

## **DIVERSITY AND ROLE OF INSECTS IN FIR FOREST ECOSYSTEMS IN THE ŚWIĘTOKRZYSKI NATIONAL PARK AND THE ROZTOCZAŃSKI NATIONAL PARK**

Kazimierz Gądek

University of Agriculture in Krakow

**Abstract.** The study contains the results of the investigations conducted over a period of many years on the biodiversity of insect fauna of firs in strict and partial reserves of the Świętokrzyski and Roztoczański National Parks. The species structure of individual functional groups of insects was analysed, together with their role in the ecosystem and their influence on the course of natural ecological processes in the environment, depending on the health of the host plant. The degree of similarity was determined for the species composition of insect fauna found in the analysed areas of the parks. A considerable biological and scientific role which has been played for several decades by strict reserves has been stressed. The reserves are indispensable for the creation of appropriate conditions for the development and survival of insect species of great natural value, being rare in the fauna of fir stands at the north-eastern limits of the natural range of this tree species.

**Key words:** insect fauna, fir, reserves, commercial forests

### **INTRODUCTION**

The study contains the results of the investigations on the biodiversity of insect fauna in fir strict and partial reserves of the Świętokrzyski and Roztoczański National Parks. The investigations conducted in the above mentioned national parks were connected with the processes of regression or even dying back of fir observed throughout Central Europe within the natural range limits of this species. In Poland, where the north-eastern range of this tree is found, the beginnings of regression symptoms were reported for fir as early as over 150 years ago. This process was particularly intensified after WWI and WWII. A significant role in this process has been played by different groups of insects. The results of the detailed studies conducted over a period of several decades and concerning the function of the insect fauna of fir in Poland have been disseminated in many publications [Gądek 1976, 1980, 1985, 1992, 1993 a, b, 1995, 2000, 2001, Michalski and Ratajczak 1989, 1994].

The fir strict reserves selected for the purpose of this study, being the oldest in Poland and functioning without human intervention for several decades, located in the Świętokrzyskie Mountains and in the Roztocze region, make it possible to evaluate the role of individual groups of insects in semi-natural ecosystems in comparison to their role in partial reserves and commercial forests.

## MATERIAL AND METHODS

1. Detailed investigations on the insect fauna of fir were conducted in the Świętokrzyski National Park in the Święty Krzyż and Łysica strict reserves (established in 1924) and in the Roztoczański National Park, in the Bukowa Góra strict reserve (established in 1934), as well as the Nart and Czerkies strict reserves (established in 1957).

2. Data collected in the strict reserves were compared with those recorded in partial reserves and in selected reference mean sample plots in fir stands of adjacent commercial forests.

3. The analysis included groups of insects feeding on the assimilatory organ of firs (foliophages), damaging cambium of weak trees (cambiophages), those feeding on wood (xylophages), insects causing the decomposition of fir wood structure (carionphages, i.e. saprophages feeding on dead wood) as well as species of parasitic and predatory insects.

4. Individual species of insects were caught in mid-air when feeding on the assimilatory organ of firs, on standing or lying, wind-fallen fir dead wood, under bark and in fir wood at different degrees of its decomposition.

5. In order to obtain more detailed quantitative data laboratory insect cultures were conducted on the material collected in specific positions in strict and partial reserves.

## RESULTS

### Insect fauna of firs in the Świętokrzyski National Park

For many years considerable threat to fir stands in the Park was posed by outbreaks of tortrix moths, causing damage to the assimilatory organ. The primary role was played by the European fir budworm (*Choristoneura murinana* Hb.), which was accompanied by *Zeiraphera rufimitrana* H.S. and *Epiblema nigricana* H.S.

Their last outbreak in the Świętokrzyskie Mts. started in 1948 and lasted at different intensity up to 1992. In partial reserves of the Park the outbreak started in 1953 (Fig. 1). In contrast, in strict reserves it occurred 20 years later and it ended two years earlier, i.e. in 1990, as a consequence of the action of natural limiting factors. The biggest area covered by the outbreak in one year in the Park comprised 4 thousand ha in 1975 (Fig. 2). A significant limiting factor reducing populations of tortrix moths was the incidence of parasitic insects (Tables 1, 2, 3). In the European fir budworm a total of 63 parasitoid species were recorded and in *Zeiraphera rufimitrana* there were 16, while in *Epiblema nigricana* there were 17 species, respectively [Gądek 1984].

