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Radio-Tracking Suggests High Dispersal Ability of the Great Capricorn Beetle (*Cerambyx cerdo*)

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Abstract Dispersal ability is among the key factors affecting the survival of species in today's fragmented landscapes. One of the most straightforward methods to provide direct measures of animal dispersal is telemetry. Despite its merits, this method has rarely been used for saproxylic beetles. In this study, we examined dispersal ability of the Great Capricorn beetle *Cerambyx cerdo* (Coleoptera: Cerambycidae), an endangered veteran oak specialist. Using a radio-tracking approach, we tracked 26 individuals (15 males and 11 females) equipped with transmitters for 4 to 17 days (median 14). We observed no disturbance of movements or flight problems due to the transmitter. The daily probability of movement by an individual was 64% and the longest displacement in one day was 1498 m for males and 1080 m for females. For 15% of all individuals, the tracking distance covered was >2200 m. Our results indicate that *C. cerdo* individuals often move among trees over an area of several kilometres. Such findings contrast with previous results based on a mark-recapture study. The relatively high mobility of the species should be reflected in strategies aiming at its conservation.

Keywords Population ecology · species protection · coleoptera · flight · oak woodlands

Introduction

Knowledge of species mobility patterns might provide crucial information in management decisions concerning e.g. pest or threatened organisms. Of the several methods used to understand dispersal ability of saproxylic beetles, some are more suitable for answering

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specific questions than others (Ranius 2006). While genetic studies and occurrence patterns allow for assessing the long-term effect of dispersal at larger spatial scales, studies using mark-recapture methods (MR) or telemetry obtain direct measures of individual dispersal.

Due to the differing nature of MR and telemetry, the results are not always consistent (Chiari et al. 2013). Indeed, MR tends to underestimate mobility, especially for species with high dispersal ability (Kissling et al. 2014). As marked individuals may leave the study area, the outcome of MR is therefore highly influenced by the spatial scale of the study (Elek et al. 2014). Telemetry overcomes this limitation by focusing on just a few individuals that can be located in regular intervals. Unlike MR, however, in telemetry studies the behaviour of tracking individuals might be affected by the transmitter attached to them. Therefore, the combination of both methods appears to be the best solution how to overcome these limitations. Unfortunately, telemetry studies are restricted by the size of the study species and as such their utility in insects is highly limited (Kissling 2015). Among saproxylic beetles, only *Osmoderma eremita* (e.g. Hedin et al. 2008; Dubois and Vignon 2008) and *Lucanus cervus* (Rink and Sinsch 2007) have been studied so far in Europe.

The Great Capricorn beetle (*Cerambyx cerdo*) is a large and emblematic inhabitant of old, sun-exposed oaks (*Quercus* pp.). It is a globally threatened and internationally protected beetle (Council of the European Communities 1992), although it may hold pest status, especially in the Mediterranean region (Torres-Vila 2017). The beetle is considered to be rather mobile (Drag and Cizek 2014), a trait shared by other medium-sized and large flying longhorns (e.g. Smith et al. 2001; Drag et al. 2011; Etxebeste et al. 2016). Results of a recent MR study, however, indicated its sedentary behaviour (Torres-Vila et al. 2017). Since the beetle is both a pest and an umbrella species for nature conservation (e.g. Natura 2000 sites were established to protect the beetle), detailed information on its dispersal ability is vital for nature conservation and production forestry.

In this paper, we present the first results of the radio-tracking study focusing on *C. cerdo* beetle. We examined the movement probability and dispersal capacity of this species across three localities in the Czech Republic. We also assessed the differences between males and females and we discussed the results in the context of other studies.

Materials and Methods

The study was conducted from June to July 2016 at three sites of Pannonian oak woodlands in southern Moravia, Czech Republic. The sites included i) Lednice Chateau Park (48.8096997 N, 16.8170550E; ~350 ha), an open woodland with numerous large, veteran oaks (DBH mostly 60–120 cm); ii) Rendezvous Nature Reserve (48.7499314 N, 16.7926361E; ~24 ha) containing mainly semi-open thermophilous woodland (DBH mostly 40–80 cm). Both of the above sites are part of extensive wooded area (~8500 ha) continuously inhabited by the species (Miklín and Hradecký 2015); iii) Podyjí National Park (48.8155533 N, 15.9770694E; ~6300 ha) in the Dyje (Thaya) river canyon and its environs, covered by continuous semi-open to closed woodlands (DBH mostly <50 cm).

