JOURNAL OF FOREST SCIENCE, *56*, 2010 (4): 154–164

Variability of Norway spruce (*Picea abies* [L.] Karst.) cone entomofauna in the Tatra National Park in association with the development of cones

M. Kozioł

Department of Forest Entomology, Agricultural University of Cracow, Cracow, Poland

ABSTRACT: In the years 1987–1993 research aimed at the qualitative and quantitative composition of insects inhabiting the cones of Norway spruce (*Picea abies* [L.] Karst.) was carried out in the area of the Tatra National Park (Poland) for the first time. Approximately 72 thousand specimens of insects were obtained, representing 50 species from 8 orders. *Kaltenbachiola strobi* (Winn.), *Plemeliella abietina* Seitn. and *Cydia strobilella* L. were among the most frequently occurring species. The entomofauna of ripening, ripe and old, already lignified cones was determined, and among the insects found trophic groups were distinguished and, consequently, characterized by means of the following ecological indexes: constancy, dominance and species diversity. The qualitative and quantitative composition of spruce (*P. abies*) cone entomofauna was changing along with the development of the cones, due to the periods of occupancy and leaving the cones by species of varied bioecology. The entomofauna of ripe cones was characterized by higher species diversity (42 species) than that of ripening cones (25 species) and old cones (26 species).

Keywords: cones; entomofauna; Norway spruce; sequence; Tatra Mts.

Cones of Norway spruce (*Picea abies* [L.] Karst.) constitute a specific microhabitat for numerous species of insects from various systematic groups, where they stay permanently, seasonally or accidentally (Čermák 1952; Bakke 1955; Milišauskas 1976). Together, they form specific insect communities, characterized by their own sequence due to the periods in which particular species of varied bioecology occupy or leave the cones at different stages of their development. The initial point during the changes undergone by the communities of the cones is marked by the pollination of female inflorescences, and the final one – complete decomposition of the cones fallen onto the forest floor. This issue has been considered so far in different countries by several authors (Holste 1922; Arend 1967; Stadnickij 1969, 1971; Saksons 1973; Stadnickij, Golutvina 1975; Stadnickij et al. 1978; Dolgin, Nesin 1981; Roques 1983). In the Polish literature this issue was mentioned by Karpiński (1967) with reference to larch cones.

In Poland, research concerning the entomofauna of spruce cones was carried out in Beskid Sądecki (Skrzypczyńska 1982, 1986), Beskid Śląski and Żywiecki (Skrzypczyńska, Bysko 1997; Skrzypczyńska et al. 1998, 1999) as well as in the National Parks: Babiogórski NP (Skrzypczyńska et al. 1994), Białowieski NP (Skrzypczyńska 1989, 1994) and Gorczański NP (Witteczek 1998).

This paper presents extracts of results of research carried out for the first time in the Tatra National Park in the years 1987–1993. Parts of the results of this research, outside the scope of this thesis, were already used in separate studies (Kozioł 1997, 1998, 2000, 2007a,b).

The objectives of the study were to determine the variability of the qualitative and quantitative composition of insects inhabiting cones of Norway spruce (*Picea abies* [L.] Karst.) at different stages of development (ripening cones, ripe cones, old cones) in the stands from the Tatra National Park.

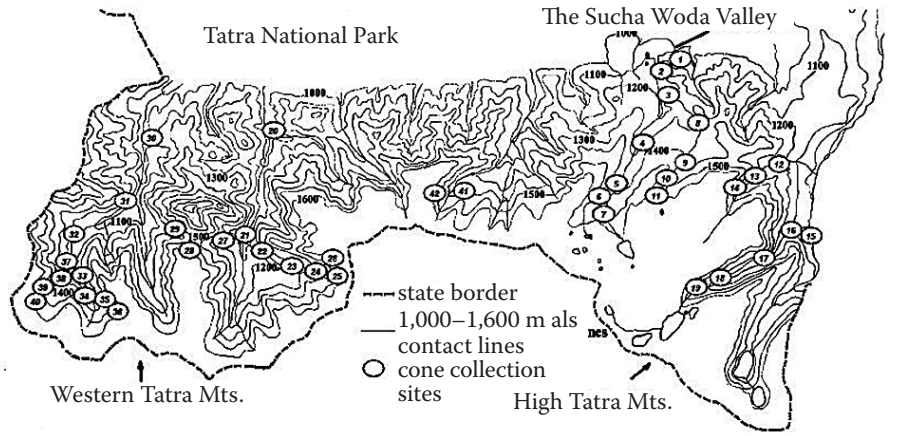


Fig. 1. Localities in the Tatra National Park where cone samples of Norway spruce (*Picea abies* [L.] Karst.) were collected during 1987–1993

This research has a scientific value because it makes it possible to fill in the gaps in faunistic and ecological knowledge of insects in the area of the Polish Tatras.

MATERIALS AND METHODS

Cone samples of Norway spruce (*Picea abies* [L.] Karst.) were collected in the years 1987–1993 from the trees growing in 42 permanent sample plots situated every 100 m of altitude, from 1,000 to 1,200 m in the lower mountain zone and from 1,300 to 1,500 m in the upper mountain zone (Fig. 1).

The observation sites were situated at the following places:

- the Sucha Woda Valley (number of position 1–5) and its branches, the Gąsienicowa Valley (6, 7), the Pańszczyca Valley (9–11),
- branches of the Białka Valley (15), the Waksmundzka Valley (12–14), the Roztoka Valley (15–19),
- in the area of Gęsia Szyja (8) and the Waksmundzka Plain (12–14),
- the Kościeliska Valley (20, 21) and by the Smytnia Glade (27) and the Tomanowa Valley (22–26),
- the Chochołowska Valley (30–32), the Jarząbcza Valley (33–36) and the Wyżna Chocholowska Valley (37–40),
- the area of the Iwaniacka Pass (26, 29) and the Kondratowa Valley (41, 42).

In total 5,780 cones from 289 trees were collected to be examined. Each year cones were collected twice:

- at the turn of July and August (ripening cones) – because of the larvae of certain species which leave the cones before they are ripe,
- at the turn of September and October (ripe cones).

