

Insect assemblages in Norway spruce [*Picea abies* (L.) Karst.] stumps in the Eastern Sudetes

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ABSTRACT

The aim of the study was to determine the species composition of insect assemblages colonising stumps of *Picea abies* (L.) Karst. in mountain conditions. Investigations were carried out in the Eastern Sudetes (south–western Poland) in forest stands situated at 600–700 m above sea level. The observations were conducted on stumps left behind after felling 70–90 years old Norway spruces.

The analysed stumps were colonised by insects from 21 families of 3 orders: Coleoptera (approximately 95%), Diptera (5%) and Raphidioptera (0.2%). There were 12 Coleoptera families determined with the dominance of Cerambycidae (almost 55%) and Curculionidae (37%) including Scolytinae (about 5%). Diptera were represented by 8 families, of which most abundant was the family Rhagionidae (almost 2%) followed by Muscidae (1.4%) and Syrphidae (1.2%). The order Raphidioptera was represented by 1 family: Raphididae (0.2%).

The spruce stumps were mainly colonised by cambio-xylophagous species which added up to 73% of all collected specimens. The European spruce longhorn beetle *Tetropium castaneum* (L.) was most numerous (15.98 ± 14.99 specimens/stump) of all observed insects as well as it showed the highest permanence of occurrence (97% stumps). Second group with regard to abundance was the genus *Hylobius* (12.08 ± 20.38 specimen/stump) found in 62% of the observed stumps.

KEY WORDS

Picea abies stumps, insect assemblages, mountains

INTRODUCTION

The stumps left behind in forest after tree felling are an important element of managed stands and provide habitat for numerous fauna species, of which insects prevail. The latter belong to various systematic groups, yet with regard to the number of species there dominate cambio- and xylophagous beetles (Coleoptera) feeding

on phloem, cambium and/or xylem tissues. In addition, important groups of insects observed in the stumps are parasitoids and predators trophically associated with cambio- and xylophagous insects as well as saprophages which feed on the stumps infected by wood-rotting fungi and other microorganisms. At the same time, tree stumps provide seasonal shelter for numerous insect species.

Among cambio- and xylophagous insects that populate forest tree stumps, the group of secondary pests is considerably numerous. In case of deficiency of more suitable breeding sites these insects can outbreak in the stumps. With increased stand vulnerability due to various abiotic or biotic factors secondary insect pests attack weakened trees, which often results in tree death, or dwell in dead, up-rooted or broken trees and cause a decrease of timber quality. Among others, for these very reasons in many countries there have been carried out investigations on the development and species composition of entomofauna colonising the stumps left behind after harvesting forest trees.

The above aspects were taken into consideration in the research conducted in Sweden (Jonsell et al. 1998, 2005; Schroeder et al. 1999; Lindhe and Lindelöw 2004; Abrahamsson and Lindbladh 2006; Lindbladh and Abrahamsson 2008). Insect assemblages were observed in *P. abies* stumps left behind on clear-cut areas. The authors compared colonisation of the stumps up to 5 m high snags and those of the height 0.5 m. The result obtained showed that most of cambio- and xylophagous insects occupied sections around the root necks of 3–5 m high snags while aboveground parts of lower stumps were inhabited to a considerably lesser extent. At the same time, it was shown that the snags were colonised by rare insect species – not found in the lower stumps. In Poland, insect assemblages in spruce stumps in mountain conditions were investigated by Starzyk (1995); Starzyk and Sęk (1983); Starzyk and Szafraniec (1989) and Kosibowicz (1987). These authors observed entomofauna on *P. abies* stumps in the Western Carpathians (southern Poland) and showed the dominance of insect species which are considered important secondary and timber insect pests negatively impacting the general health of mountain forest stands.

Up to date, literature data on insect assemblages in *P. abies* stumps situated in the Sudetes (after the Carpathians the second largest Polish mountain belt; south-western Poland) have been hardly available. Hence, the objective of the present study was to determine the species composition of insect assemblages on *P. abies* stumps in the Eastern Sudetes.

METHODOLOGY

The observations were carried out in the years 2004–2005 in the Eastern Sudetes within the Śnieżnik massif of which the highest point is the Śnieżnik mountain, 1425 m above sea level (50°12'25" N, 16°50'57" E).