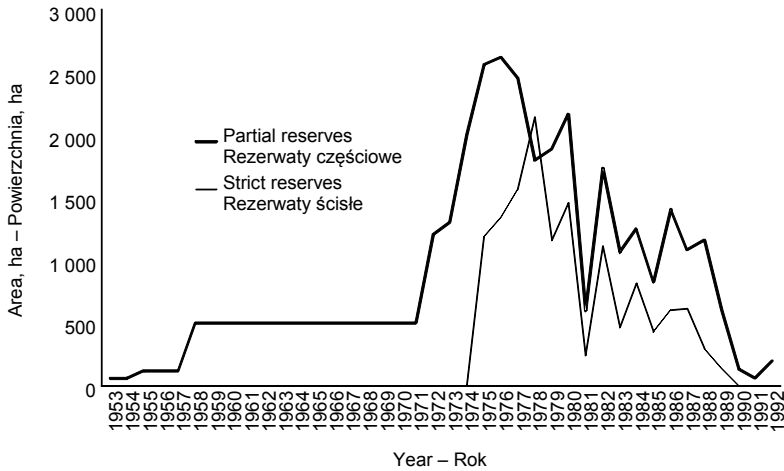


Fig. 1. Area of fir stands in reserves of the Świętokrzyski National Park threatened by feeding of tortrix moths in the years 1953-1992

Rys. 1. Powierzchnia drzewostanów jodłowych w rezerwach Świętokrzyskiego Parku Narodowego zagrożona żerem zwojek w latach 1953-1992

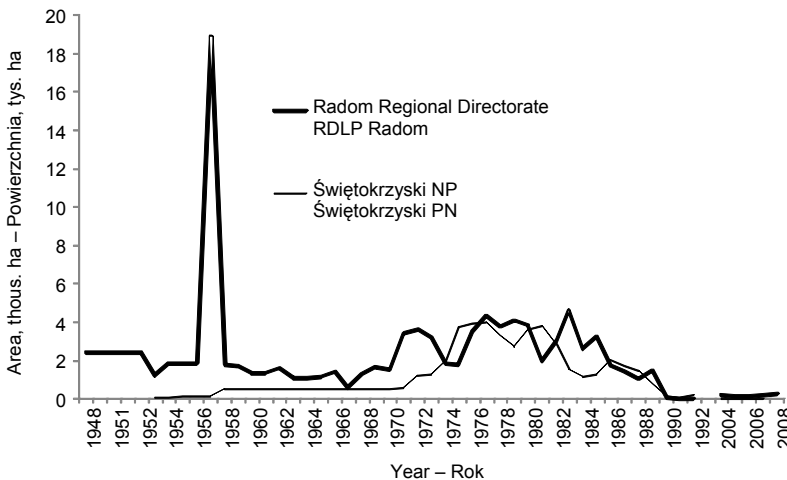


Fig. 2. Area of fir stands damaged by feeding of tortrix moths in the Świętokrzyskie Mts.

Rys. 2. Wielkość powierzchni drzewostanów jodłowych uszkodzonych żerami zwojek w Górach Świętokrzyskich

Fir needles were damaged also by insect species other than tortrix moths. Locally aphids were found on needles, primarily silver fir wooly aphid (*Dreyfusia nordmanniana* Ekst.). Feeding grounds of cockchafer (*Melolontha melolontha* L.) and weevil species of genus *Phyllobius* were also found. In the spring caterpillars of the cone pyralid (*Dioryctia abietella* Schiff.) as well as *Barbitistes constrictus* Br. were feeding on young fir shoots.

Table 1. Natural mortality of European fir budworm (*Choristoneura murinana* Hb.) in the Świętokrzyskie Mts. in 1957-1985 (laboratory analyses)Tabela 1. Śmiertelność naturalna wylogówki jedlineczki (*Choristoneura murinana* Hb.) w Górach Świętokrzyskich w latach 1957-1985 (badania laboratoryjne)

Site and date of collection Miejsce i data zbioru			Collected Zebrano		Mortality, % Śmiertelność, %		
Forest division, forest district Nadleśnictwo, leśnictwo	compartment oddział	date data	caterpillars gąsienica pupae poczwarka	no. sztuk	parasite infestation spasożyto- wanie	diseases and others choroby i inne	total ogółem
1	2	3	4	5	6	7	8
Lagów N							
Złota Woda L	84	28.05.57	P	149	40	58.5	98.5
	81	21.04.61	G	64	30	25	55.0
	81	2.05.61	G	23	–	18.5	22.0
Widelki L	131	18.06.58	G + P	138	60	17.0	77.0
	131	19.06.58	G	100	37	24.0	61.0
	3 i 5	16.06.83	G + P	36	36.1	36.1	72.2
Paprocice L	9	14.06.85	G + P	38	10.5	39.5	50.0
	31	14.06.85	G + P	37	13.5	24.3	37.8
	31	14.06.85	G + P	8	12.5	75	87.5
	31	3.07.85	G + P	256	10.9	71.1	82.0
	8	12.06.86	G + P	42	47.6	28.6	76.2
	9	13.06.86	G + P	100	40	29	69
	31	13.06.86	G + P	58	50	25.9	75.9
	31	13.06.86	G + P	145	37.3	31	68.3
Suchedniów N							
Michniów L	202	22.06.60	G + P	103	6	21	27.0
	203	17.06.60	G + P	19	10	55	65.0
	203	17.06.60	P	48	2	48	50.0
	202	30.05.61	G	43	44	16	60.0
	202	6.07.61	G + P	226	32.3	23.4	55.7
	202	10.07.61	G + P	59	56	44	96.0
	202	19.06.62	G	31	19	10	29.0
	202	4.07.62	G + P	100	38	24	62.0
	202	26.07.62	G + P	20	45	30	75.0
Kleszczyny L	208 c	8.06.84	G	36	11.2	33.3	44.5
	208 c	15.06.84	G + P	27	7.4	37	44.4
	208 c	20.06.84	G + P	63	34	23.8	77.8