Each sample contained 20 cones. In the laboratory, from each cone sample 5 cones were randomly selected for the analysis, then they were cut along the axis, the cone scales were separated and seeds were extracted and cut as well. This procedure yielded larvae and pupae of various insect species. They were counted and identified. The remaining 15 cones from each sample were used for mass rearing in photoeclectors or glass jars.

In order to determine the variability of the qualitative and quantitative composition of insects inhabiting old cones, observations were carried out for four years (1990–1993) in five permanent observation stands localized in the Sucha Woda Valley.

Isolators were used for determination of entomofauna in old cones hanging in the crowns, which had a form of the cylinder. The isolators were made of transparent celluloid, covered with a nylon net at both ends. Having been filled with previous year's cones, collected from standing trees, they were hung in the spruce crowns.

Light boxes (photoeclectors) were used for determination of entomofauna in old cones which fell down from the trees. The box rearing containers were built of dark pots with holes made in their bottoms, to which pipes with non-transparent jars were attached, provided with covers with holes. Pot-like rearing containers, turned upside down, were placed upon forest litter, with cones lying on the earth, underneath (changed every year).

The inspection of occurrence of insects from the isolated cones was carried out periodically.

The insects obtained during the study were grouped according to the trophic associations as in the studies carried out by Skrzypczyńska (1982, 1986). The following division into groups was adopted:

- conophagous insects – whose larvae feed on various parts of cones, damage seed scales and seeds,
- seminiphagous insects – whose larvae feed exclusively within seeds,

Table 1. The list of insects obtained from cones of Norway spruce (*Picea abies* [L.] Karst.) by orders in relation with the development of cones in the Tatra National Park during 1987–1993

Order	Ripening cones			Ripe cones			Old cones			Total		
	No. of species	No. of individuals	(%)	No. of species	No. of individuals	(%)	No. of species	No. of individuals	(%)	No. of species	No. of individuals	(%)
Dermaptera	0	0	0.00	0	0	0.00	1	5	0.11	1	5	0.01
Heteroptera	0	0	0.00	1	22	0.04	2	318	6.81	2	340	0.47
Raphidioptera	0	0	0.00	0	0	0.00	1	2	0.04	1	2	0.00
Neuroptera	0	0	0.00	0	0	0.00	1	4	0.09	1	4	0.01
Coleoptera	1	1	0.01	7	67	0.12	6	773	16.55	7	841	1.17
Hymenoptera	7	136	1.38	18	4,298	7.49	8	1,565	33.51	19	5,999	8.35
Lepidoptera	5	2,294	23.35	3	6,480	11.30	1	778	16.66	5	9552	13.29
Diptera	12	7,392	75.26	13	46,488	81.05	6	1,225	26.23	15	55,105	76.70
Total	25	9,823	100	42	57,355	100	26	4,670	100	50	71,848	100

– saprophagous and coprophagous insects – whose larvae feed on dead organic matter and excrements of other insects,
– parasitoids and predators,
– seasonal insects, for which cones provide shelter, frequently accidental.

A tabular chart of the obtained insects was drafted (Tables 1 and 2), according to the distinguished trophic groups, which were consequently characterized by means of calculations of ecological indexes (constancy – C, dominance – D, species diversity – d) using Szujecki's method (1980). In the analysis of the material the following types of constancy were distinguished:
– euconstants – species with the constancy index of more than 75%;
– constants – species with the constancy index between 50.01% and 75%;
– subconstants – 30.01% to 50%;
– accessory species – 15% to 30%;
– accidents – below 15%.

The following types of dominance (D) were also distinguished:
– eudominants – species with the dominance index above 10%;
– dominants – 5.01% to 10%;
– subdominants – 2.01% to 5%;
– recedents – 1% to 2%;
– subrecedents – below 1%.

The paper examined the statistical significance of observed differences in the structure of insect clusters colonizing cones, for different stages of their development, using the computer program Statistica for Windows (StatSoft Inc. 1997).

For this purpose, before the statistical analysis was carried out, transformations of the obtained results were done using the square root, and in the case of percentages angular transformations were used. The concordance of their schedule with normal distribution was examined by the Kolmogorov-Smirnov test. Bartlett's test was used to determine whether the stage of cone development had a significant impact on the diversity of insect clusters colonizing cones, and then Tukey's test was used. The stage of cone development was treated as an independent variable, whereas the percentage of trophic groups and orders of separate clusters of insects were taken as dependent variables.

Faunal similarity of insect clusters colonizing cones was assessed using a numerical cluster analysis. The study examined the abundance and species composition of insect clusters found in ripening, ripe and old cones on the plots located in three segments of altitude: 1,000–1,100 m a.s.l., 1,200–1,300 m a.s.l., 1,400–1,500 m a.s.l. Ward's algorithm was used to distinguish the particular groups and Euclidean distance was adopted as a measure of affinity.

RESULTS

As a result of 7 years of research, both in the field and in the laboratory, in total 71,848 insect specimens were collected from the cones of spruce (*P. abies*), representing 50 species from 8 orders (Table 1).

Table 2. Listing of the number (*n*) and ecological indicators: dominance (D), constancy (C) and species diversity (d) in distinguished trophic groups of insects obtained from cones of Norway spruce (*Picea abies* [L.] Karst.), collected in the Tatra National Park during 1987–1993

