Caterpillar assemblages on introduced blue spruce: differences from native Norway spruce

(With 2 Figures and 2 Tables)

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1. INTRODUCTION

Blue spruce (*Picea pungens* Engelm.) is native to the central and southern Rocky Mountains of the USA (DAUBENMIRE, 1972), from where it has been introduced to other parts of North America, Europe, etc. In Central Europe, blue spruce was mostly planted in ornamental settings in urban areas, Christmas tree plantations and forests too. In the Slovak Republic, blue spruce has patchy distribution. Its scattered stands cover the area of 2,618 ha and 0.14% of the forest area (data from the National Forest Centre, Zvolen). Compared to the Slovak Republic, the area afforested with blue spruce in the Czech Republic is much larger –8,741 ha and 0.4% of the forest area (KŘIVANEK *et al.,* 2006, ÚHUL, 2006). Plantations of blue spruce in the Czech Republic were largely established in the western and north-western parts of the country (BERAN and ŠINDELAŘ, 1996; BALCAR *et al.,* 2008b).

The moth (Lepidoptera) associates of blue spruce in Europe were studied only marginally. Greater attention was paid to *Coleotechnites piceaella* (KEARFOTT, 1903), the moth originating from North America which had been introduced to urban areas along with blue spruce (FÜHRER, 1963; HOLZSCHUH, 1987; KULFAN *et al.,* 1998; SCHNEE, 2000). In Central Europe a few other moth species were documented to be developing on the introduced blue spruce (HRUBIK, 1988; HOLUŠA *et al.,* 2004; KULA, 2007; KULFAN *et al.,* 2007). There are approximately 50 monophagous and oligophagous moth species associated with conifers which develop on the native Norway spruce [*Picea abies* (L.) KARST.] in Central Europe (PATOČKA and KULFAN, 2009). Some polyphagous moth species associated with deciduous trees and shrubs, or herbs, may also take their development on Norway spruce in Central Europe.

It is therefore likely that blue spruce introduced to the forests in Central Europe will host moth species occurring on Norway spruce, a native congeneric tree species (ROQUES *et al.,* 2006), as well as non-native moth species introduced from North America (MATTSON *et al.,* 2007).

In this study from Central Europe we addressed the questions as to whether (1) blue spruce and Norway spruce have similar moth fauna, (2) blue spruce planted in forests is a host for *Coleotechnites piceaella* (the moth already recorded in urban areas in Central Europe) or other moth species introduced from North America and (3) afforestation with the introduced blue spruce affects the diversity of Lepidoptera on the native Norway spruce.

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2. MATERIAL AND METHODS

2.1 Study areas

The study was carried out in the two geographically distant regions (forest areas) in Central Europe. They were the following: West Carpathians Mountains in the Slovak Republic and Hercynian Mountains in the Czech Republic. Each region represents a different situation with regard to the occurrence of blue spruce. In West Carpathians the stands of blue spruce are small and patchily distributed, surrounded by large complexes of Norway spruce or mixed forests. In Hercynian Mountains, in contrast, the stands of blue spruce are much larger in area compared to those in West Carpathians, established in areas affected by air pollution.

The study area in West Carpathians is situated in Veporské vrchy Mountains, Central Slovakia, in the vicinity of the village Detvianska Huta (48°34'N, 19°35'E, 910 m a.s.l). It is characterized by mountain climate (mean temperature in January –5 to –6.5 °C, mean temperature in July 13.5 to 16 °C, annual precipitation 800–1100 mm) (MICHALKO *et al.,* 1986). Beech forests (Eu-Fagenion p. p. min.) are the potential vegetation (MICHALKO *et al.,* 1986) in the study area where blue spruce was planted in the form of stripes. The stripes are 30–40 m wide, alternating with the stripes of Norway spruce. The area of an open-canopy blue spruce forest is approximately 2 ha. The proportion of tree species in the study area is the following: blue spruce (45%), Norway spruce (45%), beech (9%), ash, birch and goat willow together (1%). The aspect is south-west, slope approximately 20°. Plantations of blue spruce and Norway spruce were about 40 years old when the study was made.