The study included 40 *P. abies* stumps which had been left behind in managed forest stands situated at latitude 600–700 m above sea level. The stumps came into being in September–October 2002, after harvesting 70–90 years old Norway spruces. The stump diameter was from 25 to 68 cm (on average 43 ± 9 cm), and their height was from 10 to 63 cm (on average 35 ± 10 cm). In the period of April–May 2004, aboveground stump parts together with roots down 30 cm were debarked. Next, samples of roots with bark were cut out with the use of chainsaw. Then, from each stump there were taken 4 samples of wood blocks (20 × 15 cm) After sampling, the stumps were covered with black canvas sheets with 4 glass jars/stump for collecting insects, which were fixed in the holes made in the sheets. Insects trapped in the jars were collected in the period May–July 2004.

The species of insect adults as well as of some larvae found in the bark removed from the stumps (including root parts) were determined right after sample collection in the field or else the larvae were reared in the laboratory until they reached the stage of imago. The samples of bark and roots earlier gathered in the field were placed in photoelectors made of cardboard boxes (40 × 30 × 20 cm) with tight covers. In each cover there was placed a glass tube adjusted firmly. In order to protect the bark and root samples from drying out, inside each photoelector there was placed a container with water covered with a mesh cap. Additionally, not covered with bark parts of root samples were coated with wax so as to decrease the process of tissue drying out. Insect breeding was carried out in $22 \pm 2^\circ\text{C}$ and 65% humidity. Emerging insects were taken out from the glass tubes every day and their species or membership to the family and the order were determined.

The ecological indicators, such as dominance and frequency (Szujceki 1987) were used for analyses of the structure of insect assemblages on *P. abies* stumps. The dominance (D) was calculated as a percentage ratio of the number of specimens of a given species (s) and the total number of specimens of all species within a given

assemblage (N). The calculations were done following the formula $D = s/N \times 100\%$. The frequency (C) of a given species was expressed by the percentage of samples where it was found. In calculation of the latter an individual stump was treated as one sample.

RESULTS

Insect species composition and population numbers in *P. abies* stumps

In total 1525 insect specimens were collected from all observed *P. abies* stumps. The insects belonged to 21 families of 3 orders. On average there occurred 37.45 ± 35.21 specimens per 1 stump (from 2 to 169).

Almost 95% (1445) of collected insects comprised beetles (Coleoptera) from 12 families. the family Cerambycidae was most numerous, being represented by 831 specimens (54%) belonging to 6 species. In the assemblages there prevailed 2 species (53%) – *Rhagium inquisitor* (L.) and *Tetropium castaneum* (L.). These species were found in 39 stumps, mainly in the thickest root sections (diameter > 10 cm). Next most abundant family was Curculionidae, represented by weevils of the genus *Hylobius* (about 32% of the total number of collected entomofauna) found in 25 stumps and 4 species of Scolytinae (almost 5% of all collected insects). Most Scolytinae beetles (2.7%) were determined as *Dryocoetes autographus* (Ratz.) and *Ips typographus* was relatively less abundant (1.2%). Even though also represented by 4 species, the family Staphylinidae was considerably less numerous (16 specimens) and the total number of these specimens added up to 1% of all collected insects. Other 9 Coleoptera families were represented by from 1 (Histeridae and Lymexylonidae) to 12 (Cleridae) specimens found.

About 5% (79 specimens) of all collected insects were flies (Diptera) from 8 families, 2 species of which belonged to the family Asilidae and 1 species and 1 genus were determined as members of the family Xylophagidae. Insect specimens from remaining 6 families were determined to a systematic family level.

In the analysed material there was found 1 snake-fly *Raphidia ophiopsis* (L.) (Raphidioptera, Raphidiidae). The numbers and species composition of entomofauna colonising the observed stumps are presented in Tab. 1.

