Integrated Management of Little Spruce Sawfly (*Pristiphora abietina*): Design Pattern

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Abstract

This paper presents the design of a regulation model of the little spruce sawfly that is based on monitoring of defoliation. This method is based on the assessment of the percentage of defoliation of each whorl from ca. 100+ trees, beginning from the top and using four classes of defoliation. The critical value influencing the height of current increment of trees is six. Consequently 20 yellow sticky boards installed in lines on every other tree could monitor the next spring abundance of sawfly adults. Critical value is about 11 to 19 females per one sticky board (format A5). Impact of low temperature on sawfly populations during swarming is still not clear. Possibilities for using chemical measures for control are discussed.

Several outbreaks of the little spruce sawfly (*Pristiphora abietina* (Christ 1791)), covering thousands of hectares of spruce forests, have occurred in Europe (Pschorn-Walcher 1982). Little spruce sawfly is the most numerous tenthredinid in both young and older spruce stands from an altitude of 250 to 700 m a.s.l. in the eastern part of the Czech Republic (Holusa 1999, 2002). Every year spraying of a portion of this region is necessary (e.g. Pschorn-Walcher 1982, Liska 1999, 2000, Liska et al. 1991), because an integrated pest management (IPM) approach to address this problem is lacking.

In spite of this, the pest status of little spruce sawfly is not clear (Regulation no. 101/1996 Sb. dated March 28th 1996 of Ministry of Agriculture, Czech Republic), because larvae feed only on current year needles and therefore do not cause total defoliation of trees (Pschorn-Walcher 1982). Therefore it suggests that some level of economic threshold should be established, however, we lack appropriate methods to monitor this pest. *Pristiphora abietina* is usually monitored by estimating the density of cocoons in the soil (Bogenschütz 1986, Pschorn-Walcher 1982); however this procedure is time consuming, is not practical on a large scale, and is very unreliable (Janásek 1964). Thus, a new method of evaluation is needed. (Bogenschütz 1986). An assessment of defoliation (i.e. larval feeding) provides an indirect, objective method to determine the intensity of tenthredinid infestations (see Svestka and Holusa 2000, Holusa and Holusa 2002, Holusa and Drápela in press.). In order to work out an approach to develop an IPM system for *P. abietina*, the following questions needed to be answered:

1. What degree of defoliation causes a decrease of height tree increment?

Pristiphora abietina population fluctuations are of the temporary-distractive type, thus causing outbreaks that may last from a few years to several decades (Pschorn-Walcher 1982). Outbreaks of the little spruce sawfly can be only eruptive, because cocoons lying 10 months in the litter can be attacked by predators (in *Neodiprion sertifer* discussed by Larsson et al. 1993) and larvae that drop to the ground to pupate can be attacked by fungi. There is also a possibility that cocoons can overwinter in the soil for more than one year (Pschorn-Walcher 1982), however the first author found that this occurs in less than 1% of overwintering cocoons in the eastern part of the Czech Republic (Holusa 1999).

2. What is the best method to assess the abundance of sawfly adults in the following spring?

1. Impact of defoliation on the height of current increment of trees

Introduction

Nageli (1936) found that *P. abietina* caused a loss of 33-40% height tree increment in 1917-1934 in Switzerland. In Mooswald at Freiburg i.B., loss of height tree increment reached an average above 2 m (Niechziol 1958 in Pschorn-Walcher, H. 1982). In the case of very heavy defoliation, height tree increment declines rapidly and after several years of repeated defoliation, it decreased to zero; the loss is greater in younger forests. In spite of these observations no data exists that defines the relationship between the density of populations and increment loss.