The study area in Hercynian Mountains is situated in Děčínská vrchovina hills, north-west Bohemia, in the vicinity of the village Sněžník (50°47'N, 14°05'E, 600 m a.s.l.). It is located at an open plateau characterized by mountain climate (mean temperature in January –2.3 °C, mean temperature in July 15.5 °C, annual precipitation 700–800 mm) (data from Sněžník Meteorological Station, Czech Hydrometeorological Institute, Ústí nad Labem). The forests in the study area were heavily affected by air pollution, sulphur dioxide (SO_2) being most serious pollutant in the past. Over the period 1969–1987 concentrations of sulphur dioxide were exceeding 60 $\mu g.m^{-3}$ $year^{-1}$, the current load of sulphur dioxide (2001–2008) is much lower (11.0 up to 12.4 μg m^{-3} $year^{-1}$). Due to air pollution, Norway spruce, predominant tree species in the region over the first half of the 20th century, was substituted with monocultures of blue spruce (approximately 500 ha). The proportion of tree species in the study area is the following: blue spruce (40%), Norway spruce (40%), birch (15%), beech, alder, oak, sycamore, rowan, Scots pine, European larch together (5%). As in West Carpathians, canopy cover of blue spruce stands is open. At the end of the 20th century monocultures of Norway spruce have been re-established in the study area. Plantations of blue spruce were approximately 30 years old, those of Norway spruce 12 years old over the study period.

2.2 Data collection during the growing season

The beating method (BASSET *et al.,* 1997) was used to sample caterpillars from blue spruce and Norway spruce. Caterpillars were knocked from the lower branches of trees using a stick and circular beating tray (diameter 1.0 m). Caterpillars that had dropped into the beating tray held under the branches being knocked were collected manually, using tweezers. The sampling heights in particular trees varied from 1.0 m up to 3.0 m, measured from the ground. Caterpillars were sampled only if weather conditions were favourable, that is, sampling was not made on rainy days or shortly after the rain, or on windy days. The larvae were preserved in 70% ethanol and identified in the laboratory. Some larvae (small caterpillars of the genera *Macaria* spp. and *Eupithecia* spp.) were taken alive, reared in the laboratory and identified in older instars, as pupae or imagines. Caterpillars were sampled monthly, from May to September in 2006 (West Carpathians) and 2007 (Hercynian Mountains). A total of 10 samples from blue spruce and a total of 10 samples from Norway spruce were obtained every month. One sample constituted caterpillars knocked from the 20 terminal parts of branches, 1 m long each, from different trees. At each sampling occasion different branches were knocked to obtain caterpillars.

Tab. 1

Dominance (%) of caterpillars collected from blue spruce (*P. pungens*) and Norway spruce (*P. abies*) over the growing season in West Carpathians and Hercynian Mountains. (Guild: N-S – needle-spinning; F-L – free-living; L – lichenophagous larvae).

Dominanz (%) der Schmetterlingsraupen von der Stech-Fichte (*P. pungens*) und der Gemeinen Fichte (*P. abies*) während der Vegetationsperiode in den Westlichen Karpaten und in dem Herzynischen Gebirge gesammelt. (Gilde: N-S – Raupen spinnen die Nadeln zusammen; F-L – freilebende Raupen; L – lichenophage Raupen).

Family/Species **Familie**/Art	Guild Gilde	West Carpathians Westliche Karpaten		Hercynian Mountains Herzynisches Gebirge	
		P. pungens	*P. abies*	*P. pungens*	*P. abies*
Gelechiidae					
Chionodes electella (Zeller, 1839)	N-S	0.2			
Tortricidae					
Acleris abietana (Hübner, 1822)	N-S	0.4		4.4	1.7
Archips oporana (Linnaeus, 1758)	N-S	0.7	0.2		
Pandemis cinnamomeana (Treitschke, 1830)	N-S		0.2		
Dichelia histrionana (Frölich, 1828)	N-S	6.0	2.0	3.8	2.6
Pseudohermenias abietana (Fabricius, 1787)	N-S	1.1	0.5	1.5	
Epinotia tedella (Clerck, 1759)	N-S	1.1	0.5		
Epinotia nanana (Treitschke, 1835)	N-S	8.2	2.0	3.0	
Epinotia pygmaeana (Hübner, 1799)	N-S		0.3	3.0	2.6
Zeiraphera ratzeburgiana (Saxesen, 1840)	N-S			0.8	
Lasiocampidae					
Dendrolimus pini (Linnaeus, 1758)	F-L	0.2	0.2		
Geometridae					
Macaria spp. including:	F-L	6.7	5.0	7.6	6.9
M. signaria (Hübner, 1809)					
M. liturata (Clerck, 1759)					
Odontopera bidentata (Clerck, 1759)	F-L	0.6		0.8	
Peribatodes rhomboidarius (Den. & Schiff., 1775)	F-L			1.5	
Peribatodes secundarius (Den. & Schiff., 1775)	F-L	5.8	6.4	6.1	4.3
Deileptenia ribeata (Clerck, 1759)	F-L	2.4	0.8		
Alcis repandata (Linnaeus, 1758)	F-L	0.8	0.3		
Hylaea fasciaria (Linnaeus, 1758)	F-L	1.9	1.5	0.8	
Pungeleria capreolaria (Den. & Schiff., 1775)	F-L	17.4	18.2		
Thera variata (Den. & Schiff., 1775)	F-L	4.3	8.6	12.8	7.8
Eupithecia tantillaria (Boisduval, 1840)	F-L	25.6	38.7	21.2	22.4
Eupithecia lanceata (Hübner, 1825)	F-L	12.7	12.9	21.2	45.7
Noctuidae					
Orthosia gothica (Linnaeus, 1758)	F-L		0.2	0.8	
Lymantriidae					
Orgyia antiqua (Linnaeus, 1767)	F-L			0.8	
Lymantria monacha (Linnaeus, 1758)	F-L	2.8	0.8	0.8	
Arctiidae					
Atolmis rubricollis (Linnaeus, 1758)	L				0.9
Eilema complana (Linnaeus, 1758)	L			3.0	1.7
Eilema depressum (Esper, 1787)	L	0.9	0.5		
Lithosia quadra (Linnaeus, 1758)	L	0.2	0.2	6.1	3.4

