THE SEASONAL POPULATION DYNAMICS OF MOTH LARVAE FEEDING IN BIRCH STANDS OF THE KRUŠNÉ HORY MOUNTAINS (THE CZECH REPUBLIC) FROM 1986–2004

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Abstract

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In the air-polluted area of the eastern Krušné hory Mts (Czech Republic), crown fauna of moth larvae was studied by the method of shaking down in the period 1986–2004. Of 145 species caught during our study the most important were *Cabera pusaria* (L.) (29.13%), *Operophtera fagata* (S c h a r f.) (15.21%), *Cyclophora albipunctata* (H u f n.) (7.02%), *Coleophora serratella* (L.) (4.29%), *Teleiodes proximellus* (H ü b n.) (3.23%), *Orthotaenia undulana* (D e n. and S c h i f f.) (3.07%), *Agriopis aurantiaria* (H ü b n.) (2.87%) and *Ochropacha duplaris* (L.) (2.60%). The seasonal and population dynamics of more numerous species was determined and the rate of threat to birch stands by these phytophages is discussed.

Key words: moth larvae, birch forests, Krušné hory Mts, seasonal, population dynamics

Introduction

After the large-area dieback of spruce stands (1979–1980) in the air-polluted area of the eastern Krušné hory Mts (Czech Republic), birch (*Betula pendula* R o t h) stands were established on the area exceeding 10 000 ha in the 1980s. The origin of extensive birch monocultures is related to the occurrence of phytophagous pests particularly Lepidopterans endangering their health condition. In the region of the Krušné hory Mts, the outbreaks of the following species have previously been noticed: *Erannis defoliaria* (C l e r c k) (Badalík, 1988), *Coleophora serratella* (L.) (Kula, 1995; Kula, Vaca, 1995) and the genus *Eriocrania* (Kula, 2000). Moth larvae represent the most important defoliators of birch (Kula et al., 1999; Kula, Ząbecka, 2001).

Birch is attacked by the broad spectrum of moth larvae which can result in outbreaks and complete defoliation. Reiprich (2001) mentions 367 species of moth larvae related by their food to birch. Previous studies have observed numerous species of Lepidopteran larvae feeding on birch (Kutenkova, 1986; Koponen, 1974; Eidmann, 1964). Krampl (1978) provided information about the moth fauna in this area merely on the basis of a 2-day entomological excursion. The fauna of moths caught by a light trap in birch stands of the air-polluted region of Forest District Snežník (northern Bohemia) includes 861 species some 123 of which are food-related to birch (Kula, 1997).

The aim of the paper is to verify a hypothesis that specific site conditions (air pollution, non-standard species composition) will change the faunistic richness of moths of poor communities of spruce stands, to define the rate of their harmfulness in birch stands and the potential threat of other species in the region, to use the long-term monitoring of the species occurrence to specify the existing findings on the seasonal and population dynamics of moth larvae.

Material and methods

Larvae were collected by means of shaking down on the sheet (2x2 m). During 1986–2004 five trees of each control birch stand (total 6, age 5–15 years, 450–600 m a.s.l.) were shaken down in 14 day intervals (April 1st–Oct. 30th) without repeated sample tree control. Larvae were killed and conserved in 75% ethanol. Before the growing seasons, seven photoeclectors sized 1×1×0.3 m were placed within birch crown projections in each year. Samples were taken in seven days during the whole growing period (April 1st–Oct. 30th) in 1992–2004. The killing and fixing medium was 75% ethanol.

Identification of larvae was carried out in collaboration with Doc. dr. J. Patočka, DrSc. (Slovak Academy of Science in Zvolen, Slovak Republic). Only in 7% caught larvae, determination of a species was not successful. Nomenclature was adapted according to Laštůvka (1998).

The categories of dominance were used according to Tischler (1949): > 10% eudominant, 5–10% dominant, 2–5% subdominant, 1–2% recedent, < subrecedent species.

Seasonal aspects according to Tischler (1955) proposed for Central European conditions were used: early spring (prevernal) March 15th–April 30th, spring (vernal) May 1st–June 10th, summer (estival) June 11th–August 15th, late summer (serotinal) August 16th –September 15th, autumnal September 16th–October 30th.