Table 1 – cont. / Tabela 1 – cd.

	1	2	3	4	5	6	7	8
Świętokrzyski National Park – Świętokrzyski Park Narodowy								
Św. Katarzyna L	148	12.06.58	P	23	30	20	50.0	
	147	13.04.59	G + P	26	24	24	48.0	
	192	22.06.60	G + P	81	45	30	75.0	
	193	22.06.60	G + P	37	35	35	70.0	
	194	22.06.60	G + P	63	34	23	57.0	
	195	22.06.60	G + P	41	12	34	46.0	
	194	22.05.61	G	87	36	1.8	37.8	
	194	29.05.61	G	51	26	16	42.0	
	147	16.05.62	G	57	26	–	26.0	
	147	16.05.62	G	93	12.8	10.7	22.6	
	147	18.06.62	G	28	21.4	–	21.4	
	147	30.07.62	G + P	39	64	18	82.0	
	148	19.06.82	G + P	52	51.9	36	88.5	
	148	25.05.83	G	143	25.8	28	53.8	
	148	9.06.84	G + P	35	5.7	8.6	14.3	
	148	13.05.85	G + P	17	53	29.4	82.4	
Św. Krzyż L	147	13.06.85	G + P	14	21.5	42.8	64.3	
	147	1.06.86	G + P	18	33.3	–	33.3	
	197	25.06.82	G + P	24	48.8	38.7	87.5	
	197	16.06.83	G + P	13	61.4	69.2	100.0	
	202 f	9.06.84	G + P	29	13.3	80	93.3	
Dąbrowa L	208	14.06.85	G + P	57	22.8	31.6	54.4	
	203	12.06.86	G + P	48	18.8	20.8	39.6	
	100	29.05.92	G + P	18	50	11.1	61.1	

N – forest division, L – forest district, G – caterpillars, P – pupae.

N – nadleśnictwo, L – leśnictwo, G – gąsienica, P – poczwarka.

Firs weakened by damage to their assimilatory organ were killed by cambiohages and xylophages, causing the formation of dead wood and wood depreciation (Fig. 3). In the years 1975-1999 from partial reserves approx. 150 thousand m<sup>3</sup> fir dead wood was removed (Table 4), while in strict reserves dead trees were left to naturally decompose. The survey conducted in 1984 in the Park reported 190 thousand m<sup>3</sup> dead trees. Out of the amount in strict reserves there were 123 thousand m<sup>3</sup>, which per 1 ha amounted to 105 m<sup>3</sup> [Gądek 2000].

Table 2. Natural mortality in population of redheaded silver fir bud moth (*Z. rufimitrana* H.S.) in the Świętokrzyskie Mts. (laboratory analyses)Tabela 2. Śmiertelność naturalna populacji wskaźnicy jodlaneczki (*Z. rufimitrana* H.S.) na terenie Gór Świętokrzyskich (badania laboratoryjne)

Site and date of collection Miejsce i termin zbioru			Collected Zebrano		Mortality, % Śmiertelność, %		
Forest division, forest district Nadleśnictwo, leśnictwo	compartment oddział	date data	caterpillars gąsienica pupae poczwarka	no. sztuk	parasite infestation spasożyto- wanie	diseases and others choroby i inne	total ogółem
Suchedniów N							
Michniów L	202	20.05.61	G	50	56	6	62
Świętokrzyski National Park – Świętokrzyski Park Narodowy							
Św. Katarzyna L	194	22.05.61	G	19	–	47	47
Lagów N							
Złota Woda L	81	21.04.61	G	124	3	27	30
		4.07.61	G + P	78	84	8	93
		4.07.61	P	100	45	26	71

Explanation as in Table 1.  
Objaśnienia jak w tabeli 1.