The faunal data (number of caterpillars) obtained from the five monthly collected samples were pooled. Thus, both blue spruce and Norway spruce were represented by one data set (10 replicates) for each study area.

2.3 Data collection at the end of winter

The lower branches were cut (at heights of 1.0 m to 3.0 m above the ground) from blue spruce and Norway spruce at the end of winter so as to get a more detailed information on overwintering caterpillars. In the study area in West Carpathians a total of 10 samples were obtained from both blue spruce and Norway spruce in March 2008. Each sample consisted of the 40 terminal parts of the branches which were 0.5 m long each. Then, the branches were placed into photoeclectors in the laboratory. Caterpillars and/or hatched adults of moths that had emerged from photoeclectors were collected and identified. In Hercynian Mountains caterpillars were also sampled in March 2008. In this particular case, each sample consisted of the 15 terminal parts of the branches which were 0.5 m long each.

2.4 Data processing

The taxonomic separation of caterpillars of the species *Macaria signaria* and *M. liturata* (both species collected over the growing season) is impossible. Some caterpillars of the genus *Macaria* were reared to adults and then identified to the species level. Also, the imagines of the genus *Argyresthia* obtained through photoeclectors are difficult to identify. This was why not all individuals within these two genera were identified to the species level. The representatives of the genera *Macaria* spp. and *Argyresthia* spp. were considered as one taxon in the quantitative data analyses. In the species lists (*Table 1*, *2*) they were included as particular species.

Diversity of moth assemblages was characterized by the Simpson's index (HAMMER *et al.,* 2001). Mann-Whitney U-test (STATSOFT, 2005) was used to test for the differences in the abundance of caterpillars between blue spruce and Norway spruce. Number of caterpillar species expected in the samples collected over the growing season was estimated by rarefaction analysis (HURLBERT, 1971; HAMMER *et al.,* 2001).

3. RESULTS

3.1 Growing season

In West Carpathians a total of 1,145 caterpillars belonging to a total of 24 moth species were collected from blue spruce and Norway spruce over the growing season. In Hercynian Mountains a total of 248 caterpillars and 21 moth species were obtained from the two spruce species (*Table 1*). All the species recorded are native to Central Europe.

In West Carpathians the total number of moth species recorded on blue spruce and Norway spruce was equal (22 species). However, the species density (number of caterpillar species on the 20 branches, 1 m long each) was significantly higher on blue spruce than Norway spruce ($p < 0.05$, $Z = -2.98$, U-test; *Macaria* spp. being considered as one taxon in the data analysis). Based on rarefaction, the number of moth species expected on blue spruce and Norway spruce was almost equal if the samples were large (*Fig. 1*). For example, in the sample constituting a total of 500 caterpillars the number of species expected was 20.8 (SD = 0.43) in the case of blue spruce and 20.0 (SD = 0.90) in the case of Norway spruce (*Macaria* spp. being considered as one taxon). In smaller samples, more species were expected on blue spruce than Norway spruce. Most species recorded occurred on both blue spruce and Norway spruce. Caterpillar assemblage feeding on blue spruce was slightly more diverse (Simpson's index of diversity D = 0.866) compared to that feeding on Norway spruce (D = 0.784).