Species in trophic groups	Listing of insects species obtained from cones								
	ripening cones			ripe cones			old cones		
	n	ecological indexes		*n*	ecological indexes		*n*	ecological indexes	
		D	C		D	C		D	C
Conophagous insects		d = 0.88			d = 0.48			d = 0.13	
Cydia strobilella L. (Lep., Tortricidae)	2,230	77.46	98.02	6,465	17.71	98.40	778	41.88	100.00
Cydia illutana H. S. (Lep., Tortricidae)	42	1.46	12.87	–	–	–	–	–	–
Dioryctria abietella (Den. et Schiff.) (Lep., Phycitidae)	4	0.14	3.96	4	0.01	2.14	–	–	–
Eupithecia analoga Djakonov (Lep., Geometridae)	11	0.38	7.92	–	–	–	–	–	–
Eupithecia abietaria Goeze (Lep., Geometridae)	7	0.24	5.94	11	0.03	3.74	–	–	–
Strobilomyia anthracina (Czerny) (Dipt., Anthomyiidae)	124	4.31	34.65	5	0.01	1.60	–	–	–
Earomyia sp. (Dipt., Lonchaeidae)	3	0.10	1.98	8	0.02	4.28	–	–	–
Kaltenbachiola strobi (Winn.) (Dipt., Cecidomyiidae)	458	15.91	56.44	30,019	82.22	100.00	1,090	58.12	100.00
Seminiphagous insects		d = 0.00			d = 0.10			d = 0.00	
Plemeliella abietina Seitn. (Dipt., Cecidomyiidae)	–	–	–	14,351	99.97	88.77	10	100.00	54.54
Megastigmus strobilobius Ratz. (Hym., Torymidae)	–	–	–	4	0.03	0.53	–	–	–
Saprophagous and coprophagous insects		d = 0.81			d = 0.93			d = 0.97	
Ernobius abietis Fabr. (Col., Anobiidae)	–	–	–	21	1.13	5.35	48	27.75	54.54
Lycoriella solani Winn. (Dipt., Sciaridae)	975	17.45	21.78	513	27.54	6.42	92	53.18	54.54
Asynapta strobi (Kieffer) (Dipt., Cecidomyiidae)	388	6.95	40.59	274	14.71	24.06	16	9.25	27.27
Camptomyia sp. (Dipt., Cecidomyiidae)	477	8.54	42.57	490	26.30	31.02	–	–	–
Clinodiplosis cilicrus (Kieffer) (Dipt., Cecidomyiidae)	3,498	62.62	62.38	556	29.84	30.48	–	–	–
Gaurax strobilum Karps (Dipt., Chloropidae)	15	0.27	4.95	4	0.21	1.60	10	5.78	36.36
Conioscinella flavifrons Duda (Dipt., Chloropidae)	–	–	–	1	0.05	0.53	–	–	–
Hapleginella laevifrons (Loew) (Dipt., Chloropidae)	9	0.16	3.96	4	0.21	1.07	7	4.05	18.18
Drosophila sp. (Dipt., Drosophilidae)	137	2.45	7.92	–	–	–	–	–	–
Palloptera laetabilis Loew. (Dipt., Pallopteridae)	87	1.56	8.91	–	–	–	–	–	–
Parasites and predators		d = 0.88			d = 2.02			d = 0.95	
*Torymus azureus (*Boheman) (Hym., Torymidae)	40	2.95	9.90	1,239	27.22	73.80	298	19.04	63.63
Torymus caudatus (Boheman) (Hym., Torymidae)	2	0.15	1.98	37	0.81	11.23	–	–	–
Tetrastichus strobilanae Ratz. (Hym., Eulophidae)	24	1.77	8.91	1,178	25.88	58.82	221	14.12	54.54
Triplatygaster contorticornis Ratz. (Hym., Platygastridae)	30	2.21	5.94	781	17.16	48.13	29	1.85	63.63
Anogmus hohenheimensis Ratz. (Hym., Pteromalidae)	–	–	–	152	3.34	22.99	446	28.50	63.63
Anogmus piceae (Ruschka) (Hym., Pteromalidae)	–	–	–	4	0.09	2.14	–	–	–
Anogmus strobilorum (Thomson) (Hym., Pteromalidae)	–	–	–	11	0.24	4.81	–	–	–
Anogmus sp. aff. *vala* (Walker) (Hym., Pteromalidae)	2	0.15	0.99	490	10.77	19.79	458	29.27	45.45
Trichomalus campestris (Walker) (Hym., Pteromalidae)	–	–	–	1	0.02	0.53	–	–	–
Venturia transfuga Grav. (Hym., Ichneumonidae)	35	2.58	10.89	348	7.65	36.90	81	5.18	63.63
Liotryphon strobilorum (Thomson) (Hym., Ichneumonidae)	3	0.22	1.98	19	0.42	6.95	17	1.09	45.45
Phaeogenes osculator Thunb. (Hym., Ichneumonidae)	–	–	–	10	0.22	1.07	15	0.96	36.36

Table 2 to be continued

Species in trophic groups	Listing of insects species obtained from cones								
	ripening cones			ripe cones			old cones		
	n	ecological indexes		*n*	ecological indexes		*n*	ecological indexes	
		D	C		D	C		D	C
Stenomacrus femorelis Holmgr. (Hym., Ichneumonidae)	–	–	–	11	0.24	3.74	–	–	–
Enizemum nigricornis Ths. (Hym., Ichneumonidae)	–	–	–	1	0.02	0.53	–	–	–
Bracon variator Nees (Hym., Ichneumonidae)	–	–	–	5	0.11	2.14	–	–	–
Blacus exilis Nees (Hym., Ichneumonidae)	–	–	–	6	0.13	2.67	–	–	–
Blacus hastatus Hal. (Hym., Ichneumonidae)	–	–	–	1	0.02	0.53	–	–	–
Lestodiplosis holstei (Kieffer) (Dipt., Cecidomyiidae)	1,221	89.98	46.53	261	5.74	24.60	–	–	–
Seasonal insects		d = 0.00			d = 1.65			d = 1.01	
Gastrodes abietum Bergr. (Heter., Lygaeidae)	–	–	–	22	31.43	4.81	303	28.75	45.45
Oxytelus nitidulus Grav. (Col., Staphylinidae)	1	100.00	0.99	–	–	–	–	–	–
Staphylinidae (Coleoptera)	–	–	–	12	17.14	3.21	5	0.47	36.36
Corticaria serrata (Payk.) (Col., Lathridiidae)	–	–	–	25	35.71	6.42	644	61.10	90.90
Latridius nodifer Westw. (Col., Lathridiidae)	–	–	–	2	2.86	1.07	17	1.61	36.36
Cryptophagus subfumatus Kraatz. (Col., Cryptophagidae)	–	–	–	5	7.14	2.67	52	4.93	45.45
Rhizophagus depressus (Fabr.) (Col., Rhizophagidae)	–	–	–	1	1.43	0.53	–	–	–
Trechus striatulus Putz. (Col., Carabidae)	–	–	–	1	1.43	0.53	7	0.66	45.45
Episyrphus cinctellus (Zeet) (Dipt., Syrphidae)	–	–	–	2	2.86	1.07	–	–	–
Forficula auricularia L. (Derm., Forficulidae)	–	–	–	–	–	–	5	0.47	27.27
Hemorobius pini Leach. (Neur., Hemorobidae)	–	–	–	–	–	–	4	0.38	27.27
Acompocoris alpinus Rent. (Heter., Anthocoridae)	–	–	–	–	–	–	15	1.42	45.45
Raphidia ophiopsis Schumm. (Raph., Raphididae)	–	–	–	–	–	–	2	0.19	18.18

