Saproxylic beetles in Europe: monitoring, biology and conservation, p. 23–32

GDK 145.76(497.4)

Biodiversity of saproxylic beetles of pine forests in Slovenia with emphasis on *Monochamus* species

Maja Jurc[1], Srdjan Bojovic[2], Roman Pavlin[3], Gregor Meterc[4], Andreja Repe[5], Danijel Borkovič[6], Dušan Jurc[7]

Abstract

From 2007 to 2010, we assessed the presence of entomofauna in two ecological regions of Slovenia on three locations: on limestone parent rock in monocultures of *Pinus nigra*, on flysch in a stand of *Pinus halepensis* (both in the Sub-mediterranean ecological region) and in a stand of *Pinus sylvestris* on brown soil (Pre-alpine ecological region). The samples were collected in one-month intervals from May to November using four cross vane funnel traps per location with wet collecting cups and attractants (ethanol+α-pinene, Pheroprax® and Gallowit®). Collected insects from the order Coleoptera belonged to the families Curculionidae (and subfam. *Scolytinae*), Cerambycidae and Buprestidae. The most important saproxylic groups were Scolytinae as the primary saproxylic beetles at 90.7% (21,820 specimens), containing 21 taxa and 18 species; Cerambycidae at 6.4 % (1534 specimens), 24 taxa, 20 species; Curculionidae at 2.5% (613 specimens), eight species and Buprestidae at 0.4% (90 specimens) and one species. With respect to the number of species identified, the most numerous family was Cerambycidae; the dominant species was *Spondylis buprestoides*, followed by *Rhagium inquisitor, Arhopalus rusticus, Acanthocinus aedilis, Neoclytus acuminatus, Monochamus galloprovincialis, Leiopus nebulosus, Arhopalus ferus, Sticoleptura rubra* and *Cerambyx scopoli*. Collected species of long-horned beetles represent ca. 10% of all known species of Cerambycidae in Slovenia. With regard to our findings, we can conclude that Slovenian forestry legislation (Act of Forestry 1993 and Rules on the Protection of Forests 2009) regarding the protection of forest biodiversity is appropriate for the preservation of saproxylics.

Key words: Pine forests, saproxylic beetles, Cerambycidae, ethanol+α-pinene, Pheroprax®, Gallowit®

1. Introduction

According to the data of the Slovenian Forest Service, in 2010 forests occupied 1,185,169 ha, which represents 58.8% of the total surface area of the country. The growing stock of Slovenian forests was 330,982,374 m³ or 279.72 m³/ha. Conifer trees' growing stock is 46.43%, and deciduous trees' stock is 53.57%. The yearly increment of trees in the forests is 8,117,325 m³ or 6.85 m³/ha (ZGS 2010).

In 2008, the share of all species of pines in the growing stock amounted to 19,527,961 m³, which represents 5.9% in the total growing stock of forests. In Slovenia the following species of pines are present: *Pinus nigra, P. sylvestris, P. mugo, P.halepensis, P. pinea, P. strobus, P. cembra, P. pinaster*, but only four of them are native (*P. nigra, P. sylvestris, P. mugo* and *P. cembra*). *P. sylvestris* dominates among all pines, its proportion in the pine growing stock is 72.8% or 14,216,874 m³ and it appears on 310,513 ha, while the area of stands with more than 50% of *P. sylvestris* in the growing stock amounts to 36,833 ha. Up to 51.4% of *P. sylvestris* is (according to diameter of breast height (dbh)) classified in the thickness class of 30–50 cm, 37.3% in thickness class of 10–30 cm and 8.3% in the thickness class of over 50 cm dbh. The second most common species of pine in Slovenia is *P. nigra*; its proportion the wood stock of pine is 25.3% or 4,935,411 m³ and appears on 67,882 ha, while the area of stands with more than 50% of *P. nigra* trees in the growing stock is 23,516 ha. The largest number of *P. nigra* trees according to the dbh is in the thickness class 30–50 cm and it comprises 49.4%; in the thickness class of 10–30 cm it is 43.4% and 7.2% of the trees in the thickness class of over 50 cm dbh (ZGS 2008a).

In Europe and also in Slovenia, anthropogenic impacts on natural forest vegetation have been very substantial; the result of those effects was (among others) the loss of habitats of saproxylic organisms. In prehistoric times, inappropriate treatment with forests on the territory of Slovenia took place, stacks of charcoal and ashes in karst caves have been detected (JURHAR *et al.* 1963). After the 15th century, areas were deforested with slash and burning; this continued until the 19th and 20th centuries (Enciklopedija Slovenije 1995). *P. nigra* is found in the Sub-mediterranean ecological region and was planted in the 19th and 20th centuries during the period of the Austro-Hungarian Empire; since then, it has been regenerating on abandoned land. This afforestation has been large and successful. Until recently, it has encompassed more than 20,000 ha of plantations and areas with natural regeneration

[1] prof. dr. M. J., Biotechnical Faculty, Dpt. of Forestry and Renewable Forest Resources, Večna pot 83, 1000 Ljubljana, Slovenia; maja.jurc@bf.uni-lj.si
[2] dr. S. B., Institute for Biological Research S. Stankovic, University of Belgrade, Bulevar Despota Stefana 142, 11060 Belgrade; Serbia; bojovic.s@ibiss.bg.ac.rs
[3] R. P., Biotechnical Faculty, Dpt. of Forestry and Renewable Forest Resources, Večna pot 83, 1000 Ljubljana, Slovenia; roman.pavlin@bf.uni-lj.si
[4] G. M., Biotechnical Faculty, Dpt. of Forestry and Renewable Forest Resources, Večna pot 83, 1000 Ljubljana, Slovenia; gregor.meterc@bf.uni-lj.si
[5] A. R., Biotechnical Faculty, Dpt. of Forestry and Renewable Forest Resources, Večna pot 83, 1000 Ljubljana, Slovenia; andreja.repe@bf.uni-lj.si
[6] D. B., Biotechnical Faculty, Dpt. of Forestry and Renewable Forest Resources, Večna pot 83, 1000 Ljubljana, Slovenia; danijel.borkovic@bf.uni-lj.si
[7] prof. dr. D. J., Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, Slovenia; dusan.jurc@gozdis.si

of *P. nigra*. In the study area, *P. nigra* is not native, and it has been weakened by exposure to biotic and abiotic damage.