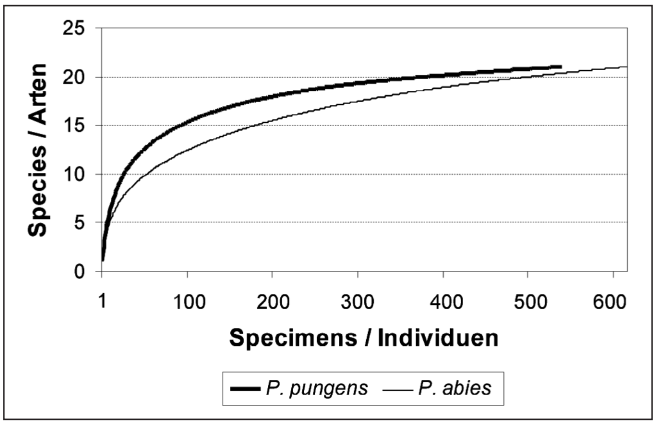

Fig. 1

Rarefaction curves for the expected number of moth species on blue spruce (*Picea pungens*) and Norway spruce (*Picea abies*) in West Carpathians. Moth caterpillars were collected during the growing season.

Rarefaction-Kurven für die erwartete Anzahl der Schmetterlingsarten, deren Raupen sich auf der Stech-Fichte (*Picea pungens*) und der Gemeinen Fichte (*Picea abies*) in den Westlichen Karpaten entwickeln. Schmetterlingsraupen wurden während der Vegetationsperiode gesammelt.

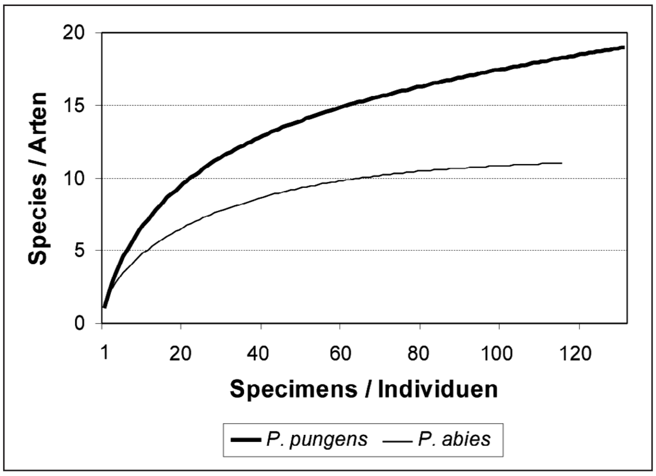

Fig. 2

Rarefaction curves for the expected number of moth species developing on blue spruce (*Picea pungens*) and Norway spruce (*Picea abies*) in Hercynian Mountains. Moth caterpillars were collected during the growing season.

Rarefaction-Kurven für die erwartete Anzahl der Schmetterlingsarten, deren Raupen sich auf der Stech-Fichte (*Picea pungens*) und der Gemeinen Fichte (*Picea abies*) in dem Herzynischen Gebirge entwickeln. Schmetterlingsraupen wurden während der Vegetationsperiode gesammelt.

In Hercynian Mountains the total number of moth species recorded was higher on blue spruce (20 species) than Norway spruce (12 species). As in West Carpathians, the species density (number of caterpillar species on the 20 branches, 1 m long each) was significantly higher on blue spruce than Norway spruce ($p < 0.001$, $Z = -3.6$, U-test; *Macaria* spp. being considered as one taxon). Rarefaction showed that the number of species expected is higher on blue spruce than Norway spruce irrespectively of sample size. Differences in the number of species expected on blue spruce and Norway spruce were increasing as the sample size increased

(*Fig. 2*). As in West Carpathians, the caterpillar assemblage feeding on blue spruce was only slightly more diverse (Simpson's index of diversity D = 0.873) than that on Norway spruce (D = 0.725).

Over the growing period the total number of moth species recorded on blue spruce was lower in Hercynian Mountains than West Carpathians. However, when comparing equal sample sizes from the two study areas the number of species expected on blue spruce was higher in Hercynian Mountains than West Carpathians (rarefaction; *Macaria* spp. being considered as one taxon, *Figs 1*, *2*). Similarly, the total number of moth species recorded on Norway spruce was lower in Hercynian Mountains than West Carpathians. In rarefaction, too, the number of moth species expected on Norway spruce was lower in Hercynian Mountains than West Carpathians (*Figs 1*, *2*).

In West Carpathians a total of 535 caterpillars (all species considered) were collected from blue spruce and a total of 610 caterpillars were obtained from Norway spruce. The number of caterpillars did not differ significantly between blue spruce and Norway spruce ($p > 0.1$, $Z = 0.68$, U-test). In Hercynian Mountains, a total of 132 caterpillars were collected from blue spruce and a total of 116 caterpillars were gathered from Norway spruce. As in West Carpathians, the number of caterpillars was not significantly different between the two spruce species ($p > 0.1$, $Z = -0.9$, U-test).

The moth species recorded on blue spruce and/or Norway spruce were classified into the three feeding guilds: (1) needle-spinners (Gelechiidae and Tortricidae), (2) free living species (Geometridae, Noctuidae and Lymantriidae) and (3) lichenophagous species (Arctiidae) (*Table 1*).