Tab. 1. Insect species composition and numbers in *Picea abies* stumps

Order	Family	Genus, species	Number of colonised stumps			Number of specimens	Average number of specimens/stump \pm standard dev.
			Aboveground-parts	Underground parts	Total		
1	2	3	4	5	6	7	8
Coleoptera	Carabidae	<i>Pterostichus</i> sp.	2	0	2	2	0.05 ± 0.22
		<i>Arhopalus rusticus</i> (L.)	2	0	2	5	0.13 ± 0.56
	Cerambycidae	<i>Corymbia rubra</i> (L.)	1	0	1	3	0.08 ± 0.47
		<i>Obrium brunneum</i> (Fabr.)	1	0	1	5	0.13 ± 0.79
		<i>Oxymirus cursor</i> (L.)	0	1	1	1	0.03 ± 0.16
		<i>Rhagium inquisitor</i> (L.)	10	14	17	178	4.45 ± 7.14
		<i>Tetropium castaneum</i> (L.)	3	39	39	639	15.98 ± 14.99
		<i>Thanasimus formicarius</i> (L.)	7	0	7	12	0.30 ± 0.72
	Cleridae						

1	2	3	4	5	6	7	8	
	Curculionidae	<i>Dryocoetes autographus</i> (Ratz.)	1	1	1	41	1.03 ± 6.48	
		<i>Hylastes ater</i> (Payk.)	0	1	1	6	0.15 ± 0.95	
		<i>Hylastes cunicularius</i> (Er.)	0	1	1	4	0.10 ± 0.63	
		<i>Hyllobius</i> spp.	10	22	25	483	12.08 ± 20.38	
		<i>Ips typographus</i> (L.)	2	0	2	19	0.48 ± 2.12	
		<i>Ampedus pomorum</i> (Herbst.)	0	1	1	2	0.05 ± 0.32	
		<i>Hemicrepidius</i> sp.	0	1	1	1	0.03 ± 0.16	
		<i>Melanotus</i> spp.	0	3	3	5	0.13 ± 0.46	
					1	0	1	0.03 ± 0.16
					0	1	1	0.03 ± 0.16
	Lymexylonidae	<i>Hylecoetus dermestoides</i> (L.)	0	1	1	1	0.03 ± 0.16	
		<i>Rhizophagus dispar</i> (Payk.)	1	2	3	4	0.10 ± 0.38	
		<i>Rhizophagus ferrugineus</i> (Payk.)	1	0	1	1	0.03 ± 0.16	
		<i>Eपुरaea</i> spp.	0	1	1	3	0.08 ± 0.47	
		<i>Glischrochilus quadripustulatus</i> (L.)	0	1	1	3	0.08 ± 0.47	
		<i>Calopus serraticornis</i> (L.)	0	2	2	4	0.10 ± 0.44	
		<i>Schizotus pectinicornis</i> (L.)	0	2	2	6	0.15 ± 0.80	
		<i>Atheta fungi</i> (Grav.)	0	1	1	1	0.03 ± 0.16	
		<i>Nudobius lentus</i> (Grav.)	2	1	3	10	0.25 ± 0.95	
		<i>Quedius punctatellus</i> (Herr.)	0	1	1	2	0.03 ± 0.16	
	Staphylinidae	<i>Philonthus decorum</i> (Grav.)	0	1	1	3	0.08 ± 0.47	
<i>Laphria flava</i> (L.)		1	0	1	1	0.03 ± 0.16		
<i>Laphria gibbosa</i> (L.)		1	0	1	1	0.03 ± 0.16		
		1	0	1	1	0.03 ± 0.16		
		3	0	3	21	0.53 ± 2.11		
		0	8	8	29	0.73 ± 2.00		
		3	0	3	18	0.45 ± 1.84		
		0	1	1	3	0.08 ± 0.47		
		0	1	1	1	0.03 ± 0.16		
		0	1	1	1	0.03 ± 0.16		
Diptera	Xylophagidae	<i>Xylophagus ater</i> (Meigen)	0	1	1	1	0.03 ± 0.16	
		<i>Xylophagus</i> spp.	0	2	2	3	0.08 ± 0.35	
		<i>Raphidia ophiopsis</i> (L.)	0	1	1	1	0.03 ± 0.16	
Raphidioptera	Raphidioptera							

Characteristics of trophic groups

Collected insects belonged to the following trophic groups: cambio-xylophages, cambiophages, xylophages, predators and parasitoids.

Cambio-xylophages, which develop and feed on inner bark, phloem, cambium and xylem were the most abundant trophic group. In this group there were in total 1122 specimens (73% of the total number collected) which belonged to the families Cerambycidae (*T. castaneum*) and Curculionidae (*Hylobius* spp.).