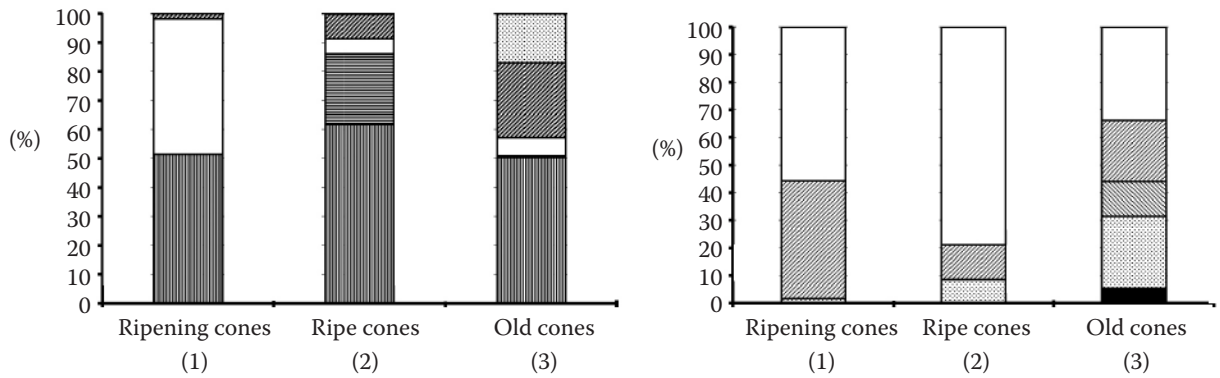
Dipterans turned out to be the most numerous orders of insects inhabiting the cones analyzed. Lepidopterans were also relatively numerous, followed by hymenopterans. The representatives of the remaining orders were scarce or they occurred rarely.

Variability of the qualitative and quantitative composition of insects inhabiting spruce cones at different stages of development

The community structure and abundance of species composition of insects in spruce cones varied with the development of cones. It was slightly different in ripening cones, collected in July and August, from the ripe cones at the turn of September and October. The composition of old and lignified cones hanging in spruce crowns and that of the cones which had dropped from the trees and were lying on the earth were still different.

Observed differences between the structures of isolated insect clusters proved to be statistically significant. It is indicated by Tukey's tests carried out in relation to the significance of differences between the percentage shares of insect trophic groups and orders, inhabiting ripening, ripe and old cones (Fig. 2).

Numerical analysis of the species similarity of insect clusters colonizing spruce cones divided the insect clusters colonizing ripening, ripe and old cones into two separate groups (Fig. 3). The insect cluster colonizing old cones lies between the insect clusters colonizing ripe and ripening cones that are the most different from each other. This should be explained by the fact that the old cones are inhabited by species that are found in both types of cones: ripening and ripe ones. These are the species that have extended development and move into diapause in cones, as well as protect themselves against unfavourable



	Conophagous insects				Coleoptera		
1	–	0.01223	0.94846	1	–	0.9794	0.00002**
2	0.01223	–	0.00453**	2	0.9794	–	0.00002**
3	0.94846	0.00453**	–	3	0.00002**	0.00002**	–
	Seminiphagous insects				Hymenoptera		
1	–	0.00002**	0.94343	1	–	0.00003	0.00002
2	0.00002**	–	0.00002**	2	0.00003	–	0.00002
3	0.94343	0.00002**	–	3	0.00002		–
	Saprophagous and coprophagous insects				Lepidoptera		
1	–	0.00002**	0.00002**	1	–	0.00002**	0.00002**
2	0.00002**	–	0.96317	2	0.00002**	–	0.00768
3	0.00002**	0.96317	–	3	0.00002**	0.00768	–
	Parasites and predators insects				Diptera		
1	–	0.00003**	0.00002**	1	–	0.00002**	0.00002**
2	0.00003**	–	0.00002**	2	0.00002**	–	0.00002**
3	0.00002**	0.00002**	–	3	0.00002**	0.00002**	–
	Seasonal insects				Heteroptera and other orders		
1	–	0.99422	0.00002**	1	–	0.993208	0.00002**
2	0.99422	–	0.00002**	2	0.993208	–	0.00002**
3	0.00002**	0.00002**	–	3	0.00002**	0.00002**	–

Fig. 2. Analysis of significance of the differences between the percentage shares of insect trophic groups and orders inhabiting ripening, ripe and old cones. Tukey's test

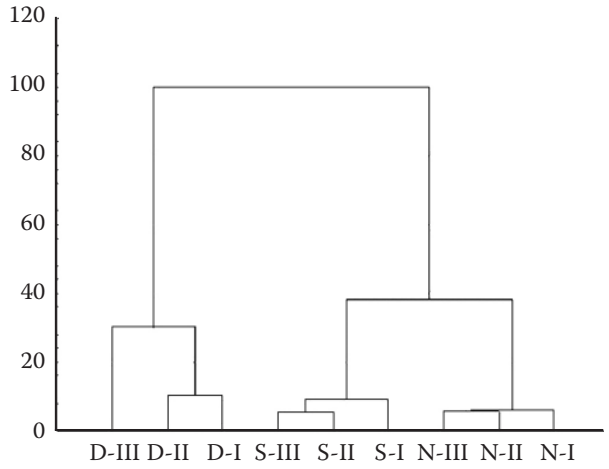


Fig. 3. Species similarity of insect clusters colonizing ripening (N), ripe (D) and old cones (S) on the plots located at three segments of altitude: 1,000–1,100 m a.s.l. (I), 1,200–1,300 m a.s.l. (II), 1,400–1,500 m a.s.l. (III). Ward's method, Euclidean distance

external conditions. In spring during the flowering and development of fresh cones some of these species leave the old cones and colonize ripening and ripe cones.

