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ORIGINAL ARTICLE

Entomofauna of dying young spruces *Picea abies* (L.) Karst. in the area after forest decline in the Izerskie Mountains

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Abstract

The results of the study on entomofauna infesting young (25–45 years) Norway spruces (*Picea abies* [L.] Karst.) in the area formerly affected by forest decline in the Izerskie Mountains (Western Sudetes), are presented in the paper. Entomological analyses were carried out on tree sections (0.5 m long) obtained from 50 trees (3 sections each) as well as during photoeclector rearing of tree samples (28 sections 0.5 m long). Bark- and wood-boring insects of 21 species and 1 genus were found. The dominant species was *Pityogenes chalcographus* L. (88% frequency in field analyses) usually accompanied by *Ips amitinus* (68%). Both species frequently infested whole stems (found in all 3 sections in 62% of analyzed trees). In the group of predators and commensals, 13 species were found, with most frequent *Corticeus linearis* (Fabr.), *Crypturgus* spp. and *Medetera signaticornis* (Loew.). Among the parasitoids belonging to 7 species and 4 genera, Braconids and Pteromalids known as parasites of Scolytid bark beetles, were most common. Taking into consideration reccurence of natural processes such as insect outbreaks, probability of the scenario described in the paper, i.e. shifting bark beetle attack from old into young spruce stands after *Ips typographus* L. outbreak, is very high in the area of current decline of the Norway spruce in the Western Carpathians.

Key words

young stands, cambiophagous insects, xylophagous insects, parasitoids, predators, commensals, Sudetes

Introduction

During the last two decades of the twentieth century, large areas in the Western Sudetes in Poland were impacted by extended forest decline. The process, which affected mainly (or exclusively) Norway spruce (*Picea abies* [L.] Karst.) stands, started in 1977 by the outbreak of *Zeiraphera griseana* Hbn. (Lepidoptera, Tortricidae), which larvae feed on the youngest spruce needles. The total area of damaged stands was estimated to 31.4 thous. ha. Subsequently, in defoliated stands remaining in deep physiological stress enhanced by air pollution effects, in 1980 there started a bark beetle outbreak as a result of favorable weather conditions and wind damage. Intensive mortality of spruces infested by bark beetles culminated in 1984, and the outbreak lasted till 1987 (Capecki and Grodzki 1998). Due to this process and connected sanitary felling the area of 13.2 thous. ha was deforested (Pietruńko 2004).

In this period, several studies were carried out in order to identify patterns and factors that drive population dynamics of spruce bark beetles and their natural

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enemies in the conditions of forest decline and reduced biodiversity (e.g. Capecki and Grodzki 1998; Grodzki 1995, 1997 a, b, c). Observations were conducted mainly in old Norway spruce stands, which were most affected by decline processes, thus data concerning similar problems in younger stands are hardly available. This paper aims to present the results of investigations on the above processes in young spruce stands which survived the outbreak of bark beetles.

The cambio- and xylophagous insects occurring in young stands have been already studied, however related insect groups such as natural enemies have not been fully reported. Several studies have been carried out in relatively diverse stands of the Beskid Sądecki mountains (Starzyk and Wójcik 1985; Starzyk and Siemek 1987), as well as in the western part of the Beskidy mountains in the Czech Republic (Kula and Ząbecki 2003; Kula *et al*. 2007, 2009). It seems interesting to compare the data on occurrence of bark- and wood-boring insects in similar stands as well as in the stands with reduced biodiversity growing in the Sudetes. Such comparison could help better understanding of both already finished and still ongoing processes which take place in mountain Norway spruce stands.

During the last two decades, at least two big bark beetle outbreaks took place in spruce stands in the Carpathians. The last, still ongoing outbreak affected the Beskidy mountains on the western edge of the Carpathians (Grodzki 2009). Even if the causes and course of this process are not same as in the Sudetes, main patterns of bark beetles' occurrence remain unchanged. This also concerns a potential threat to younger stands, which – taking into account high mortality of old stands – need to survive. The results presented in this paper should help in better recognition of future threats and in appropriate planning of necessary forest protection activities.