In the past, a method of assessing defoliation caused by Tenthredinids (without discrimination of species) was prescribed but lacked precision (CSN 482718: Ochrana lesa proti pilatkám na smrku. 1958). The loss of needles was classified into four groups (loss of 1/3 of needles, 1/3 - 2/3, more than 2/3, and total defoliation). We have developed a scale of damage on spruce (Svestka and Holusa 2000, Holusa and Holusa 2002, Holusa and Drápela in press) which allows us to provide an objective evaluation of insect defoliation. This method was used to establish the degree of defoliation that can cause the decrease of tree height increment.

Method

About 100 trees in each plot were investigated to assess the percentage of defoliation of each whorl beginning from the top of the tree using four classes of defoliation:

Rare (value 0,1) - very light defoliation of annual shoots – below 10% of shoots were eaten;
light defoliation (value 1) - 10-50% of annual shoots were eaten;
heavy defoliation (value 2) - 50–90% of annual shoots were eaten
total defoliation of annual shoots (value 3) –over 90%.

A damaged tree leader (terminal) is evaluated by 1 (no feeding by 0). The average defoliation of each whorl was calculated per tree and then the results of all whorls were accumulated (this value is named as the degree of defoliation in this work).

We have determined the mean height current increment of young forests. We have measured height current increment of young forests 4-5 m (i.e. 6-12 years old) using a special measuring pole with 1 dm scale. In all places a set of 100 trees was investigated. Forests were separated according to condition of growth. Three types of potential habitats (*Querceto-Fagetum*, *Fagetum*, *Abieto-Fagetum*) were examined. Statistical analyses including correlation and regression analyses of the influence of defoliation on height current tree increment were performed using Statistica 6.0 (a = 0.05).

Results

Defoliation data sets are non-normal, because they are positively skewed and leptokurtic or platykurtic. Because Box-Cox transformation on normality was often not successful, the median value of defoliation distribution is used. The method is easy and fast; on average it is possible to evaluate 100 trees in less than half an hour, which is an important consideration for forestry applications.

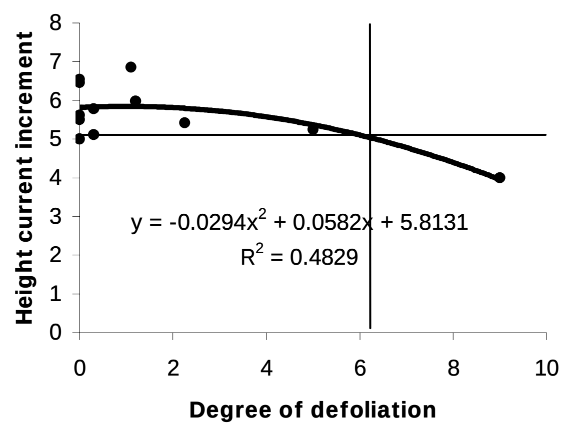

Figure 1.—Correlation between the degree of defoliation and current height tree increment (habitat *Fagetum*)

The forests of the habitat *Querceto-Fagetum* were very weakly defoliated, therefore no correlation was found between the degree of defoliation and mean of height current increment. In the other two habitats, positive correlations were found however it was necessary to confirm the relation due to other statistical calculation (Figures 1, 2). The parabola was used to characterize the relationship because it corresponds better to the consideration that only more intensive defoliation should negatively influenced the tree height current increment.

No correlation was found between the degree of defoliation and the height tree current increment in the next year.

Based on this result, we can conclude that a degree of defoliation equal to six can negatively influence tree height current increment. There is an exception as e.g. the point in Fig. 2, which is probably caused by drought or fungus (or an unknown factor).