Study area

The area of the forest district Sněžník (14°04´ E, 50°46´ N) (Krušné hory Mts – N Bohemia) is situated mostly on an upland plateau in an altitude of 450–700 m, mountainous climate, annual temperatures of 6–7 °C, annual total rainfall of 700–800 mm, 110–120 days of growing season (with average daily temperatures over 15 °C). The area has been affected by air-pollutants for a long period. SO_2 was among the main pollutants (concentrations exceeded 60 $\mu g.m^{-3}$ per year during 1969–1987). Since 1990s the pollutants SO_2 (1995 – 44.1 $\mu g.m^{-3}$; 1998 – 22.4 $\mu g.m^{-3}$; 2001 – 12.4 $\mu g.m^{-3}$) and NO_x (1995 – 26.3 $\mu g.m^{-3}$; 1998 – 21 $\mu g.m^{-3}$; 2001 – 16.1 $\mu g.m^{-3}$) fell down. Investigations were carried out in 6 birch stands of the 1st age class (0–20 years). The birch stands differ in altitude, exposure, weed infestation, type of soil preparation before stand establishing by seeding or planting.

Results

In 1986–2004, some 11 617 larvae of 145 moth species were caught. Eudominant species of were restricted to: *Cabera pusaria* (L.) (29.1%) and *Operophtera fagata* (S c h a r f.) (15.2%). *Cyclophora albipunctata* (H u f n.) (7%) was the only species to be categoried in a dominant position. Subdominant species included: *Coleophora serratella* (4.3%), *Teleiodes proximellus* (H ü b n.) (3.2%), *Orthotaenia undulana* (D e n. and S c h i f f.) (3.1%), *Agriopis aurantiaria* (H ü b n.) (2.9%) and *Ochropacha duplaris* (L.) (2.6%) (Table 1). A yearly occurrence in crowns of birch trees was corroborated in *Cabera pusaria, Teleiodes proximellus, Biston betularius* (L.). Among sub-recessive members (131), some 45 species were caught once in birch crowns and 16 species twice. It refers to larvae less frequent in the studied region or accidentally caught, however, without a marked food relation to birch.

Geometridae creating the decisive part of the crown fauna of larvae (69.3%) noted the highest population density in 1988, 1992, 1995 and 2003. Members of the family Noctuidae (7%) and Tortricidae (7.4%) can be considered to be associated (Table 2).

Seasonal dynamics shows that in the period of a spring and late summer aspect, birch is endangered by larva feeding. An early-spring period poor in fauna with the only important species *Orthotaenia undulana* (70.4%) is alternated by the species-rich spring aspect (77 species) with the high proportion of individuals. A crucial position is occupied by pests with a outbreak potential such as *Operophtera fagata* (45.4%), *Coleophora serratella* (12.5%), *Agriopis aurantiaria* (7.5%) and *Orthotaenia undulana* (6.1%) (Table 3).

In the summer aspect, the species diversity increases (82 species) but the number of individuals decreases. In the late summer aspect, not only species diversity (98 species) but also the amount of larvae in crowns culminate.

A decisive position demonstrates *Cabera pusaria* (54.7%) accompanied by *Cyclophora albipunctata* (9.3%), *Teleiodes proximellus* (4.9%) and *Ochropacha duplaris* (4.1%). In the autumn aspect (55 species), the late summer aspect with *Cabera pusaria* (33.1%), *Cyclophora albipunctata* (10.2%) and *Teleiodes proximellus* (9%) fades away (Table 3).

The long-term monitoring (1986–2004) made possible to assess the population dynamics in species generally occurring and important in birch stands.

Cabera pusaria characterized by a outbreak potential in birch stands showed usually a repeated two-year increase to peak with a consequential fast two-year decrease although after 1998, a distinct peak was noted only in 2002 (Fig. 1). The population dynamics of *Operophtera fagata* attacking mainly beech was exhibited by the repeating four-year increased occurrence (1992–1995 and 2001–2004) with the long period of a basic stock (1986–1991) (1996–2000) (Fig. 1). *Cyclophora albipunctata* (1995), *Coleophora serratella* (outbreak in 1990), *Agriopis aurantiaria* (2004) and *Ochropacha duplaris* (1996–1997) rank among species with the only increase of population density in the 19-year period of monitoring. A subdominant species *Teleiodes proximellus* manifests itself by the balanced level of occurrence with the 5–6-year retreat to the level of a subreceding member (Figs 2 and 3).