Materials and methods

The study sites were located within the area of the Forest Districts of Szklarska Poręba and Świeradów, in the Izerskie Mountains (Western Sudetes). During the vegetation season 1995 (May – September) young (25–45 years old) stands which survived forest decline were patrolled in order to identify spruce trees infested by bark- and wood-boring insects (Tab. 1). Selected trees were cut down for entomological analyses. Determination of species composition and observations on frequency of bark- and wood-boring insects and their natural enemies were conducted using the method of tree sampling. Three 0.5 m long stem sections were cut out of each tree using the following pattern: Section I: at the base of the stem (0.5–1.0 m above the ground); Section II: midway between the base and the top of the tree; Section III: in the middle of the crown. The occurrence of galleries of bark- and wood-boring insects was recorded and specimens of insect predatory species were collected from the galleries under the bark. The analyses were conducted on 50 trees in the stands characterized in Table 1. On some (9) trees, the infestation density (number of mating chambers per dm^2) by most frequent species was assessed.

Tab. 1. Location and basic characteristics of stands where entomological analyses of infested spruces were performed in the Izerskie Mountains (Western Sudetes) during the growing season in 1995

Forest District	Forest sub-district	Compartment	Altitude m a.s.l.	Share of spruce (%)	Age of spruce (years)	Number of analyzed trees
Świeradów	Świeradów	198	630	50	35	4
Szklarska Poręba	Szklarska Poręba	220	980	60	32	3
		224	980	60	32	21
		225	980	100	33	2
		247	850	70	26	3
		250	820	50	37	3
	Piechowice	101	800	100	45	9
		103	600	90	25	5

In order to better evaluate species composition of insects infesting analyzed spruces, 0.5 m long sections were cut out from selected trees and put into photoeclectors for laboratory insect rearing. The photoeclectors are wooden, dark boxes with exit holes closed by transparent containers for collecting emerging insects attracted by the light. In total, 28 tree samples were put into the photoeclectors which were stored in a special, unheated chamber in the Department of Forest Management in Mountain Regions, Forest Research Institute, in Kraków. All emerged insects were collected and their species were determined.

The data from forest inventories conducted in the years 1975, 1989 and 1999 presented in this paper were kindly provided by the Forest District Szklarska Poręba.

Results

After dramatic forest decline in the period 1980–1987, the area of younger Norway spruce stands (up to 60 years old) increased: the data from forest inventories done in the Forest District Szklarska Poręba in 1975 (before the process started), in 1989 (just after forest decline) and in 1999 (after field investigations hereby described) show a visible and systematic volume increase in spruce trees of the age classes I–III (Fig. 1). In 1989–1999, the area of the stands in II–III age class increased by nearly 17% – from 4.1 to 4.8 thous. ha (Fig. 2). Many of these stands, especially those growing in higher altitudes, were of special structure, i.e. without closure regardless their age (Fig. 3). In the middle

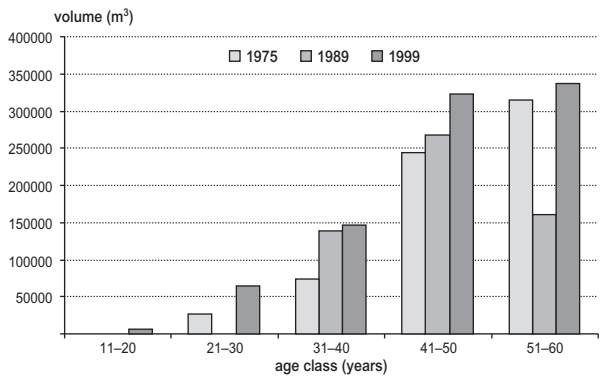

Fig. 1. Volume of spruce trees up to 60 years old divided into 10-year age classes in the Forest District Szklarska Poręba in 1975, 1989 and 1999

Fig. 2. Area of spruce stands up to 60 years old divided intoby 10-year age classes in the Forest District Szklarska Poręba in 1989 and 1999

of the 1990-ties symptoms of increased tree mortality started to appear in young Norway spruce stands growing in a large range of altitudes.