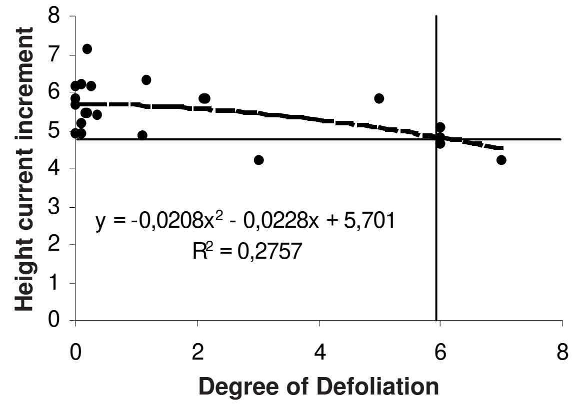

Figure 2.—Correlation between the degree of defoliation and current height tree increment (habitat *Abieto-Fagetum*)

Discussion

The impact of defoliation on the height current increment of trees is the most important factor in assessing the economic injury level though we need to determine also the impacts of treatment on non-wood-producing values of the forest, ecosystems, selection, and on the population dynamics of the pest (contraction of amplitude). The impact of control measures on the ecosystem could be reduced by using insecticides based on ecdysoids (growth regulators), whose impact on ecosystem health is minimal.

In the case of other stresses (mainly fungi in the habitat *Querceto-Fagetum*), the critical degree of defoliation should be decreased. Forest health condition will be a much more important factor than the decrease in height tree increment.

The defoliation of an entire young spruce stand (up to 40 years old) may be evaluated using a modified method. For the entire stand, a scale with four levels was deployed using a critical mean defoliation value of approximately 50% of trees (see Fig. 3). The degree six of critical defoliation corresponds approximately with the total defoliation of forests if three or more of the top whorls are consumed on over one half of the trees. Defoliation can be displayed graphically on a grid map (Central European System) in which the map fields are delimited by parallels of latitude (6 by 6 minutes) and meridians (10 by 10 minutes) with an approximate size of 11.2 x 12.0 km in Central Europe. Circles of different size in the map field can be used to designate the degree of defoliation for an entire forest. The range and intensity of infestation and the change in defoliation from year to year are easily observed (Holusa and Holusa 2002).

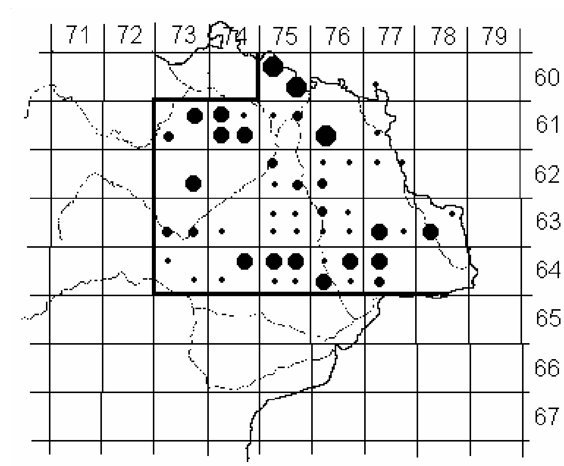

Figure 3.—The infestation caused by tenthredinids to young spruce forests in the eastern part of the Czech Republic in 2000 (marks: point - throughout the stand, only a single shoot on trees is consumed; small circle - half of trees with one or two top whorls consumed; mid-size circle - more than half of the trees with three and more top whorls consumed [this infestation reduces the growth of trees in the following year], circle of one quarter the size of the map field - stunted trees; fat line - margin of studied area) (Holusa and Holusa 2002)

Using the present method and maps in conjunction with GIS, and including information on altitude, total annual precipitation, average annual temperature, moisture, and characteristics of the habitat, pest risk assessment maps can be established.

2. Monitoring adult sawfly abundance

Introduction

Sawfly adults are generally attracted to yellow traps (Murhead-Thompson 1991). For monitoring of spruce web-spinning sawflies (*Cephalcia* spp.), some authors used yellow sticky boards (Jensen 1988, Cescatti and Battisti 1992) and correlated trap captures with the density of prepupae in the soil (Battisti and Rodeghiero 1998). Berger (1992) found that *Pristiphora abietina* adults could also be attracted to yellow traps. The number of adults captured in traps correlated with the density of cocoons in the soil.