The crown fauna of birch larvae differs in particular years due to differentiated population dynamics and response of particular species to site conditions. Owing to the outbreak posi-

T a b l e 1. Changes in the dominance of moth larvae in the crown fauna of birch (*Betula pendula* R o t h) with the aggregate dominance >1% in 1986–2004.

Species/Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Sum	%
Cabera pusaria	31.64	56.06	51.76	33.52	14.51	60.17	34.34	8.92	10.9	28.21	35.21	26.80	22.10	18.64	18.09	20.36	38.39	8.71	8.09	3384	29.13
Operophtera fagata	2.11	0	5.13	4.12	7.80	6.70	31.22	27.56	39.05	13.24	3.01	2.45	3.86	4.53	8.51	29.52	12.54	34.33	33.27	1767	15.21
Cyclophora albipunctata	0	0	0	1.76	0	1.95	0	8.40	8.76	19.03	13.74	12.68	7.37	14.36	6.38	5.09	9.91	5.85	5.58	815	7.02
Coleophora serratella	0	0	0.16	0	56.62	13.40	3.93	0	0.35	0.39	0	0	0.48	0	6.38	0.51	0	0	0.36	498	4.29
Teleiodes proximellus	12.24	8.16	5.77	5.88	0.73	0.24	0.56	0.52	0.53	2.42	5.32	3.17	7.25	12.34	3.72	1.78	1.24	1.00	0.72	375	3.23
Orthotaenia undulana	0	0.21	0	0	1.81	0.61	1.04	3.41	7.53	2.80	5.02	6.48	11.35	5.04	2.13	0.76	1.70	1.74	0.36	357	3.07
Agriopis aurantiaria	1.27	0.42	2.72	1.18	0.91	0	1.04	2.36	2.80	1.35	0.50	1.30	4.11	1.76	0	5.34	2.17	7.59	18.17	333	2.87
Ochropacha duplaris	1.69	1.26	0.16	0	0	0	0.24	2.62	0.18	1.55	9.73	12.10	6.76	2.27	0	1.27	0	1.00	0.36	302	2.60
Campaea margaritata	1.27	0	0.32	1.18	0.91	0	0.16	2.10	1.93	2.71	0.80	2.31	1.57	5.79	6.38	10.94	3.56	1.49	1.80	221	1.90
Biston betularius	4.64	1.05	0.80	2.94	2.36	1.22	1.28	0.79	0.88	1.84	1.40	2.16	0.72	2.27	0	1.27	1.39	0.87	1.62	166	1.43
Chiasmia notata	0	0	0	0	0	0	0.16	6.56	2.28	1.16	0.30	0.29	1.45	4.03	1.60	2.29	1.70	2.86	1.44	139	1.20
Epinotia trigonella	0	0.63	7.85	0	0	0	0	0	0	0	5.72	4.18	0	0	0	0	0	0	0	138	1.19
Aethalura punctulata	3.80	0.63	0	0.59	0	0.12	1.61	1.05	0.53	1.93	0.40	2.45	0.24	0.76	3.19	0.76	1.55	0.62	1.26	118	1.02
Operophtera brumata	0	0.42	6.41	0	0.54	0	0.72	0	0.35	2.22	0.50	0.58	0.36	0	0	0	0.77	1.74	1.44	118	1.02
Individuals > 1% in total	139	329	506	87	475	693	951	245	434	816	814	534	560	285	106	314	484	545	414	8731	75.16
Individuals < 1% in total	74	121	87	61	56	90	213	119	100	156	156	123	188	79	43	58	96	175	97	2092	18.08
Non-determined	24	28	31	22	20	38	82	17	37	63	27	37	80	33	39	21	66	84	45	794	6.83
Sum of individuals	237	478	624	170	551	821	1246	381	571	1035	997	694	828	397	188	393	646	804	556	11617	100
Species > 1% in total	8	9	10	8	9	8	12	11	13	13	13	13	13	11	9	12	11	12	13	14	
Species < 1% in total	35	44	26	23	27	35	41	37	31	41	39	38	45	27	14	22	33	42	24	131	
Sum of species	43	53	36	31	36	43	53	48	44	54	52	51	58	38	23	34	44	54	37	145	

T a b l e 2. Numbers of moth larvae of Lepidoptera families in the crown fauna of birch in 1986–2004.