Next considerably numerous group consisted of cambiophages, which develop and feed on inner parts of the bark as well as on phloem and cambium. In the collected research material there were determined 248 cambiophages (16% of the total number) from the family Cerambycidae (*Rh. inquisitor*) and the sub-family Scolytinae (*D. autographus*, *Hylastes ater* L., *H. cunicularius* Er., *I. typographus*).

With regard to abundance, predatory larvae feeding mainly on cambio- and xylophagous insects comprised the third trophic group. There were observed 56 predatory insects (4% of the total number) determined as: *Ampedus pomorum* (Herbst.), members of the genera: *Pterostichus* (Carabidae) and *Melanotus* (Elateridae) as well as the families: Cleridae, Histeridae, Monoto-

midae, Nitidulidae and Staphylinidae. Besides, in this group there observed Diptera larvae, such as representatives of the families Asilidae and Xylophagidae and the snakefly *Raphidia ophiopsis* L.

The group of xylophagous insects was considerably less abundant and there were determined 19 specimens (1%) as members of the families: Cerambycidae (*Arhopalus rusticus* L., *Corymbia rubra* L., *Obrium brunneum* Fabr. *Oxymirus cursor* L.), Lymexylonidae (*Hylecoetus dermestoides* L.) and Oedemeridae (*Calopus serraticornis* L.).

The least abundant was the group of parasitoids from the family Tachinidae. Only 3 specimens were found, i.e. 0.2% of all collected insects.

The species of representatives of Diptera families such as: Empididae, Muscidae, Rhaginidae, Syrphidae and Therevidae (altogether 5% of the total number of collected insects) were not possible to determine. Some of larvae of these families are predatory and some feed on xylem.

Dominance and permanence of occurrence

The results of quantity and quality analyses of the assemblages of cambio- and xylophagous insects colonising the observed spruce stumps indicated the highest dominance ($D = 41.9$) and frequency ($C = 97.5$) for the red flour bee-

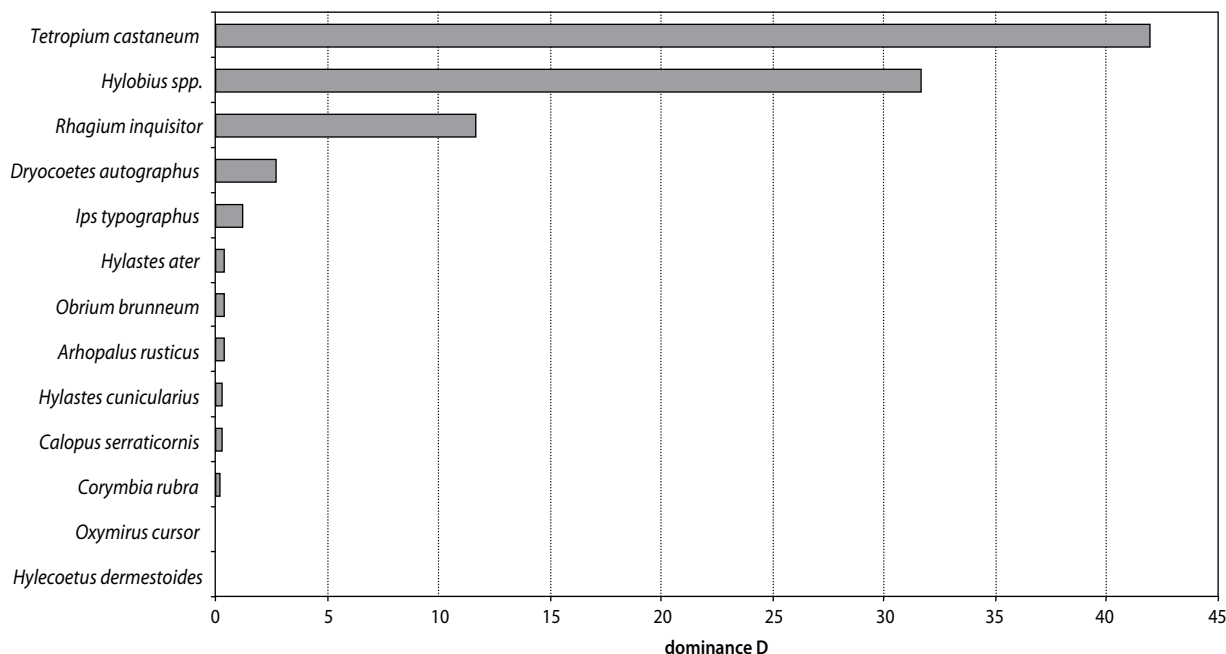


Fig. 1. The structure of dominance of cambio- and xylophagous insects in *Picea abies* stumps