Ripening cones

In the ripening cones, dipterans were the most numerous order of insects (Table 1). Dipterans were represented by 12 species, the most numerous of them being: *Clinodiplosis cilicrus* (Kieff.), *Lestodiplosis holstei* (Kieff.) and *Lycoriella solani* Winn. The less numerous species included: *Camptomyia* sp., *Kaltenbachiola strobi* (Winn.), *Asynapta strobi* (Kieff.), *Drosophila* sp., *Strobilomyia anthracina* Czerny (Table 2).

The second most numerous order was lepidopterans represented by 5 species, among which the most numerous was *Cydia strobilella* L., *C. illutana* H.-S, reported for the first time in spruce cones in Poland occurring rarely (42 specimens), similarly like the follow-

ing species: *Eupithecia analoga* Djakonov, *E. abietaria* Goeze and *Dioryctria abietella* (Den. et Schiff.).

Hymenopterans, 6 species in total, were relatively few. What was characteristic was a complete absence of coleopterans (with the exception of one specimen of *Oxytelus nitidulus* Grav.).

Among the insects obtained, *Cydia strobilella* turned out to be the euconstant; *Clinodiplosis cilicrus* and *Kaltenbachiola strobi* – constants, *Lestodiplosis holstei*, *Camptomyia* sp., *Asynapta strobi*, *Strobilomyia anthracina* – subconstants. *Lycoriella solani* was an accessory species. The remaining species were accidents.

As far as the dominance structure of the species inhabiting ripening cones is concerned, eudominants constituted 58.3% (species: *Clinodiplosis cilicrus, Cydia strobilella, Lestodiplosis holstei*), dominants 9.9% (*Lycoriella solani*), subdominants 13.5% (*Camptomyia* sp., *Kaltenbachiola strobi, Asynapta strobi*), recedents 2.7% (*Drosophila* sp., *Strobilomyia anthracina*).

Among the cones collected in July and August, the largest part was constituted by saprophagous insects (56.9%), among which two species: *Clinodiplosis cilicrus* and *Lycoriella solani* were distinctly eudominants, while the species *Camptomyia* sp. and *Asynapta strobi* were dominants. Conophagous insects constituted 29.3% of all the insects obtained from ripening cones. *Cydia strobilella* and *Kaltenbachiola strobi* were eudominants in this group. Parasitoids and predators constituted 13.8% of the insects collected from ripening cones, with *Lestodiplosis holstei* being the only eudominant in this group, while the other most commonly encountered species: *Torymus azureus* Boh., *Venturia transfuga* Grav. and *Triplatygaster contorticornis* Ratz. were subdominants.

The values of the species diversity (d) index, calculated for the groups of insects obtained from ripening cones were very similar (from 0.81 to 0.88).

Ripe cones

Like in the case of ripening cones, among the insects obtained from ripe cones collected in autumn, dipterans were the most numerous, represented by 13 species, among which *Kaltenbachiola strobi* and *Plemeliella abietina* Seitn. predominated as far as the quantity is concerned (Tables 1 and 2). What was characteristic was a considerable fall in the number of other dipterans that were more numerous before.

Among the lepidopterans *Cydia strobilella* again turned out to be the most numerous.

The qualitative and quantitative composition of the hymenopterans represented by 18 species was increased. Among them, the most numerous groups from the Chalcidoidea superfamily were: *Torymus azureus*, *Tetrastichus strobilanae* Ratz., *Triplatygaster contorticornis*, and from the Ichneumonidae family – *Venturia transfuga*. Coleopterans appeared, represented by 7 species as well as a heteropter – *Gastrodes abietum* Bergr.

Among the insects obtained, *Cydia strobilella*, *Kaltenbachiola strobi* and *Plemeliella abietina* turned out to be euconstants. *Torymus azureus*, *Tetrastichus strobilanae* Ratz. were constants and *Triplatygaster contorticornis, Venturia transfuga, Camptomyia* sp., *Clinodiplosis cilicrus* – subconstants. *Lestodiplosis holstei, Asynapta strobi, Anogmus hohen heimensis* Ratz., *Anogmus* sp. aff. *vala* (Walker) turned out to be accessory species. The remaining species were accidents.

In ripe cones, eudominants (*Kaltenbachiola strobi, Plemeliella abietina, Cydia strobilella)* constituted 88.6% of all the obtained insects, with the complete absence of dominants. There were 4.2% subdominants (*Torymus azureus, Tetrastichus strobilanae*) with 1.4% of recedents (*Triplatygaster contorticornis*).

In the cones collected from the trees in autumn, the largest group was constituted by conofagous insects (63.7%). Among them, *Kaltenbachiola strobi* and *Cydia strobilella* were eudominants. The percentage of seminiphagous insects constituted 25.0%, with *Plemeliella abietina* being the eudominant of this group. The percentage of saprophagous and coprophagous insects in comparison with other groups of insects was low and amounted to 3.2%. *Clinodiplosis cilicrus*, *Lycoriella solani, Camptomyia* sp. and *Asynapta strobi* were the eudominants of that group. Parasitoids and predators constituted 7.9%, with the eudominants being *Torymus azureus*, *Tetrastichus strobilanae*, *Triplatygaster contorticornis,* dominants: *Venturia transfuga* and *Lestodiplosis holstei.* Among seasonal insects (0.1%) eudominants and dominants belonged to *Corticaria serrata* (Payk.), *Gastrodes abietum, Cryptophagus subfumatus* Kraatz.

The values of the species diversity (d) index calculated for the groups of insects collected from ripe cones were more varied than in the case of ripening cones (d = 0.10 for the group of seminiphagous insects and d = 2.02 for the group of parasitoids and predators).