In recent years, we have acquired positive results and experience in studies using yellow sticky boards. A statistically significant relationship was found between captures in Malaise traps and those on yellow sticky boards, and a highly significant relationship was found between the number of captured adults (on five sticky boards) and the degree of defoliation in seven localities. To estimate the abundance of adults, it is sufficient to install yellow sticky boards before swarming and then check them after swarming is completed. We did not observe statistically significant difference between samples taken at different intervals (Holusa and Drápela in press).

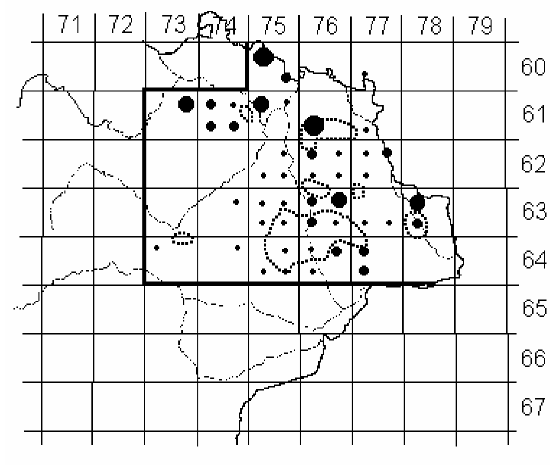

Figure 4.—The infestation caused by Tenthredinids to young spruce forests in the eastern part of the Czech Republic in 2001(dashed line - area of measures) (Holusa and Holusa 2002)

The relationships between catch number and defoliation has yet to be confirmed, however there is another important question that needed to be answered.

3. What number of traps is necessary to ascertain a statistically significant abundance of sawflies?

Method

The traps consisted of yellow plastic boards 14.8 x 21 cm, coated on both sides with entomological glue, that were suspended from the top of trees or from a branch at about 2 m above the ground. They were exposed in lines of 20 boards on the southeastern side of every other tree. All traps were installed in mid April (prior to adult emergence) and kept in place until mid-June (after the end of swarming). The number of localities studied in 2001 and 2002 were 30 and 20 respectively. The localities consisted of young spruce forests in Silesia and eastern Bohemia at an altitude 300 to 500 m a.s.l.

Captured sawfly adults were preserved in 70% alcohol (leg. J. Holusa, coll. VÚLHM Jíloviste-Strnady). Because of the inequality of variance and non-normality (tested using D´Agostino normality test) of the sets in the majority of cases, the Box-Cox transformation on normality was used to represent the mean capture. Correlation and regression analyses were performed with Statistica 6.0 (a = 0.05). The sample size necessary to achieve the desired level of precision in estimating a population mean is given by the following formula (Zar 1984):

$$n = \frac{s^2 t^2_{\alpha(2),(n-1)} F_{\beta(1),(n-1,\nu)}}{d^2}$$

s^2 is the sample variance with n degrees of freedom;
d is the half-width of the desired confidence interval (this accuracy is subjectively chosen until we have used approximately one third of catch mean);
1- α is the confidence level for the confidence interval;
1- β is the assurance that the confidence interval will not be greater than specified;
t- is the two tailed critical value of t-distribution with (n-1) degrees of freedom;
F is the one tailed critical value of F-distribution with (n-1) and n degrees of freedom.

The degree of defoliation was estimated using the same procedures that were deployed in the previous study.