In West Carpathians the needle-spinning caterpillars were significantly more on blue spruce than Norway spruce ($p < 0.001$, $Z = -3.55$, U-test). *E. nanana* and *D. histrionana* were most abundant moth species on both blue spruce and Norway spruce. They both were significantly more on blue spruce than Norway spruce (*E. nanana*: $p < 0.05$, $Z = -2.72$; *D. histrionana*: $p < 0.05$, $Z = -2.49$, U-test). In Hercynian Mountains, also, significantly more needle-spinning caterpillars were collected from blue spruce than Norway spruce ($p < 0.05$, $Z = -2.6$, U-test). *A. abietana* and *D. histrionana* predominated on both spruce species. However, the abundance of these two moth species did not differ significantly between the two spruce species ($p > 0.05$, U-test).

In both study areas and in both spruce species, too, free living caterpillars were more than needle-spinners. In West Carpathians the number of free living caterpillars (all species considered) did not differ significantly between blue spruce and Norway spruce ($p > 0.05$, U-test). The same was true for the predominat moth species *P. capreolaria*, *E. tantillaria* and *E. lanceata* (*Table 1*). In Hercynian Mountains, also, the number of free living caterpillars (all species considered) on blue spruce did not differ significantly from that on Norway spruce ($p > 0.05$, U-test). The predominant species *E. lanceata* was significantly less on blue spruce than Norway spruce ($p < 0.05$, $Z = 2.07$, U-test). *E. tantillaria* was another

Tab. 2

Dominance (%) of moths overwintering as caterpillars on branches of blue spruce (*P. pungens*) and Norway spruce (*P. abies*). (Guild: Bud-B – bud-borers; N-S – needle-spinning; Bark-B – bark-borers; F-L – free-living larvae).

Dominanz (%) der Schmetterlinge, die als Raupen an den Zweigen von der Stech-Fichte (*P. pungens*) und der Gemeinen Fichte (*P. abies*) überwintern. (Gilde: Bud-B – Minierer der Knospen; N-S – Raupen spinnen die Nadeln zusammen; Bark-B – Raupen bohren in der Rinde; F-L – freilebende Raupen).

Family/Species **Familie**/Art	Guild Gilde	West Carpathians Westliche Karpaten		Hercynian Mountains Herzynisches Gebirge	
		P. pungens	*P. abies*	*P. pungens*	*P. abies*
Yponomeutidae					
Argyresthia spp. including:	Bud-B	*0.8	17.4	**0.5	***14.6
A. glabratella (Zeller, 1847)					
A. amiantella (Zeller, 1847)					
A. bergiella (Ratzeburg, 1840)					
Batrachedridae					
Batrachedra pinicolella (Zeller, 1839)	N-S	23.7	11.6	53.0	14.6
Gelechiidae					
Chionodes electella (Zeller, 1839)	N-S	14.5	8.1	6.0	
Tortricidae					
Archips oporana (Linnaeus, 1758)	N-S	1.5			
Dichelia histrionana (Frölich, 1828)	N-S	1.5		2.5	2.1
Pseudohermenias abietana (Fabricius, 1787)	N-S	31.3	16.3	15.0	35.4
Epinotia tedella (Clerck, 1759)	N-S	3.8			
Epinotia nanana (Treitschke, 1835)	N-S	21.3	38.4	23.0	31.2
Cydia pactolana (Zeller, 1840)	Bark-B		1.2		
Geometridae					
Hylaea fasciaria (Linnaeus, 1758)	F-L	0.8	2.3		
Thera variata (Den. & Schiff., 1775)	F-L	0.8	4.7		2.1

* One specimen of *A. amiantella*.
** One specimen of *A. bergiella*.
*** *A. glabratella* and *A. bergiella*.

predominat moth recorded on both spruce species. Its abundance did not differ significantly between blue spruce and Norway spruce ($p > 0.05$, U-test).

In both West Carpathians and Hercynian Mountains only a few lichenophagous caterpillars were recorded (*Table 1*). They all may feed on spruce needles.

3.2 Winter season

In West Carpathians a total of 217 overwintering caterpillars belonging to 13 moth species were recorded on blue spruce and Norway spruce over the winter season. In Hercynian Mountains a total of 248 caterpillars and 8 moth species were recorded on the two spruce species (*Table 2*). All the species recorded are native to Central Europe.

In West Carpathians the total number of moth species recorded on blue spruce and Norway spruce was equal (10 species). The species density (number of moth species overwintering as caterpillars on the 40 branches, 0.5 m long each) was higher on blue spruce than Norway spruce, although this was not significant ($p > 0.1$, U-test; *Argyresthia* spp. being considered as one taxon in the data analysis). Diversity of caterpillar assemblage feeding on blue spruce (Simpson's index $D = 0.777$) and diversity of the assemblage on Norway spruce ($D = 0.773$) were nearly identical.