Elswere in Europe, there was also no proper method of managing forests, so primeval forests in Europe are very rare; their surfaces are small and fragmented, and therefore the saproxylic biodiversity is also diminished. The group of saproxylic beetles in Europe is, because of the small amounts of decomposing wood in forests, one of the most endangered groups of beetles; many of them are on the red list of endangered species and lists of Natura 2000.

In recent times, the saproxylic species are endangered in most of its original territory because of intensive forest management and the loss of primeval forest conditions. Under the influence of fire and others factors, specific habitats, such as old and dead trees, have disappeared. The surface area of mature forests has been reduced, and there have also been changes in the size of patches of old trees (KOUKI *et al.* 2001). Data from the World Resources Institute from Washington shows that around 40% of forests in the world still have characteristics of mature forests. In some European countries, the proportions of mature forest are lower; for example, in Sweden the proportion of mature forest is only 3% (BRYANT *et al.* 1997). Saproxylic organisms contribute significantly to forest biodiversity, representing 20–25% of all species living in forests (SIITONEN 2001).

Analysis of the conservation of the forests in Slovenia, however, shows a relatively favourable situation, contributing to conservation of the habitats of saproxylic beetles. Based on the data from permanent sample plots in forests (n = 94,660) of the Slovenian Forest Service (2008b), the amount of dead wood in forests is 3.6% of the growing stocks of forest stands, representing 10 m^3/ha of dead wood mass or 26 dead trees with diameters of more than 10 cm per ha of area. The proportion of deciduous trees is 56%, while the proportion of conifers is 44% (POLJANŠEK 2008).

Our study was conducted within the framework of national monitoring of *Monochamus* spp. (Col.: Cerambycidae) as vectors of pine wood nematode (PWN) in Slovenia; we present the part of the results related to saproxylic beetles. In recent years, interest in the *Monochamus* species has increased because these species are vectors of the PWN, *Bursaphelenchus xylophilus* (NICKLE, 1970) (Tylenchida: Aphelenchoididae), (STEINER and BUHRER 1934), which causes the fatal pine wilt disease of some pine species in Japan and other Asian and also European countries (SOUSA *et al.* 2001). EVANS *et al.* (1996) have demonstrated in pest risk assessments that the nematode can survive in Europe, but extensive damage and tree mortality are likely to be restricted to the warmer southern countries. Taking into account the bioclimatic parameters such as temperature, hosts (particularly *Pinus sylvestris* and *P. pinaster*) and vectors, pine wilt disease has the potential to become a major threat if it is introduced to other European countries; it could become one of the most serious threats to pine forests worldwide in the 21st century (ØKLAND *et al.* 2010, TOMICZEK / HOYER-TOMICZEK 2008), including in Slovenia (JURC *et al*. 2003).

A variety of approaches have been investigated for the management of wood-boring insect populations. These insects are attracted to potential hosts by volatile compounds and possibly by visual cues. Few studies have examined traps of different designs to determine the influence of silhouette and shape on the capture of *Monochamus* species. Groot and Nott (2002) have recommended a pan trap with a black silhouette for general use in capturing wood-boring Cerambycidae. Other authors have recommended the use of conventional multiple funnel traps with certain modifications, such as multiple funnel traps with water-filled collecting cups or large-bottom funnels and cross vane traps with a prominent silhouette (MOREWOOD *et al.* 2002). Some authors have recommended the suspension of multiple funnel traps from ropes between trees with the uppermost funnel at a height of 1.8 m above the ground (IBEAS *et al.* 2007).

In North America, several researchers have demonstrated a kairomonal response of *Monochamus titillator* to blends of bark beetle pheromones acting synergistically with a turpentine host (BILLINGS / CAMERON 1984, BILLINGS 1985). Other investigations have shown that ipsenol and ipsdienol, aggregation pheromones of *Ips DeGeer*, 1775 species, are highly synergistic with α-pinene and ethanol in attracting *Monochamus clamator* and *Monochamus scutellatus*, whereas pheromone compounds from *Dendroctonus Erichson*, 1836 species are not (ALLISON *et al.* 2003). In Spain, Pajares *et al.* (2004) have studied the effects of bark beetle (*Ips* spp.) pheromone components, released individually (ipsenol) or in blends (ipsenol, ipsdienol, cis-verbenol and methyl-butenol), together with host volatiles (turpentine or α-pinene and ethanol) on *Monochamus galloprovincialis* trap catches. They found that the full blend of the four *Ips* semiochemicals with the host compounds is highly attractive. The latest research shows some news on sex attraction and mating behaviour in *M. galloprovincialis* (IBEAS *et al.* 2007, IBEAS *et al.* 2009), and considerable progress has been made in the study of *M. galloprovincialis* pheromones. Pajares *et al.* (2010) have found that 2-undecyloxy-1-ethanol is a male-produced aggregation pheromone of the pine sawyer beetle, and that this compound is potentially useful at a concentration range that is suitable for trap bait.

In this paper, we report the results of field experiments designed to a) evaluate the kairomonal responses of saproxylic beetles in three types of pine forests in Slovenia, b) assess biodiversity of saproxylic beetles depending on the sampling method used, and c) establish the effectiveness of forestry legislation which regulates the quantity of dead wood in forests as habitats of saproxylic beetles.

2. Materials and methods

2.1. Field tests

Entomofauna was collected during the growing seasons from May 2007 to Novembar 2010 at three different sites in western, south-western and central Slovenia (Kastelec, Dekani, Brdo pri Kranju, respectively). We monitored saproxylic beetles, and tested the effectiveness of an ethanol+α-pinene blend and two commercial baits under different ecological conditions and in different host tree stands. The locations and sampling dates are summarised in Table 1.

In the Sub-mediterranean ecological region, the climate is Sub-mediterranean: average yearly temperature is 13.8 ºC; average growing season temperature is 21.6 ºC; maximum temperature is above 27 ºC; minimum temperature is below 16 ºC; precipitation is 1031 mm. In the Pre-alpine ecological region, the climate is alpine: average yearly temperature is 9.5 ºC; average growing season temperature is 17.8 ºC; maximum temperature is above 24 ºC; minimum temperature is below 12 ºC; precipitation is 1336 mm, (Statistical Yearbook of the Republic of Slovenia 2000 – 2010).