The mean ± standard deviation DBH of 50 trees analyzed in 1995 was 9.4 ± 2.8 (5–16) cm, and their average height was 6.9 ± 2.6 (4–14) m. The trees did not die immediately – the process of their dying was slow, with stepwise insect infestation of separate parts of stems. In some cases, middle or upper crown parts were infested first, while lower parts still remained green (Fig. 4).

The analyzed trees were infested by bark- and woodboring insects that belonged to 21 species and 1 genus (Tab. 2). During field analyses, 14 species were found and 18 species were recorded at the time of photoeclector rearing while 10 species were found using both methods. Insects from 4 species were found only by field analyses, and 7 species were collected only by the rearing. The dominant was the family Curculionidae with 14 species, from which 13 were bark beetles Scolytinae. Next family constituted longhorn beetles from the Cerambycidae family (6 species), and hymenopterans from the Siricidae family (2 species). Scolytids from the genus *Crypturgus* (Er.) were treated as egg predators, and excluded from above described groups.

Most frequently occurring species were *Pityogenes chalcographus* (L.) (88% in the field and 82% in the rearing) and *Ips amitinus* (Eichh.) (68 and 21%, respectively). *I. typographus* (L.) was more common in the rearing (25%) while both species from the genus *Dryocoetes* (Eichh.) were more often observed in the field (18%) (Tab. 2). Some species were found only in field analyses (6 trees) or at the rearing (7 samples).

Fig. 3. Young spruce stands in the upper part of the Izerskie Mountains in 1995 (photo: W. Grodzki)

Fig. 4. Dying young spruce, the Izerskie Mountains, May 1995 (photo: W. Grodzki)

The bark- and wood-boring insects found in 50 field analyses occurred in associations that comprised 2–4 species, and most frequently there were observed 2-species associations (25 cases) with *P. chalcographus* and *I. amitinus* (21 cases); in 2 cases *Dryocoetes autographus* (Ratz.) occurred instead of *I. amitinus*. In individual cases assotiations of *D. autographus* and *Xylotereus lineatus* (Ol.) as well as *Molorchus minor* (L.) – *Magdalis phlegmatica* (Herbst) were found. In 12 cases 3 species co-occurred on the same trees. Then mostly *P. chalcographus* and *I. amitinus* was found together with: *I. typographus* (4 cases), *D. autographus* (3), *D. hectographus* Reitt. (2), *X. lineatus* (1) and *Rhagium* sp. (1). Once *Xylechinus pilosus* (Ratz.) was found with *M. phlegmatica* and *M. minor*. In 4 cases there were observed 4 species together, and these were: *P. chalcographus*, *I. amitinus* and *I. typographus* with *X. lineatus* or *Hylurgops palliatus* (Gyll.); *M. phlegmatica*, *M. minor*, *D. autographus, Pityophthorus pityographus* (Ratz.), as well as *P. chalcographus*, *I. duplicatus*, *Polygraphus poligraphus* L., *Orthotomicus laricis* (Fabr.). The occurrence of only 1 species was observed in 9 cases, from which in 7 it was *P. chalcographus* and in 2 – *X. pilosus*. During rearing experiments (28 tree samples) the associations consisted of up to 7 species. Most common were 2-species associations (7 cases) in which *P. chalcographus* occurred in 6 cases, as a rule (5 cases) accompanied by one of *Ips* De Geer species. *P. chalcographus* occurred also individually in all 6 cases. Associations of 2–4 species were found in 2 cases each. In one case there was observed an association of 7 species the majority of which were not found in other samples. In 4 cases no

Tab. 2. Frequency of bark- and wood-boring insect species on 50 analyzed trees and 28 reared stem samples collected in young spruce stands in the Izerskie Mountains

