Red-listed *Aradus laeviusculus* (Hemiptera: Aradidae) inhabits burnt restoration sites in the Koli National Park, North Karelia, Finland

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We present new records of the flat bug *Aradus laeviusculus* Reuter, 1875, a near threatened species, in North Karelia, Eastern Finland. Three adult individuals were caught in spruce bark beetle pipe traps during the consecutive time periods of 22.V–22.VI.2006, 21.VII–22.VIII.2006 and 23.VII–25.VIII.2008 at a site that had been burnt for restoration purposes on 7.VII.2005. *A. laeviusculus* had been considered to be an extinct species in Finland until one specimen was found in Koli National Park in 1996. Here we discuss the possibility that slash-and-burn and restoration burn treatments may sustain the continuum of post-fire habitats essential for the *A. laeviusculus* population.

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1. Introduction

The amount of decaying wood is one of the key factors affecting the diversity of forest species. Quantitative aspects of decaying wood are also strongly associated with the quality of decaying wood. In Finland, the reduction of burnt forest areas and other young stages of natural succession is the primary cause endangering 58 threatened species, the reason of decline for 30 near threatened (NT) species, and the cause of extinction for altogether seven species (Rassi *et al.* 2010). Extensive management measures can improve the situation, since threatened forest species benefit significantly from specific habitat restoration actions such as prescribed burning (Hyvärinen *et al.* 2006).

However, there are good reasons to assume that restoration treatments of mature spruce forests mimicking the consequences of natural hazards result in higher densities of many insects that depend on decaying or burnt trees, such as bark beetles (e.g., Eriksson *et al.* 2005). The techniques commonly applied for the production of decaying wood in boreal forests with a management history are ring-barking and the felling of individual trees or groups of trees. Highly intensive burning treatments may damage living trees even outside the edges of burnt-over restoration areas. The higher the treatment intensity is, the greater is the risk of bark-beetle infestations. Therefore, extensive use of those techniques may not be practical close to forestry areas.

Various techniques have been applied in order to produce decaying and burnt round wood in the restoration of even-aged managed spruce stands

within the area of the Koli National Park (Koli NP) (Eerikäinen *et al*. 2007). Restoration burnings, including slash-and-burn treatments, have been carried out in the NP to produce the freshly burnt boreal forests necessary to preserve the habitats required by many red-listed species such as *Aradus laeviusculus* Reuter, 1875, a flat bug found for the first time in the Koli NP in 1996 (Lappalainen & Simola 1998). This study reports new evidence of this near threatened fire-adapted flat bug and evaluates the current status of the species in Finland. Three adult specimens were found in one burnt restoration site as a non-target catch of *Ips typographus* L. pheromone trapping in the Koli NP, North Karelia.

2. Material and methods

2.1. Pheromone trapping

In order to monitor the possible changes in the spruce bark beetle (*I. typographus*) population originating from restoration, a pheromone trapping programme, implemented annually, was launched in 2005. Spruce bark beetle trapping was conducted using the 1979 black drainage pipe trap model described by Bakke *et al.* (1983) and produced by Borregaard Ind. Ltd., Sarpsborg, Norway. The tube is 135 cm long and 12 cm in diameter and has about 900 evenly distributed holes. The traps were baited with Ipsowit® standard pheromone dispensers (Witasek Pfanzen-Schutz GmbH, Germany). The dispensers contained methyl-butenol, cis-verbenol and ipsdienol permeated in a cellulose sheet enclosed in a polyethylene bag attached inside the pipe trap. The fluid containers of pipe traps were filled to halfway with 70% alcohol.

A triangle comprising three traps spaced 2 m apart was placed at each collection site on 22.V.2005. Each of the trap groups was located in an open area about 50 m from the nearest forest edge. The traps were attached to dry wooden sticks about one meter from ground level. The traps were emptied once a month, always around the 22nd day of the month, during the period from May to September. The methodology applied in Koli NP corresponds to that used by Weslien *et al.* (1989) and Valkama *et al.* (1997). In this paper, the trapping data that revealed the occurrence of *A. laeviusculus* span the period from 2005 to 2008.

2.2. Study area and sites

The Koli NP is located in one of the easternmost regions of Southern Finland and comprises the central areas of the Karelian forest hill area considered to be the Finnish national landscape. The Koli NP is particularly famous for its heritage landscapes, namely wooded pastures and meadows, which are the remnants of the traditional slash-and-burn agriculture that was widely practiced in Koli from the 18th century until the 1930s. The restoration of slash-and-burn-derived habitats and landscapes began in the NP in 1994 (e.g. Eerikäinen *et al.* 2007). The forest inventories as well as habitat and species-specific surveys implemented in the 1990s showed that the conservation status of the area was not optimal since more than 20% of the forests of Koli had been established by planting and were being managed intensively before the establishment of the NP in 1991. The forests lacked decayed wood and natural fires, and in herb-rich forests, spruces were inevitably becoming dominant.