Material was collected using black cross vane funnel traps (WitaPrall IntPt – Nassfalle, Witasek PflanzenSchutz GmbH) equipped with wet collecting cups and attractants; in each location, there were four traps at a height of about 2 m on self-supporting stages, the distance between the traps was at least 50 m. At each location, one trap contained a blend of ethanol (p.a., Merck) and α-pinene (98%, Sigma-Aldrich), released at about 2 g/day at 25–28 °C; one contained the pheromone Pheroprax® (BASF) (ingredients: 2-methylbut-3-en-2-ol); one contained Gallowit® (Witasek PflanzenSchutz GmbH) (ingredients: ipsdienol CAS 14434-41-4, ipsenol CAS 60894-96-4, DMWK CAS 115-18-4, cis-verbenol CAS 18881-04-4, α-pinene CAS 80-56-8, ethanol CAS 64-17-5); and one contained no attractants as a control. All collecting cup were filled with 200 ml of propylene glycol to preserve the collected entomofauna. The samples were collected at one-month intervals, fixed with 0.1% benzoic acid (C_6H_5COOH) (p.a., Merck), prepared, identified (determination keys and catalogue used: BENSE 1995, FREUDE *et al.* 1966, GRÜNE 1979, PFEFFER 1995¸ SAMA 2002, LÖBL / SMETANA 2006) and deposited in the entomological collection of the Biotechnical Faculty, Department of Forestry and Renewable Forest Resources, in Ljubljana.

2.2. Statistical analysis

Variables were ln (x+1) transformed whenever found to be non-normal ($P<0.05$ in χ^2 normality test). The data were analysed using three-way ANOVA. The LSD, post-ANOVA test was used to detect significant differences between the mean log transformed values. The variability of frequency of entomofauna was investigated for three factors: localities (three levels: *P. nigra*, Kastelec; *P. halepensis*, Dekani and *P. sylvestris*, Brdo pri Kranju), attractants (three levels: ethanol+α-pinene, Pheroprax® and Gallowit®) and years (four levels: 2007, 2008, 2009 and 2010). We also used Correspondence Analysis (CA) as a descriptive/exploratory technique designed to analyse

Table 1: Descriptive details for the sampling locations.

Location	**1. Kastelec**	**2. Dekani**	**3. Brdo pri Kranju**
Ecological region	Sub-mediterranean	Sub-mediterranean	Pre-alpine
Trap coordinate	N 45º 34', E 13º 52'	N 45º 32', E 13º 49'	N 46º 17', E 14º 20'
Altitude	308 m a.s.l.	95 m a.s.l.	338 m a.s.l.
Parent material / soil type	limestone / eutric brown soil	carbonate flysch / eutric brown soil	silicates and carbonate sediment rock, dolomite, limestone / brown soil
Forest community	*Seslerio autumnalis-Quercetum pubescentis*	*Seslerio autumnalis-Quercetum pubescentis*	*Hacquetio-Fagetum*
Dominant tree species	*Pinus nigra* – monoculture	*Pinus halepensis* - monoculture	*Pinus sylvestris* - monoculture
Age of trees	50–60 years	70–80 years	60–65 years
Sampling period	03.07. – 07.11.2007	03.07. – 07.11.2007	05.07. – 14.11.2007
	20.05. – 15.10.2008	20.05. – 15.10.2008	16.07. – 13.08.2008
	22.06. – 20.10.2009	22.06. – 20.10.2009	01.07. – 23.10.2009
	21.06. – 28.10.2010	21.06. – 28.10.2010	09.06. – 27.10.2010

correspondence between the rows (insect species) and columns (type of attractants) and structure of frequency data. Analyses were performed using the Statistica 5 statistical software for Windows and Statgraphics Plus (version 5.0; Statistical Graphics Corporation, USA).

3. Results

3.1. Entomofauna collected

Three families of the woodborers from the order Coleoptera were identified: Curculionidae (and subfamily *Scolytinae*), Cerambycidae and Buprestidae. The most numerous group was the weevil subfamily Scolytinae with 90.7% of the total number of specimens (21,820), followed by the long-horned beetle family, Cerambycidae with 6.4% (1534) and the weevil subfamily *Curculioninae* (2.5%) (613). With respect to the number of species identified, the most numerous groups were Cerambycidae (24 taxa, 20 species), *Scolytinae* (21 taxa, 18 species), *Curculioninae* (8 species) and Buprestidae (1 species). In the *Scolytinae* subfamily, the most frequent species were *Hylastes attenuatus, Ips sexdentatus and Ips typographus*. We also identified (in order of abundance): *Hylastes opacus, Gnathotrichus materiarius, Hylastes ater, Tomicus piniperda, Xyleborus germanus, Hylastes angustatus, Pityogenes chalcographus, Xyleborinus saxesenii, Tomicus minor, Hylurgus ligniperda, Ips acuminatus, Dryocoetes autographus, Pityokteines spinidens, Hylurgops palliatus* and *Orthotomicus laricis*. From all collected sample of bark beetles, 1808 specimens (8.29%) were determined to the species level.

The most diverse saproxylic family was Cerambycidae, of which we collected 24 taxa and identified 20 species. The dominant species was *Spondylis buprestoides*, followed by *Rhagium inquisitor, Arhopalus rusticus, Acanthocinus aedilis, Neoclytus acuminatus, Monochamus galloprovincialis, Leiopus nebulosus, Arhopalus ferus, Sticoleptura rubra* and *Cerambyx scopoli* (Table 2).

Of the total number of long-horned beetles collected, *M. galloprovincialis* represented 17.54%, *M. sutor* represented 0.09%, and *M. sartor* represented 0.04%.

The dominant species in the weevil subfamily *Curculioninae* was *Dryophthorus corticalis* (seven species were determined in total). The only identified species from Buprestidae family was *Buprestis haemorrhoidalis*.

The main reason for a large part of damaged and unidentified long-horned beetles (86 specimens) was dilution of propylene glycol by rain water and subsequent deterioration of the samples.

There is a connection between the season of collecting (June, July, Avgust, September and October) and attractants regarding the number of collecting taxa of Cerambycidae. Dynamic temporal changes (monthly and annual) in Cerambycidae (24 taxa) captured by three attractants are presented in Figure 1. In 2007, only ethanol+α-pinene was used (Gallowit® and Pheroprax® were not used). A line chart shows the direction and intensity changes occur during the time. On all locations, the most Cerambycidae individuals were collected in July. The most effective attractant for Cerambycidae

Table 2: Collected long-horn beetles (Cerambycidae) by different attractants and locations.