Family/Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Sum	%
Arctiidae		1				2	2	1				1						2		9	0.08
Coleophoridae			1		312	110	49		2	4			4		12	2			3	499	4.30
Drepanidae	8	19	1	4	2	12	20	13	1	29	117	90	74	13		8	8	23	3	445	3.83
Endromidae												2								2	0.02
Eriocraniidae				1	1					47	2			2	16	4		8		81	0.70
Gelechiidae	29	40	43	10	4	2	8	2	5	25	54	29	66	52	15	12	18	11	7	432	3.72
Geometridae	134	300	468	125	188	617	1033	275	439	793	615	407	450	234	90	328	490	611	456	8053	69.32
Gracillariidae		3																		3	0.03
Herminiidae									1											1	0.01
Lasiocampidae		2		1		3	1		2	2							1			12	0.10
Lymantriidae	3		5		3	3	13	2	3	1	3	4	8	8		1	6	5	3	71	0.61
Noctuidae	20	29	10	9	19	32	56	51	57	45	64	62	131	38	14	15	50	76	30	808	6.96
Notodontidae	3	8	3	2	4	7	14	12	12	23	18	15	8	17	4	7	18	6	8	189	1.63
Oecophoridae		4		2	2	2	3	2			4				2		5	1		27	0.23
Psychidae							2	1	2	1							1			7	0.06
Pyralidae	1	1	2		1		2	1	3	1	1	1	3		1	1	3	2		24	0.21
Sphingidae										1							1			2	0.02
Thyatiridae	4	3	1		3			2	1				3	2				1	1	21	0.18
Tortricidae	28	46	89	13	11	29	41	19	43	59	116	82	79	30	14	13	44	57	46	859	7.39
Yponomeutidae	7	22	1	3	1	2	2			4		1	1	1	20	1				66	0.57
Ypsolophidae											3		1				1	1		6	0.05
Total	237	478	624	170	551	821	1246	381	571	1035	997	694	828	397	188	392	646	804	557	11617	100.00

T a b l e 3. Seasonal dynamics of the most important caterpillars of butterflies of birch *Betula pendula* R o t h.

Species	Early spring 15.3.– 30.4.	Spring 1.5.–10.6.	Summer 11.6.–15.8.	Late summer 16.8.–15.9.	Autumn 16.9.– 30.10.	Sum
Operophtera fagata		1759	7	1		1767
Coleophora serratella	4	483	10	1		498
Agriopis aurantiaria	1	294	22	16		333
Orthotaenia undulana	119	235	2	1		357
Cyclophora albipunctata		16	185	493	121	815
Cabera pusaria		8	92	2890	394	3384
Teleiodes proximellus		1	7	260	107	375
Ochropacha duplaris		5	9	218	70	302
Campaea margaritata	9	17	2	122	71	221
Biston betularius			1	140	25	166
Others	36	1054	763	1144	402	3399
Total	169	3872	1100	5286	1190	11617

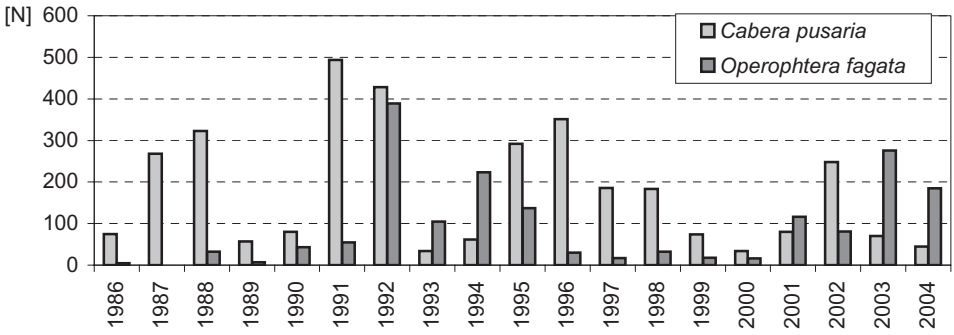

Fig. 1. Population dynamics of eudominant members of the crown fauna of birch (1986–2004, method of shaking down, Sněžník).

