extended trapping programs. In contrast, this study showed that dormice can easily be recaptured, and that they might even be attracted to traps. A possible explanation of this variation between studies is differences in habitat structure, since our study was made in a shrub habitat without a high canopy (where dormice might avoid the traps), while the study by Bright and Morris (1990) was made in areas where canopy-forming trees were also present.

Our study suggests that about 175 trap-nights per ha, are required to capture most adults in shrubby habitats with no or few tall trees (Fig. 2). However, the trapping efficiency was significantly higher later in the season, possibly due to increased movements just before the hibernation period, when finding high quality food is crucial. Thus, the number of trap-nights required might be lower when the trapping is concentrated in late season.

4.1. Density and sex ratio

The estimated density of the dormice found in this study (up to 6.7 adults per ha) was relatively high, even though few other studies provide data on density of dormice expressed as individuals ha^{-1}. Gaisler *et al.* (1977) estimated the density of hazel dormice at 3–4 adults per ha, while Bright & Morris (1993) estimated the density of dormice in a diverse low-growing woodland at about 12 indiv. ha^{-1} and to about 6 indiv. ha^{-1} in a deciduous woodland managed as coppice-with-standards in the past. However, in the study by Bright & Morris (1993) it was not specified whether or not juve-

Table 3. Recapture rates between years (sexes and ages combined) and and trapping effort (trap nights per ha and year) for the years 1989–1992.

Year	Trap-nights ha^{-1}	Recapture rate (%)
88–89	193.8	57.6
89–90	252.5	58.8
90–91	170.9	52.6
91–92	96.2	32.6

niles were included in these estimates, and densities may have been increased considerably, due to the use of nest boxes. However, as compared with other small mammals, such as voles (*Clethrionomys spp.*) or wood mice (*Apodemus spp.),* the densities of hazel dormice is generally very low (French *et al.* 1975).

In our study, the proportion of males (57.3% of adults) was found to be slightly higher than that of females, although the difference was not significant. There are several possible explanations to this observation. The observed skewed sex ratio may be due to a higher mortality in females, but it may also be a result of a higher trappability of males, since females are likely to be more stationary during breeding. However, a slightly skewed sex ratio is also found in other studies of the species (Catzeflis 1984, Likhachev 1966a, Schultze 1970, 1986), where the captures were made in nestboxes. Thus, the size of the reproducing population, i.e. the effective population size, may be smaller than the number of captured individuals, due to a skewed sex ratio. Furthermore, the size of the reproducing population is lowered considerably, due to the high proportion of non-reproducing females.

4.2. Survival and site fidelity

Few other studies on the hazel dormouse have attempted to estimate survival rates. Catzeflis (1984) made a three-year study with marked individuals in nestboxes, and estimated the survival rate of adults between years at about 40%. This estimate is considerably lower than the estimated survival rates of 56%–74% for adults in our study. Catzeflis (1984) also marked 82 juveniles in the second year of his study and recaptured 35% of these in the third year. Likhachev (1966b) estimated the proportion of juveniles that survived the first year to be 30%. These survival rates are probably also lower than in our site, although our sample size makes it impossible to calculate survival rates for juveniles that are corrected for trapping effort and edge effects.

4.3. Conclusion

In conclusion live-trapping of dormice in shrubby habitats without canopy trees seems to be a suitable method for studying density and survival, especially if natural conditions are preferred, since nest boxes might increase the density of dormice (Morris *et al.* 1990). One hundred and seventy five trap-nights per ha seem to be required for trapping most adults, although trapping effort probably could be reduced by concentrating trapping to late season (August and September). However, the trapping area should preferably be larger than the 3.2 ha used in our study to avoid underestimates caused by a large edge-area ratio. Bondrup-Nielsen (1983) concluded that the grid size should be at least 16 times an average home range to minimize effects of the home range size, shape and dispersion patterns when estimating density. In the present study, the grid size was approximately 12 times an average home range, and thus probably too small to give reliable estimates. Our study showed that the dormice density was high in the studied temporary shrub habitat, suggesting that similar habitats might harbour relatively large proportions of the Swedish population. However, the effective population size was reduced due to a large proportion of non-reproducing females. The studied population showed high year-to-year survival rates (56%–74% for adults), and survival rates of dormice seem high compared with other small mammals. Theoretical models of population dynamics predict that relatively long-lived species can withstand fluctuations in reproductive success and juvenile survival more than decreases in adult survival (Burgman *et al.* 1993). Thus, factors related to survival of adult dormice, e.g., high quality hibernation sites, might be more important for the viability of populations than those related to reproductive success. These ideas need further investigations, since the reasons for variation in adult survival at present are poorly known.

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