	Ethanol + α –pinene (4 years)	Gallowit® (3 years)	Pheroprax® (3 years)	Control (4 years)	Number of specimens	Locations
Spondylis buprestoides	469	66	0	16	551	1,2,3
Rhagium inquisitor	33	260	4	8	305	1,2,3
Arhopalus rusticus	261	4	5	9	279	1,2,3
Acanthocinus aedilis	3	38	31	0	72	1,2,3
Neoclytus acuminatus	45	13	1	12	71	1,2
Monochamus galloprovincialis	6	45	0	1	52	1,2,3
Leiopus nebulosus	2	18	0	0	20	1,2,3
Arhopalus ferus	18	1	0	0	19	1,2
Sticoleptura rubra	6	5	0	3	14	1,2,3
Cerambyx scopoli	5	6	0	1	12	1

Prionus coriarius	2	6	0	0	8	1
Monochamus sutor	1	4	0	0	5	1,2,3
Acanthocinus griseus	0	3	1	0	4	2,3
Hylotrupes bujulus	2	1	1	0	4	2
Monochamus sartor	1	2	0	0	3	1,2
Rutpela maculata	3	0	0	0	3	1
Clytus arietis	1	0	1	0	2	1
Tetropium fuscum	1	1	0	0	2	3
Strangalia melanura	0	1	0	0	1	3
Leptura aurulata	0	1	0	0	1	1
Monochamus sp.	12	1	0	0	13	1,2,3
Arhopalus sp.	1	0	1	2	4	1,2,3
Leiopus sp.	0	0	2	0	2	1,2,3
Rhagium sp.	1	0	0	0	1	2
Total 1	873	476	47	52	1448	
Damaged specimen	79	3	3	1	86	1,2,3
Total 2	952	479	50	53	1534	

Locations: Kastelec (1), Dekani (2), Brdo pri Kranju (3)

was ethanol+α-pinene, followed by Gallowit®; the least effective was Pheroprax® ($F=30.38$, $P<0.05$). The response of *S. buprestoides, A. rusticus, N. acuminatus* and *A. ferus* shows clear preference to the combination of ethanol+α-pinene. However, Gallowit® attracted more specimens of *R. inquisitor, A. aedilis, M. galloprovincialis* and *L. nebulosus*. *A. aedilis* was also attracted by the pheromone Pheroprax®.

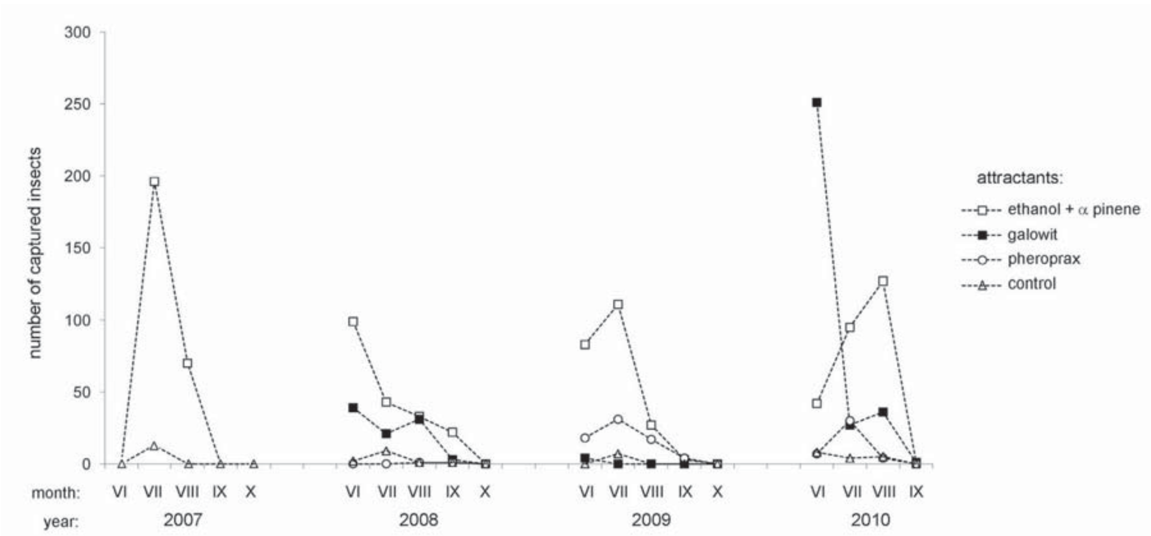

Figure 1: Dynamic temporal changes in Cerambycidae captured by different attractants

The first insight to the entomofauna collected can be viewed via ANOVA (three factors of variability: location, attractants and years). There are statistical difference between years ($F=14.90$, $df=2$, $P<0.05$), attractants ($F=16.61$, $df=2$, $P<0.05$), but not between localities (species) ($F=2.22$, $df=2$, $P>0.05$).

Affinity between the attractant and insects was summarized through the CA into two dimensions (2 axes) which explained 61% of the total variation (Figure 2). The closeness between the points and a triangle on the figure is interpreted as the affinity of the insect to a given attractant. Regarding attractants, the greatest amount of Cerambycidae specimens were attracted by the traps with ethanol+α-pinene.

Black dots represent the species from the family Cerambycidae. White dots represent other insect species (a total of 234 taxa, most of them are overlapping in the graph). The triangles are attractants in different years. The closeness of points to triangles means affinity for specific attractants.