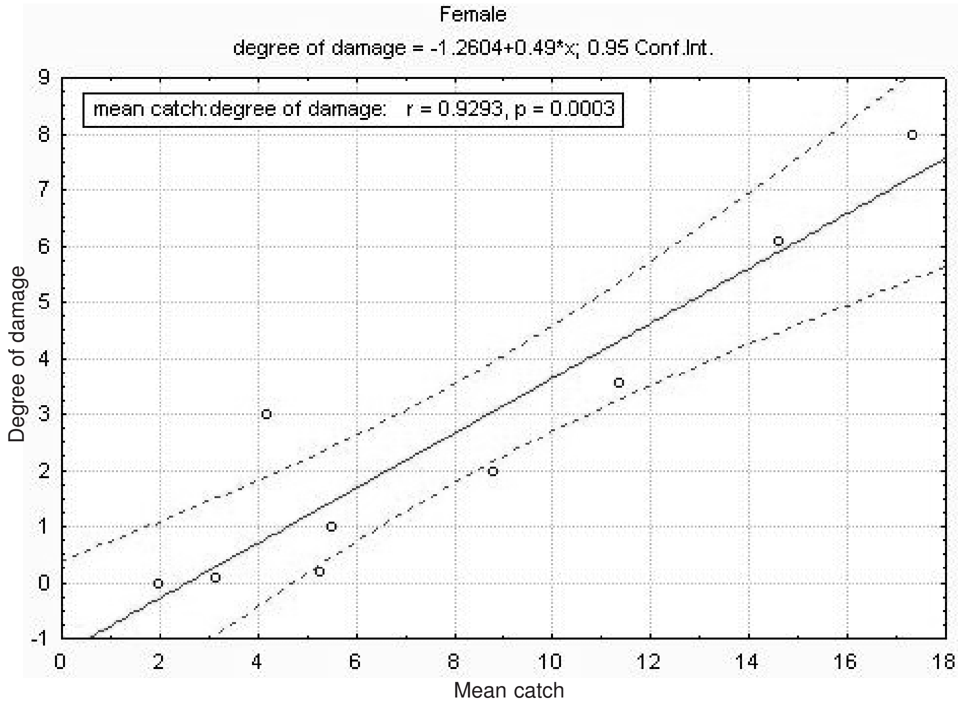

Figure 5.—Relationship between the number of captured *Pristiphora abietina* females and the subsequent defoliation of forest stands (y=-1.2604+0.49x; — confidence interval of model)

Results

We found a highly positive correlation between catch mean of females and subsequent defoliation (Fig. 5) in nine localities in 2002 (The majority of localities were treated chemically therefore they could not be used in the regression). No correlation was found when male sawflies were used.

Based on data on the distribution of females on sticky boards, we have established that from 20 to 40 yellow sticky boards are needed to obtain an accuracy equivalent to one third of the mean. If less efficiency is acceptable, about 20 boards are needed. (Tables 1, 2). In 2001, in the majority of localities, the numbers of females captured were too low for analysis.

Discussion

A positive correlation was found only between the mean catch of females and subsequent defoliation possibly because the distribution of females in forests is more equal, resulting in data sets that are much more homogeneous. This is related to the bionomics and behavior of this species. Female sawflies actively search along the twigs looking for suitable places to oviposit; on the other hand, male sawflies are much more active and vagile and fly around the tops of trees mainly on sunny sites. Therefore the distribution of males is more aggregated. If the defoliation degree of six is critical, about 11 to 19 females would correspond to this value.

Based on the experiments in 2001 and 2002, the number of boards sufficient to obtain an accuracy equivalent to one third of the catch mean varies between 20 and 30. The number varies between 20 and 30 because it depends strongly on the sample variance, which differs from place to place. The use of this number is practical because the time required for the installation of 20 boards is about 30 minutes. Counting the number of captured sawflies depends, of course, on the total number of adults captured and is sometimes time consuming.

Table 1.—Number of yellow sticky boards sufficient for monitoring sawfly abundance in 2001. (A…accuracy, NB…number of boards)