In Hercynian Mountains a total of 6 moth species were recorded on blue spruce, and a total of 7 moth species were recorded on Norway spruce. As in West Carpathians, the species density (number of moth species overwintering as caterpillars on the 15 branches, 0.5 m long each) did not differ significantly between blue spruce and Norway spruce ($p > 0.1$, U-test). The caterpillar assemblage feeding on blue spruce was slightly less diverse (Simpson's index of diversity $D = 0.639$) than that on Norway spruce ($D = 0.734$).

In West Carpathians a total of 131 caterpillars (all species considered) overwintering on blue spruce and a total of 86 caterpillars overwintering on Norway spruce were recorded. However, overwintering caterpillars were not significantly more on blue spruce than Norway spruce ($p = 0.052$, $Z = -1.9$, U-test). In Hercynian Mountains a total of 200 caterpillars overwintering on blue spruce were recorded and a total of 48 caterpillars overwintering on Norway spruce were documented. In this particular case, significantly more overwintering caterpillars were recorded on blue spruce than Norway spruce ($p < 0.001$, $Z = -3.13$, U-test).

The overwintering moths were classified into the four feeding guilds: (1) needle-spinning species (Batrachedridae, Gelechiidae and Tortricidae except for *Cydia pactolana*), (2) free-living species (Geometridae), (3) bud-borers (Yponomeutidae) and (4) bark-borers, represented by a single species *Cydia pactolana* (Tortricidae) (*Table 2*).

In both study areas significantly more needle-spinning caterpillars were recorded on blue spruce than Norway spruce (West Carpathians: $p < 0.05$, $Z = -2.61$; Hercynian Mountains: $p < 0.001$, $Z = -3.13$, U-test). In West Carpathians, *B. pinicolella*, *P. abietana* and *E. nanana* were predominant on both spruce species. *P. abietana* and *B. pinicolella* were significantly more on blue spruce than Norway spruce (*P. abietana*: $p < 0.05$, $Z = -2.23$; *B. pinicolella*: $p < 0.05$, $Z = -2.31$, U-test). In Hercynian Mountains, the two needle-spinning species, *B. pinicolella* and *Ch. electella*, were most abundant. They both were significantly more on blue spruce than Norway spruce (*B. pinicolella*: $p < 0.001$, $Z = -3.13$; *Ch. electella*: $p < 0.05$, $Z = -2.68$, U-test).

In West Carpathians bud-boring caterpillars were significantly less on blue spruce (only a single specimen of *A. amiantella* recorded) than Norway spruce ($p < 0.05$, $Z = 2.04$, U-test). In Hercynian Mountains, only a few representatives of this feeding guild were recorded.

4. DISCUSSION

In the two geographically distant regions (forest areas) in Central Europe, West Carpathians and Hercynian Mountains, a total of 31 moth species (caterpillars) were documented to be developing on the non-native blue spruce, and the equal number of moth species was recorded on the native Norway spruce (*Tables 1*, *2*). All moth species recorded on blue spruce are developing on Norway spruce (cf. KULFAN, 1994; KARISCH, 1995; PATOČKA and KULFAN, 2009). However, a comparison between blue spruce and Norway spruce revealed some differences in the structure of caterpillar assemblages. A significantly higher abundance of needle spinning caterpillars and significantly lower abundance of bud-boring caterpillars on blue spruce compared to Norway spruce was the most pronounced difference.

Plantations of blue spruce established in the study area in Hercynian Mountains were much larger than those in the study area in West Carpathians. This could affect the structure of caterpillar assemblages (DAJOZ, 2000; SUMMERVILLE and CRIST, 2003; SCHMIDT and ROLAND, 2006). In the study area in Hercynian Mountains more moth species may be expected on blue spruce if more caterpillar specimens are collected (rarefaction, *Fig. 2*). Low number of moth species recorded on Norway spruce in the study area in Hercynian Mountains might be explained by a large-scale decline of Norway spruce forests due to air pollution over the period 1970–1990, and by re-establishment of Norway spruce plantations only 12 years ago. In both West Carpathians and Hercyniam Mountains afforestation with blue spruce was made over the same time period (over the second half of the 20th century). It is therefore supposed that the time since the introduction of blue spruce has had an equal effect on the moth fauna in each study area (cf. BRÄNDLE *et al.,* 2008).