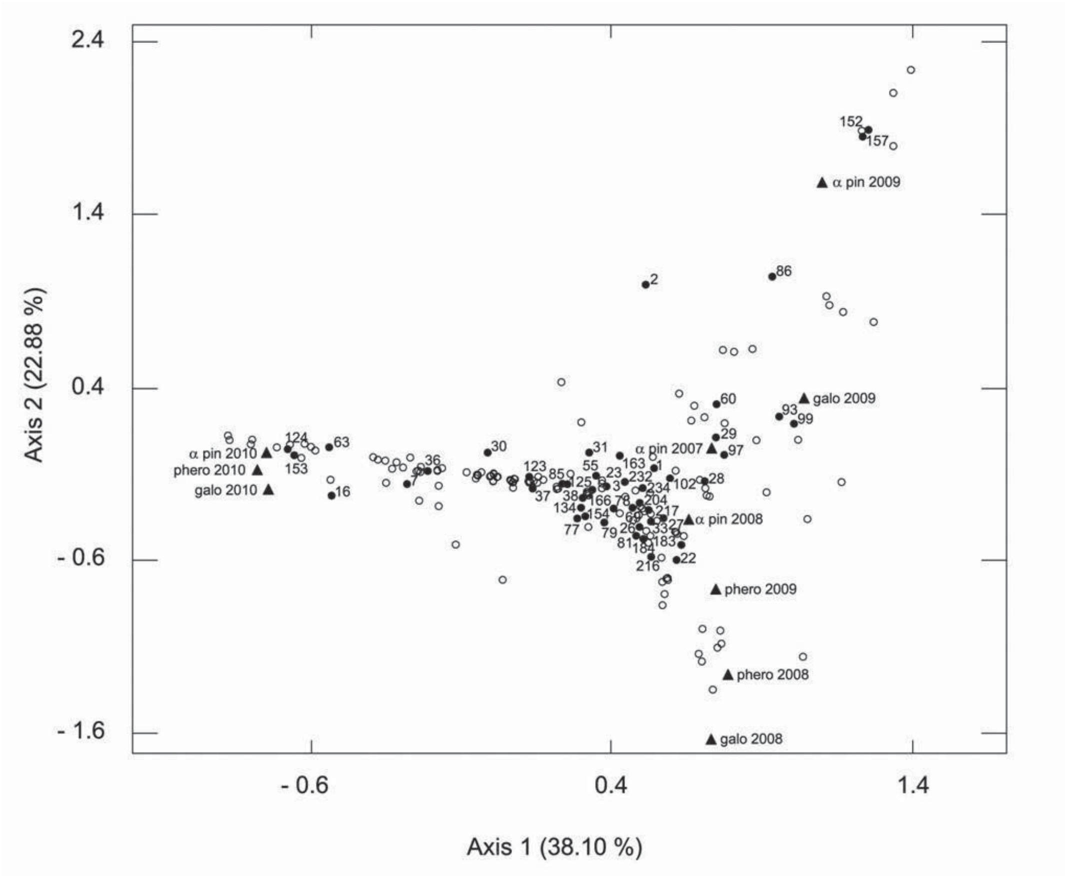

Figure 2: Two-dimensional plot of the correspondence analysis (CA): samples of entomofauna captured by ethanol+α-pinene, Gallowit® and Pheroprax® (2007-2010).

Legend: 1. *Spondylis buprestoides* (Kastelec), 2. *Arhopalus rusticus* (Kastelec), 3. *Arhopalus ferus* (Kastelec), 7. *Neoclytus acuminatus* (Kastelec), 16. *Rhagium inquisitor* (Kastelec), 22. *Monochamus galloprovincialis* (Kastelec), 23. *Sticoleptura rubra* (Kastelec), 26. *Monochamus sartor* (Kastelec), 27. *Acanthocinus aedilis* (Kastelec), 28. *Monochamus* sp. (Kastelec), 29. *Leiopus nubelosus* (Kastelec), 30. *Prionus coriarius* (Kastelec), 31. *Rutpela maculata* (Kastelec), 33. *Leiopus* sp. (Kastelec), 36. *Cerambyx scopoli* (Kastelec), 37. *Clytus arietis* (Kastelec), 38. *Monochamus sutor* (Kastelec), 55. *Leptura aurulata* (Kastelec), 60. *Arhopalus rusticus* (Dekani), 63. *Arhopalus ferus* (Dekani), 69. *Rhagium* sp. (Dekani), 77. *Monochamus sutor* (Dekani), 78. *Neoclytus acuminatus* (Dekani), 79. *Rhagium inquisitor* (Dekani), 81. *Sticoleptura rubra* (Dekani), 85. *Arhopalus sp.* (Dekani), 86. *Monochamus sp.* (Dekani), 93. *Leiopus nebulosus* (Dekani), 97. *Monochamus galloprovincialis* (Dekani), 99. *Acanthocinus aedilis* (Dekani), 102. *Acanthocinus griseus* (Dekani), 123. *Sticoleptura rubra* (Dekani), 124. *Acanthocinus aedilis* (Dekani), 125. *Monochamus sartor* (Dekani), 134. *Hylotrupes bujulus* (Dekani), 152. *Spondylis buprestoides* (Brdo pri Kranju), 153. *Rhagium inquisitor* (Brdo pri Kranju), 154. *Acanthocinus aedilis* (Brdo pri Kranju), 157. *Arhopalus rusticus* (Brdo pri Kranju), 163. *Sticoleptura rubra* (Brdo pri Kranju), 166. *Leiopus nebulosus* (Brdo pri Kranju), 183. *Tetropium fuscum* (Brdo pri Kranju), 184. *Acanthocinus aedilis* (Brdo pri Kranju), 204. *Strangalia melanura* (Brdo pri Kranju), 216. *Monochamus sutor* (Brdo pri Kranju), 217. *Acanthocinus griseus* (Brdo pri Kranju), 232. *Monochamus galloprovincialis* (Brdo pri Kranju), 234. *Rhagium inquisitor* (Brdo pri Kranju).

3.2. Dietary behaviour and hosts of long-horned beetles collected

All long-horned beetles are phytophagous. In the larval stage, they live under the bark and in the wood of trees and bushes. They can use wood in different conditions (freshness, humidity, degree of decay, etc.) and thickness. Some species live in lignified parts of herbs. Adults are usually present on their host plants, where they nibble leafs, needles or blossoms. Adults can also eat pollen or lick the sap from damaged trees. The dietary behaviour and host trees for the trapped species are shown in Table 3.

From 20 collected long-horn beetle species, 10 can be classified as oligofagous on coniferous trees. Different pine species might be their host: mainly, occasionally or at least rarely. The other 10 species can be classified as polyphagous. They feed mostly on deciduous trees, but for seven of them, pines might also be an eventual host. Two captured species (*Cerambyx scopoli* and *Leptura aurulenta*) are polyphagous in deciduous trees only (Table 3).

Table 3: Dietary behaviour and host trees for captured Cerambycidae species.