The role of individual species of cambioptophages and xylophages in the process of dead wood formation and wood depreciation was presented in a separate study [Gądek 1995]. Characteristic insect species for this group included the fir weevil (*Pissodes piceae* Ill.), *Acanthocinus reticulatus* Rozoum, *Phaenops knoteki* Reitt. and *Anastrangalia dubia* Scop. Outbreaks of fir weevils were observed for many years, mainly in maturing stands. In 1978 the species infected 94% dead standing trees. *Acanthocinus reticulatus* infested weakened trees also simultaneously with bark beetles of fir and its populations exhibited high dynamics, particularly in trees with wind- or snow-broken tops. The occurrence of *Phaenops knoteki* in the Park and in the Świętokrzyskie Mts. was observed for the first time only during this outbreak and its populations in the period of analysis were not numerous. Females of *Anastrangalia dubia* laid eggs on fir dead wood immediately after it was abandoned by fir weevils and bark beetles of fir.

Populations of cambioptophages and xylophages of fir were effectively controlled by parasitic and predatory insects. Maximum parasite infestation of fir weevil larvae by *Aliolus atricornis* Ratz. (*Braconidae*) was 83%. Other parasitoids, such as *Rhyssa persuasoria* L., *Rhyssa amoena* Gravenhorst and *Ibalia leucospoides* Hoch. were also found in abundance. Moreover, the following species of predatory insects were reported: *Zeteotomus brevicornis* (Er.) and *Quedius plagiatus* (Mannerheim) (*Staphylinidae*), *Rhysodes sulcatus* (Fabr.) (*Rhysodidae*), *Tanasimus formicarius* L. (*Cleridae*) and *Cucujus cinnabarinus* (*Cucujidae*).

Dead fir wood remaining in strict reserves constitutes the food resources for numerous species of insects causing its further decomposition. This group of the so-called carioptophages included e.g. *Corymbia rubra* L. (*Cermbycidae*), *Peltis grossum* L. (*Peltidae*),

Table 3. Natural mortality in population of caterpillars of *Epiblema nigricana* H.S. in the Świętokrzyskie Mts. in 1961-1985 (laboratory analyses)Tabela 3. Śmiertelność naturalna populacji gąsienic wydrążki czerniejeczki (*Epiblema nigricana* H.S.) na terenie Gór Świętokrzyskich w latach 1961-1985 (badania laboratoryjne)

Site and date of collection Miejsce i termin zbioru			Collected (no. of specimens) Zebrano (sztuk)	Mortality, % Śmiertelność, %		
Forest division, forest district Nadleśnictwo, leśnictwo	compartment oddział	date data		parasite infestation spasożytność	diseases and others choroby i inne	total razem
1	2	3	4	5	6	7
Świętokrzyski National Park – Świętokrzyski Park Narodowy						
Św. Katarzyna L	194	1.04.61	25	40.00	–	40.00
	147	15.04.66	89	23.30	6.70	30.00
	173A	27.04.83	38	13.15	18.41	31.56
	147	27.04.83	19	26.30	36.72	63.02
	148	28.04.83	26	34.56	26.88	61.44
	147	12.05.84	32	75.00	–	75.00
	148	12.05.84	23	65.20	–	65.20
	148	9.05.85	26	23.10	36.20	69.30
Pogórze L	110	29.04.83	5	–	20.00	20.00
	111	12.05.85	21	66.70	9.50	76.20
	110	10.05.85	29	65.50	6.90	72.40
Św. Krzyż L	79-85	9.05.85	25	64.00	12.00	76.00
Łagów N						
Złota Woda L	81	20.04.61	13	33.00	–	33.00
Paprocice L	31	8.05.85	22	45.50	–	45.50
Suchedniów N						
Michniów L	202	26.04.62	10	30.00	20.00	50.00
	202	28.12.68	114	39.40	3.30	42.70

Explanation as in Table 1.  
Objaśnienia jak w tabeli 1.

*Ostoma ferrugineum* L. (Peltidae), *Ceruchus chrysomelinus* Łochw. (Lucanidae), *Rhyncolus chloropus* L. (Curculionidae), *Ptilinus peticicornis* (L.) (Anobiidae) and *Colydium elongatum* (Fabr.) (Colydidae). In the course of the study numerous larvae of *Ceruchus chrysomelinus* were observed in decomposed wood, even up to a depth of 15 cm. Feeding of larvae of this species practically completed the decomposition of fir wood structure. Moreover, repeated eating into decomposed wood by imagoes of *C. chrysomelinus* was observed, where in larval galleries, remaining after feeding of other