Beetles collected at each site were weighed and equipped with LB-2X transmitters (Holohil Systems Ltd., Canada) with a unique frequency (range 150–152 MHz with steps of ~40 kHz). Two transmitter models and two different methods of attachment were used. Larger transmitters (0.31 g, standard life 21 days, Rendezvous) were flat and had a relatively large surface to attach them to a beetle. They were thus directly attached to the roughened pronotum of the beetles with a drop of superglue (Loctite, type 404). Smaller transmitters (0.27 g, standard life 12 days, Lednice and Podyjí) had battery placed on their tops. As their surface was smaller, they were attached using superglue and a silicone cast in order to fill the space between the transmitter and the beetle's pronotum. The length of the transmitter antenna was set to 5 cm and directed backwards. Signal was detected using the SIKA Radio Tracking Receiver (Biotrack Ltd., UK) and the three elements Yagi antenna designed for this system. The transmitter-equipped beetles were released on the day of their capture or the following day on or near the tree they were collected on. We searched for the tagged beetles once a day starting at the last known position. Since it was often difficult to locate the exact position of tracked individuals (hidden in tree canopies), for analyses only daily displacements >10 m were counted. The distance from which we could detect the radio signal was highly habitat dependent, ranging from several tens of meters in a dense forest up to 1.5 km over the river valley in Podyjí. Usually, beetles could be detected from the distance of a few hundred metres.

To characterize the beetle's dispersal and to allow for its comparison to other studies, numerous parameters were calculated for each individual. (a) The tracking period was defined as the time between the release of an individual and the last day when its signal was detected. (b) The number of movement days represented the number of tracking days when an individual changed its position. (c) The number of tracking days represented the number of days between the individual's releases and its last movement. Days when the signal was temporarily lost and days after the last observed movement were excluded as it was often not clear if the beetle had moved, and whether it was still alive or if the transmitter was still attached to it, respectively. As the number of tracking days was highly unbalanced among individuals, the (d) tracking distance (i.e. the sum of all daily displacements covered by an individual during the tracking days) was supplemented by two more characteristics. (e) The movement distance was computed as the tracking distance divided by the number of movement days, and (f) the displacement distance was calculated as the average distance covered by an individual for which we had sequential daily measurements of its position.

Results and Discussion

Altogether, we equipped 34 individuals with transmitters. Out of these, we immediately lost connection with one male. Another male and one female did not change their position during the whole tracking period (probably due to loss of the transmitter or death). Two females and three males moved only once and then they lost their transmitters (fallen transmitters found on the ground). The fallen transmitters were of the smaller type. Hence using the larger transmitters can minimize such problems. All analyses are thus based on 26 individuals (15 males and 11 females) that moved at least twice. Their tracking period ranged from 4 to 17 days (median 14).

We observed no disturbance of movements or flight problems due to the transmitter weight or size. The mean mass of equipped beetles was 2.98 g (± 0.46) for males and 2.82 g (± 0.24) for females (Table 1). Correspondingly, the transmitter loads (transmitter weight/ body mass) were 8–14% of the individuals' body mass. Although little is known about the effect of transmitter load on beetle's behaviour and energy consumption, the previous telemetry studies of flying beetles have ranged from 5 to 29%

Table 1 Individual parameters calculated for the 26 individuals of *Cerambyx cerdo* included in the main analysis

		Males ($N = 15$)		Females ($N = 11$)	
Code	Name	Mean (±SD)	Median (range)	Mean (±SD)	Median (range)
	Body mass (g)	2.98 (±0.46)	2.96 (2.15–3.82)	2.82 (±0.24)	2.87 (2.45–3.13)
a	Tracking period (days)	12.9 (±4.5)	14 (4–17)	13.2 (±3.8)	14 (6–17)
b	Movement days (days)	5.9 (±3.4)	5 (2–13)	7.4 (±3.6)	8 (2–13)
c	Tracking days (days)	9.9 (±5.3)	10 (2–17)	10.8 (±3.8)	13 (3–14)
d	Tracking distance (m)	554 (±630)	279 (23–2358)	1301 (±1231)	559 (214–4027)
e	Movement distance (m) [d/b]	93 (±192)	39 (10–1498)	177 (±280)	83 (10–1566)
f	Displacement distance (m)	51 (±146)	16 (0–1498)	85 (±151)	24 (0–1080)

(Kissling et al. 2014). Differences in weight of males and females were not significant (Student's T-test, $p = 0.335$).

The daily probability of movement of an individual was 64% (170 movement days recorded during 267 tracking days) and it was not affected by sex (males: 60%; females: 68%; Fisher's Exact Test, $p = 0.202$). The probability of movement remained high (46%; 175 movement days in 379 tracking days) even after inclusion of the full tracking period of all 33 individuals (the one remaining male we immediately lost the connection with could not be included).

The longest displacement in one day was 1498 m for a male and 1080 m for a female. The longest tracking distance was recorded for a female (4027 m; Fig. 1). For 15% of individuals (both sexes), the tracking distance was >2200 m (Fig. 2). Median movement distance differed between males and females (males: 39 m, range 10–1498 m; females: 83 m, 10–1566 m; Mann–Whitney U-test: $p = 0.006$). So did the median tracking distance (males: 279 m, 23–2358 m; females: 559 m, 214–4027 m; Mann–Whitney U-test: $p = 0.021$). Daily displacements were not affected by the time since beetle release, as also observed by Torres-Vila et al. (2017). Therefore, we suggest that adult age (although unknown) is unlikely to affect beetle dispersal, as it has been observed for *Lucanus cervus* (Rink and Sinsch 2007).