In order to ensure the protection of the valuable habitat types and the diversity of species found in the Natura 2000 area, a LIFE-Nature project entitled "LIFE to Koli – Restoration of the forests and meadows of the National Park" (LIFE2003NAT/FIN/000035) was carried out in the Koli National Park in 2003–2006. The project was coordinated by the Finnish Forest Research Institute and was partly funded by the European Union through its LIFE-Nature programme. The LIFE-Nature project drew up long-term management and restoration plans for forests, meadows, bog woodlands and slash-and-burn habitats, respectively. By the end of the project there were ca. 45 hectares of freshly burnt boreal forest habitats (subtype for boreal forests), ditches blocked within 28 hectares of drained bog woodlands and an increase in decaying wood within 107 hectares of former managed forests on mineral soils (Eerikäinen *et al.* 2007).

The sites monitored with spruce bark beetle pheromone trapping until 2008 comprised two burnt and two ring-barked forest compartments

Table 1. Location of study sites in 2005 (sites 1–8) and 2006–2008 (sites 1–11). The geographical coordinates given are from the WGS84 system.

Trap group / Site	Treatment	N / lat.	E / lon.
1 Paimenenvaara	Mature forest	63° 5.134’	29° 47.704’
2 Paimenenvaara	Mature forest	63° 5.635’	29° 47.633’
3 Ukko-Koli, lower slope	Burning	63° 5.816’	29° 49.053’
4 Likolahti (along the road “Rantatie”)	Burning	63° 5.34’	29° 50.008’
5 Sikoniemi, Autiolahti	Clear-cutting	63° 4.23’	29° 51.974’
6 Sikoniemi, Autiolahti	Clear-cutting	63° 4.135’	29° 52.142’
7 Ala-Murhi	Ring-barking	63° 2.42’	29° 55.516’
8 Ala-Murhi	Ring-barking	63° 2.447’	29° 55.649’
9 Savikylä, Riihilahti	Clear-cutting	63° 8.87’	29° 41.593’
10 Savilahti farm, Savilahti	Clear-cutting	63° 7.733’	29° 39.561’
11 Ukko-Koli, lower slope	Burning	63° 5.785’	29° 49.145’

(Table 1). For reference data, we trapped insects in four fresh clear-cut areas and two mature managed forests in the surrounding areas of the Koli NP (Table 1). The monitoring started in 2005 and was based on two trap groups for each of the four treatment (sites 1–8), but in 2006 it was enlarged to two fresh logging sites which had been logged during the previous winter 2005–2006, (sites 9, 10). In addition, one trap group (site 11) was located within the same restoration burning area as trap group 3, at the slope of Ukko-Koli.

3. Results

One adult female individual of *A. laeviusculus* was caught between 22nd May and 22nd June 2006 (Ukko-Koli, Lieksa, *Kb*, Finland, Geographic WGS84 coordinates: N 63° 5.785’ and E 29° 49.145’) and another adult female between 21st July and 22nd August 2006 (Ukko-Koli, Lieksa, *Kb*, Finland, coordinates: N 63° 5.816’ and E 29° 49.053’) in the very same burnt clearing with standing tree stems and stems lying on the forest floor but from different groups of traps (see Fig. 1 for locating the sites). In addition to the findings for 2006, one adult female individual was caught from the same restoration site between 23rd July and 25th August 2008 (coordinates: N 63° 5.785’ and E 29° 49.145’. There were no other observations of the species in 2007 or in other trapping sites.

The trap groups were located on the lower slope in a clearing of about 1.5 hectares (compartment no. 1383) where mature Norway spruce trees had been cut down in the second half of June 2004 and which had been burnt on 7th July 2005. The distance between the restored compartment no. 1383 and the slash-and-burn area in which the first *A. laeviusculus* specimen was caught in 1996 is less than two kilometres. All Aradidae species caught in traps were checked; no other *A. laeviusculus* individuals were observed at other trapping sites.

4. Discussion

The slash-and-burn and restoration operations carried out in the Koli NP in Eastern Finland have inevitably created a continuum of burnt wood in the area, leading to favourable breeding sites for *A. laeviusculus*. It is worth mentioning that slash-and-burn treatments have been carried out continuously in the northernmost sites of the Koli NP since 1994, making it possible for fire-adapted species to survive in the protected area (Fig. 1). There is probably a permanent *A. laeviusculus* population in Russian Carelia, where forest fires are more common than on the Finnish side of the border. The species has a northern boreal occurrence in Russia but is absent from Central Europe (Sandström & Wikars 2007). According to Johansson *et al.* (2010), the much higher total abundance and species richness in the burnt area in the first summer after the fire indicates that a forest fire attracts flat bugs from relatively great distances.