The results presented here support the conclusions of ROQUES *et al.* (2006) about the recruitment of phytophagous arthropods on exotic conifers coming from congeneric native tree species. Colonisation of introduced plant species by insects feeding on related indigenous plants was also observed in some other plant taxa (CONNOR *et al.,* 1980; FRENZEL and BRANDL, 2003). LINDELÖW and BJÖRKMAN (2001) and DALIN and BJÖRKMAN (2006) pointed out that the recruitment of insects on lodgepole pine (*Pinus contorta*) introduced to Sweden was influenced by the native congeneric Scots pine (*P. sylvestris*). Almost all monophagous moth species that feed on Scots pine in Sweden occurred also on the lodgepole pine. FRASER and LAWTON (1994) recorded over 2% of British angiosperm-feeding moths on conifers introduced to Britain. In the case of blue spruce introduced to West Carpathians and Hercynian Mountains, Central Europe, we did not record any moth species originally feeding on angiosperms.

Blue spruce in Europe might be colonized and consequently damaged by specialized moth species introduced from North America (DA ROS *et al.,* 1993; ROQUES *et al.,* 2006; MATTSON *et al.,* 2007; ZUBRIK *et al.,* 2007). The moth *Coleotechnites piceaella* introduced to Europe from North America, causing serious damage to *P. pungens* in ornamental settings in urban areas including towns (FÜHRER, 1963; HOLZSCHUH, 1987; KULFAN *et al.,* 1998; SCHNEE, 2000), is a good example of this. However, we have recorded neither *C. piceaella* or any other exotic moth species in the study area in West Carpathians or Hercynian Mountains, respectively.

Planting of alien woody plants in forests usually affects the structure and functioning of native ecosystems, especially in the case of invasive species (BERAN and ŠINDELAŘ, 1996; FADY, 2003; KŘIVANEK *et al.,* 2006; PARITSIS and AIZEN, 2008). This is true in general for many introduced plant species (VITOUSEK, 1997). In Europe, blue spruce is not an invasive tree species (RICHARDSON and REJMANEK, 2004; KŘIVANEK *et al.,* 2006; BALCAR *et al.,* 2008a). In the past it was considered as a suitable substitute forest woody plant at sites where afforestation with Norway spruce had not been successful (SOUKUPOVA *et al.,* 2001; BALCAR *et al.,* 2008b). In polluted areas, young stands of blue spruce (less than 20 years old) were healthy and showed no symptoms of insect damage (BALCAR *et al.,* 2008a). This is in agreement with the enemy release hypothesis stating that specialist enemies of an exotic plant species are absent in areas where this plant species has been introduced (KEANE and CRAWLEY, 2002; SIEMANN and ROGERS, 2003; ADAMS *et al.,* 2009). However, in both West Carpathians and Hercynian Mountains the abundance of needle spinning caterpillars was higher on blue spruce than Norway spruce. This feeding guild also included serious needle-mining borers. Thus, the results corroborate the biotic resistance hypothesis (MARON and VILÀ, 2001) rather than the enemy release hypothesis. The biotic resistance hypothesis suggests that introduced plant species are controlled by their native associates. In the study area in West Carpathians and Hercynian Mountains no outbreak of caterpillars on blue spruce has been documented. Some species, however, might increase their abundance in the further future.

It may be concluded that in the forests in Central Europe blue spruce and Norway spruce have similar moth fauna. All moth species documented here to be developing on the introduced blue spruce are coming from Norway spruce, a native congeneric tree species. It is highly likely that natural enemies of moths feeding on both spruce species will also be identical (requires special study). Taken in aggregate, the introduction of blue spruce to the Central European forests is only slightly influencing the diversity of moth assemblages on Norway spruce.

5. SUMMARY

Blue spruce has locally been introduced to the forests in Central Europe. It was considered as a suitable substitute tree species in areas where afforestation with the native Norway spruce had not been successful, e.g. in areas heavily affected by air pollution. Young plantations of blue spruce were healthy, without serious insect damage.

We studied the moth associates of blue spruce (*Picea pungens*) and Norway spruce (*Picea abies*) in the two distant regions (study areas) in Central Europe represented by West Carpathians (Veporské vrchy Mountains, Central Slovakia) and Hercynian Mountains (Děčínská vrchovina hills, north-west Bohemia) and addressed the questions as to whether (1) blue spruce and Norway spruce have similar moth fauna, (2) blue spruce planted in forests is a host for *Coleotechnites piceaella* (the moth already recorded in urban areas in Central Europe) and/or other moth species introduced from North America and (3) afforestation with the introduced blue spruce affects the diversity of Lepidoptera on the native Norway spruce.

Over the growing season 2006 (West Carpathians) and 2007 (Hercynian Mountains) the beating method was used to collect caterpillars from the lower branches of blue spruce and Norway spruce. In addition, photoeclectors in the laboratory were used to record moth caterpillars (or hatched adults) overwintering on blue spruce and Norway spruce in the two study areas in March 2008. The sample branches of blue spruce and Norway spruce were placed into photoeclectors. Moth specimens that had emerged from photoeclectors were collected and identified.