Old cones

In old lignified cones, the most numerous group was hymenopterans, followed by dipterans and lepidopterans. Among the insects recorded, what was characteristic was a relatively high occurrence of coleopterans, in particular *Corticaria serrata*, various developmental forms of a heteropter *Gastrodes abietum* and a predatory heteropter *Acompocoris*

alpinus Reut. Among the coleopterans, the species commonly found comprised: *Cryptophagus subfumatus*, *Ernobius abietis* Fabr. and also species associated with the environment of the forest floor, e.g. *Trechus striatulus* Putz., as well as representatives of the Staphylinidae family. Representatives of the following orders: Dermaptera, Neuroptera and Raphidioptera were also reported.

In old lignified cones, *Cydia strobilella, Kaltenbachiola strobi, Corticaria serrata* turned out to be euconstants. *Torymus azureus, Anogmus hohenheimensis* Ratz., *Tetrastichus strobilanae. Venturia transfuga, Triplatygaster contorticornis, Lycoriella solani, Ernobius abietis, Plemeliella abietina* were constants. *Anogmus* sp. aff. *vala, Gastrodes abietum, Cryptophagus subfumatus*, *Acompocoris alpinus*, *Latridius nodifer* Westw., *Gaurax strobilum* Karps were subconstants.

In old cones, eudominants constituted 53.8% (*Kaltenbachiola strobi, Cydia strobilella, Corticaria serrata*), dominants 32.2% (*Anogmus* sp. aff. *vala, Anogmus hohen heimensis, Gastrodes abietum, Torymus azureus*), subdominants 4.7% (*Tetrastichus strobilanae*), recedents 4.7% (*Venturia transfuga, Cryptophagus subfumatus, Ernobius abietis*).

The percentages of conophagous insects (40.0%) as well as of parasitoids and predators (33.5%) were the highest. Seasonal insects accounted for 22.6% of all obtained insects, and sapro-coprophagous insects for 3.7%. In the group of parasitoids and predators, *Anogmus* sp. aff. *vala*, *A. hohen heimensis*, *Torymus azureus*, *Tetrastichus strobilanae* were eudominants, and *Venturia transfuga* was dominant. In the group of seasonal insects, *Corticaria serrata* and *Gastrodes abietum* were definite eudominants, and *Cryptophagus subfumatus* – dominant.

The groups of parasitoids, predators and seasonal insects showed the highest species variety (d = 0.95 and d = 1.01, respectively).

In old cones, lying on the ground, the quantity of the typical entomofauna of the cones was much more limited. As far as conophagous insects are concerned, 25 specimens of *Cydia strobilella* and 45 specimens of *Kaltenbachiola strobi* were obtained, among seminiphagous insects – 10 specimens of *Plemeliella abietina*, and among parasitoids – 29 specimens of Chalcidoidea. *Ernobius abietis* and dipterans from the family Sciaridae were found more often. Among the coleopterans, apart from *Corticaria serrata* (31 specimens), species associated with the forest floor e.g. *Trechus* sp. (7 specimens), representatives of the Staphylinidae family (5 specimens) and Dermaptera (3 specimens) were found.

DISCUSSION

Microcoenosis (merocoenosis) of coniferous tree cones has its own developmental dynamics and sequence: its initial point in time is the process of female inflorescence pollination and the final one – the complete decomposition of cones fallen onto the forest floor (Karpiński 1967).

In the sequence undergone by spruce cones as they develop with the passage of time; what is characteristic is the qualitative and quantitative changes taking place in the entomofauna related to them. For the ripening cones collected in July and August what was typical was the fact that the index of species diversity between the selected trophic groups of conophagous, sapro- and coprophagous insects and predators and parasitoids was very much balanced between one another, with the nearly complete absence of species from the group of seasonal insects. In the ripening cones the presence of such species as *Strobilomyia anthracina*, *Cydia illutana*, *Drosophila* sp., *Palloptera laetabilis* Loew. was reported, which were not found later in ripe cones at all or not in comparable numbers.

As cones are left by certain conophagous and saprophagous insects and inhabited by several species of parasitoids, predators and seasonal insects, the entomofauna of ripe cones in autumn was characterized by the higher species diversity among the selected trophic groups in comparison with ripening cones. The qualitative and quantitative composition of the group of parasitoids and predators was visibly increased, in particular by the species from the Chalcidoidea superfamily as well as the Ichneumonidae and Braconidae families, while in the ripening cones, the previously mentioned species, *Lestodiplosis holstei* was the eudominant of this trophic group, in ripe cones the representatives of the Chalcidoidea superfamily: *Torymus azureus* and *Tetrasstichus strobilanae* became eudominants. In the cones collected in autumn, there were reported 9 species of insects which represented the group of seasonal insects. The majority of them probably appeared in the cones accidentally, using them as a comfortable shelter. Among the seed scales of the cones, individual specimens of *Anogmus* spp. and *Gastrodes abietum*, which often spend the winter in cones in the imago phase (Stadnickij 1969), were also reported.

After winter, in May and June old, previous year's cones hanging in the trees were numerously inhabited by coleopterans from the Lathridiidae and Cryptophagidae families. Until then, very small numbers of these coleopterans had been found in cones. It was believed that the above mentioned insects were related

to cones accidentally. Having proved the presence of coleopterans from the above-mentioned families in cones Jakovlev (1961), Stadnickij (1969) and Milišauskas (1976) drew a conclusion that they were feeding in cones on fungal spores of *Thecopsora padi* Kleb. and *Chrysomyxa pirolae* Rost. The research conducted seems to confirm this hypothesis and shows that the species *Corticaria serrata, Latridius nodifer* and *Cryptophagus subfumatus* are more closely associated with spruce cones than it had previously been believed. It concerns mostly *Corticaria serrata*, which appeared in those cones in particularly high numbers. Another typical element of the entomofauna of old cones hanging in the trees seems to be also the heteropter *Gastrodes abietum*, which was found in young cones in autumn only sporadically. In the literature, some authors presume that *Gastrodes abietum* feeds only at the expense of cones or seeds, while other authors claim that this insect feeds on the juice coming from the needles or thin and delicate bark of spruce sprouts (e.g. Holste 1922; Nägeli 1933; Roques 1983). As the observations proved, this species undergoes its whole process of development in old cones but probably feeds outside them, as, when isolated from the outer environment, it experienced mass necrosis.

