

## Taxonomy, habitat choice and distribution of *Kimunpsocus flavonimbatus* (Rostock, 1879) comb. n. (Psocodea: 'Psocoptera': Psocidae)

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The bark lice *Psocus flavonimbatus* Rostock, 1879 and *Ptycta chubsugulensis* Günther, 1982 are assigned to the genus *Kimunpsocus* Yoshizawa, 2009. The male terminalia of *K. flavonimbatus* are described for the first time and compared to the corresponding structures of the other known species of the genus. Previously only known from the type locality in Estonia and the municipality of Kuhmo in Finland, *K. flavonimbatus* is now reported from 13 new sites and as a new species for four municipalities in eastern Central Finland. Analyses of an extensive material strongly suggest that *K. flavonimbatus* is a habitat-specialist species, confining its occurrence to pristine and semi-natural spruce-dominated forests. Nonetheless, its occurrence seems to be sporadic even in the old-growth forests. Forest structure of a subset of occupied and unoccupied sites is described and the conservation biology of *K. flavonimbatus* discussed.

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### 1. Taxonomy

*Kimunpsocus flavonimbatus* (Rostock, 1879)  
**comb. n.** (Fig. 1)

*Psocus flavonimbatus* Rostock, 1879: 129.

*Amphigerontia flavonimbatus* [sic!] (Rostock). Mühlen 1884: 331 (incorrect spelling).

*Psocidus flavonimbatus* (Rostock). Smithers 1967: 108; Lienhard & Smithers 2002: 444.

*Psocus flavonimbatus* Rostock. Lienhard & Kanervo 2002: 59 (redescription).

### 1.1. Introduction

This interesting species has been redescribed by Lienhard & Kanervo (2002), based on newly discovered material from Kuhmo, eastern Central Finland. The male terminalia could not be examined for that redescription, because all males available were damaged, lacking the abdomen. Therefore it was not possible to assign the species to one of the modern genera of the family Psocidae. Thus, in the World catalogue published by Lienhard & Smithers (2002), it was assigned to the genus *Psocidus* Pearman (*s. l.*), a heteroge-



Fig. 1. A female *Kimunpsocus flavonimbatus* from Teerisuo-Lososuo Mire Reserve, Kuhmo, eastern Central Finland. Photo: G. Várkonyi

neous group within Psocidae containing many species, which cannot be allocated to one of the genera defined in this family after the redefinition, in a narrow sense, of *Psocus* Latreille by Pearman (1932).

Lienhard & Kanervo (2002) suggested that *Psocus flavonimbatus* could be close to or even identical with *Ptycta chubsugulensis* Günther, described from Mongolia (Günther 1982). Unfortunately, as only the male holotype is known of this species, and no intact males were available of *Psocus flavonimbatus*, it was impossible to make any detailed comparison of these species.

The morphology of male terminalia of *Ptycta chubsugulensis* indicates the close relationship of this species with *Kimunpsocus takumai* Yoshizawa, recently described from northern Japan (Hokkaido Island) and considered by Yoshizawa (2009) as the type species of a new monotypic genus, *Kimunpsocus* Yoshizawa. Therefore we propose here the following new combination: *Kimunpsocus chubsugulensis* (Günther, 1982)

**comb. n.** for *Ptycta chubsugulensis* Günther, 1982.

We had now the chance to examine a perfectly preserved male from Finland (Suomussalmi, Murhisalo, beating, 71765:36448, 31.vii.2008, leg. P. Kähkönen), which was collected together with typical females. As indicated by Lienhard & Kanervo (2002), the specific identification of both sexes is easy due to their characteristic forewing pattern. The general morphology of both sexes and the female terminalia have been described in detail by these authors. The male terminalia are here described for the first time, based on the above mentioned specimen. The following measurements of this male complete the data already given in the redescription of the species (Lienhard & Kanervo 2002): body length (BL) = 3.2 mm; forewing length (FW) = 5.0 mm; length of hind femur (F) = 0.95 mm; length of hind tibia (T) = 1.85 mm; length of hind tarsomere 1 (t1) = 600 µm; length of hind tarsomere 2 (t2) = 175 µm; minimum distance between compound eyes