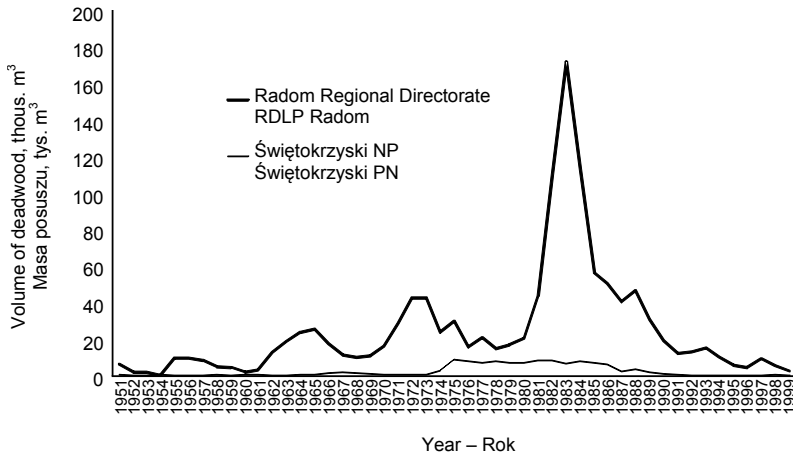


Fig. 3. Dead fir wood in the Świętokrzyskie Mts. in the years 1951-1999

Rys. 3. Posusz jodłowy wydzielony w Górach Świętokrzyskich w latach 1951-1999

Table 4. Volume of fir dead wood in partial and strict reserves of the Świętokrzyski National Park in 1975-1997, m<sup>3</sup>Tabela 4. Masa posuszu jodłowego wydzielonego w rezerwatach częściowych i ścisłych Świętokrzyskiego Parku Narodowego w latach 1975-1997, m<sup>3</sup>

Year Rok	Partial protection – Volume of dead wood			Strict protection – formed dead wood Ochrona ścisła – posusz wydzielony	Total formed Ogółem wydzielony
	removed usunięty	marked for re- moval do usunięcia	formed wydzielony		
1	2	3	4	5	6
1975	940	2 530	3 470	2 530	6 000
1976	5 913	21 988	27 901	11 343	39 244
1977	7 824	22 030	29 854	11 500	41 354
1978	7 082	12 856	19 938	13 886	33 824
1979	6 249	14 134	20 383	16 540	36 923
1980	5 167	18 275	23 442	18 556	41 998
1981	5 605	15 187	20 792	21 688	42 480
1982	3 925	12 915	16 840	19 084	35 924
1983	2 733	10 313	13 046	18 007	31 053
1984	4 127	7 348	11 475	17 374	28 849
1985	3 310	3 635	6 945	10 827	17 772
1986	2 144	949	3 093	8 331	11 424
1987	548	804	1 352	6 942	8 294
1988	2 483	466	2 949	2 651	5 600
1989	1 824	427	2 251	597	2 848
1990	1 162	289	1 451	539	1 990



Table 4 – cont. / Tabela 4 – cd.

1	2	3	4	5	6
1991	1 013	172	1 185	421	1 606
1992	852	388	1 246	340	1 586
1993	1 253	145	1 398	245	1 643
1994	72	142	214	250	464
1995	555	75	630	252	882
1996	473	169	642	279	921
1997	1 221	118	1 339	246	1 585
1998	464	90	554	228	782
1999	346	42	388	170	558
<b>Total Razem</b>	<b>67 294</b>	<b>145 487</b>	<b>212 787</b>	<b>182 826</b>	<b>395 604</b>

xylophagous species, specimens of both sexes were found together. Imagoes of *Peltis grossum* and *Ostoma ferrugineum* fed on fruiting bodies of bracket fungi such as *Ganoderma lucidum* Karst. and *Fomitopsis pinicola* (Sw.) Karst., etc.

Following a period of serious health crisis of firs in the Świętokrzyski National Park and the entire Świętokrzyskie Mountains – particularly in the 1970's and 1980's – starting from 1992 the condition of firs has improved markedly. This made it possible in recent years to leave in partial reserves a certain number of dead trees in order to enhance biodiversity. In the Park in the years 2003-2007 a total of 2435 m<sup>3</sup> fir wood, mainly dead trees and trees damaged by gale winds, were harvested from protected stands. At the same time 37 717 m<sup>3</sup> damaged wood were left for natural decomposition and in order to enrich the environment. In the course of a survey conducted in 2007 in stands a total of 34 717 m<sup>3</sup> dead wood at different stages of decomposition was recorded, of which fir comprised 15 233 m<sup>3</sup>. In fir dead standing wood 2399 m<sup>3</sup> were comprised of dying trees, infested by cambiohages and xylophages. This shows a marked increase in the threat to fir stands posed by them.