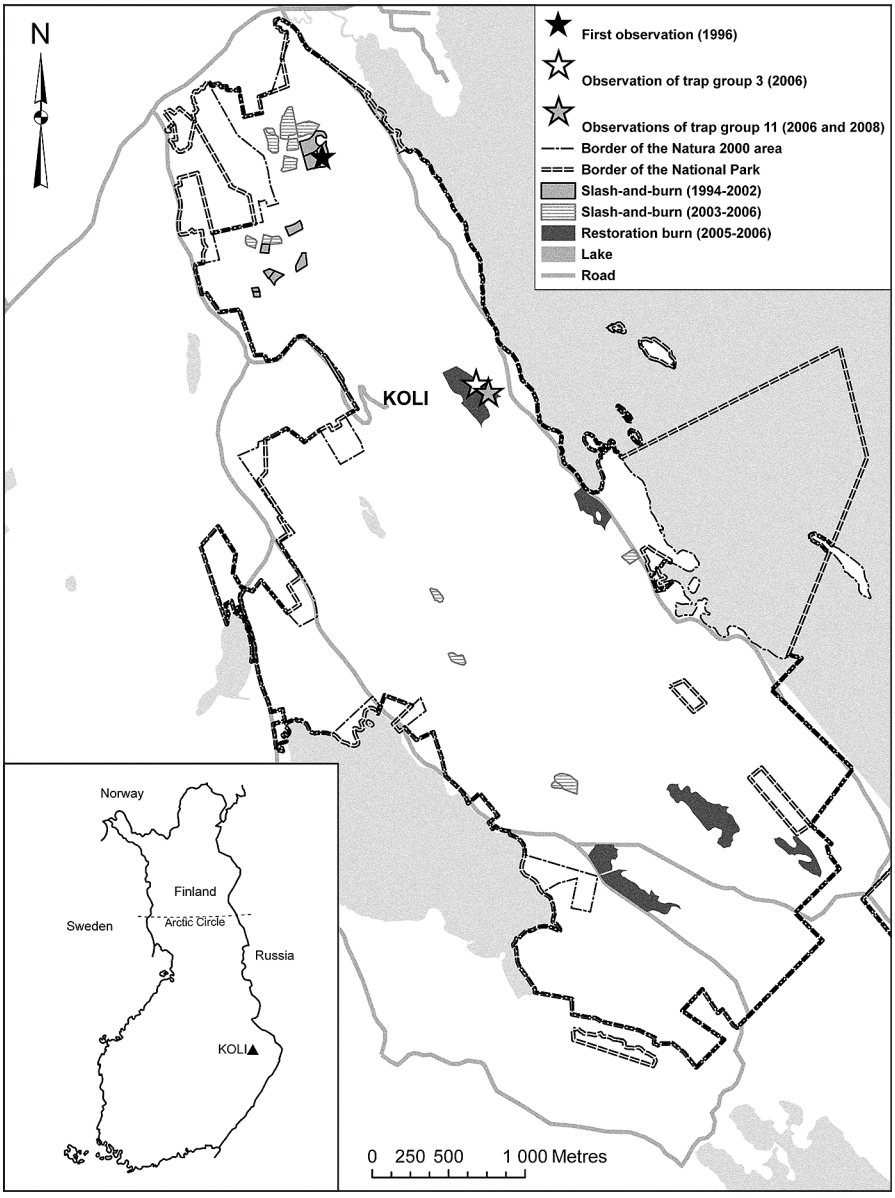

Fig. 1. *Aradus laeviusculus* records on slash-and-burn and burnt restoration areas in the Koli National Park, Eastern Finland.

Records of *A. laeviusculus* have remained rare in Finland, Norway and Sweden (Sandström & Wikars 2007). The species was considered to be common in Finland in the beginning of the 1900s, when it was found almost everywhere in Varsinais-Suomi (*Ab*), Uusimaa (*N*), Satakunta (*St*), South Häme (*Ta*), South Ostrobothnia (*Oa*), North Häme (*Tb*), Middle Ostrobothnia (*Om*), Kainuu (*Ok*), North Ostrobothnia (*Ob*), Kemi Lapland (*Lk*, W Part) and Inari Lapland (*Li*) (Lammes & Rinne 1990). *A. laeviusculus* was listed as extinct in Finland on the Red List of the early 1990s (Rassi *et al.* 1992), when the most recent recording was the one made in 1949 in Lammi, South Finland (Heliövaara & Väisänen 1983). The species was re-discovered in Finland as late as 1996 when it was detected in the Koli NP (Lappalainen & Simola 1998). Later it was discovered that the species had previously been observed in 1990 and 1993 in *Kb*:Lieksa and *Ok*:Suomussalmi, respectively (ref. Hemiptera Information Database). In the evaluation of 2001,

A. laeviusculus, was classified into the "Red List category" of "endangered", whereas in 2010 the species was categorized as "near threatened" (cf. Rassi *et al*. 2001 and 2010).