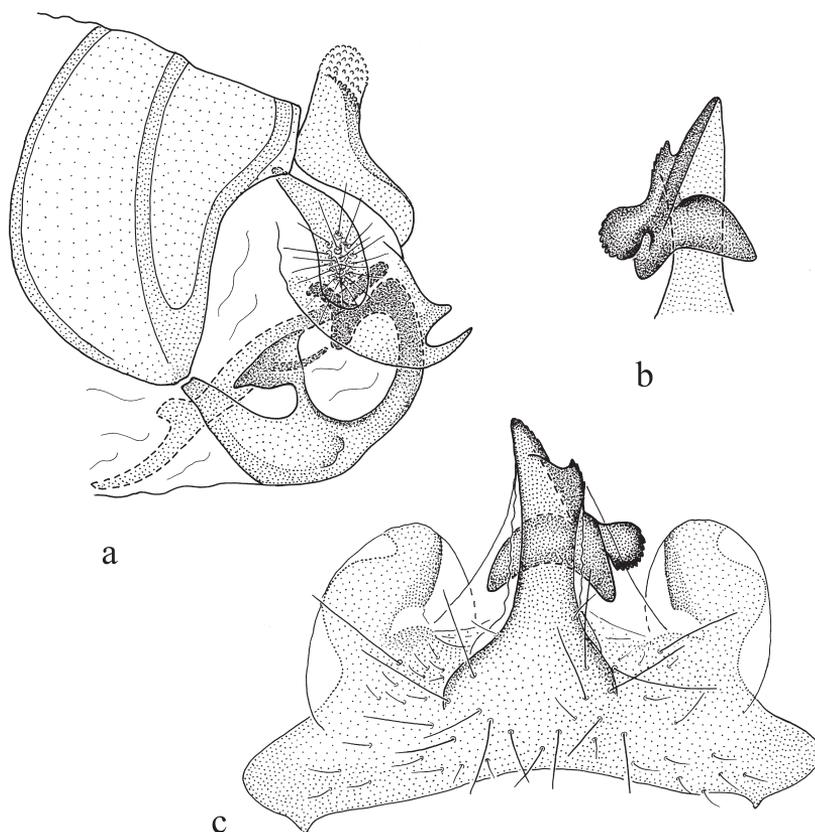


Fig. 2. *Kimunpsocus flavonimbatus* (Rostock), male. – a. Terminalia (lateral view). – b. Hypandrium, apical part of median strap (anterior view). – c. Hypandrium (posterior view).

divided by the antero-posterior diameter of compound eye, in dorsal view (IO/D) = 1.2. The characters of male terminalia confirm the close relationship of this species with *Kimunpsocus chubsugulensis* **comb. n.** but justify the separation of the European and the Mongolian forms as two distinct species. Thus, this European species has also to be assigned to the genus *Kimunpsocus*.

### 1.2. Description of male terminalia (Figs. 2a–c, 3a–d)

Clunium characteristically shaped, anterior margin with a deep medio-dorsal notch (Fig. 3d), postero-lateral region slightly concave in lateral view (Fig. 2a). Epiproct chair-shaped in lateral view (Fig. 2a), its basal lobe broad and rugose, slightly prominent medially (Fig. 3b). Paraproct (Fig. 3a) lacking laterally projecting basal lobe, with a pointed apical hook and a well-differentiated subapical prominence, the latter bearing a

slightly clubbed seta near its anterior base (see detail of Fig. 3a), trichobothrial field oval, not subdivided. Hypandrium (Fig. 2a–c) with a slightly asymmetrical, strongly sclerotized median strap and with a partly membranous, partly sclerotized rounded lateral lobe on each side. The apical part of the median strap antero-ventrally curved and asymmetrically trilobate, one of its terminal lobes rounded and denticulate (Fig. 2b–c). Phallosome (Fig. 3c) distally slightly asymmetrical, with a toe-shaped smooth submedian process, on each side in distal half with a sclerotized ventro-lateral longitudinal band.

