Andrzej Borkowski

Self – presentation

(appendix 4)

1. First name and surname: **Andrzej Borkowski**.

2. Degrees:

2.1. studies: biology (1984 – 1989); **degree: biology MSc Eng., Pedagogical University, Kielce, 1989**;

2.2. PhD: PhD in forestry sciences, speciality: forest protection, Faculty of Forestry, University of Life Sciences SGGW, Warsaw, 1999.

3. Employment Record: since 1989 for the Institute of Biology, The Jan Kochanowski University in Kielce:

3.1. 1989, Scientific/Technical Position;

3.2. 1989 – 1999, Gradulate Assistant M.Sc. (in Biology);

3.3. since **1999** – Assistant Professor D.Sc. (in forestry).

4. Presenting an achievements resulting from Article 16 Paragraph 2 of the bill dated 14th March 2003, concerning degrees and a scientific title as well as degrees and titles in the field of art (The Official Journal of Law number 65, item 595, with further amendments)

4.1. Title of the academic (artistic) achievements

Borkowski A. 2013. The use of trap trees by larger pine-shoot beetle *Tomicus piniperda* (L.). Ecology and modeling. Ed. UJK, Kielce: 85 pp. (appendix 7).

4.2. Presentation

<u>Introduction and aim of the studies</u>

The ecological model of forest protection, functioning under the sustainable forestry development concept implemented in our country, is based on the principle of minimizing the environmental damage that may occur as a result of treatments used against harmful organisms. In practice, this means the application of the methods with the least side effects to forest ecosystems while ensuring their high efficiency (Instruction on Forest Protection 2012). Therefore, it is still important for forest conservation practice to ensure little laborious, yet precise methods of monitoring the xylophagous and cambiophagous insects. The availability of data on their density and population dynamics is the basis for the assessment of the scale of risk to the stand by a given insect species and selection of the appropriate method of reducing its population.

This paper proposes a novel, model approach to predicting the number of xylophagous and cambiophagous insects on the example of larger pine-shoot beetle *Tomicus piniperda* (L.) (Col., Curculionidae, Scolytinae) being one of the major pests of Scots pine (*Pinus sylvestris* L.) (Szujecki 1998; Lieutier 2004). The paper is a summary of the long-term, laborious research carried out in the years 1992-2010 in five Regional Directorates of the State Forests in the stands growing at different distances from insect outbreak centres.

In spite of the studies carried out in research institutes all over the world (e.g. Långström 1983, Poland et al. 2002; Humble and Allen 2006) and in Poland (e.g. Michalski and Szmidt 1957; Kolk 1995; Korczyński 1995; Starzyk 1996; Leśniak 2003 , Borkowski 2007) no effective methods have been developed to assess the population density of this insect species. In a recent 30-year period, four methods of indirect assessment of the population density of *T. piniperda* have been used in forest practice, including (Instruction on Forest Protection 2004):

- fallen shoot collection;
- pheromone traps (IBL – 2, IBL – 3 with Tomodor dispenser);
- quantity of deadwood;
- infested trees.

In all the four methods it is assumed that, respectively, the number of damaged shoots, the number of caught insects, the amount of deadwood, and the number of egg galleries is directly proportional to the actual size of the population of pine-shoot beetles. The presented methods of estimating the population density of larger pine-shoot beetle are not statistically based, do not permit the calculation of the estimation error and, therefore, can be very inaccurate.

In the proposed model, knowing:

a. the number of egg galleries on the 4th meter of a trap tree;
b. the diameter of a trap tree in the thicker end under bark;
c. the status of the zone for a sample or a single tree resulting from the assignment of the tree to a given population density class of *T. piniperda*,

one can calculate the total number of insects colonizing trap trees and the mean, relative estimation error. In forest practice, the developed model could be used to monitor the population of *T. piniperda* under the protection treatments using trap trees (Instruction on Forest Protection 2012). In addition, in managed forests, as well as in those under different forms of conservation, wind-fallen and wind-broken trees can well be used for monitoring the population size of *T. piniperda*. Natural traps of this type are particularly useful for monitoring in nature's most valuable areas placed under strict protection. In nature reserves or national parks, trees cannot generally be cut down and setting pheromone traps is an "artificial" interference in the forest ecosystem.