This situation is also confirmed by data from neighbouring fir stands administered by forest divisions belonging to the Regional Directorate of State Forests in Radom. In commercial forests of this Directorate the following amounts of fir dead standing wood, broken and fallen trees were harvested in recent years: 2005 – 14 491 m<sup>3</sup>, 2006 – 11 151 m<sup>3</sup>, 2007 – 47 890 m<sup>3</sup> and 2008 – 29 590 m<sup>3</sup>. Another disturbing aspect is the return, observed starting from 2004, of outbreaks of tortrix moths in the immediate neighbourhood of the Świętokrzyski National Park in the Łągów Forest District. Every year their outbreak was observed in an area of approx. 200 ha, which made it necessary in 2008 to perform a chemical application in an area of 270 ha (Fig. 2).

### **Insect fauna of fir in the Roztoczański National Park**

The present health condition of fir stands in the Roztoczański National Park, in comparison to the other national parks and commercial forests where fir is found in large groups, is relatively advantageous. This is reflected in the very good condition of the assimilatory organ in firs and the overall good condition of fir stands.

Although foliophagous tortrix moths appeared in that area in the early 1950's, after several years their outbreaks disappeared and have not been observed since. At present such insects as silver fir wooly aphid (*Dreifusia nordmanniana* Ex.), *Polydrosus impar* Gozis and weevil species (*Phylobius* sp.) may be found locally. However, they do not cause any major damage to the assimilatory organs of firs.

The biggest threat for ecosystems of fir forests in this Park is posed by gale-force winds, snow pressure, periodical droughts in the summer or delayed spring frost. The fact that the Roztocze region is located on the path of frequent heat waves is conducive of the formation of periodical hurricane damage. Moreover, strict reserves are established on ground elevations covered by stands of older age classes. This promotes the formation of gale-force winds. In the period starting from the establishment of the Park, i.e. from 1974 up to 2001, in the Roztoczański National Park a volume of 296 thousand m<sup>3</sup> wood damaged by hurricanes and snow pressure, as well as dead standing wood was harvested. Throughout the entire investigated period the amount of wood obtained from dead and dying trees was distinctly correlated with the volume of damage caused by abiotic factors. Groups of cambiophages and xylophages used the readily available food resources, infesting broken and fallen trees and next trees growing on the edges of the formed gaps in stands.

In partial reserves dead standing wood and trees felled in clean-up cuttings were removed from the forest, similarly as it is the case in commercial forests. In contrast, in strict reserves damaged trees were left as they were, gradually becoming infested by insects and decomposing. This made it possible to conduct quantitative analyses on the dynamics of reproduction in individual groups and species of insects, as well as natural factors limiting their populations. In the course of the study such a situation occurred e.g. after the damage inflicted on 18 August 1989, when in the Nart and Czerkies strict reserves the volume of trees damaged by a hurricane was over 12 thousand m<sup>3</sup>, while in partial reserves it was 14 thousand m<sup>3</sup>.

Based on detailed analyses the species composition of characteristic cambiophages and xylophages of fir could be determined. It turned out that generally it did not differ from that recorded in the Świętokrzyskie Mts. or the Świętokrzyski National Park [Gądek 1995]. However, individual species exhibited a more limited tendency to outbreaks, due to the different magnitude and type of occurring natural factors limiting these outbreaks, which was related with the good health condition of firs in the Roztoczański National Park. In the Nart strict reserve, following damage caused by foliophages in 1989, the density of cambiophage and xylophage populations initially increased; however, after three years they were naturally reduced. In the Nart strict reserve parasite infestation of European silver fir weevil larvae by *Aliolus atricornis* Ratz. (*Braconidae*) in 1991 was 70%, while in 1992 it was 71%. The total mortality in the population of the European silver fir weevil in 1992 caused by different natural limiting factors was 88%. In case of the European fir engraver beetle the parasite infestation of its larvae by *Ecpbylus silesiacus* Ratz. (*Braconidae*) amounted to 54%.

The activity of woodpeckers was a significant factor limiting populations of cambiophages and xylophages of fir. However, their prey were also parasitic insects, both species mentioned earlier and *Rhyssa persuasoria* L., *Rhyssa amoena* Gravenhorst as well as *Ibalia leucospoides* Hoch.