### 1.3. Discussion

*Kimunpsocus flavonimbatus* (Rostock) is closely related to the two other members of the genus *Kimunpsocus* Yoshizawa, the Mongolian species *K. chubsugulensis* (Günther) **comb. n.** (= *Ptycta chubsugulensis* Günther, see Section 1.1.) and the

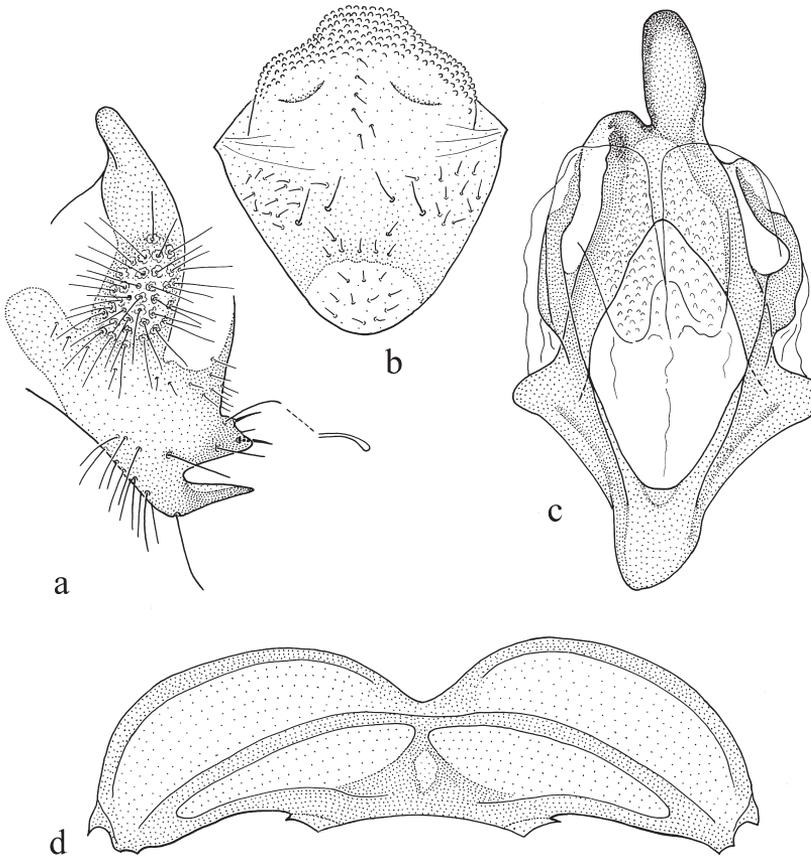


Fig. 3. *Kimunpsocus flavonimbatus* (Rostock), male. – a. Left paraproct. – b. Epiproct (posterior view). – c. Phallosome (ventral view). – d. Clunium (dorsal view, spread out).

Japanese *K. takumai* Yoshizawa. Male terminalia are very similar in all three species, in particular their characteristically shaped phallosomes are almost identical (here shown in ventral view, see Fig. 3c; same view in Fig. 2E by Yoshizawa 2009; depicted in dorsal view by Günther 1982: Fig. 5). However, the male of *K. chubsugulensis* can be distinguished from the male of *K. flavonimbatus* by the shape of the antero-ventrally curved apical part of the median strap of the hypandrium: it is simple in *K. chubsugulensis* (see Günther 1982: Fig. 4) and trilobate in *K. flavonimbatus* (Fig. 2b–c). This striking difference could be confirmed by the examination of the holotype of *Ptycta chubsugulensis* (mounted on three microscopical slides by K. K. Günther, deposited in the Zoological Institute of the Russian Academy of Sciences, St. Petersburg), while the remaining terminalia of this specimen (i.e. clunium, epiproct, paraproct, phallosome) are the same as described above for *K. flavonimbatus*. The Japanese *K. takumai* can be distinguished from these species by its dis-

tinctly trilobate epiproct lobe (see Yoshizawa 2009: Fig. 2B). The median strap of the hypandrium of *K. takumai* is probably very similar to *K. flavonimbatus* (according to the somewhat schematic Fig. 2D in Yoshizawa 2009).