In the fragment of the paper presenting the results of the research on the ecology of *T. piniperda*, biocoenotic relationships between the bark beetle and the host plant are described and the mechanisms of coexistence of different bark beetle species in the same habitat are shown. This is the first research of the kind in Poland and one of the few in the world, including studies first carried out in the pine stands representing older age classes. Individual studies describing the biotic interactions in the populations of bark beetle species were carried out on spruce *Picea abies* (L.) Karst. (Grünwald 1986), as well as on different pine species: *P. sylvestris* (stands in age classes I (0–20 years) and II (21–40 years), *Pinus radiata* (D. Don) (Amezaga and Rodríguez 1998) and *Pinus taeda* (L.) (Paine et al. 1981).

The main objectives of the paper are to:

1. Develop population assessment model for *T. piniperda* in trap trees;
2. Assess biotic interactions in the populations of bark beetle species colonizing trap trees.

<u>Results</u>

The analysis of the spatial distribution pattern of beetle egg galleries shows that, in the study plots established in stands within and on the edge of the impact area of timber yards, beetles colonize trap trees as per diagrams S-1a or S-2, and in those out of the impact of timber yards they colonize trap trees as per diagrams S-1b, or S-2.

<u>The model for estimating the population density of *T. piniperda* colonizing trap trees</u>

As a result of the statistical analysis, the following explanatory variables were chosen from a set of selected variables that significantly ($p < 0.05$) describe the total number of *T. piniperda* feeding on trap trees:

a. the number of feeding sites of *T. piniperda* on the 4th meter of a trap tree (N_{3-4});
b. the diameter of the trap tree at the thicker end under bark (*d*);
c. the distance between the stand and the timber yard (A, B, C).

The estimated total number of egg galleries of *T. piniperda* in selected sections of trap trees is described by the multiple regression model:

$$N_c = 118.170 + 5.519 \times N_{3-4} + 5.069 \times d - 64.316 (\times B) - 178.817 (\times C)$$

The model explains about 90 per cent ($R^2_{adj.} = 0.8857$) of the variation in the total number of egg galleries of *T. piniperda* in trap trees. The high value of the coefficient of determination indicates that the regression model used fairly well describes the observed variation in the total number of egg galleries of *T. piniperda*. The mean relative error of estimation is 20.8 per cent.

Among the explanatory variables used in the model, the number of egg galleries in the highlighted section of the trap ($p < 0.001$) has the greatest impact on the colonization of trap trees by *T. piniperda*. The total number of egg galleries increases with the number of egg galleries on the 4th meter of the trap tree.

The infestation rate of trap trees by *T. piniperda* depends largely on the distance of the stand from the timber yard (zone C, $p < 0.001$, zone B, $p = 0.0278$). A minus sign of the coefficients for these variables indicates that, with the increasing distance from the reproduction centre the number of beetles colonizing trees decreases, which is consistent with the biological interpretation of this relationship. In trap trees in the stands located in the periphery area under the impact of timber yards, the infestation of trap trees is lower compared to the trap trees in the stands within the impact of timber yards, and higher than in the stands beyond their impact.

Evaluation of the accuracy of the model for estimating the *T. piniperda* population density

The statistical evaluation of the accuracy of the developed model is based on the results of the entomological analyses of trap trees in sample plots selected for validation, which represent all stand categories (A, B and C). On all the plots, regardless of the method of determining the zone parameter, the actual and model means do not differ significantly.

The mean relative errors of estimation of the total number of *T. piniperda* egg galleries on trap trees obtained using a zone parameter for a single tree do not exceed 20 per cent and generally are lower than when using a zone parameter for the sample (up to 26.5 per cent).

Analysis of biotic relationships in the populations of bark beetle species

The research results concerning the use of trap trees by bark beetles indicate that *T. piniperda* niche width depends mainly on the availability of the adequate number of trap trees to colonize. *Tomicus piniperda* preferred the thickest trap trees. On the study plots characterized by similar infestation of trap trees, significant differences in niche width are in the stands with both high and low population density, which indicates that the number of infested trees does not depend on the population density of this beetle species. The comparison of niche width of *T. piniperda* to with the availability of trap trees in each category of stands indicates a very low suitability for feeding of the thinner section of trap trees within 300 meters of the timber yard. Similar relationships between the width of the niche and the availability of trap trees are shown for *Tomicus minor* (Hrtg.). On the majority of study plots infested exclusively by the two species of pine shoot beetles, the niche of *T. piniperda* is significantly wider than the niche of *T. minor*. In the trap trees infested by bark beetle assemblages, niche widths for the population of *T. piniperda* are similar and higher than those calculated for other species of bark beetles. The infestation level of trap trees by other species of bark beetles do not differ significantly.