Taxa	Dietary behaviour and host trees
Spondylis buprestoides	Oligophagous in *Pinus* and other coniferous trees: *Picea, Abies* and *Larix.*
Rhagium inquisitor	Polyphagous in *Pinus* and other coniferous trees: *Abies, Picea, Larix,* and also deciduous trees: *Betula, Fagus, Quercus.*
Arhopalus rusticus	Oligophagous in *Pinus*, seldom in other coniferous trees: *Abies, Picea* and *Larix.*
Acanthocinus aedilis	Oligophagous in *Pinus* (*P. nigra, P. sylvestris*), exceptionally in other conifers: *Abies, Picea* and *Larix.*
Neoclytus acuminatus	Extremely polyphagous in deciduous trees, exceptionally in conifers: *Abies.*
Monochamus galloprovincialis	Oligophagous in *Pinus*, especially *P. sylvestris* and *P. nigra*, occasionally in *Picea*.
Leiopus nebulosus	Extremely polyphagous in deciduous trees, exceptionally in conifers: *Picea*, *Abies* and *Pinus.*
Arhopalus ferus	Oligophagous in coniferous trees, mostly in *Pinus*, (*P. sylvestris, P. nigra, P. halepensis*) and *Picea*.
Stictoleptura rubra	Polyphagous in coniferous trees: *Pinus, Picea, Abies* and *Larix*, infrequently in deciduous trees: *Betula, Fagus* and *Quercus.*
Cerambyx scopoli	Polyphagous in deciduos trees.
Prionus coriarius	Polyphagous mostly in *Fagus*, *Quercus* and other deciduous trees, also occasionally in conifers: *Picea* and *Pinus.*
Monochamus sutor	Oligophagous in *Picea* and occasionally *Abies* (in central Europe) or in *Pinus* (in Scandinavia).
Acanthocinus griseus	Oligophagous in *Pinus*, also in *Picea* and *Abies*.
Hylotrupes bajulus	Oligophagous in coniferous wood: *Picea, Abies* and *Pinus.*
Monochamus sartor	Oligophagous in *Picea*, very rarely in *Abies* and *Pinus*.
Rutpela maculata	Extremely polyphagous in deciduous trees and also in conifers: *Pinus, Picea* in *Abies.*
Clytus arietis	Extremely polyphagous in deciduous trees, exceptionally also in conifers: *Juniperus* and *Picea.*
Tetropium fuscum	Oligophagous in *Picea* and occasionally *Pinus*.
Strangalia melanura	Extremely polyphagous in deciduous trees and also in gymnosperms: *Juniperus*, *Pinus, Picea* and *Abies.*
Leptura aurulenta	Polyphagous largely in *Fagus* and other deciduous trees.
Monochamus sp.	Oligophagous species in coniferous trees.
Arhopalus sp.	Oligophagous species on coniferous trees, mostly in *Pinus*.
Leiopus sp.	Oligophagous to extremely polyphagous species on deciduous trees and occasionally in conifers: *Picea, Abies* and *Pinus.*
Rhagium sp.	Polyphagous species on deciduous and coniferous trees.

Ecologic descriptions based on Brelih *et al.* 2006 and Koch 1992.

4. Discussion and conclusions

Our results show that the largest number of Cerambycidae was caught with the use of the attractants ethanol+α-pinene and the Gallowit®. As for the number of *Monochamus* species, most of them were caught with Gallowit®, followed by ethanol+α-pinene. Our results are consistent with findings by other researchers. Numerous wood-boring insects are known to be attracted by host odours, and commercial baits are based on host monoterpenes (α-pinene) and ethanol (FAN *et al.* 2007, PHILLIPS *et al.* 1988). The roles of ipsdienol, ipsenol, cis-verbenol, methyl-butenol and α-pinene+ethanol as attractants for M. galloprovincialis have been field-tested in Spain and were successful in obtaining an operative kairomonal lure for the management of this species (IBEAS *et al.* 2007).

With respect to the number of species identified in our case, the most numerous family was Cerambycidae, of which we collected 24 taxa and identified 20 species (Table 2).

Of the total number of long-horned beetles collected, *M. galloprovincialis* represented 17.54%, *M. sutor* represented 0.09%, and *M. sartor* represented 0.04%. The collected species of long-horned beetles represent ca. 10% of all known species of this family in Slovenia. Based on the latest research and data from the literature, index files and collections, there are 213 species of long-horned beetles (Cerambycidae) in Slovenia (BRELIH *et al.* 2006); 72 of them were found on pines. During our trapping, we collected 17 (23.6%) of these species on only three different locations. This could be considered high, since no specific pheromones for this group are known, and only kairomonal attraction is applicable. The population density of *Monochamus* beetles in the Iberian Peninsula appears to be high in comparison to Slovenia. However, this difference may be due to the catch method used. Our traps were installed approximately 2 m above the ground. In Portugal, 2.7% of the specimens were captured on the base of the trunk, 20.9% were captured on the trunk, 41.8% were captured in the lower canopy and 34.5% were captured in the upper canopy (Phrame final report 2007, VIVES 2000). This difference may also be due to the intensive forest protection measures adopted in most conifer stands in Slovenia, which include the removal of injured and dead trees in due time. *Monochamus sutor* and *M. sartor* are more frequent in the colder and more northern parts of Slovenia. High population densities of *M. galloprovincialis* in Austria have been observed only in forests that are in poor condition due to environmental or biotic conditions (Phrame final report 2007).

According to Brelih *et al.* (2006), *M. g. ssp. pistor* feeds on *Pinus* (*P. sylvestris* and *P. nigra*) and seldom on *Picea*. In our research, *M. galloprovincialis* was found in stands of *P. nigra, P. halepensis* and *P. sylvestris. Pinus sylvestris* has been experimentally bred in France, and French populations of *M. galloprovincialis* have higher fecundity and longevity compared to Portuguese populations (KOUTROUMPA *et al.* 2008). Palatability tests have been conducted by Austrian researchers, who found that *M. g. ssp. pistor* could be successfully fed on *P. sylvestris* and that *M. suto*r and *M. sartor* could be successfully fed on *Picea abies* (HOYER-TOMICZEK / TOMICZEK 2005). To evaluate the degree of sensitivity (frequency of occurrence of symptoms or dead trees) of 13 different pine species in Europe, an inoculation test using different strains of *B. xylophilus* from different origins (USA, China and Portugal) has been carried out (Phrame final report 2007). The results indicated three groups of *Pinus* species with different mortality rates. Trees in the first group (*P. nigra, P. sylvestris, P. cembra* and *Larix decidua*) all died within three months of inoculation. In the second group (*P. strobus, P. pinaster, P. radiata, P. mugo* and *Larix kaempferi*), the mortality rate was also high but did not reach 100%. Species in the third group (*P. pinea, P. halepensis, Picea abies* and *Abies alba*) showed a high tolerance against strains of *B. xylophilus*, with the exception of *Pinus pinea* inoculated with Portuguese strain. In Slovenia, *M. sartor* was found in stands of *P. nigra* and *P. halepensis* and *M. sutor* was found in a stands of *P. sylvestris, P. nigra* and *P. halepensis*.

According to our findings, we can conclude that Slovenian legislation provides, in regard to the protection of forest biodiversity, the conservation of saproxylic species.

The primary regulatory document for the protection of biodiversity in Slovenia is the Environmental Protection Act (2004). Other documents which regulate biodiversity are the Nature Conservation Act (1999), the Forestry Act (1993), The Resolution of National Forest Programme (2007) and Rules on the Protection of Forests (2009).