The forewing pattern is essentially the same in all three species, but of varying intensity (probably also with considerable intraspecific variability): highly contrasted pattern as depicted by Lienhard & Kanervo (2002: Fig. 1a, b) for *K. flavonimbatus*; medium contrast in Yoshizawa (2009: Fig. 1) for *K. takumai*; weakly contrasted pattern in Günther (1982: Fig. 2) for *K. chubsugulensis*. The female of the latter species is not known, in the two other species the morphology of female terminalia is very similar (Lienhard & Kanervo 2002: Fig. 1g, i; Yoshizawa 2009: Fig. 3A, B). However, Lienhard & Kanervo (2002: Fig. 1h) illustrate a weakly sclerotized, asymmetrically structured spermapore region (internal plate) for *K. flavonimbatus*; in *K. takumai* the internal plate is “without obvious sclerotization nor

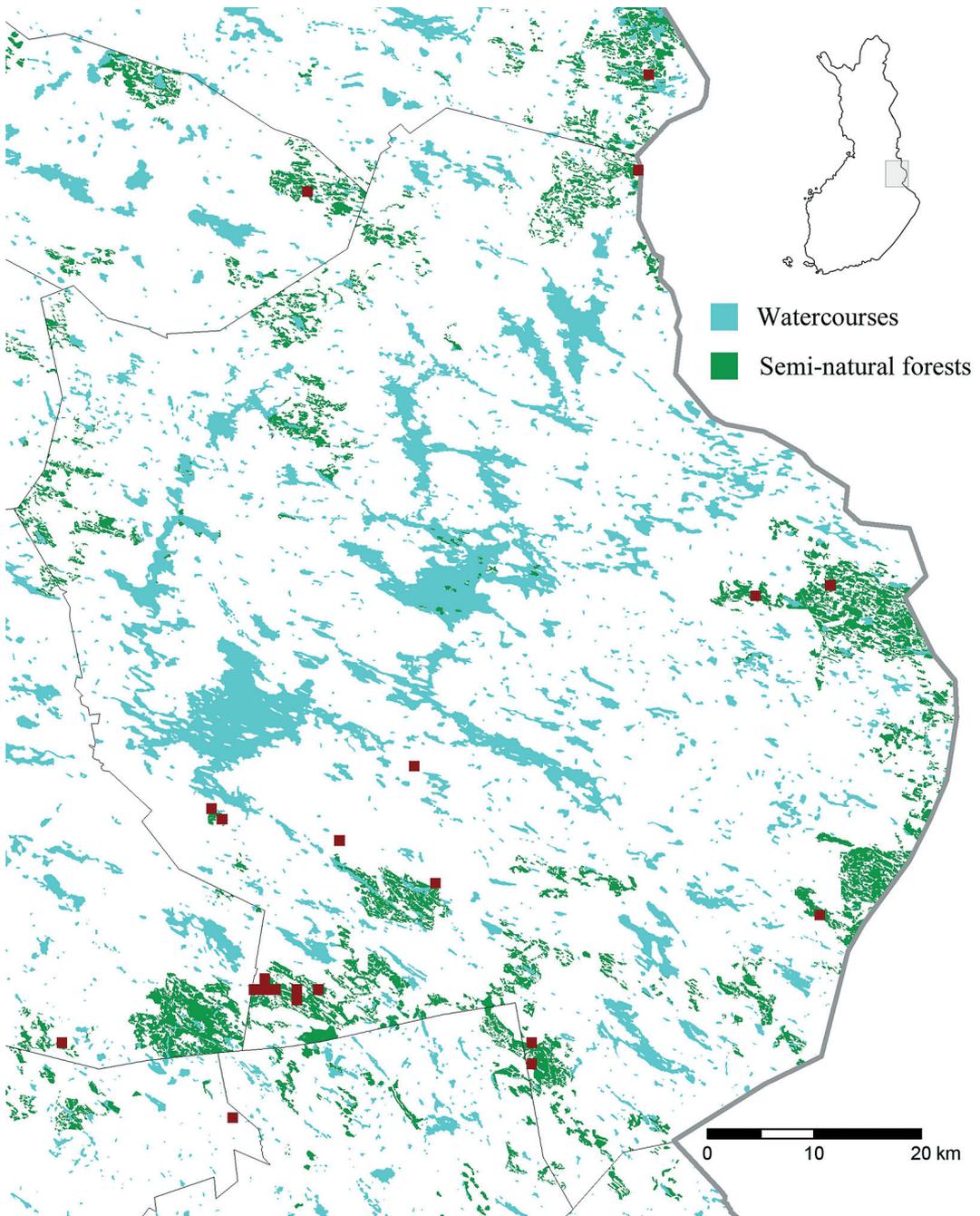


Fig. 4. Distribution of *Kimunpsocus flavonimbatus* in eastern Central Finland. The small square symbols denote the 1-km<sup>2</sup> squares where the species has been recorded during 1997–2008. Thin black lines delineate municipalities, of which Kuhmo is shown in its entirety. The two most central squares, isolated from large semi-natural forest areas, denote remnant populations of *K. flavonimbatus* that have gone extinct during the past decade due to forestry measures.

pigmentation” (Yoshizawa 2009: 153). In this context it may be of interest to mention a single female from Eastern Russia (Primorski Kray,

East of Ussuriysk, Kamenushka village, 19.vi.1992, leg. S. Kurbatov), deposited in the collection of the Geneva Natural History Mu-

seum and tentatively assigned to *K. flavonimbatus* because of the presence of a highly contrasted wing pattern and of the above mentioned asymmetrical structure of the internal plate. In the absence of information on the female of *K. chubsugulensis* and on details concerning the structure of the internal plate of *K. takumai*, this specific identification remains tentative. However, the genus *Kimunpsocus* appears to be an eastern Palaearctic element, reaching north-eastern Europe with *K. flavonimbatus*.

