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High-accuracy sampling of saproxylic diversity indicators at regional scales with pheromones: The case of *Elater ferrugineus* (Coleoptera, Elateridae) ☆

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ABSTRACT

The rare beetle *Elater ferrugineus* was sampled at 47 sites in the county of Östergötland, Sweden by means of pheromone-baited traps to assess its value as an indicator species for hollow oak stands rich in rare saproxylic beetle species. In addition, *Osmoderma eremita* was also sampled with pheromone baits. These data were then compared against species survey data collected at the same sites by pitfall and window traps. Both species co-occur with many Red Listed saproxylic beetles, with *E. ferrugineus* being a somewhat better indicator for the rarest species. The conservation value of a site (measured as Red List points or number of Red Listed species) increased with the number of specimens of *E. ferrugineus* and *O. eremita* caught. Accuracy of sampling by means of pheromone trapping turned out to be radically different for the two model species. *E. ferrugineus* traps put out during July obtained full accuracy after only 6 days, whereas *O. eremita* traps needed to be out from early July to mid-August in order to obtain full accuracy with one trap per site. By using *E. ferrugineus*, or preferably both species, as indicator species, accuracy would increase and costs decrease for saproxylic biodiversity sampling, monitoring and identification of hotspots.

1. Introduction

Identifying, protecting and monitoring key areas or habitat types that support a high number of rare or threatened species is essential in conservation (Myers et al., 2000; Henle et al., 2013). However, complete surveys are expensive, time-consuming and often prevented by the lack of taxonomic experts. Therefore, indicator species are often used instead of complete surveys to locate sites with high species richness and/or conservation value (Simberloff, 1998; Duelli and Obrist, 2003; Fleischman and Murphy, 2009). Many of the indicator species used are plants or invertebrates, the latter being used principally in marine and aquatic environments and recently also in terrestrial environments. The most notable terrestrial indicators are butterflies and wild bees, particularly for open environments like grasslands (Rosenberg et al., 1986; Sparrow et al., 1994; Nilsson et al., 1995; McGeoch, 1998; Bazelet and Samways, 2011, 2012; Bommarco et al., 2012; Gerlach et al., 2013). Despite the fact that conspicuous day flying species such as these are often sampled several times per year, there is still a substantial risk of species being under-reported in broad surveys (e.g. Wikström et al., 2009; Jonason et al., 2010; Quinto et al., 2013). Hence we risk generating expensive data of low accuracy and precision.

Saproxylic insects and other invertebrates constitute a significant overall proportion of threatened biodiversity and a major component of the biodiversity of old-growth forest habitats (Speight, 1989; Grove, 2002; Toivanen and Kotiaho, 2007). As the dynamics of old-growth forest habitats are slow, conservation of old-growth forest biodiversity requires a multi-layered strategy. In the short term, this includes identification and preservation of key habitats that still harbor a diverse range of species, whereas long-term measures might focus on regeneration of future

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old-growth habitat in order to expand or integrate isolated habitat fragments into a larger landscape framework (e.g. Margules and Pressey, 2000; Lindenmayer et al., 2006). In order to achieve both the short- and long-term aims, reliable indicators are needed. In this context, saproxylic fauna provide a significant challenge as they are notoriously elusive, difficult to sample, and comprise great taxonomic diversity, requiring an unusually high level of taxonomic expertise to identify completely (e.g. Horak and Pavlicek, 2013). As yet, there seem to be only a few cases of useful indicator species, e.g. *Osmoderma eremita* (Ranius, 2002; Jansson et al., 2009).

At present, there is a paucity of tools for the multiple parallel tasks required for effective conservation of the saproxylic fauna: urgent identification of the most valuable saproxylic biodiversity hotspots, and subsequent monitoring of the processes involved in long-term preservation efforts. In the last decade, trapping systems based on pheromones and other attractive semiochemicals (information chemicals) have offered a potential solution for efficient sampling and monitoring of insect biodiversity. Pheromone systems of a limited number of red-listed species have been studied specifically for conservation purposes (Larsson et al., 2003; Tolasch et al., 2007; Harvey et al., 2010; Millar et al., 2010) and semiochemicals have been employed to study insect distribution, population and dispersal dynamics, and effects of landscape processes (Gandhi et al., 2009; Larsson and Svensson, 2009, 2011; Svensson et al., 2011, 2012; Musa et al., 2013). Pheromone-based trapping systems for insects have been used for decades in efficient monitoring of a wide range of pest species in both agriculture and forestry (Johnson et al., 2006; Witzgall et al., 2010). Hence, we might very well assume pheromone monitoring to be appropriate also for conservation purposes (Larsson et al., 2009), especially for saproxylic insects, which are dominated by beetle families known or expected to rely extensively on pheromone communication (Francke and Dettner, 2005). Pheromone-based trapping has the potential to entirely reverse the present situation for sampling and monitoring of saproxylic biodiversity, by opening up the possibility of sampling insect groups previously disregarded as indicators because of costly and cumbersome sampling procedures. In this manner, the conservation value of sites and the status of cryptic and/or difficult-to-sample species of high conservation value, could be assessed and monitored much more efficiently.