The occurrence of the following predatory insect species was recorded:

1. *Zeteotomus brevicornis* (Er) (*Staphylinidae*)
2. *Quedius plagiatus* Mannerheim (*Staphylinidae*)

3. *Quedius xantopus* (Er.) (*Staphylinidae*)
4. *Quedius messomelinus* (Marsham) (*Staphylinidae*)
5. *Rhysodes sulcatus* (Fabr.) (*Rhysodidae*)
6. *Thanasimus formicarius* L. (*Cleridae*)
7. *Cucujus cinnabarinus* Scop. (*Cucujidae*)
8. *Uleiota planata* (L.) (*Cucujidae*)
9. *Rhisophagus nitidulus* Fabr. (*Rhisophagidae*)

Decaying fir wood was infested by the following species of insects:

1. *Corymbia rubra* L. (*Cerambycidae*)
2. *Anastrangalia dubia* Scop. (*Cerambycidae*)
3. *Peltis grossum* L. (*Peltidae*)
4. *Ostoma ferrugineum* L. (*Peltidae*)
5. *Ceruchus chrysomelinus* Hoch. (*Lucanidae*)
6. *Eurythyrea austriaca* L. (*Buprestidae*)
7. *Ryncolus chloropus* L. (*Curculionidae*)
8. *Uloma culinaris* (L.) (*Tenebrionidae*)
9. *Mycetina cruciata* (Schall.) (*Endomyphidae*)
10. *Colydium elongatum* (Fabr.) (*Colydidae*)
11. *Ipidia quadrimaculata* (Quens) (*Nitidulidae*)
12. *Anisotoma humeralis* (Fabr.) (*Leiodidae*)
13. *Grynocharis oblonga* (L.) (*Peltidae*)

Decomposed, rotting fir wood and loose, dead bark were the living environment for numerous species of ground beetles (*Carabidae*) and click beetles (*Elateridae*).

*Ceruchus chrysomelinus* (Hochw.) was scarce in the Park. Single specimens of this species were found only in the Bukowa Góra strict reserve. In turn, golden buprestid (*Eurythyrea austriaca* L.) was abundant in the Bukowa Góra, Nart and Czerkies strict reserves. Females of this species laid eggs in fir dead standing wood with still rust-coloured needles and in dead standing wood from which bark had already fallen off. During swarming adult specimens of golden buprestid moved upwards on stems of dead standing trees towards well-lighted upper sections. They fed on fir needles. During swarming imagoes were caught on walls of a wooden building at a distance of 3 km from the Bukowa Góra reserve. The development of larvae lasted for several years, depending on wood moisture content. Larvae bit into wood up to the pith of trees of as much as 95 cm in diameter and their feeding was observed at stem sections of up to 15 m in length. Food resources for imagoes of *Peltis grossum* and *Ostoma ferrugineum* (Sw.) Karst. consisted of fruiting bodies of bracket fungi such as *Ganoderma lucidum* Karst., *Fomitopsis pinicola* (Sw.) Karst., and particularly *Pycnoporellus fulgens* (Fr.) Donk. Bracket fungi were also feeding grounds for *Diaperis boleti* L. (*Tenebrionidae*) and *Boletophagus reticulatus* (L.) (*Tenebrionidae*).

The year 1999 turned out to be particularly advantageous for the creation of new food resources for cambiphages and xylophages of fir, since excessive wet snowfall in April and November caused damage to stands amounting in the Roztoczański National Park to 66 052 m<sup>3</sup> wood, including 9685 m<sup>3</sup> fir wood (6243 m<sup>3</sup> in stands with partial protection and 3442 m<sup>3</sup> in stands covered by strict protection). Losses in the neighbouring stands of the Zwierzyniec Forest Division in that period amounted to 150 thousand m<sup>3</sup> wood.

## RECAPITULATION

A comparison of insect fauna of fir between the Parks showed that there are many similarities in the species composition, but on the other hand marked differences are also observed. This was caused, among other things, by the different health condition of fir in the Świętokrzyskie Mts. than in the Roztocze region, the influence of climatic factors and the distance between these two areas of abundant incidence of firs.

The complex effect of different damage-causing biotic, abiotic and anthropogenic factors on fir forests in the Świętokrzyskie Mts. created advantageous conditions for outbreaks of foliophages, cambiophages and xylophages of fir, markedly accelerating the processes of its regression or even local dying-back. This process was found in fir stands in the Świętokrzyski National Park and to a much higher degree also in the neighbouring commercial forests. In forests of neighbouring forest divisions it was necessary in fir stands to undertake very intensive protection measures, including chemical treatments applied for many years. In the Świętokrzyski National Park only a biological insecticide was used, which protected, particularly strict reserves, against disturbance of natural succession of groups of insect fauna.

In the Roztoczański National Park a threat to the stability of fir stands was caused mainly by abiotic factors, promoting local intensification of density of cambiophage and xylophage populations (Fig. 4).