## 2. Habitat choice and distribution

### 2.1. Introduction

*Kimunpsocus flavonimbatus* (Rostock) was originally described on the basis of a single individual found near Lake Peipus, eastern Estonia, in 1878 (Rostock 1879). It was not until 1997 that the species was rediscovered in Kuhmo, eastern Central Finland (see Lienhard & Kanervo 2002). During the following decade, a total of 42 specimens were obtained from semi-natural spruce-dominated forests in Kuhmo (see Kanervo & Várkonyi 2007). Since *K. flavonimbatus* was never collected in any other habitat nor in any other region in Finland, Kanervo & Várkonyi (2007) suggested that this species is associated with old-growth forests and restricted to the easternmost part of the country. Nonetheless, these authors also addressed the need for further study.

In this study, our aim was to explore the distribution pattern and habitat preferences of *K. flavonimbatus* by extensive sampling in both semi-natural and managed mature spruce-dominated habitats. The sampling area was extended to adjacent municipalities of Kuhmo in the north, west and south. Additionally, we aimed at measuring and comparing the forest structure of a subset of occupied and unoccupied study sites.

### 2.2. Material and methods

*Kimunpsocus flavonimbatus* was searched for on low branches of Norway spruce (*Picea abies* (L.) Karsten) by the beating method (e.g. Sutherland 1996) during the peak flight period of the species,

27.vii.–11.viii.2006 and 18.vii.–14.viii.2008. Beating was performed in early mornings when the ambient temperature was low enough to prevent bark lice from flying away from the beating sheet put under the spruce branches. Though the number of individuals sampled was recorded in each site, only the information on the presence or absence of the focal species was used in the analyses.

The study area included the entire municipality of Kuhmo and adjacent areas as follows: southern parts of Suomussalmi and Hyrynsalmi, eastern parts of Ristijärvi and Sotkamo (region Kainuu), north-eastern Valtimo, as well as northern parts of Nurmes and Lieksa (region North Karelia) (Fig. 4).