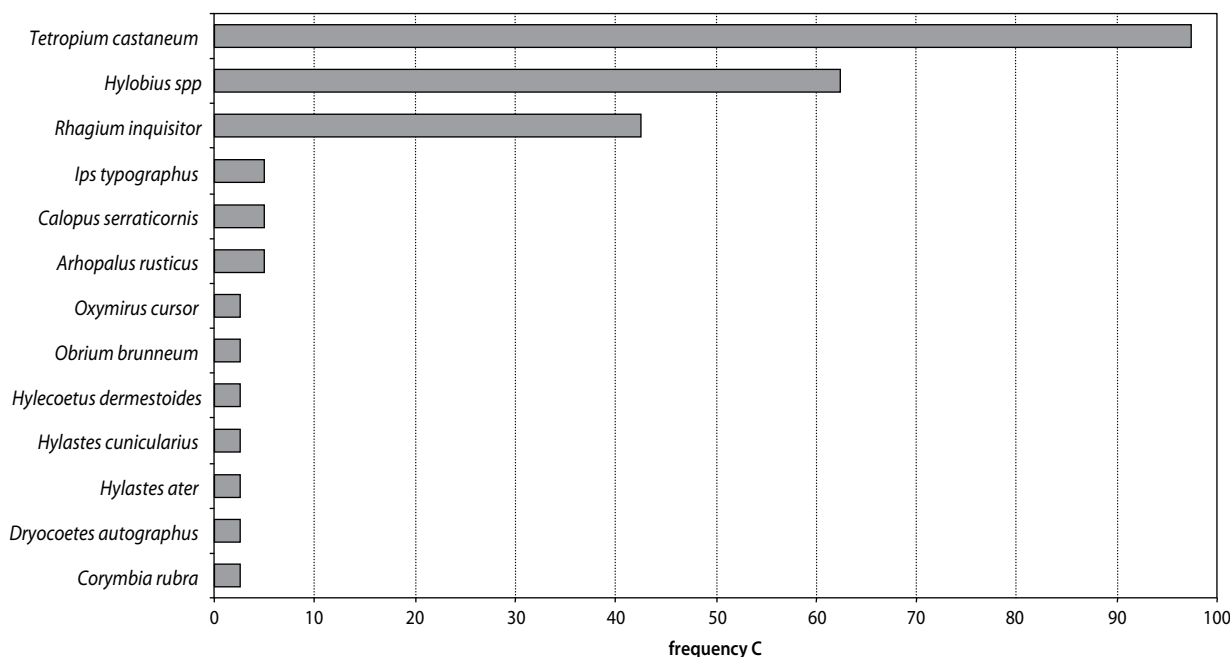


Fig. 2. Frequency of cambio- and xylophagous insects in *Picea abies* stumps

tle *T. castaneum*. Also, the genus *Hylobius* showed high values of the indicators of dominance and frequency, 31.7 and 62.5, respectively. Next the longhorn beetle *R. inquisitor* indicated the high dominance ($D = 11.7$), and its occurrence was recorded in 17 spruce stumps ($C = 42.5$). The remaining species were represented by several specimens occurring in sparse stumps. For example, the bark beetle *D. autographus* ($D = 2.7$) was observed in 1 stump only, thus showed the low indicator of frequency ($C = 2.5$). The larger European spruce bark beetle *I. typographus* showed the dominance relatively low ($D = 1.3$) and was found only in 2 stumps ($C = 5$). Other species occurred sporadically ($0.07 < D < 0.79$) and indicated the frequency from 2.5 to 7.5.

Figures 1 and 2 present the indicators of dominance and frequency characteristic of the assemblages of cambio- and xylophagous entomofauna colonising *P. abies* stumps.