Locality	Longitude; Latitude	Female catch mean ± SD	Transformed female catch mean ± SD	A	NB	A	NB	A	NB
Metylovická hùrka hill	18°21'; 49°37'	4.30±3.05		2	12	1	39		
Paskovský les wood	18°17'; 49°43'	51.20±21.20		35	6	25	9	15	20
Slavíè Mt. Nr. 1	18°35'; 49°34'	6.31±9.74		4	13	3	21		
Slavíè Mt. Nr.2	18°35'; 49°34'	29.00±41.61		15	15	20	29		
Rovná wood	18°41'; 49°38'	64.00±45.57		30	12	20	23	15	38
The village of Pustá Polom Nr. 1	17°58'; 49°51'	21.73±13.55	19.40±12.67	10	10	7	17	5	30
The village of Pustá Polom Nr. 2	18°00'; 49°51'	11.85±21.79	0.60±2.81	10	21	7	40		
Kubalánky place	18°19'; 49°36'	16.11±30.98	0.43±2.27	15	19	12	29	8	60
Stoláøka Mt.	18°19'; 49°36'	3.38±5.15	0.12±0.63	3	14	2.5	20	2	29

Table 2.—Number of yellow sticky boards for monitoring of sawfly abundance in 2002. (A…accuracy, NB…number of boards)

	Longitude; Latitude	Female catch mean ± SD	Transformed female catch mean ± SD	Accuracy - ca 1/3 of mean	NB	A	NB
Kabátice hill	18°16'; 49°39'	3.11±2.7		1.0	21		
Paskovský les wood	18°17'; 49°43'	4.13±4.36	2.83±3.69	1.5	35	2.0	21
Slavíè Mt.	18°35'; 49°34'	3.15±3.53	1.95±2.90	1.2	36	1.7	19
Rovná wood Nr. 1	18°41'; 49°38'	13.16±10.65	10.14±8.34	4.0	30	5.0	20
Rovná wood Nr. 2	18°41'; 49°38'	8.20±5.48		3.0	16		
The village of Pustá Polom Nr. 1	17°58'; 49°51'	12.38±11.80	8.78±8.41	4.0	36	6.0	18
The village of Pustá Polom Nr. 2	18°00'; 49°51'	18.76±15.00	14.61±13.15	6.0	27	8.0	16
The village of Pustá Polom Nr. 3	18°00'; 49°51'	7.14±7.67	5.26±5.86	2.5	37	.5	21
Kubalánky place	18°19'; 49°36'	8.78±9.38	5.51±8.12	3.0	41	4.3	21
Na horách hill	16°09'°; 50°23'	4.15±2.85		1.4	19		
The village of Pøibyslav	16°10'°; 50°22'	25.91±15.76	22.48±13.34	8.0	18		
The village of Brná	16°20'; 50°05'	10.10±8.40	7.63±5.44	3.3	28	4.0	20
The village og Nýdek Nr. 1	18°44'°; 49°39'	17.30±11.24		6.0	16		
The village og Nýdek Nr. 2	18°44'°; 49°40'	1.15±2.43	failed	0.4	145	1.2	19
The village of Nýdek Nr. 3	18°44'°; 49°40'	13.35±11.33	11.33±7.33	4.0	21		

Conclusion

According to these results, we suggest the following model of regulation. Two main criteria are the degree of defoliation and the abundance of adults in the following spring.

Model of regulation

S (step) 1 Monitoring of forest defoliation

Criterion: If the degree of defoliation exceeds the value 5, go to S2 otherwise continue monitoring of defoliation.

S2 Monitoring of swarming adults next spring

Criterion: if an average of 15 females or more are caught on yellow sticky boards, go to S3 otherwise continue monitoring of defoliation.

S3 Coincidence of sawfly swarming with spruce budbreak

Cool and rainy weather can directly influence the swarming of adults, or fecundity of females could be decreased by low temperature as reported by Gruppe (1998) for *Cephalcia abietis* (Linnaeus 1758). Both cases resulted in a weaker attack of shoots by larvae. We do not know any exact criterion and the decision is based only on field observations. In the case of high abundance of eggs on shoots, go to S4.