tion of *Coleophora serratella* the year 1990 varies. In the most occurring Geometridae, the proximity of particular years can be derived particularly from the proportion of eudominant species (*Cabera pusaria, Operophtera fagata, Campaea margaritata* (L.)) (Table 1).

In the course of a 19-year period (1986–2004) when the decrease of an air pollution stress occurs in the studied region, an increase showed in *Agriopis aurantiaria* and *Campaea margaritata* populations. *Coleophora serratella* and *Ochropacha duplaris* larval numbers have been low throughout the study except for during 3 years outbreaks in 1990–1992 and 1996–1998 respectively. *Cyclophora albipunctata* numbers exhibited a sharp peak in

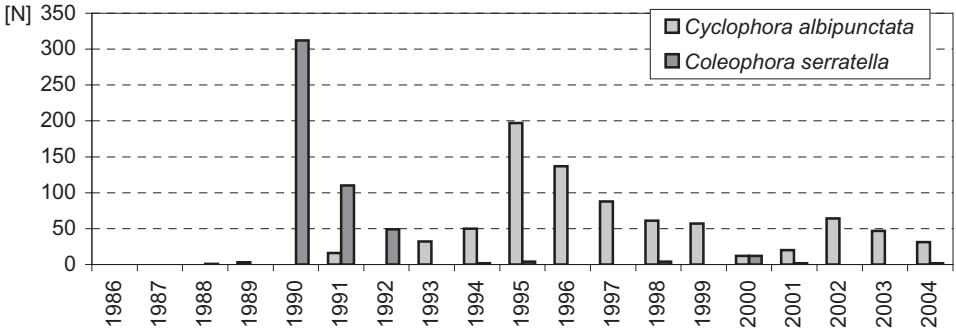

Fig. 2. Population dynamics of *Cyclophora. albipunctata, Coleophora serratella* in the crown fauna of birch (1986–2004, method of shaking down, Sněžník).

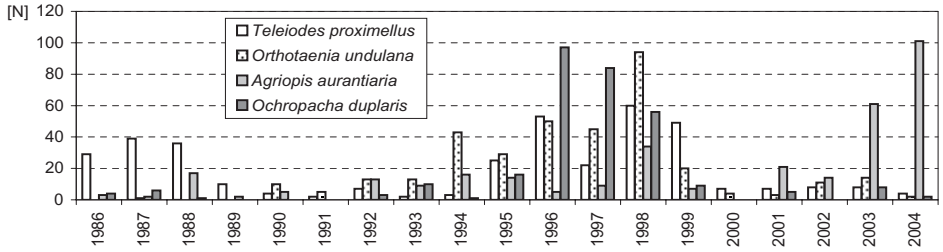

Fig. 3. Population dynamics of subdominant members of the crown fauna of birch (1986 2004, method of shaking down, Sněžník).

numbers in 1995 followed by a gradual decline over the rest of the study period, whereas in contrast *Orthotaenia undulana* showed a gradual increase in numbers to a peak in 1998 followed by a sharp drop in numbers in subsequent years. *Cabera pusaria* numbers have actually decreased over the period 1991-2004. Repeated culminations were in *Operophtera fagata* and *Teleiodes proximellus* (Table 4).

Discussion

Regions with the high proportion of birch differ by the proportion of main insect pests and structure of the crown fauna. It refers mostly to polyphagous species (*Operophtera brumata*, *Erannis defoliaria*, *Lymantria dispar*, *Biston betularius*). *Epirrita autumnata* in northern Scandinavia is of local importance. The fauna of larvae of moths of the eastern

T a b l e 4. Average annual sampling of moth larvae in the crown birch fauna and its changing in the period 1986–2004.