Species (Genus)	no of cases with species presence		frequency (%)	
	analyzed trees	reared samples	analyzed trees	reared samples
Pityogenes chalcographus (L.)	44	23	88	82
Ips amitinus (Eichh.)	34	6	68	21
Dryocoetes autographus (Ratz.)	7	1	14	4
Ips typographus (L.)	6	7	12	25
Xylechinus pilosus (Ratz.)	3	3	6	11
Xyloterus lineatus (Ol.)	3	1	6	4
Molorchus minor (L.)	3	6	6	21
Dryocoetes hectographus Reitt.	2		4	
I. duplicatus (Sahlb.)	1	5	2	18
Polygraphus poligraphus (L.)	1		2	
Hylurgops palliatus (Gyll.)	1	1	2	4
Rhagium sp. (young larvae)	1		2	
Pityophthorus pityographus (Ratz.)	1	2	2	7
Orthotomicus laricis (Fabr.)	1		2	
Tetropium castaneum (L.)		3		11
Magdalis phlegmatica (Herbst)	3	3	6	11
Clytus lama Muls.		2		7
Urocerus gigas (L.)		2		7
Cryphalus abietis (Ratz.)		1		4
Pogonochaerus fasciculatus (Deg.)		1		4
Obrium brunneum (Fabr.)[1]		1		4
Sirex juvencus (L.)		1		4

[1] 1 ex. emerged from sample coll. 13.07.1995, Szklarska Poręba Forest District, Subdistrict Piechowice comp. 105k, leg. 15.05.1997

bark- and wood-boring insects were found. *X. pilosus* occurred in a separate and very stable association with *M. phlegmatica* and *M. minor* This was found in the field analyses and confirmed by rearing.

The occurrence of two most frequent species on analyzed trees varied depending on stem sections (Fig. 5). The variability of occurrence was lesser for *P. chalcographus* (68–84%). In most cases this species infested the whole length of tree stems (in 62% cases was found in all 3 tree sections, and 18% – in 2). *I. amitinus* preferred the middle zone of the stem, where its frequency was the highest (60%), and the infestation of 3 stem sections was found in 40% cases. Similar pattern was observed for the infestation density, especially in the case of *P. chalcographus* (Fig. 6). No relationship

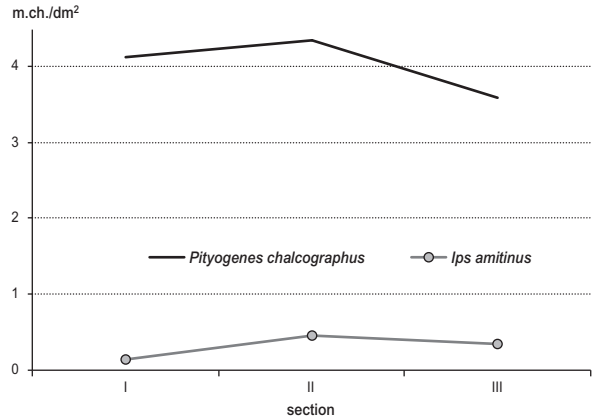

Fig. 5. Frequency of two most frequent bark beetle species observed on tree sections of 50 sampled trees in the Izerskie Mountains in 1995

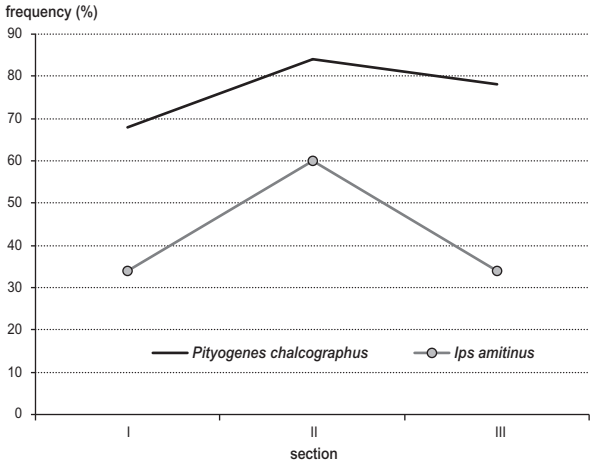

Fig. 6. Infestation density by two most frequent bark beetle species observed on tree sections of 9 sampled trees in the Izerskie Mountains. in 1995 (m.ch. – mating chambers)

was found between the infestation density and the DBH of observed trees. The effect of the DBH is visible in the case of *I. typographus*, where its mean value on trees infested by this species – 12.2 (8–15) cm was higher than the average DBH of all analyzed trees.