The most recent unpublished findings have concentrated on restoration and forest burning sites in Eastern Finland (Rintala & Rinne 2010). According to the Hemiptera Information Database, *A. laeviusculus* has been detected from Finland during the 1990's at six sites in North Carelia (*Kb*) and Kainuu (*Ok*), four of these sites being slash-and burning sites. Recordings after 2000 comprise 12 sites in Lieksa (*Kb*), Ilomantsi (*Kb*) and Mäntyharju (*Sa*) in Eastern Finland. Altogether 30 individuals have been found during the years 1990–2008, and ten of them were found from the Koli NP. Therefore it is worth to assume that the conservational status of *A. laeviusculus* has improved through restoration burnings carried out, especially, in the eastern part of Finland, near the vast Russian boreal forest areas with regularity of natural forest fires.

Forest fires are quite rare in Finland nowadays. There was an average of 1465 reported forest fires annually with an average size of 155 hectares in Finland during the time period 2000 to 2008. Between 1980 and 1991 the number of forest fires was even lower. Due to the intensive management of forests and the small amount of dead wood and forest fires many Aradidae species in Finland are rare or threatened. There are 19 Aradidae species in Finland and six of them are classified as regionally extinct (RE), vulnerable (VU) or near threatened (NT) (Rassi *et al.* 2010, Rintala & Rinne 2010). Most of these threatened *Aradus* species are fire-adapted, requiring recently burnt wood and pyrophilic fungi to be successful. For some species, there are so few records that their habitat requirements are not known.

Many European and North American countries are reintroducing prescribed burning since fire suppression has decreased the probability of catastrophic fires and may be a cause of the extinction of many plant and animal species that are dependent on fire habitats. In Russia, the situation is different as its fire suppression system has never been very effective in managed forests and huge parts of the country remain outside the scope of forest fire suppression. Human activity is believed to cause 80–90% of all fires in Russia and millions of hectares are burnt annually (Karpachevskiy 2004). In 2009 a total of 2.1 million hectares of forest was burnt in Russia and there were 23 200 registered forest fires which destroyed 25.4 mill. m^3 of wood (Anonymous 2011). This amount has remained fairly consistent over recent decades.

In the current study, two flat bug individuals were caught in traps on burnt areas about one year after a fire. *A. laeviusculus* and *A. crenaticollis* have been described as pyrophilous flat bugs (Wikars 1997). According to Schmitz *et al*. (2010), it is not clear that these species are attracted by fire. They proposed that *A. laeviusculus* and *A. crenaticollis* arrive later than species equipped with IR receptors and, thus, have not developed IR sensilla. Recently it has been shown that *A. laeviusculus* lacks this type of sensillum (Schmitz *et al.* 2010). A possible reason for their pyrophilus-like behaviour may be that *A. laeviusculus* and *A. crenaticollis* are mycophagous and feed on fast-growing post-fire fungi. It is not known which fungi this would be in the case of *A. laeviusculus*. Thus, there is a need to study the habitat requirements of *A. laeviusculus* more specifically. Jonsell *et al.* (2005) showed that the occurrence of polyporous fungi *Fomitopsis pinicola* (Sw.:Fr.) P. Karst. is crucial for the presence of *Aradus corticalis* (L.).

From the species conservation point of view, the restoration of managed forest close to existing source areas is the most efficient approach (Hanski 2000) for preserving suitable habitats for *A. laeviusculus*. It is therefore recommended that restoration burning in former managed forests be continued in the Koli NP in order to sustain the recovering populations of flat bugs (*Aradus* spp.) and possibly other fire-habitat-dependent species. While planning further implementation of such treatment, both the spatial and temporal continuum of sites of restoration burning should be examined, and a procedure for annual burning treatments of even small forest blocks should be considered. More detailed information on the habitat requirements of *A. laeviusculus* would benefit planning and the selection of sites for restoration burning. Finally, it is concluded that our results support the findings of Rassi *et al*. (2010) who stated that the fire-adapted Heteropteran

species seem to have benefited from ongoing restoration burning activities.

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