Regarding to the protection of habitats of saproxylic beetles, one particularly important measure is the systematic provision of dead wood in the forest. The 6th article of the Rules on the Protection of Forests prescribes that on average at least 3% of dead wood in forests in relation to growing stock of particular forest stand shall remain. According to the results of the analysis of data obtained from permanent sample plots of Slovenian forest service (n = 94,660), the average amount of dead wood quantity in Slovenia is 10 m^3 per hectare, which represents 3.6% of growing stock of stands (POLJANŠEK 2008). That research has shown that the amount of dead wood is even higher as prescribed by statutory instrument.

In addition to the relevant legal bases and the preservation of forests, the protected areas of nature also contribute considerably to the preservation of saproxylic habitats. In Slovenia, there is one national park, three regional parks and 44 nature parks, and more than 36% of Slovenia is under the special regime of NATURA 2000 (*http://www.arso.gov.si/narava/zavarovana%20obmo%c4%8dja/SeznamParkov.htm*).

The general conclusion based on the presented results is that Slovene forestry provides good conditions for saproxylic organisms by considering suitable forest legislation and professional rules of conduct in forest management in present time.

Acknowledgements

We are grateful to B. Košiček, M. Prebevšek and B. Gasparič (Forestry Service of Slovenia) and N. Orgis (Slovenian Forestry Institute) for their assistance with the fieldwork. We also thank S. Brelih (Natural History Museum of Slovenia) for reviewing the insect identifications presented here. Financial support was provided by the Slovenian Research Agency, the Ministry of Higher Education, Science and Technology of the Republic of Slovenia and the Ministry of Agriculture, Forestry and Food of the Republic of Slovenia through the research programs P4-0059 and P4-0107 and research projects L4-9585, V4-0493 and L4-985-040-06.

4. References

ALLISON, J. D. / MOREWOOD, W. D. / BORDEN, J. H. / HEIN, K. H. / WILSON, I. M. 2003. Differential bio-activity of *Ips* and *Dendroctonus* (Coleoptera: Scolytidae) pheromone components for *Monochamus clamator* and *M. scutellatus* (Coleoptera: Cerambycidae). Environ. Entomol. 32: 23-30.

BENSE, U. 1995. Longhorn Beetles. Illustrated Key to the Cerambycidae and Vesperidae of Europe. Margraf Verlag, 512 pp.

BILLINGS, R. F. 1985. Southern pine bark beetles and associated insects. Effects of rapidly released host volatiles on response to aggregation pheromones. Z. Angew. Entomol. 99: 483-491.

BILLINGS, R. F. / CAMERON, R. S. 1984. Kairomonal responses of Coleoptera, Monochamus titillator (Cerambycidae), *Thanasimus dubius* (Cleridae), and *Temnochila virescens* (Trogossitida), to behavioural chemicals of southern pine beetles (Coleoptera: Scolytidae). Environ. Entomol. 13: 1542-1548.

BRELIH, S. / DROVENIK, B. / PIRNAT, A. 2006. Gradivo za favno hroščev (Coleoptera) Slovenije. 2. prispevek, Polyphaga: Chrysomeloidea (= Phytophaga): Cerambycidae. (Material for the Beetle Fauna (Coleoptera) of Slovenia. 2nd contribution, Polyphaga: Chrysomeloidea (= Phytophaga): Cerambycidae). Scopolia 58: 1- 442.

BRYANT, D. / NIELSEN, D. / TANGLEY, L. 1997. The Last Frontier Forests: Ecosystem & Economies on the Edge. World Resources Institute, 49 pp.

Enciklopedija Slovenije (Encyclopedia of Slovenia), 1995. Mladinska knjiga, 416 pp.

EVANS, H. F. / McNAMARA, D. G. / BRAASCH, H. / CHADOEUF, J. / MAGNUSSON, C. 1996. Pest risk analyses (PRA) for the territories of the European Union (as PRA area) on *Bursaphelenchus xylophilus* and its vectors in the genus *Monochamus*. EPPO Bull. 26: 199-249.

FAN, J. / SUN, J. / SHI, J. 2007. Attraction of the Japanese pine sawyer, *Monochamus alternatus*, to volatiles from stressed host in China. Ann. For. Sci. 64: 67–71.

FREUDE, H. / HARDE, K. W. / LOHSE, G. A., 1966. Die Käfer Mitteleuropas. Band 9: Cerambycidae, Chrysomelidae. Krafeld, Goecke & Evers Verlag, 299 pp.

GROOT, P. / NOTT, R., 2002. Evaluation of traps of six different designs to capture pine sawyer beetles (Coleoptera: Cerambycidae). Agric. For. Entomol. 3: 107-111.

GRÜNE, S. 1979. Handbuch zur Bestimmung der europäischen Borkenkäfer. Verlag M. & H. Schaper, 182 pp.

HOYER-TOMICZEK, U. / TOMICZEK, C. 2005. PHRAME – eine EU-Forschungskooperation: Wie gefahrlich ist der Kiefernsplintholznematode fur Europa? Forstschutzaktuell 34: 21–25.

IBEAS, F. / GALLEGO, D. / DIEZ, J. J. / PAJARES, J. A. 2007. An operative kairomonal lure for managing pine sawyer beetle *Monochamus galloprovincialis* (Coleoptera: Cerambycidae). J. Appl. Entomol. 131: 13–20.

IBEAS, F. / GEMENO, C. / DIEZ, J. J. / PAJARES, J. A. 2009. Female recognition and sexual dimorphysm of cuticular hydrocarbons in the pine sawyer *Monochamus galloprovinicalis* (Coleoptera: Cerambycidae). Ann. Entomol. Soc. Am. 102: 317-325.

JURC, M. 2004. Pomen saproksilnih hroščev in njihovo ohranjanje v Sloveniji. V BRUS, R. (ur.). Staro in debelo drevje v gozdu: zbornik referatov XXII. gozdarskih študijskih dni, 25.-26. marec 2004 (The importance of saproxylic beetles and their conservation in Slovenia. Conference proceedings of the 22nd Forestry Study Days, 25.–26., March 2004): 57–74.

JURC, M. / UREK, G. / ŠIRCA, S. / MIKULIČ, V. / GLAVAN, B. 2003. Borova ogorčica, *Bursaphelenchus xylophilus* (Steiner & Buhrer, 1934) Nickle, 1970 - nova nevarnost za slovenske gozdove? (Pine wood nematode, *Bursaphelenchus xylophilus* (Steiner & Buhrer, 1934) Nickle, 1970 - a new threat to forests in Slovenia?). Zb. gozd. lesar. 72: 121-156.