The second group of observed insects embraced predators, commensals and parasitoids (Tab. 3). Among predators, insects of 13 species were found. Due to some injured specimens in a few cases the collected insects were determined only to a level of genus (3 cases) or family (4 cases). In the total number of predatory species, 7 species and 1 family were determined for specimens emerged in the rearing, 7 species and 1 genus were collected in the field, and 3 species were collected by both methods. The families represented the most were the Staphylinidae (5 species), Curculionidae: Scolytinae (3 species) and Monotomidae (at least 2 species), while beetles from the Tenebrionidae, Trogossitidae and Histeridae as well as flies from the Dolichopodidae were represented by 1 species each. Most common species were *Corticeus linearis* (Fabr.) and *Crypturgus* spp. (both in field and rearing analyses), as well as *Medetera signaticornis* Loew (rearing only). *C. linearis* and *Nemozoma elongatum* (L.) were found mainly in the galleries of *P. chalcographus* while *Rhizophagus* spp. and *Crypturgus* spp. were found in the galleries of various bark beetles. Staphylinid beetles were collected in the galleries of *I. amitinus* and *I. typographus*, but *Nudobius lentus*

Tab. 3. Frequency of predators, commensals and parasitoids on 50 analyzed trees and 28 reared stem samples collected in young spruce stands in the Izerskie Mountains

Species (Genus)	number of cases with species presence		frequency (%)	
	analyzed trees	reared samples	analyzed trees	reared samples
1	2	3	4	5
predators/commensals				
Medetera signaticornis Loew		9		32
Corticeus linearis (Fabr.)	7	8	14	29
Crypturgus hispidulus Thoms.	5	6	10	21
Crypturgus cinereus (Herbst)		5		18
Latridiidae		4		14
Nemozoma elongatum (L.)	1	3	2	11
Plegaderus vulneratus (Panz.)		1		4
Crypturgus pusillus (Gyll.)		1		4
Rhizophagus sp.	3		6	
Rhizophagus depressus (Fabr.)	2		4	
Phloeonomus punctipennis Thoms.	2		4	
Phleoepora teres (Grav.)	2		4	
Nudobius lentus (Grav.)	2		4	
Placusa depressa Maekl.	2		4	
Quedius plagiatus Mann.	1		2	

1	2	3	4	5
parasitoids				
Dinotiscus eupterus (Walk.)		13		46
Pteromalidae undetermined		13		46
Rhopalicus tutela (Walk.)		4		14
Ecphylus silesiacus (Ratz.)		4		14
Braconidae undetermined		3		11
Helcostizus restaurator (Fabr.)		3		11
Tomicobia seitneri (Ruschka)	1	2	2	7
Ibalia leucospoides (Hoch.)		2		7
Liotryphon sp.		2		7
Pyracmon sp.		2		7
Deuteroxorides elevator (Panz.)		1		4
Rhimphoctona sp.		1		4
Aliolus sp.		1		4

(Grav.) and *Quedius plagiatus* (Mann.) were also observed in the galleries of *Hylurgops palliatus* (Gyll.). Some taxa, such as Latridiidae beetles or Histerid *Plegaderus vulneratus* (Panz.), were treated as commensals dwelling bark beetle galleries.