DISCUSSION

The results of observations carried out on the assemblages of insects colonising spruce stumps indicated abundance of cambio- and xylophagous insects which

added up to 91% of all collected insects. The family of longhorn beetles (54%) was most numerous, and the cambio-xylophagous insect species, i.e. the black spruce longhorn beetle *Tetropium castaneum* showed the highest values of the indicators of dominance and frequency ($D = 41.9$, $C = 97.5$, respectively). In this study, another longhorn beetle – the ribbed pine borer *Rhagium inquisitor* dominated in the group of cambio-xylophagous insects and this species was the second with regard to the dominance ($D = 11.6$) and frequency ($C = 42.5$). Both species commonly occur in *P. abies* stumps but also attack weakened or dying and those fallen (up-rooted) or broken (Dominik and Starzyk 1989). Comparable results were obtained by Starzyk and Sęk (1983) during their investigations conducted on insect assemblages in the Beskid Sądecki mountains (the Western Carpathians). The results of these authors indicated the apparent dominance of *T. castaneum* ($D = 72.6$), while *Rh. inquisitor* was less abundant ($D = 32.7$), even though it showed the dominance among cambio-xylophagous insects. The results of the study on entomofauna of *P. abies* stumps carried out by Kosibowicz (1987) in the Beskid Żywiecki mountains (the Western Carpathians) also pointed out that *T. castaneum* and *Rh. inquisitor* showed some of the highest indicators of dominance and frequency. Furthermore, the results of

investigations conducted in Sweden confirmed that insect species of the genus *Tetropium* most often colonised low and high spruce stumps (Eidmann 1992, Schroeder and Eidmann 1993, Schroeder et al. 1999).

The results of the present study indicated that other than described above Cerambycidae species occurred in small numbers. In this case the values of indicators of dominance and frequency did not exceed 1 and 5, respectively. In the group of these species, there were observed the longhorn beetle *Arhopalus rusticus* (one of the most important timber pests) and the red longhorn beetle *Corymbia rubra* which is an important pest of near-ground parts of wooden constructions (Dominik i Starzyk 1989). Pine stumps provide key breeding bases for these two species, thus on spruce stumps they are observed considerably less frequently (Dominik 1954). However, Starzyk (1980) and Kosibowicz (1987) observed higher Red longhorn beetle numbers ($D = 5.8$) in spruce stumps and reported occurrence of this pest in 17% of analysed stumps. Other species of longhorn beetles observed in the present study (*Obrium brunneum* and *Oxymirus cursor*) colonise also other than spruce conifer stumps and are not important as timber pests.

In the assemblages of cambio-xylophagous insects, the genus *Hylobius* showed the high values of the indicators of dominance and frequency ($D = 31.7$, $C = 62.5$). The genus *Hylobius* is represented in conifer stumps mainly by weevils *Hylobius abietis* and *Hylobius pinastri* Gyll. – the species known as extremely important pests of reforested areas. The results of Starzyk and Sęk (1983) confirm that with regard to population numbers the large pine weevil is the second most abundant cambio-xylophagous species colonising *P.abies* stumps in the Beskid Sądecki mountains. On the other hand, Kosibowicz (1987), stated that *H. abietis* is a rare on *P. abies* stumps ($D = 2$) in view of the fact that he observed this species only on 3 of 100 analysed stumps. It seems that the intensity of spruce stump colonisation by the large pine weevil depends on the availability of other conifer stumps or up-rooted trees or wood debris, especially those of *P. silvestris*, i.e. preferred breeding base of this species. The results obtained in Sweden proved that with the same availability of *P. abies* and *P. silvestris* stumps, the large pine weevil colonised the latter more intensively (Tunset et al. 1993, von Sydow and Birgesson 1997). The results of this research indicated that *H. abietis* females laid eggs more often on nearby pine roots, even

though a distance to reach spruce roots was same as to pine roots. In the case of eggs laid close to spruce roots but in close proximity to pine roots, hatching larvae migrated in soil towards pine material. The authors believe that under-bark tissues of *P. sylvestris* represent better food for *H. abietis* larvae than those of *P. abies*. Another reason of observed higher intensity of pine stumps colonisation can be differences in amounts of *H. abietis* volatile attractants released by pine stumps. Lekander et al. (1985) indicated that pine stumps emanated more ethanol in comparison with spruce stumps, and ethanol is believed to be a strong attractant for *H. abietis*.