JURHAR, F. / MIKLAVŽIČ, J. / SEVNIK, F. / ŽAGAR, B. 1963. Gozd na Krasu Slovenskega Primorja. Tehniški muzej Slovenije, 120 pp.

KOCH, K. 1992. Die Käfer Mitteleuropas. Ökologie, Band 3. Krafeld, Goecke & Evers, 389 pp.

KOUKI, J. / LÖFMAN, S. / MARTIKAINEN, P. / ROUVINEN, S. / UOTILA. A. 2001. Forest fragmentation in fennoscandia: linking habitat requirements of wood-associated threatened species to landscape and habitat changes. Scand. J. For. Res. Suppl. 3: 27-37.

KOUTROUMPA, F. A. / VINCENT, B. / ROUX-MORABITO, G. / MARTIN, C. / LIEUTIER, F. 2008. Fecundity and larval development of *Monochamus galloprovincialis* (Coleoptera: Cerambycidae) in experimental breeding. Ann. For. Sci. 65: 707.

LÖBL, I. / SMETANA, A. 2006. Catalogue of Palearctic Coleoptera. Vol. 3: Scarabaeoidea, Scirtoidea, Dascilloidea, Buprestoidea and Byrrhoidea. Apollo Books, 690 pp.

MOREWOOD, W. D. / HEIN, K. E. / KATINIC, P. J. / BORDEN, J. H. 2002. An improved trap for large wood-boring insects, with special reference to *Monochamus scutellatus* (Coleoptera: Cerambycidae). Can. J. For. Res. 32: 519-525.

ØKLAND, B. / SKARPAAS, O. / SCHROEDER, L. M. / MAGNUSSON, C. / LINDELÖW, Å. / THUNES, K. 2010. Is eradication of the pinewood nematode (*Bursaphelenchus xylophilus*) likely? An evaluation of current contingency plans. Risk Anal. 30: 1424–1439.

PAJARES, J. A. / IBEAS, F. / DIEZ, J. J. / GALLEGO, D. 2004. Attractive responses by *Monochamus galloprovincialis* (Col., Cerambycidae) to host and bark beetle semiochemicals. J. Appl. Entomol. 128: 633–638.

PAJARES, J. A. / ÁLVAREZ, G. / IBEAS, F. 2010. Identification and field activity of a male-produced aggregation pheromone in the pine sawyer beetle, *Monochamus galloprovincialis*. J. Chem. Ecol. 36: 570-583.

PFEFFER, A. 1995. Zentral- und westpaläarktische Borken- und Kernkäfer (Coleoptera: Scolytidae, Platypodidae). Pro entomologia, c/o Naturhistorisches Museum Basel, 310 pp.

PHILIPS, T. W. / WILKENING, A. J. / ATKINSON, T. H. / NATION, J. L. / WILKINSON, R. C. / FOLTZ, J. L. 1988. Synergism of turpentine and ethanol as attractants for certain pine-infesting beetles (Coleoptera). Environ. Entomol. 17: 456-462.

PHRAME – Plant Health Risk And Monitoring Evaluation, FINAL REPORT, JULY 2007. QLK5-CT-2002-00672: Developement of Improved Pest Risk Analysis Techniques for Quarantine Pests, Using Pinewood Nematode, *Bursaphelenchus xylophilus*, in Portugal as a Model System. Available from http://www.forestresearch.gov.uk/pdf/PHRAMEJuly07.pdf/$FILE/PHRAMEJuly07.pdf 29.4.2011.

POLJANŠEK, S. 2008. Količina in struktura odmrlega drevja v gozdovih Slovenije: diplomsko delo – univerzitetni študij. [Amount and structure of dead wood in forests of Slovenia: graduation thesis-university studies]. Samozaložba, 45 pp.

Pravilnik o varstvu gozdov (Rules on the protection of the Forest). - Ur. l. RS št. 114/2009

Resolucija o nacionalnem gozdnem program (Resolution of National Forest Programme). – Ur. l. RS št. 111/2007

SAMA, G. 2002. Atlas of the Cerambycidae of Europe and the Mediterranean Area, Volume 1. Nakladatelství Kabourek, 173 pp.

SIITONEN, J. 2001. Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. Ecoll. Bull. 49: 11-41.

SOUSA, E. / BRAVO, M. A. / PIRES, J. / NAVES, P. / PENAS, A. C. / BONIFACIO, L. / MOTA, M. M. 2001. *Bursaphelenchus xylophilus* (Nematoda: Aphelenchoididae) associated with *Monochamus galloprovincialis* (Coleoptera: Cerambycidae) in Portugal. Nematology 3: 89–91.

Statistical Yearbook of the Republic of Slovenia. Methodological notes in "Territory and climate" 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010. Available from http://www.stat.si/tema_okolje_ozemlje.asp

TOMICZEK, C. / HOYER-TOMICZEK, U. 2008. Biology studies relevant to the vector role of *Monochamus* species for pinewood nematode, in MOTA, M. M. / VIEIRA, P. (Eds.), Pine Wilt Disease: A Worlwide Threat to Forest Ecosystems, Part IV. C Springer Science+Business Media BV 2008: 215-220.

VIVES, E. 2000. Fauna Ibérica. 12 Coleoptera Cerambycidae. Museo Nacional de Ciencias Naturales, CSIC.

Zakon o gozdovih (Act of Forestry). – Ur. l. RS št. 30/1993

Zakon o ohranjanju narave (Act of Nature Conservation). – Ur. l. RS št. 56/1999

Zakon o varstvu okolja (Act of Environmental Protection). – Ur. l. RS št. 41/2004

ZGS – Zavod za gozdove Slovenije (Forestry Service of Slovenia). 2008a. Digitalna baza podatkov – stanje 2008 [Digital database – situation 2008].

ZGS – Zavod za gozdove Slovenije (Forestry Service of Slovenia). 2008 b. Podatki s stalnih vzorčnih ploskev – stanje 2008 [Data from the permanent sample plots – situation 2008].

ZGS - Zavod za gozdove Slovenije (Forestry Service of Slovenia). 2010. Poročilo Zavoda za gozdove Slovenije o gozdovih za leto 2010 [Forest report of Forestry Service of Slovenia for year 2010], 127 pp.

Širša zavarovana območja (Large protected areas) (http://www.arso.gov.si/narava/zavarovana%20obmo%C4%8Dja/ (29.1.2012)