The group of parasitoids collected from the rearing only embraced 7 species and 4 genera determined. Some hymenopteran specimens from Braconidae and Pteromalidae were determined only to a family level. Insects from the latter families were the most abundant, while representatives of Ichneumonidae and Ibaliidae most often occurred individually. The species from the Braconidae and Pteromalidae families emerged from the samples infested by most frequently occurring bark beetle species, on the other hand *Tomicobia seitneri* (Ruschka), besides the specimens collected from rearing, was also found by an emergence hole in a dead *I. typographus* beetle which remained in the gallery. *Ibalia leucospoides* (Hoch.) emerged from samples infested by *Urocerus gigas* (L.). All collected Ichneumonidae came from samples infested by Cerambycid beetles, mainly *Molorchus minor* (L.).

Discussion

The occurrence of cambio- and xylophagous insects in young spruce stands has already been studied by several authors, but outside the area of research presented. Young spruce stands (in their initial development phase) are generally not attractive for cambio- and xylophagous insects (Starzyk and Wójcik 1985), as most predisposed for attacks of these insects are stands in the age above 100 years (Netherer and Nopp-Mayr 2005). Starzyk and Siemek (1987), when studied this topic in the Beskid Sądecki mountains (Carpathians), found the association of of cambio- and xylophagous insects that consisted of 12 species, with absolute domination of *Pityophthorus pityographus* (100% stability of incidence), *Poligraphus poligraphus* and *Xylechinus pilosus*, and these were found as rare in the Izerskie Mountains. The opposite pattern can be seen in the case of *Pityogenes chalcographus* dominating in the Sudetes, while in the Carpathians it reaches only 40% stability. Similar results were reported by Kula and Ząbecki (2003) from spruce stands aged below 60 years situated in the Beskidy Mountains (Western Carpathians). The dominant species on standing trees were *P. pityographus*, *Molorchus minor* and *Rhagium inquisitor* (L.), whilst the frequency of *P. chalcographus* was less than 30%. Described by Kula *et al*. (2007) entomofauna in snow-broken young spruce stands in the Western Carpathians also differed from entomofauna in spruce stands the Izerskie Mountains. This can be explained by differences in breeding material (lying vs. standing trees), however high frequency of *P. chalcographus* on broken, thick trees was also observed in this study.

The associations of insects found in the young stands in the Izerskie Mountains were also different than

those described by Konca (1993) in neighboring area of the Karkonosze Mountains, which probably results mainly from differences in analyzed breeding material – much thicker in older spruce stands. This especially concerns dominating position of *P. chalcographus* on thicker trees in the Izerskie Mountains, and also the associations of *X. pilosus*, completely different than those found in older stands.

The dominant position of *P. chalcographus* in analyzed material can be explained by two reasons: very high ecological plasticity of this species and the effect of deep changes which occurred in the forest ecosystems of the Western Sudetes after forest decline. At the final phase of this process, which should be understood as the retrogradation phase of *Ips typographus* outbreak (beginning of 1990-ties), there was observed a fast increase in population density of other bark beetle species, usually known as only accompanying *I. typographus*. This concerned mainly *P. chalcographus*, of which increased occurrence was observed on standing trees in older spruce stands as an effect of disturbed interspecific competition mechanisms due to selective pest control (*I. typographus* synthetic pheromones) and abundant breeding/feeding base offered by logging residues left in forest (Grodzki 1997a). The species *P. chalcographus* is highly ecologically plastic and able to colonize phloem space left by other – greater bark beetle species. With its small dimensions it infests tree stems regardless their diameter and bark thickness (as also demonstrated in presented results). Size is a limiting factor in case of *I. typographus* (Grünwald 1986). In favorable breeding conditions and at high population density, *P. chalcographus* is able to be a winning part in the competition with other bark beetles, such as *I. typographus* or *I. amitinus* (Grodzki 1997a) or to kill older trees alone (Grodzki 1997c). This species was considered as playing the essential role in bark beetle associations infesting old spruces in higher montane zone (above 1000 m a.s.l.) in Karkonosze (Mazur *et al*. 2006), which also indicates its high plasticity. Observed in younger stands intensive attacks of this species could also be enhanced by changing breeding resources due to the decline of older spruce stands. Similar phenomenon was observed in the Bieszczady Mountains in the final phase of *I. typographus* outbreak (Grodzki 1995). Taking into account present decline of Norway spruce in the Western Carpathians, the repetition of such scenario in this area is of high probability, as the symptoms of increasing *P. chalcographus* frequency have already become visible also in this mountain area (Grodzki 2004).