A total of 998 caterpillars (or hatched adults) were collected from blue spruce, and a total of 860 caterpillars (or hatched adults) were obtained from Norway spruce. The moth fauna on blue spruce was similar to that on Norway spruce. Blue spruce and Norway spruce were found to host equal number of moth species (31 species). All species recorded on blue spruce are developing on the native Norway spruce. Comparisons between blue spruce and Norway spruce revealed some differences in the species composition of caterpillar assemblages. A significantly higher abundance of needle spinning larvae (Batrachedridae, Gelechiidae and Tortricidae) and significantly lower abundance of bud-boring larvae (genus *Argyresthia*, Yponomeutidae) on blue spruce compared to Norway spruce, was the most pronounced difference. No moth species introduced from North America were recorded. Based on the results, the introduction of blue spruce to the Central European forests is only slightly influencing the diversity of moth assemblages on Norway spruce.

6. Zusammenfassung

Titel des Beitrages: *Raupengesellschaften an der eingeführten Stech-Fichte: Differenzen zur einheimischen Gemeinen Fichte.*

Die Stech-Fichte wurde lokal in zentraleuropäischen Wäldern als Ersatzbaumart für die Gemeine Fichte gepflanzt, wo die Aufforstung mit *Picea abies* nicht erfolgreich war. Dies galt beispielsweise für die Immissionsgebiete. Die Stech-Fichte zeichnete sich durch eine gute Gesundheit aus, ohne wesentliche Beeinträchtigungen durch Insekten.

In zwei zentraleuropäischen Gebirgen – in den Westlichen Karpaten (Gebirge Veporské vrchy, Zentralslowakei) und in dem Herzynischen Gebirge (Elbsandsteingebirge – Děčínská vrchovina, NW Böhmen) wurde die Gemeinschaft der Schmetterlinge, deren Raupen sich auf der Stech-Fichte (*Picea pungens*) und der Gemeinen Fichte (*Picea abies*) entwickeln, untersucht. Die Studie zielte auf folgende Fragestellungen ab: (1) Stimmen die Schmetterlingsgesellschaften von *P. pungens* und *P. abies* überein; (2) Kommen in den Untersuchungsgebieten an *P. pungens* Schmetterlinge vor, die aus nordamerikanischen Waldökosystemen eingeschleppt wurden (z. B. *Coleotechnites piceaella*); (3) wirkt sich die Pflanzung der Stech-Fichte in zentraleuropäischen Wäldern auf die Schmetterlingsgemeinschaft der Gemeinen Fichte aus.

Während der Vegetationsperiode (2006 in den Westlichen Karpaten, 2007 in dem Herzynischen Gebirge) wurden die Raupen von den Fichtenzweigen mittels Klopfschirme gesammelt. Überwinternde Raupen (oder die sich aus ihnen entwickelnden Schmetterlinge) wurden mit Hilfe von Photoeklektoren erfasst. Im März 2008 wurden die Zweige von den Fichten abgenommen und im Labor in Photoeklektoren gebracht. Die in den Fangdosen erfassten Raupen bzw. Imagines wurden determiniert.

Von *P. pungens* wurden insgesamt 998 Raupen (bzw. die sich aus ihnen entwickelnden Schmetterlinge) und von *P. abies* 860 gewonnen. Die Fauna der Schmetterlinge beider untersuchter Fichtenarten stimmte weitgehend überein. Auf jeder Fichtenart wurde die gleiche Anzahl an Schmetterlingsarten (31) festgestellt. Obwohl die Artenspektren der Schmetterlinge auf den untersuchten Fichtenarten nicht identisch waren, entwickeln sich alle von der Stech-Fichte gewonnenen Arten in Zentraleuropa auch auf der heimischen Gemeinen Fichte. Als auffälligste Unterschiede zwischen beiden Fichtenarten wies die Stechfichte eine sehr niedrige Anzahl an Knospenminierern (Gattung *Argyresthia*, Familie Yponomeutidae) und eine signifikant höhere Abundanz an Raupen auf, die Nadeln zusammenspinnen (Familien Batrachedridae, Gelechiidae und Tortricidae). Auf unseren Untersuchungsflächen wurde an *P. pungens* keine vom Nordamerika eingeschleppte Schmetterlingsart nachgewiesen. Unsere Ergebnisse belegen, dass die Diversität der Schmetterlinge, die sich in den zentraleuropäischen Wäldern auf der Gemeinen Fichte entwickeln, nur gering durch die Pflanzung der Stech-Fichte beeinflusst werden.

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