S4 Chemical (biological) measures

There is no effective biological control for *P. abietina* so that only chemical treatments are available. However, there is a possibility of using fungal spores against mature larvae before they fall into the litter (Führer et al. 2001). To eliminate negative impacts on the ecosystem, the following recommendations should be considered:

1. We should prefer using ecdysoid-based insecticides; synthetic pyrethroids should be considered for use only against strong insect infestations. On the foothill of the Moravskoslezske Beskydy Mountains (Czech Republic), three insecticides (Dimilin 48 SC, Mimic 240 LV, Trebon 10 F) were sprayed on 25 ha plots using ULV aerial application. Results from this experiment suggest that ULV aerial applications of both Trebon 10 F and Dimilin 48 SC are effective in protecting stands against sawfly larval feeding (Svestka and Holusa 2000).

2. Chemical treatments should be applied in mid-May when *P. abietina* larvae are in the first to second instars. However, it is very difficult to determine the timing of application. During the period 1997-1999 the forests in the hills (altitudes around 300 m a.s.l.) were sprayed from May 19 to 22 (i .e. the period when the larvae of 1st and 2nd instars are most numerous), stands in the highlands (500 m a.s.l.) about one day later, and stands at an altitude of 700 m a.s.l. until May 26 (Holusa and Svestka 2000) (Fig. 4).

3. Criteria for selecting forests for treatment are as follows:

– Spruce stands should be younger than 40 years, when the impact on height tree increment is most severe. Only very heavily damaged older forest stands should be considered for spraying.

– Prevalence of spruce must be more than 70%, otherwise the percentage of spruce could be eliminated by tending and other planting measures.

– Aerial application should be used to spray only those spruce stands that are larger than 1 ha. However smaller areas must be treated from the ground to prevent the increase and spread of populations to adjacent areas.

In forests situated in broken highlands, it is necessary to use helicopters that can maneuver better under flight speeds of 80 km/hour and therefore provide more precise applications.

Further studies are needed to confirm parameters in the proposed regulation model:

- Confirm the degree of defoliation that influences height current increments of trees.
- Assess the impact of fungal infestation on the incidence of defoliation.
- Confirm the relationship between the number of captured females and defoliation.
- Determine the coincidence of sawfly swarming and budbreak of spruce.
- Determine the impact of low temperatures on female fecundity.
- Establish an economic threshold level (which will be based on a comparison of increment loss and costs of control measures.
- Evaluate the use of fungi for biological control.

References Cited

Battisti, A. and Rodeghiero, M. 1998. Monitoring spruce web-spinning sawflies *Cephalcia* spp.: the correlation between trap catches and soil sampling. Ent. Exp. Appl. 88: 211-217.

Berger, R. 1992. Gelbtafeln: eine Methode zur Kontrolle von Fichtenblattwespen. Mitt. Dtsch. Gesell. allg. angew. ent. 8: 196-200.

Bogenschütz, H. 1986. Monitoring populations of defoliating sawflies in forests of southwest Germany. For. Ecol. Management 15: 23-30.

Cescatti, A. and Battisti, A. 1992. Distribution and ecology of *Lymantria monacha* and *Cephalcia* spp. in non-outbreak areas of Trentino (N-Italy). Anz. Schäd.-Kde Pfl.- Umweltschutz. 65: 92-99.

Führer E., Rosner A., Schmied A. and Wegensteiner R. 2001. Studies on the significance of pathogenic fungi in the population dynamics of the Lesser Spruce Sawfly, *Pristiphora abietina* Christ. (*Hym*., *Tenthredinidae*). J. Appl. Ent. 125: 235-242.

Gruppe, A. 1998. Influence of genotype and temperature on the fitness of the webspinning sawfly Cephalcia abietis (Hymenoptera: Symphyta, Pamphilidae), pp. 439-440. In: Brunnhofer V. & Soldán T. (eds.): Book of abstracts, VIth Eur. Congr. Ent. Ceske Budejovice, August 23-29, 1998, 760 pp.

Holusa, J. 1999. Bionomie pilatky smrkové (*Hymenoptera:Tenthredinidae*) na severní Morave a ve Slezsku v letech 1998-1999. Zprávy lesnického výzkumu 44: 19-27.