Quite interesting seems to be the occurrence of *Obrium brunneum* (Fabr.), collected from reared stem samples from the lower montane zone of the Izerskie Mountains. Konca (1993) pointed out that this species had been noted in the area of Western Sudetes before 1925 in the Jelenia Góra Basin. According to the *Catalogus Faunae Poloniae* (Burakowski *et al*. 1989), this insect was reported from the Western Sudetes, as collected (after 1925) no more than in Maciejowiec near Lwówek Śląski (Śliwiński 1961), which is located somewhat in Lower Silesia (outside the mountains). The species was not found in neighboring areas in the Czech Republic (Slama 1998). Then *O. brunneum* occurrence in the lower montane zone of the Western Sudetes could be noted for the first time in this paper.

Staphylinids *N. lentus* and *Q. plagiatus* are known from the Karkonosze mountains as occurring frequently under the bark of dead spruces infested by bark beetles (Mazur 1993, 1998). These two species and *Placusa depressa* Maekl. were obseved on old spruces in the Izerskie Mountains (Grodzki 1997b). At the beginning of 20. century, *Phloeopora teres* (Grav.) and *Phloeonomus punctipennis* Thoms. were observed living in the bark beetle galleries in stands in the Western Sudetes (Burakowski *et al*. 1979, 1981; Szujecki 2008), however, recently these species have not been reported as occurring in this area (Mazur 1998). Other predators (beetles and *Medetera signaticornis*) and commensals observed in this study had been previously found in the Sudetes as related to bark beetles in older spruce stands (Grodzki 1997b).

The same concerns all collected parasitoids from the Braconidae and Pteromalidae families, already shown as related to bark beetle species reported in this study, as well as *Ibalia leucospoides* parasitizing *Urocerus gigas* (Grodzki 1998). As for Ichneumonids, all determined in this study species (and genera) are known as parasitoids of Cerambycid beetles (Kenis and Hilszczański 2004), in this study – *M. minor*. The obtained results support previous conclusions concerning reduced biodiversity in ecosystems which were affected by spruce decline in the Sudetes (Grodzki 1997b).

The ecological phenomena and processes are cyclical, however their causes, course and effects can vary.

In almost every case there is however a possibility to depict and define their patterns and driving factors. This applies also to the phenomena described in this paper – the attack of bark beetles on young spruce stands after their outbreak in older stands. The presented data and resulting conclusions should be used for the assessment of potential threats in mountain areas affected by Norway spruce decline. Most relevant is the area of western part of Carpathians, where extended bark beetle outbreak is just ongoing in old spruce stands. The similar scenario to the one presented for the Sudetes can occur also in this region.

Conclusions

- On young dying Norway spruces analyzed in the area formerly affected by forest decline in the Izerskie Mountains there were found bark- and wood boring insects of 21 species and 1 genus. The insect associations in the Izerskie Mountains were different from those reported in other mountain areas in Poland.
- The main cause of tree mortality was infestation by *Pityogenes chalcographus*, which usually infested the whole stem lengths and in most of cases was accompanied by *Ips amitinus*. The dominate position of *P. chalcographus* among other observed insect species results from very high ecological plasticity of this species as well as deep changes that occurred in forest ecosystems of the Western Sudetes after forest decline.
- The results concerning natural enemies support earlier conclusions about reduced biodiversity in forest ecosystems affected by spruce decline in the Sudetes.
- Current decline of the Norway spruce in the Western Carpathians creates high probability of the above scenario, as symptoms of increasing *P. chalcographus* frequency have already been observed in this area.

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