A larger use of trap trees colonized exclusively by pine-shoot beetles was found on one sample plot established in the stands growing under the impact of the timber yard. The niche overlap index is significantly higher for both *T. piniperda* and *T. minor*. On other plots, the observed differences in the degree of niche overlap for both species of the pine-shoot beetle are not relevant. The niche overlap index for trap trees infested by bark beetle assemblages has significantly lower values for the pairs of species sharing food resources with the larger pine-shoot beetle. The strongest co-existence among the analyzed species of bark beetle pairs expressed by the niche overlap index was demonstrated for *T. minor* sharing food resources with *Hylurgops palliatus* (Gyll.) ($\alpha = 0.68$, Tm-Hp) and was significantly higher than the value of this indicator observed in the pairs of species involving *T. piniperda*. The values of niche overlap for *Pityogenes bidentatus* (Hrbst.) and *H. palliatus* of respectively 0.69 (Pb-Hp) and 0.65 (Hp-Pb) were significantly higher than the values of this indicator observed in the pairs of species with *T. minor*, *P. bidentatus* and *H. palliatus* sharing resources with *T. piniperda* ((Tm–Tp, Hp–Tp and Pb–Tp)). In the other combinations of pairs of bark beetle species, the infestation of their common resources is on a similar level. The percentage share of these bark beetle species in the use of food resources of trap trees, expressed by a niche overlap index, showed no significant dominance of one species within the pair of bark beetle species.

The co-occurrence of bark beetle species was detected only for *H. palliatus* using the resources of a thinner section of trap trees jointly with *P. bidentatus*. The strongest niche separation is on trap trees infested only by these two species. Only under the conditions of high population density of *T. piniperda*, spatial niche separation is weaker. Higher values of the proportion similarity index, and thus a stronger co-occurrence, were obtained for the pairs of species in the trap trees infested by a larger number of bark beetle species.

<u>Summary and conclusions</u>

1. Natural traps made of trunks of cut pine trees are an effective method of reducing the *T. piniperda* population density regardless of the suitability of its food resources.
2. Niche width of *T. piniperda* depends on the availability of adequate resources to colonize trap trees. In the stands growing outside the area of intensive feeding of beetles in the crowns of pine trees, the degree of infestation of resources increases with the increase of tree thickness.
3. *Tomicus piniperda* is the species of high competitive ability. Its niche width is larger than those of the co-occurring bark beetle species in most study areas.
4. Niche separation of both pine-shoot beetle species indicates spatial specialization in colonizing the available trap trees. Where the resources were limited, *T. piniperda* generally colonized thicker trees unlike *T. minor* which colonized thinner tree traps. With the high availability of resources, the two species may co-occur on the entire length of trap trees.
5. The co-occurrence of *H. palliatus* and *P. bidentatus* in trap trees under the conditions of limited resources is the result of different ecological requirements of both bark beetle species as regards the moisture content of the reproduction material.
6. Of the analysed characteristics, the number of egg galleries on the 4th metre of the trap tree trunk, the diameter of the trunk under bark in its thicker part and the

distance of the edge of the stand to the insect outbreak centre had the greatest impact on the assessment of the *T. piniperda* population density.

7. In assessing the population density of *T. piniperda* using the proposed model, the equation parameter resulting from the distance zone status should be established separately for each tree in the sample.
8. The proposed model is universal and after testing and implementation into forest practice, it can be applied in the monitoring of *T. piniperda* in any stand with the participation share of *P. sylvestris*.
9. The applied method of estimating the total density of infestation of trap trees, using the model presented in this paper, is only marginally invasive because it involves debarking of only one 1-metre-long stem section. Therefore, this type of the model can be applied to areas placed under strict protection – in the reserves and national parks, wind-fallen trees can be used as sample trees.
10. The presented model has been designed for fallen trees; it would be advisable to verify whether similar relationships occur in the case of standing dead trees. Should similar relationships be confirmed for standing trees, it would not be necessary for the dead or dying pines (e.g. biocoenotic trees left for the protection of biological diversity) to be cut for analysis. This may be the subject of further study.