Old cones, hanging in the trees were penetrated in spring by predatory Dermaptera, Neuroptera, and by the predatory representative of Heteroptera, for the first time reported in spruce cones – *Acompocoris alpinus*. Apart from the above-mentioned numerously represented group of seasonal insects, one-year-old cones were inhabited by conophagous insects and their parasitoids, which appeared out of them at the time of flowering and development of young cones. Seminiphagous insects mostly left the cones due to their opening and seed spread. The group of saprophagous and coprophagous insects also left lignified cones and was represented by rare specimens.

The results of cone rearings show that in the courses of two years the largest parts of *Cydia strobilella's, Kaltenbachiola strobi's* and their parasitoids' population brood. Next, cones fall upon the forest floor where in the damper environment a further sequence of the entomofauna inhabiting them takes place. A small percentage of perfect forms of *Plemeliella abietina* among the imagines reared in laboratory conditions shows that this species requires a damper environment for its development, provided in the natural conditions by forest litter. It was proved by the cone rearings in photoeclectors located in the forest litter.

During the analysis of ripening cones, no case of feeding of the larvae of *Ernobius abietis* was observed. The observations seem to point out that this species lays eggs into fresh cones, yet the larvae grow and damage the cones only later, when the cones are ripe and have lost their seeds. Consequently, following such authors as Čermák (1952), Stadnickij et al. (1978) it can be stated that *Ernobius abietis* does not contribute to spruce seed damage.

CONCLUSIONS

The presence of 50 insect species (71,848 specimens) from 8 orders proves the relatively rich entomofauna of spruce (*Picea abies* [L.] Karst.) cones in the area of the Tatra National Park.

The qualitative and quantitative composition of spruce cone entomofauna underwent gradual changes with the development of cones, due to its inhabiting and leaving by species of varied bioecology.

The entomofauna of ripening cones was characterized by a high percentage of dipterans representing the group of saprophagous and coprophagous insects and a low percentage of hymenopterans from the group of parasitoids and by the nearly complete absence of coleopterans and other species from the group of seasonal insects.

Entomofauna of ripe cones was characterized by a bigger species variability within trophic groups, decrease in the number of certain dipterans species from the group of saprophagous and coprophagous insects, increase in the qualitative and quantitative percentage of parasiting hymenopterans and the presence of seasonal insects.

The entomofauna of old lignified cones, hanging in spruce crowns, was characterized by the quantitative predominance of hymenopterans from the group of parasitoids and a high number of coleopterans from the families: Latridiidae and Cryptophagidae, heteropters and other species from the group of seasonal insects, not found in higher quantities in cones (ripening or ripe ones).

Corticaria serrata (Payk.), *Latridius nodifer* (Westw.), *Cryptophagus subfumatus* (Kraatz.) turned out to be bioecologically associated with old spruce cones.

The heteropter *Gastrodes abietum* Bergr. undergoes its whole process of development in old cones, however it feeds outside them.

Ernobius abietis Fabr. lays eggs into fresh cones, yet develops in them later, without damaging the seeds.

Acquiring the knowledge of trophic associations of *Drosophila* sp., *Palloptera laetabilis* Loew., *Acompocoris alpinus* Reut., *Stenomacrus femorelis* Holar in spruce cones require further research as these

species are probably bioecologically associated with cones.

The major part of the conophagous population and their parasitoids leave the cones they used to inhabit within two years. After that time, cones usually fall onto the forest floor, where a further sequence of the entomofauna inhabiting them takes place in the damp environment.

Acknowledgements

I would like to express my gratitude for the first identification and for verification of my identification of selected insects to: Dr. Josef Šedivý (Crop Research Institut, Prague, Czech Republic) (Ichneumonidae), Dr. Zdenek Bouček (British Museum – Natural History, London, UK) (Chalcidoidea), Dr. Jerzy Lis (Museum of Natural History, Bytom, Poland) (Heteroptera), Mgr. Andrzej Palaczyk (Institute of Systematic Zoology and Animal Ecology of Polish Academy of Sciences, Cracow, Poland) (Diptera), Dr. Janusz Sawoniewicz (Zoology Institute of Polish Academy of Sciences, Warsaw, Poland) (Ichneumonidae).

Moreover, the late Dr. Bolesław Burakowski (Zoology Institute of Polish Academy of Sciences, Warsaw, Poland) (Coleoptera) and Dr. Miroslav Čapek (Forest Research Institute, Banská Štiavnica, Slovakia) (Braconidae) have done the identifications.

References

Arend H. (1967): Über den tierischen Abbau von Fichtenzapfen. Zeitschrift für angewandte Entomologie, ***59***: 74–109.

Bakke A. (1955): Insects reared from spruce cones in northern Norway 1951. Norsk Entomologisk Tidsskrift, ***9***: 152–212.

Čermák K. (1952): Insects attacking seeds of Czechoslovakian forest species. Práce výzkumných ústavů lesnických. I. Ochrana lesa, ***5***: 5–87. (in Czech)

Dolgin M.M., Nesin A.P. (1981): Parasites of spruce cones and seeds. Lesnoje Chozjajstvo, ***3***: 61–63. (in Russian)

Holste G. (1922): Fichtenzapfen- und Fichtensamenbewohner Oberbayerns. Zeitschrift für angewandte Entomologie, ***8***: 125–160.

Jakovlev B.P. (1961): Parasites of spruce cones and seeds. Petrozavodsk, Gosudarstvennoe Izdatel'stvo Karel'skoj Akademii Sovetskoj Socjalisticeskoj Republiki: 3–46. (in Russian)

Karpiński J.J. (1967): Insects and *Arachnoidea* developing or over-wintering in cones of *Larix decidua* var. *polonica* and *L. decidua*. Prace Instytutu Badawczego Leśnictwa, ***314–319***: 81–112. (in Polish)

Kozioł M. (1997): Influence of altitude on adult emergence, abundance and dynamics of *Cydia strobilella* populations in the Tatra National Park, Poland. In: Battisti A., Turgeon J.J. (eds): Proceedings of the 5th Cone and Seed Insects Working Party Conference IUFRO S7.03-01, Monte Bondone (Italy), September, 1996. Padova, Institute of Agricultural Entomology, University of Padova: 75–85.