To address the basic habitat requirements of *K. flavonimbatus*, we first compared its incidences in semi-natural vs. managed mature spruce-dominated forests using all available data, collected using various methods between 1997 and 2008, at two spatial scales. At the scale of individual study sites, beating sites, sites with window traps, a single site with a light trap and a single site where *K. flavonimbatus* was reared from a sample of wood block, were considered as sampling units (for details see Kanervo & Várkonyi 2007 and Fig. 1 within). At a coarser ‘landscape’ scale, a 1-km<sup>2</sup> grid was put on the map showing all sampling sites, and sites sharing a grid cell were combined as follows: if *K. flavonimbatus* occurred in any of the sites within a cell, the cell was considered as occupied. At both spatial scales, if a site was repeatedly sampled in different years, a single occurrence detected in any year rendered the site occupied. The incidence of *K. flavonimbatus* in semi-natural vs. managed forests was analysed using Fisher’s exact test (e.g. Sokal & Rohlf 1995). This test is suggested to be used in Model I 2 × 2 tables if the count numbers in any cell are lower than five (Ranta *et al.* 1997).

Forest structure was measured within a 10-m-radius circle around 44 study sites in 2008. Due to the relative rarity of mature managed spruce-dominated forests in the study area, only five study sites out of the 44 represented this type of habitat, while the remaining 39 sites were semi-natural spruce-dominated forests. However, the rarity of *K. flavonimbatus*, found only in 12 out of 44 sites, warranted us to compare the forest struc-

Table 1. Habitat choice of *Kimunpsocus flavonimbatus* in eastern Central Finland with significance of Fisher's exact tests (2-sided). For explanations of the spatial scales employed, see Section 2.2.

Spatial scale	Semi-natural sites		Managed sites		P
	present	absent	present	absent	
Individual sites	29	88	0	16	0.022
1-km <sup>2</sup> grid cells	22	45	0	12	0.017

Table 2. Forest structure in 10-m-radius circles around occupied and unoccupied sites of *Kimunpsocus flavonimbatus* in eastern Central Finland. All variable values are expressed as mean  $\pm$  SD.

	N	Number of living trees				Stand area (m <sup>2</sup> /ha)	Stumps
		Spruce	Birch	Pine	Total		
Occupied	12	24.5 $\pm$ 7.3	2.9 $\pm$ 3.1	2.5 $\pm$ 5.0	30.2 $\pm$ 9.8	28.1 $\pm$ 4.8	0 $\pm$ 0
Unoccupied	32	23.8 $\pm$ 7.0	1.7 $\pm$ 1.7	0.5 $\pm$ 0.9	26.2 $\pm$ 6.7	28.1 $\pm$ 4.6	1.7 $\pm$ 4.4

ture of occupied and apparently unoccupied sites. In each study site, we recorded the number and diameter (measured at 1.3 m height) of living trunks for each tree species occurring in the study area, i.e. Norway spruce, Silver birch (*Betula pendula* Roth), Scots pine (*Pinus sylvestris* L.), European aspen (*Populus tremula* L.), Grey alder (*Alnus incana* (L.) Moench) and Goat willow (*Salix caprea* L.). We also recorded the number of man-made stumps found in the circular plots and estimated the basal area of the trees in the forest stands using a relascope.

### 2.3. Results

The surveys conducted in 2006 and 2008 yielded a total of 23 *K. flavonimbatus* specimens. *Kimunpsocus flavonimbatus* was discovered in 13 new sites (cf. Kanervo & Várkonyi 2007) and recorded as a new species to the municipalities of Suomussalmi, Hyrynsalmi and Sotkamo in Kainuu, and to Valtimo in North Karelia (Fig. 4).

A total of 133 sites, of which 16 and 117 sites represented managed mature and semi-natural spruce forests, respectively, were included in the habitat-choice analyses. Consistent with earlier results (Kanervo & Várkonyi 2007), not a single *K. flavonimbatus* was found in the managed sites. The occurrence of *K. flavonimbatus* was clearly

associated with the semi-natural spruce-dominated forests at both spatial scales (Table 1).