In the collected material, the sub-family Scolytinae was the third most abundant group represented by 4 species. Among bark beetles there prevailed *Dryocoetes autographus* ($D = 2.7$), which at the same time indicated the low frequency ($C = 2.5$) since it was found only in 1 stump. *D. autographus* is a cambio-phagous species that commonly occurs within Poland's area and feeds on decomposing conifer trees and stumps most often situated in shadowed and humid forest parts. Kuś and Kuś (2004) who carried out research on entomofauna on decomposing wood within the Karkonosze National Park reported that for 1-year old spruce material (standing trees, up-rooted trees, broken trees and stumps), the value of dominance indicator for *D. autographus* was higher than 10. In the 2nd year of observations the value raised to more than 40, whereas between 3rd and 5th years it decreased to approximately 10. In the following years of observations, no occurrence of *D. autographus* was observed in the analysed spruce material. Schroeder et al. (1999) conducted research on entomofauna of high spruce stumps (up to 5 m) during 2 years after tree felling and reported occurrence of *D. autographus* exclusively on 2-year-old stumps (27%). Abundance of *D. autographus* in spruce stumps within the area of the Beskid Sądecki mountains was reported by Starzyk and Sęk (1983) who observed this species in 90% of analysed stumps and showed its highest dominance ($D = 54$) among observed cambio-phagous insects. Similar dominance ($D = 52$), but considerably lower frequency ($C = 11.5$) of *D. autographus* was observed by Kosibowicz (1987) during his study on insect assemblages in spruce stumps within the Beskid Żywiecki mountains. On the other hand, the results of studies on entomofauna by Starzyk and Starzyk (1981) carried out in the Niepołomicka Forests (about 20 km

east of Kraków) showed no occurrence of *D. autographus* in *P. abies* material (branches and stumps).

The results of this study indicated relatively low numbers ($D = 1.25$) and frequency ($C = 5$) of the spruce bark beetle *Ips typographus*. It is possible that one of the reasons of such low incidence of this species was the fact that it prefers different breeding sites, and the stumps are colonised only when more sufficient breeding material is not available. Göthlin et al. (2000) carried out 2-year observations on wind damaged spruce stands and compared levels of infestation of up-rooted and broken trees as well as stumps of the height up to 1 m. Based on the results obtained, the authors concluded that in the 1st year after the damage the spruce bark beetle most often colonised broken trees (39%), and in the 2nd year – up-rooted (31%). The stumps were colonised by *I. typographus* to the least extent. It was recorded in the stumps just in the 2nd year of research and its numbers added up to only 6% of the total number of then observed insects. Low numbers of this species in spruce stumps were also reported by Kosibowicz (1987). In this author's study the value of indicators of dominance and permanence of occurrence for *I. typographus* were 3 and 5.4, respectively. Similar values of these indicators ($D = 3$, $C = 3$) for *I. typographus* were obtained by Starzyk (1995) during his research on entomofauna of spruce stumps in the region of southern Poland. At the same time, the results of earlier studies by this author in the Beskid Sądecki mountains showed no occurrence of *I. typographus* in *P. abies* stumps in this area (Starzyk i Sęk 1983).

Considerably low frequency of occurrence of common pests of mountain reforested areas and young spruce stands, such as the black pine beetle *Hylastes ater* ($D = 0.39$; $C = 2.5$) and the bark beetle *H. cunicularius* Er. ($D = 0.26$; $C = 2.5$) observed in this study is worth noting. Similar results were obtained by Kuś and Kuś (2004). During their studies on entomofauna on decomposing spruce trees, the authors observed no occurrence of *H. ater* and *H. cunicularius* Er. on broken, up-rooted and trap trees as well as branch piles and stumps in the Karkonosze National Park. Also, Starzyk and Sęk (1983) did not find insects of these species on *P. abies* stumps in the Beskid Sądecki mountains. On the other hand, the results of 20-year study conducted by Starzyk (1995) in many lowland and mountain forest districts, located in southern Poland, indicated occurrence of

H. ater and *H. cunicularius* in *P. abies* stumps. Based on these results the author classified the black bark beetle as the dominant species ($D = 5.1$ – 9%), great numbers of which often developed in spruce stumps. At the same time, the population of *H. cunicularius* was much less abundant and this species was positioned in the lowest class of dominance, i.e. subrecendents ($D \leq 1\%$). Also, Kosibowicz (1987) reported very low incidence of *H. cunicularius* ($D = 0.05$) in spruce stumps in the Beskid Żywiecki mountains.