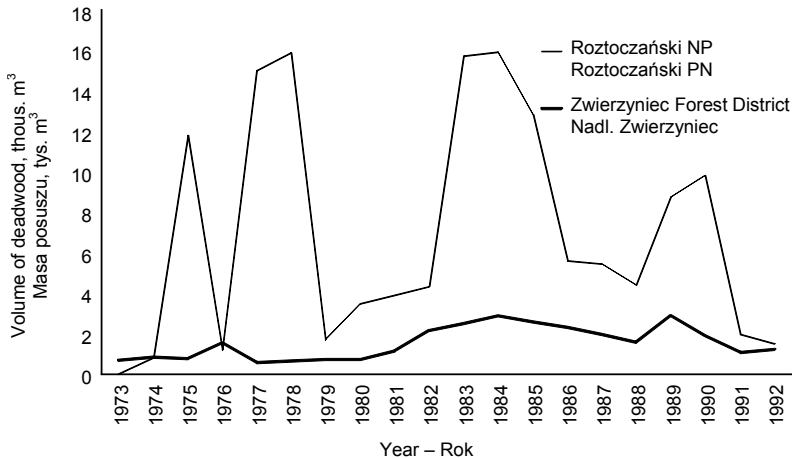


Fig. 4. Volume of dead fir wood in the Roztoczański National Park and the Zwierzyniec Forest District

Rys. 4. Masa jodłowego posuszu wydzielonego na terenie Roztoczańskiego Parku Narodowego i Nadleśnictwa Zwierzyniec

In partial reserves of both Parks the insect fauna of fir in its species composition did not differ from that observed in commercial forests. In contrast, in strict reserves, in ecosystems comparable to natural ones, diversity of the existing insect fauna was significantly wider. We need to stress here the abundant occurrence of *Ceruchus chrysomelinus* in the Świętokrzyski National Park, while in the Roztoczański National Park is an extremely rare species. In turn, in the Świętokrzyski National Park golden buprestid (*Eurytyrea austriaca*) was not found, whereas in the Roztoczański National

Park in the strict reserves it was abundant. In the period of the study *Phaenops knoteki* was recorded only in the Świętokrzyski National Park. Both species of *Buprestidae* are characteristic of the southern limit of the natural range of fir in Europe.

A marked improvement of condition of fir observed throughout Poland, starting from the 1990's, reduced the tendency towards outbreaks of most insect species. However, damage intensified in the years 2006-2007, caused by abiotic factors and the return of outbreaks of tortrix moths of fir in the Świętokrzyskie Mountains (the Łagów Forest Division) require increased control of the population dynamics of fir insect fauna not only in commercial forest, but also in National Parks in areas covered by partial and strict protection.

## CONCLUSIONS

1. Insect fauna of fir in the Świętokrzyski National Park and the Roztoczański National Park had a significant effect on the sanitary and health condition of stands and on the course of natural ecological processes.

2. A bigger diversity of the species composition of insects enhanced stability of ecosystems in fir forests.

3. The diversification of functions and importance of different groups of insects was connected with the health condition of the host plant. The periodically deteriorated health condition of fir in the Świętokrzyski National Park caused a marked increase in the population density of certain insect species.

4. Strict reserves of the analyzed National Parks, existing for many decades, create advantageous conditions for the preservation of several rare species of insects deserving full protection. For this reason in such areas any human intervention in the course of occurring natural biological processes needs to be eliminated.

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## RÓŻNORODNOŚĆ I ZNACZENIE OWADÓW W EKOSYSTEMACH LASÓW JODŁOWYCH ŚWIĘTOKRZYSKIEGO PARKU NARODOWEGO I ROZTOCZAŃSKIEGO PARKU NARODOWEGO

**Streszczenie.** Praca zawiera wyniki wieloletnich badań nad bioróżnorodnością entomofauny jodły na terenie rezerwatów ścisłych i częściowych Świętokrzyskiego i Roztoczańskiego Parku Narodowego. Przeanalizowano strukturę gatunkową poszczególnych grup funkcjonalnych owadów, ich rolę w ekosystemie oraz wpływ na przebieg naturalnych procesów ekologicznych w środowisku w zależności od stanu zdrowotnego rośliny żywicielskiej. Określono stopień podobieństwa składu gatunkowego entomofauny występującej na analizowanych powierzchniach parków. Podkreślono wielką rolę biologiczną i naukową rezerwatów ścisłych funkcjonujących od wielu dziesiątków lat. Są one niezbędne do tworzenia właściwych warunków rozwoju i przetrwania cennych przyrodniczo gatunków owadów, będących rzadkością w faunie drzewostanów jodłowych na północno-wschodniej granicy obszaru naturalnego występowania jodły.

**Słowa kluczowe:** entomofauna, jodła, rezerваты, lasy gospodarcze

*Accepted for print – Zaakceptowano do druku: 30.10.2009*

*For citation – Do cytowania: Gądek K., 2009. Diversity and role of insects in fir forest ecosystems in the Świętokrzyski National Park and the Roztoczański National Park. Acta Sci. Pol., Silv. Colendar. Rat. Ind. Lignar. 8(4), 37-50.*