The most important innovative achievements described in the monograph as an important contribution to the development of science are:

1. Development of a universal model enabling quick and accurate assessment of the number of *T. piniperda* in each stand regardless of its population density;
2. Development of population density classes for *T. piniperda* which can be used to assess the degree of threat to stands by this bark beetle species;
3. Description of the pattern of infestation of trap trees by *T. piniperda*;
4. Description of biocoenotic interactions between the bark beetle and the host plant and biotic interactions in the populations of bark beetle species.

Literature cited

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Poland T. M., Haack R. A., Petrice T. R. 2002. *Tomicus piniperda* (Coleoptera: Scolytidae) initial Flight and shoot departure along a North-south gradient. *Journal of Economic Entomology*, 95, 6: 1195–1204.

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5. Presenting the remaining achievements in science and research

5.1. Monitoring of pine stands in areas under the impact of insect outbreak centres

Acontinuous improvement of forest protection methods has reduced the area of losses from pine-shoot beetles (*Tomicus* spp.) mainly to forests around sawmills and timber yards. Recent papers dealing with this problem have been based on the studies carried out in the stands growing throughout the period of insect outbreak. The lack of comparable data relating to the period after the elimination of outbreak centres prevents a fully objective assessment of threats to pine stands in their entire period of growth, under a constant stress caused by persistent foraging of beetles in pine shoots.

The research was conducted in the stands growing in the period of operation of wood-processing plants and after their closure in 1992-2005.

The aim of the research was to:

a) assess the level of damage to tree crowns;
b) determine DBH growth trends;
c) determine the site index;
d) determine the amount of fallen shoots.

The most important results:

<u>Stand growth during the operation of wood-processing plants</u>

– the correlation between the spatial distribution pattern of losses in tree diameter and height growth with the degree of damage to the crowns and shoots of pine trees indicates an intensive feeding of pine-shoot beetles migrating from the outbreak centre of this species;

– significant losses in tree growth occur within a distance of about 200 metres from the outbreak centre;

– the average current annual DBH increment in the first period of forest growth in all distance zones is characterized by a rapid decrease which is typical for the undergrowth phase after the culmination phase, with local deviations from the downward trend. In ca 25-year-old stands located within a distance of 500 metres from the reproduction centre the separation of growth curves indicates the beginning of intense feeding of pine-shoot beetles in pine shoots;

– the stands located within 200 metres from the sawmill yard demonstrated a poor and negative growth response, and the actual ring width chronologies are more or less synchronized showing lower variability compared to the control stand, which is indicative of the impact of a disturbing factor such as an intense feeding activity of pine-shoot beetles in pine shoots;

– in the stand adjoining the outbreak centre, the DBH basal area is about 50 per cent lower compared to the control stand, and the difference in tree height is close to 100 per cent.

Stand growth after the closure of wood-processing plants

– pine stands gradually increased their diameter growth after their strong weakening in the period of operation of the wood-processing plants;

– in the stands located within 300 meters from the timber yard, the average 5-year diameter growth at breast height in spatial distribution did not increase with the distance, as it did in the previous year; on the contrary, it shows a downward trend;

– regenerative processes in tree crowns were noted, resulting in a partial restoration of the assimilatory apparatus in the top part of the crowns.

An analysis of DBH growth in pine trees in the stand affected by a one-year outbreak of pine-shoot beetles after the closure of wood-processing plants

– the relative values of diameter growth in the years before and after the outbreak of pine-shoot beetles show that the strong supplementary feeding of beetles in the shoots of pine crowns did not cause the weakening of the growth dynamics of trees in damaged stand. In the compared ring-width chronologies, the relative value of diameter growth of damaged and control stands was not significantly different.

The results obtained were published in:

Borkowski A. 2001. Threats to pine stands by the pine shoot beetles *Tomicus piniperda* (L.) and *T. minor* (Hart.) around a sawmill in southern Poland. *Journal of Applied Entomology*, 125: 1–4 **(IF=0,354)**.