The noticeably smaller group of predatory beetles encompassed 2% of the total number of collected specimens. Nearly 1% of this group belonged to the family of rove beetles (Staphylinidae), which embraces many predatory species preying under the bark of forest tree stumps. Tree stumps with a variety of insect larvae in feeding galleries create a sufficient habitat for rove beetles – also differentiated with regard to food quantity. At the same time the stumps provide shelter from detrimental effects of the environment outside (Mazur 1995). In the collected materials, the most numerous representative of Staphylinidae was *Nudobius lentus* (Grav.), which commonly occurs in feeding galleries of longhorn and bark beetles and colonises the stumps together with other 3 observed in this study species: *Athea fungi* Grav., *Philonthus decorum* Grav. and *Quedius punctatelius* Herr.

Among other predatory insects there was observed the ant beetle (*Thanasimus formicarius* L.) – one of the most common natural enemies of bark beetles, which in this study occurred in low numbers (0.8% of the total number of observed specimens) and was found only in a few stumps (7). Similarly low numbers showed the family Elateridae (0.5%) which was represented by the genera *Hemicrepidius* and *Melanotus*. In the analysed stumps, there also was determined the species: *Ampepus pomorum*, which commonly occurs in the stumps, and the larvae (wireworms) of which attack larvae of longhorn and bark beetles (Szujewski 1995).

Next group of predatory beetles feeding under the bark was the family Monotomidae – root-eating Beetles. A few of its representatives were observed in the analysed stumps, and first of all these were specimens of *Rhizophagus dispar* (Payk.) and *Rh. ferrugineus* (Payk.). The family of Nitidulidae was represented by specimens determined as members of the genus *Epu-raea* and the species *G. quadripustulatus*. Remaining

beetle families (Carabidae, Histeridae, Pyrochroidae) were represented by individual specimens found in 1–2 stumps. Occurrence of these predatory insects in the stumps was also reported by Starzyk and Sęk (1983) in their study on entomofauna of spruce stumps in the Beskid Sądecki mountains. The results of this study were similar to the results obtained in the present investigation and the authors classified most of observed predatory beetle to the group of subprecedents.

In general, predatory beetles feeding under the bark have been a subject of many studies due to their effects on populations of cambio- and xylophagous insects. The predatory beetles observed in this study belong to predatory entomofauna associated with cambio- and xylophages commonly occurring in Poland. Poland's predatory entomofauna was described among others by Bałazy and Michalski (1960), Bałazy (1995), Mazur (1995), Grodzki (1997) and Hilszczański (2008). A review on parasitoids and predators of Europe's bark beetle species is available in publications by Kenis et al. (2004a,b,c).

Representatives of the order Diptera (5% of all collected insects), which feed either on dead wood or are predatory, formed an important group of observed insects. Most of collected flies belonged to predatory snipe flies Rhagionidae (2%) and Muscidae (1.4%) as well as to Syrphidae (1.2%). The latter feed mostly on decaying bark of trees. About 0.3% of flies were determined as Xylophagidae, which prey on larvae of various xylophagous insects developing in galleries under the bark. The family Tachinidae was represented sparsely (0.2%). It embraces parasitoids of many leaf-eating forest insects. Most Diptera specimens found in this study were determined to the systematic level of family, however representatives of robber flies Asilidae were determined as 2 species of the genus *Laphria* (0.1%). The larvae of these species are predatory and prey in galleries of Cerambycidae and Scolytinae. Additionally, individual specimens from the families Empididae, Therevidae and Raphidiidae were observed in the analysed stumps.

CONCLUSIONS

- The results of quality analyses of entomofauna colonising *P. abies* stumps indicated incidence of insects from 21 families from 3 orders: Coleoptera

(12 families which comprised approximately 95% of all collected insects), Diptera (8 families, 5%) and Raphidioptera (1 family, 0.2%).

- The highest values of indicators of dominance (D) and frequency (C) were found for the species *Tetropium castaneum* (D = 41.9; C = 97.5) and the genus *Hylobius* (D = 31.7; C = 62.5).
- The stumps were colonised mainly by cambio-xylophagous and cambiophagous insect species (73% and 16%, respectively). Predatory insects comprised almost 2% and xylophages about 1.5% of the collected entomofauna, whereas parasitoid species were least abundant (0.2%).

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