Species/Year	1986–1990	1991–1995	1996–2000	2001–2004	1986–2004
Agriopis aurantiaria	5.8	10.4	10.4	49.3	17.4
Cabera pusaria	160.6	262.0	165.6	110.8	178.1
Campaea margaritata	2.4	9.8	14.4	22.0	11.6
Coleophora serratella	62.6	33.0	3.2	1.3	26.3
Cyclophora albipunctata	0.6	59.0	71.0	40.5	42.9
Ochropacha duplaris	2.2	6.0	49.2	3.8	15.9
Operophtera fagata	17.4	181.8	22.6	164.5	93.0
Orthotaenia undulana	2.2	20.6	42.6	7.5	18.8
Teleiodes proximellus	23.6	7.8	38.2	6.8	19.7
Average	412.0	810.8	620.8	559.8	611.4

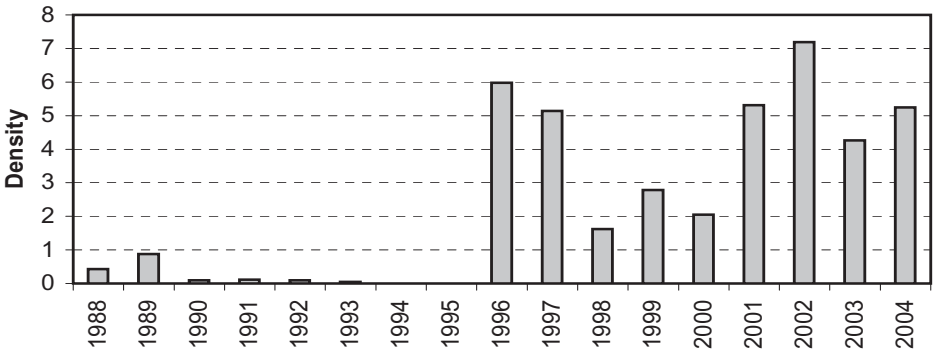

Fig. 4. Population dynamics of hibernating larvae of genus *Eriocrania* in the birch stands (Sněžník, photoeclectors, 1988–2003, m^2).

Krušné hory Mts differs particularly by the occurrence of *Cabera pusaria* not mentioned yet. The species is the most important defoliator of birch in the summer aspect. Although the hatching of moths is protracted (June–July), potential outbreaks cannot be excluded. Possible late-summer heavy defoliation could cause (similarly as in *Lochmaea capreae* (L.)) insufficient maturation of shoots and subsequently their winter killing.

In the 80s of the 20th century, outbreak was noted of *Operophtera brumata* and *Erannis defoliaria* on birch requiring control measures on the area of 2500 ha (Badalík, 1988; Šrot, Skuhravý, 1988; Skuhravý, Šrot, 1991). *Operophtera brumata* and *Operophtera fagata* gradated on *Sorbus aucuparia* L. in Seiffen in Germany (the Krušné hory Mts, 1981–1983) and repeatedly in 1992–1993 when in consequential years (1994–1997), an increase occurred in the population of *Operophtera fagata* from 18 to 55% (Lemme, 2001). In birch

stands (1986–2004), *O. fagata* was an eudominant species supporting the cyclic type of outbreaks while *O. brumata* occurred sporadically (1.02%). *O. fagata* attacking beech can be considered to be an economically important pest in the regeneration of the Krušné hory Mts stands.

Although *Biston betularius* is significantly represented in the fauna of moths (7.7%) of the region under study (Kula, 1997) in the fauna of crowns the species was classified as receding (1.4%). Insect outbreaks are noted from western Siberia from broadleaved stands (Gninenko, 2002) and China in *Betula platyphylla* (S u k.) (Sun-Fan et al., 2000). *Pheosia gnoma* (F a b r.) related exclusively to birch is missing in the crown fauna of young stands although its trapping by light traps was significant (5.5%) (Kula, 1997).