Holusa, J. 2002. Species composition of spruce tenthredinids (*Hymenoptera: Tenthredinidae*) in the eastern part of the Czech Republic. Biologia, Bratislava 57: 213-222.

Holusa, J. and Drápela, K. In press. Yellow sticky boards: a possible way of monitoring the little spruce sawfly (*Pristiphora abietina*) (*Hymenoptera: Tenthredinidae*). J. Appl. Ent.

Holusa, J. and Holusa, O. 2002. Monitoring of sawfly (*Hymenoptera: Tenthredinidae*) infestation on spruce. J. For. Sci. 48: 219-224.

Holusa, J. and Svestka, M. 2000. Pilatka smrková na severovýchodní Morave a ve Slezsku. Výsledky studia bionomie a zkusenosti z obranných zásahu v letech 1997-1999. Lesnická práce 79: 270-272.

Janásek, M. 1964. Ke kontrole pilatky smrkové (*Pristiphora abietina* Christ.). Lesn. Cas. 10: 195-208.

Jensen, T. S. 1988. Phenology and spatial distribution of *Cephalcia* (Hym., Pamphilidae) imagines in a Danish spruce forest. J. Appl. Ent. 106: 402-407.

Larsson S., Björkann, C. and Kidd, N.A. 1993. Outbreak in diprionid sawflies: why some species and not others ? pp. 453-484. In: Wagner M.R. & Raffa K.F. (eds.): Sawfly Life History Adaptations to Woody Plants. Academic Press Inc., San Diego, London, 581 pp.

Liska, J. 1999. Listozravý hmyz, pp. 21-27. In: Kolektiv: Výskyt lesních skodlivých cinitelù v roce 1998 a jejich ocekávaný stav v roce 1999. Zpráv. Ochr. Lesa 1999 (Suppl.): 1-66 pp.

Liska, J. 2000. Listozravý hmyz, pp. 24-31. In: Knízek M. & Kapitola P. (eds.): Výskyt lesních skodlivých cinitelù v roce 1999 a jejich ocekávaný stav v roce 2000. Zpráv. Ochr. Lesa 2000 (Suppl.): 1-45 pp.

Liska, J., Píchová, V., Knízek, M. and Hochmut, R. 1991. Prehled výskytu lesních hmyzích skùdcù v ceských zemích. Lesnický prùvodce 1991 (3): 1-37 pp.

Murhead-Thompson, R.C. 1991. Trap responses of flying insects. The influence of Trap Design on capture Efficiency. Academic press, London, San Diego, New York, Boston, Sydney, Tokyo, Toronto, 288 pp.

Nägeli, W. 1936. Die kleine Fichtenblattwespe. (*Lygaeonematus pini* Retz. = *Nematus abietinus* Christ). Mitt. Schweiz. Anst. forstl. Vers.-Wes 19: 213-381.

Pschorn-Walcher, H. 1982. Unterordnung Symphyta, Pflanzenwespen. In: Schwenke W. (ed.): Die Forstschädlinge Europas 4. Haufflügler und Zweiflügler. Parey, Hamburg, Berlin, 4-234 pp.

Rannert H. and Minneli H. 1961. Uber Zuwachsverluste an Fichten – verursacht durch mehrjahrigen frass der kleinen Fichtenblattwespe (*Pristiphora abietina* Christ) – im Kartner befallsgebiet Wolschartwald. Allg. Forstztg. 72: 167-171.

Svestka, M. and Holusa, J. 2000. Úcinnost letecké aplikace prípravku° Dimilin 48 SC, Mimic 240 LV a Trebon 10 F na housenice pilatky smrkové (*Pristiphora abietina*). Zprávy lesnického výzkumu, 45 (3): 15-29.

Zar J. 1984. Biostatistical analysis. Prentice Hall, New Jersey, 718 pp.