Owing to (i) the general scarcity of mature managed spruce-dominated forests in the study area, (ii) the apparent rarity of *K. flavonimbatus* even in semi-natural sites and (iii) the risk of false zeros in the incidence data, we did not attempt to analyse the differences of forest structure between occupied and unoccupied sites. Instead, we rather aimed at describing the basic statistics of the measured variables (Table 2). The structure of the forest stands surrounding the sampling sites was, on the average, fairly similar in occupied and unoccupied sites. The only notable differences were found in the numbers of living pines and of man-made stumps.

### 2.4. Discussion

One of the main goals of the present study was to clarify the basic habitat requirements of *K. flavonimbatus*. Our data strongly suggest that *K. flavonimbatus* is a habitat specialist species, confining its occurrence to pristine and semi-natural spruce-dominated forests. This hypothesis was originally put forward by Kanervo & Várkonyi (2007), but only our extensive survey in both (semi-) natural and managed spruce forests made it possible to test the hypothesis.

Found in one-fourth (24.8%) of the old-growth sites, *K. flavonimbatus* seems to be relatively rare even in the semi-natural forests. Some of its observed rarity may account for false zeros, i.e. undetected occurrences in the sampled sites. Such sampling error may arise from the sampling method employed. Beating can only be used for sampling from the lower branches of trees and, on the other hand, there is a stochastic risk that a rare species will not be sampled due to the short duration of the sampling event. Window traps, in turn, were operated for the entire flight season of *K. flavonimbatus*, which dramatically lowered the risk of undetected occurrences. Nonetheless, even in south-western Kuhmo, where window traps were used extensively, *K. flavonimbatus* was only found in 9 out of 35 (Teerisuo-Lososuo Mire Reserve) and 2 out of 21 (Jauhovaara) 1-ha areas, each containing four window traps (see Kanervo & Várkonyi 2007). Therefore we conclude that the observed rarity *K. flavonimbatus* does mainly account for a real pattern of sporadic occurrence, rather than for a sampling effect.

Though the small-scale habitat requirements of *K. flavonimbatus* could be specified using the present data (Table 2), forest structure could not be used to explain the occurrence of the species. The majority (32 out of the 44) of the sites, where forest measurements were performed, was unoccupied and only 5 out of these situated in managed forests. Thus, most of both occupied and unoccupied sites represented semi-natural forests and, obviously, there was no reason to expect major differences in the forest structure of those. Nevertheless, we noticed that in some of the occupied sites, the number of pine trees was considerably higher than on average, and their basal area exceeded the basal area of spruce. This is the usual case in mesic semi-natural forests, where the main tree age cohort is composed by spruce and birch, scattered with some old and large pines representing an earlier generation of trees. The higher average frequency of man-made stumps in the unoccupied sites can be explained by the inclusion of managed sites in the comparison.

*Kimunpsocus flavonimbatus* was recently discovered in two old-growth forest areas in Finnish North Karelia (Petri Martikainen, personal communication; Kanervo 2010). This area is situated some 100 km south-east of Teerisuo-

Lososuo Mire Reserve, where most Finnish individuals have been collected from. While it seems to be clear that *K. flavonimbatus* is confined to pristine and natural-like spruce-dominated boreal forests, it is likely that further populations in easternmost Finland and in Northwest Russia will be discovered. Nonetheless, given the rapid and extensive loss and fragmentation of old-growth forests in this region during the past 60 years, it seems likely that the Finnish population will be declining even in protected areas due to delayed population dynamic responses to habitat loss (also see Fig. 4).

In the current Red List of Finnish Species (Kanervo & Söderman 2010), the conservation status of *K. flavonimbatus* (as *Psocidus flavonimbatus*) was assessed as Near Threatened. Kanervo & Söderman (2010) suggested that the cause of threat facing this species is “reduction of old-growth forests and the decreasing number of large trees” (category Mv). While acknowledging this, we stress the importance of understanding the underlining population dynamic processes for the successful conservation of this rare psocid species.

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