Our results indicate a relatively high probability of movement as well as high dispersal ability of *Cerambyx cerdo* adults at the study sites. This is in the contrast to the previous findings based on a large-scale mark-recapture study in Spain (Torres-Vila et al. 2017). Their results suggested a "low-dispersal tendency and sedentary behaviour" of this species. There are several possible explanations for the inconsistent outcomes. In general, the mark-recapture tends to underestimate movements compared to radio-tracking (Kissling et al. 2014). Further, in MR study of Torres-Vila et al. (2017) beetles were captured using baited traps and after marking, they were all released on a single tree. The density of the traps and hence also the recapture probability decreased with the distance from the "release" tree. Mobility patterns likely differ among *C. cerdo* populations for various reasons (e.g. habitat structure, climatic conditions, landscape configuration). It is, nevertheless, possible that the method used, together with the study design contributed to the observed lower mobility of *C. cerdo*.

We found that individuals of *C. cerdo* often move among trees over an area of several kilometres. These results are still rather underestimated since the period we measured the

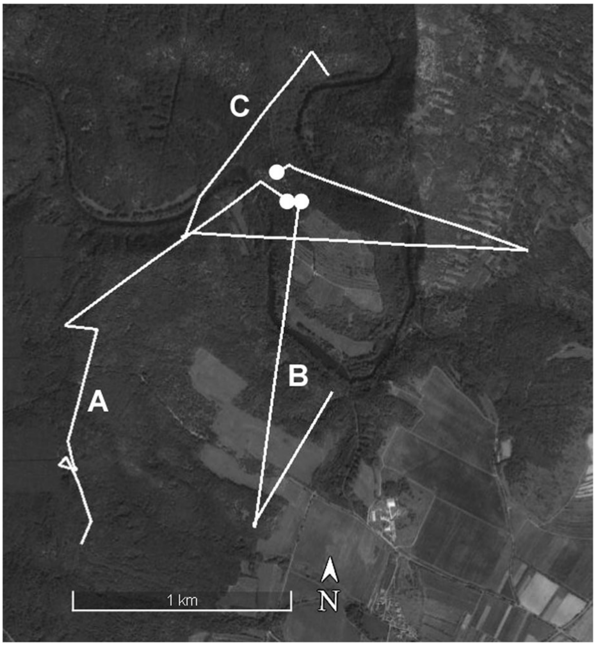

Fig. 1 The three longest tracking distances of nine radio-tracked *Cerambyx cerdo* individuals in Podyjí National Park. **a** female, 2.45 g, tracking period 16 days, distance 2688 m; **b** male, 2.22 g, tracking period 16 days, distance 2358 m; **c** female, 2.86 g, tracking period 15 days, distance 4027 m

beetle's dispersal was always shorter than the beetle's real life expectancy. Mobility of the species is thus comparable to that of other large, mobile saproxylic beetles, such as *Lucanus cervus* (up to ♂701 m and ♀1720 m in a single flight; Rink and Sinsch 2007), *Scapanes australis* (up to 835 m and >1000 m; Beaudoin-Ollivier et al. 2003), *Rosalia alpina* (up to 634 m and 1628 m; Drag et al. 2011), or, perhaps, more sedentary *Osmoderma eremita* (about 150 m; Hedin and Ranius 2002, but up to 297 m and 1442 m in Chiari et al. 2013).

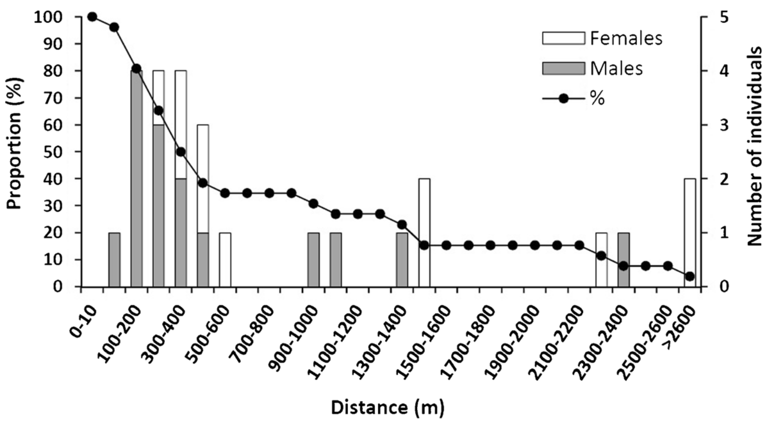

Fig. 2 Cumulative proportion of radio-tracked *Cerambyx cerdo* individuals that covered at least the given distance during their tracking period (black circles) and the number of beetles that covered the given distance during the tracking period (bars) ($N = 26$)

This should be reflected in conservation or pest management strategies of the species. Our results suggest that instead of focusing on the small-scale habitat connectivity, conservation management should put the emphasis on habitat area and that larger habitat patches within several kilometres from inhabited sites, for example, are likely to suit the species better than a few small patches in close vicinity to inhabited sites. More information is, however, needed to allow more authoritative conclusions.

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