A dominant *Cyclophora albipunctata* in the crown fauna of birch is characterized by acyclic population dynamics. Two generations are not noticed every year. In the period of low population density (1986–1994), the species was not caught or exhibited only one generation (1993–1994). In the year of culmination (1995), two generations were corroborated (the 2nd generation was larger). The period 1996–2002 is characterized by the balanced proportion of the first and second generations and accentuated start of the 1st generation in 2003–2004.

The width of the species spectrum (145) supported in the stage of a larva is in an agreement with the richness of fauna (134) mentioned by Kutenkova (1986). From the economic point of view, the importance of moths is given by the proportion of outbreak members (*Cabera pusaria*, *Operophtera fagata*) and the spectrum width as a whole. Based on mapping the defoliation of birch and its causes larvae of moths participate even by 13% and obvious dynamics is manifested in them (Kula, 2005). If we add the proportion of mining species (*Coleophora serratella*, *Eriocrania* spp.) the annual current loss of an assimilatory area amounts to about 10%.

Mining species of the genus *Eriocrania* are generally characterized by their low population density. Local outbreaks are known from Scandinavia (Koponen, 1981) from localities affected by air pollutants arising from ironworks (Kozlov et al., 1995). Under conditions of birch in the Krušné hory Mts (altitude 450–600 m), the group of miners developed in birch as early as at the end of the 80s and heavy local feedings occurred in the period 1996–1997 with the abundance of wintering larvae amounting to 6 and 5.1 per m^2, respectively.

Another culmination in 2002 (7.2 larvae per m^2) characterizes the period of an increased occurrence in 2001–2004 (5.36–7.19–4.1–5.24 larvae.m^{-2}) (Fig. 4). Only species *Eriocrania semipurpurella* (S t e p.) and *E. sparrmannella* (B o s c.) with higher participation (64%) were determined. These early hatching miners with a short period of the development of larvae can cause total defoliation in the course of the first half of May and thus to disturb the health condition of particularly young stands of birch.

Control methods can be applied in members of the genus *Operophtera* (wintering eggs, trapping the apterous females ascending the tree crowns). *Cabera pusaria* winters in soil in the stage of pupa and in case of necessity hatching can be controlled by soil photoeclectors. Miners which are not objectively caught by the method of shaking down are considered to be economically important. Separate studies concerning *Coleophora serratella* (Kula,

Vaca, 1995) and *Eriocrania* (Kula, 2000; Kozlov, 1984) provide basic information on bionomy, control and protection which can be used in case of outbreak situation. Long-term monitoring the fauna of moths brought increased knowledge on the population dynamics of e.g. *Cabera pusaria* and *Operophtera fagata*. Within a 20 year period, the decline of some species from localities occurs which can be affected by the change of site conditions, growing up birch, decrease in the air pollution load but also by the response of the actual species to the development of natural enemies.

From the viewpoint of damage to birch stands the spring aspect represents the most sensitive period because the spring outbreak species (*Coleophora serratella*, *Eriocrania*, *Operophtera, Agriopis, Orthotaenia*) begin their feeding in the period of budbreak and leaf formation. From summer till the end of the growing season significant position shows only *Cabera pusaria.*

Conclusion

Larvae of moths create the species-richest (145) and the most frequent part of the crown fauna of birch in the region of the Krušné hory Mts. In the spring aspect, the stability of stands is significantly endangered by *Operophtera fagata, Eriocrania* spp., *Coleophora serratella* and in the summer aspect by *Cyclophora albipuntata* and *Cabera pusaria.* The outbreak potential in the studied region was confirmed by local outbreaks (*Coleophora serratella*) and high population density causing intense feeding (*Operophtera fagata, Eriocrania*) and high population density without significant defoliation (*Cabera pusaria*).

Based on population dynamics a cyclic, continuous and contractive outbreak type was derived in *Cabera pusaria*, cyclic, continuous with the longer period of latency and distractive *Operophtera fagata*, and acyclic, discontinual and contractive in *Coleophora serratella.*

In the development of the crown fauna (1986–2004), an increase in larvae of *Agriopis aurantiaria* and *Campaea margaritata* was demonstrated. Differences in the structure of crown fauna in particular years are affected by the complex of factors (decrease in air pollution, age of stands, weather etc.) which were not, however, studied in detail.

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