Pheromone monitoring systems are generally species-specific, although cross-attraction exists, e.g. among saproxylic species (Hanks and Millar, 2013). This selectivity would be advantageous for a focus on defined indicator species, but naturally limits the range of species that could be covered. Ultimately, the usefulness of pheromone-based indicator systems for saproxylic biodiversity would be determined by the aggregate information obtained from selected indicator species chosen to represent characteristic habitats and dynamic landscape processes. In the present study, we demonstrate how pheromone-trapping of two saproxylic beetle species, whose pheromone systems have recently been characterized, could provide extensive information about the conservation value of sites for the insect fauna associated with hollow trees.

The first pheromone identified for sampling of a rare and threatened insect species was the male-produced sex pheromone of *O. eremita* (Larsson et al., 2003), a beetle confined to hollow trees and an indicator of saproxylic biodiversity (Ranius, 2002; Jansson et al., 2009). Pheromone-baited traps have been used in the field to estimate population sizes and dispersal dynamics of this rare species, showing that populations may be significantly larger than previously suggested based on unbaited pitfall traps (Larsson and Svensson, 2009, 2011).

The rare Rusty red click beetle *Elater ferrugineus* is commonly associated with *O. eremita* but known from far fewer sites in Sweden (Svensson et al., 2004). Nilsson and Baranowski (1994) found that many click beetle species, including *E. ferrugineus*, live exclusively at sites with long hollow-tree continuity, but also assumed that these beetles would not be useful as indicators since the chance of detecting them is low. However, recent studies have shown that *E. ferrugineus* can be monitored by traps baited with the *O. eremita* sex pheromone (Svensson et al., 2004), and even more efficiently with its own highly attractive, female-produced sex pheromone (Tolasch et al., 2007; Svensson et al., 2012), thus radically expanding its potential as an indicator species. Population studies with pheromone-baited traps have suggested that population sizes of *O. eremita* and *E. ferrugineus* may sometimes be comparable, but that the latter exhibits considerably higher population fluctuations (Larsson and Svensson, 2009, 2011). *E. ferrugineus* also depends on hollow tree resources at larger spatial scales than *O. eremita* (Ranius et al., 2011; Bergman et al., 2012; Musa et al., 2013). Consequently, *E. ferrugineus* could be a very sensitive and cost-effective indicator of the biological effects of landscape fragmentation, especially given the novel potential for sampling with a highly attractive and species-specific pheromone.

The main aim of this study was to study the co-occurrence between *E. ferrugineus* and other saproxylic insects, and to evaluate the usefulness of pheromone-trapped *E. ferrugineus* as an indicator species for hollow tree stands with a rich saproxylic insect fauna. The indicator potential of *E. ferrugineus* was studied by means of pheromone trapping at sites previously sampled for saproxylic insect diversity in 1994–2010 (see e.g. Jansson, 2009; Jansson et al., 2009). Since many of the beetle species associated with hollow trees are assumed to have low dispersal rates, they are believed to depend on the continuity of hollow trees within a relatively close range (~2 km proposed by Nilsson and Baranowski, 1994; Jansson, 2006), and many are classified as threatened (Gärdenfors, 2010).

The experiment examined to what extent pheromone trap catch of *E. ferrugineus* is a good predictor for the presence of individual rare and threatened species, as well as for sites rich in rare species. Species Red Listed by the IUCN in 2010 were used to test the hypothesis that *E. ferrugineus* is more abundant at sites with high richness of Red Listed saproxylic beetle species associated with hollow oak stands. The indicator potential of *E. ferrugineus* was compared with that of *O. eremita*, which has already been shown to have high indicator potential for saproxylic beetles when using conventional trapping or search methods (Ranius, 2002; Jansson et al., 2009). Methods used in this project were matched against the data on *E. ferrugineus* and *O. eremita* sampled by Jansson (2009). In this way we have determined both the accuracy and usefulness of *E. ferrugineus* as an indicator species for hollow oak stands with high conservation value, and the efficiency of the two pheromones in detecting the species compared to other methods.

2. Material and methods

2.1. Background of trapping methodology and datasets used in this study

The study was conducted in the province of Östergötland, where sites with high density of old and/or hollow oaks were selected. These sites generally have high species richness (Nilsson et al., 1995; Økland et al., 1996) but have suffered from severe decline and fragmentation over the last 200 years in Sweden, mainly due to the change in ownership of the oaks and shifts in farming and forestry practices (Eliasson and Nilsson, 2002). The 47 sites used were all pasture woodlands with varying canopy cover, and they were selected because they were known or believed to harbor a species-rich saproxylic fauna. Several of the sites are nature