Kozioł M. (1998): Influence of altitude on adult emergence and dynamics of *Kaltenbachiola strobi* (Winnertz) (Diptera: Cecidomyiidae) populations and its parasites in the Tatra National Park, Poland. Anzeiger für Schädlingskunde Pflanzenschutz Umweltschutz, ***71***: 121–127.

Kozioł M. (2000): Cono- and seminiphagous insects of Norway spruce *Picea abies* (L.) Karst. and their parasitoids in lower and upper montane zone of the Tatra National Park in Poland. Journal of Applied Entomology, ***124***: 259–266.

Kozioł M. (2007a): Diversification of entomofauna of Norway spruce *Picea abies* (L.) Karst. Cones in the aspect of variable spruce stands masting in the Tatry National Park. Prace Instytutu Badawczego Leśnictwa, ***4***: 29–46. (in Polish)

Kozioł M. (2007b): Cone entomofauna of Norway spruce *Picea abies* (L.) Karst. in selected stands of the Tatra National Park in Poland. Electronic Journal of Polish Agricultural Universities, ***10.*** Available at http://www.ejpau.media.pl/volume10/issue4/art-18.html (accesed on October 20, 2008)

Milišauskas Z. (1976): The insect fauna of cones of Norway spruce (*Picea abies* Karst.) in the Lithuanian SSR. Acta Entomologica Lituanica, Vilnius, ***3***: 37–47. (in Lithuanian)

Nägeli W. (1933): Über Biologie und Verbreitung der beiden Langwanzen *Gastrodes abietum* Bergr. und *Gastrodes grossipes* De Geer. Mitteilungen Schweizerische Aktuarvereinigung, ***17***: 193–280.

Roques A. (1983): Les insectes ravageurs des cones et graines de conifers en France. Paris, Institut National de la Recherche Agronomique: 135. (in French)

Saksons J.A.L. (1973): The entomofauna of the generative organs of Scots pine (*Pinus silvestris* L.) and Norway spruce (*Picea abies* Karst.) in the Latvian SSR. Zaščita lesa: 29–52. (in Russian)

Skrzypczyńska M. (1982): The entomofauna of the cones of spruce, *Picea abies* (L.) Karst. in Poland. Zeitschrift für angewandte Entomologie, ***94***: 21–32.

Skrzypczyńska M. (1986): Insects of cones and seeds of Norway spruce, *Picea abies* (L.) Karst. in Poland. In: Roques A. (ed.): Proceedings of the 2nd Conference IUFRO W.P S2.07-01, Briançon (France), September 3–5, 1986. Briançon, Institut National de la Recherche Agronomique: 27–38.

Skrzypczyńska M. (1989): Studies on the occurrence and parasitization of the spruce seed pest, *Megastigmus strobilobius* Ratz. (Hym.,Torymidae) and *Plemeliella abietina* Seit. (Dipt., Cecidomyiidae) in Poland during a poor seed year. Journal of Applied Entomology, ***108***: 138–143.

Skrzypczyńska M. (1994): Über die in Zapfen und Samen der Fichte *Picea abies* (L.) Karst. fressenden Insekten und ihre Parasitoiden in Nordost-Polen. Anzeiger für Schädlingskunde Pflanzenschutz Umweltschutz, ***67***: 45–46.

Skrzypczyńska M., Bysko G. (1997): Insects inhabiting cones of Norway Spruce *Picea abies* (L.) Karst. in selected stands of the Beskid Śląski Mts. Sylwan, ***141***: 27–34. (in Polish)

Skrzypczyńska M., Kozioł M., Kosibowicz M. (1998): Pest insects and their parasitoids inhabiting cones of common spruce *Picea abies* (L.) Karst. in Beskid Slaski Mts. and Beskid Zywiecki Mts.. Wiadomości Entomologiczne, Supplement ***17***: 186. (in Polish)

Skrzypczyńska M., Kozioł M., Kosibowicz M. (1999): Insects damaging cones and seeds of Norway spruce *Picea abies* (L.) Karst. in the selected stands of the Beskid Śląski Mts. and the Beskid Żywiecki Mts., polluted at various degree by industral emissions. Acta Agraria et Silvestria, ***37***: 65–78. (in Polish)

Skrzypczyńska M., Kożuch J., Gibas S. (1994): Conophagous and seminifagous insects of Norway spruce *Picea abies* (L.) Karst. in Babia Góra National Park and its surroundings. Journal of Applied Entomology, ***118***: 321–326.

Stadnickij G.V. (1969): Parasitic Chalcidoidea and Proctotrupoidea in common spruce cones. Sbornik naučno-issledovatel'skich rabot po lesnom chozjajstve, ***12***: 229–243. (in Russian)

Stadnickij G.V. (1971):Characterization of common spruce cones (*Picea abies* [L.] Karst.) as a place of habitation and feeding ground. Entomologiceskoe obozrenie, ***50***: 85–94. (in Russian)

Stadnickij G.V., Golutvina L.S. (1975): Issue of dynamics of the population of pests of generative organs of coniferous stands. Zaščita lesa: 76–85. (in Russian)

Stadnickij G.V., Jurčenko G.I., Smetanin A.N., Grebenščikova V.P., Pribylova M.V. (1978): Pests of cones and seeds of coniferous stands. Moskva, Izdatel'stvo Lesnaja Promyšlennost': 168. (in Russian)

StatSoft Inc. (1997): Statistica for Windows (Computer program manual). Tulsa, OK, USA.

Szujecki A. (1980): Ecology of forest insects. Warszawa, Państwowe Wydawnictwo Naukowe: 603. (in Polish)

Witteczek K. (1998): Insects damaging the cones and seeds of the Norway spruce *Picea abies* (L.) Karst. in selected wood stands in the Gorce National Park. Parki Narodowe i Rezerwaty Przyrody, ***17***: 111–123. (in Polish)

Received for publication November 12, 2008
Accepted after corrections September 11, 2009

Corresponding author:

Dr. Marek Kozioł, Ph.D., Ul. Reja 12/16, 31-216 Cracow, Poland
tel.: + 048 124 161 771, fax: + 048 126 237 144, e-mail: mekoziolek@wp.pl