Borkowski A. 2001. Threats to pine forests by pine shoot-beetles *Tomicus piniperda* (L.) and *T. minor* (Hart.) in the vicinity of the sawmill in Zagnańsk. *Sylwan*, 10: 87–90.

Borkowski A. 2003. Spatial pattern of insect-induced needle drop and dbh increment in pine stands before and after liquidation of sawmill and landing. *Sylwan*, 6: 87–93.

Borkowski A. 2006. A spatial distribution of losses in growth of trees caused by feeding of pine shoot beetles *Tomicus piniperda* and *T. minor* (Col., Scolytidae) in Scots pine stands growing within the range of influence of a timber yard in southern Poland. *Journal of Forest Science*, 3: 130–135.

Borkowski A. 2006. Shoot damage and radial increment of trees in Scots pine (*Pinus sylvestris*) stands affected by a one-year's outbreak of pine shoot beetles *Tomicus piniperda* and *T. minor* (Col., Scolytidae) in southern Poland. Electronic *Journal of Polish Agricultural Universities*, Vol. 9, Issue 2.

5.2. The feeding ecology of pine-shoot beetles in pine shoots and the methods of forecasting their population size on the basis of fallen shoots

Before 2012, the collected damaged shoots and the quantity of deadwood were used in forestry practice in Poland as an indicator in the assessment of threats to forests (Instruction on Forest Protection 1988, 2004). Taking into consideration the postulates to unify the forecasting methods in Central European Countries presented at scientific conferences concerning the monitoring of threats to forests posed by pest insects, studies were conducted with the aim, *inter alia*, to:

a) assess the effectiveness of the selected methods of forecasting pine-shoot beetle populations based on damaged shoot;
b) assess the possibility of using a 10-plot method for forecasting of pine-shoot beetles in autumn searches for leaf-eating pests of pine (Instruction on Forest Protection 2004, 2012);
c) assess the potential use of multiple attacks of pine-shoot beetles in pine shoots to predict their occurrence;
d) assess the quality and quantity of pine-shoot beetles feeding in pine shoots;
e) assess the spatial distribution of damaged shoots in the stand.

The studies were conducted in 2001-2006 in the stands aged 81-100 years (age class V) under the conditions of high and low pine-shoot beetle population density.

The most important results:

– the lowest values of the relative estimation error for the density of damaged shoots indicate that the method based on the 100 m^2 transects provides the most accurate estimates. The method is considered effective regardless of the time of shoot collection and degree of stand canopy closure. In most cases, the highest effectiveness of the compared methods is in the areas with the largest number of fallen shoots.

– the optimal time of shoot collection is early and late autumn and spring after the disappearance of the snow cover;

–the beetles' regeneration and supplementary feeding activity takes place in the upper parts of pine shoots. In the case of multiple attacks, the tunnelling in the pith damaged the tissue of apical buds;

– the average length of the tunnels burrowed by the beetles in the shoots with single tunnels does not exceed 20 mm and is smaller than in the shoots with two tunnels. The average distance from the base of the second tunnel in the shoots with two tunnels was within 20 mm from the shoot top, and the average length of the burrowed tunnels by the beetles was about 10 mm;

- the population density of the beetles has a significant impact on the age distribution of damaged shoots and percentage share of multiple tunnels. With a low population density, beetles generally attack current-year shoots, in which single tunnels dominate. In the conditions of high population density, the percentage share of current-year shoots and the number of shoots with more than two tunnels (maximally 6) increases. The smaller percentage of one-year shoots and shoots with a high share of multiple tunnels in the post-gradation year, even with a very low population density, is the result of severe damage of current-year shoots in the preceding growing season;

– the significance test results indicate a cluster distribution pattern of damaged shoots in the examined stands. No agreement between empirical and theoretical (from the Poisson distribution) data was found (test χ^2; $p < 0.05$). The actual values of L indicator are statistically significantly higher than one (t-test, $p < 0,05$).

Conclusions concerning the prediction of pine-shoot beetle population with the methods based on damaged shoot collection:

1. The assessment of the density of damaged shoots beneath tree crowns allows only to calculate the indicator related, or at best proportional, to the population density of the beetles. The knowledge of the relationship between the density of fallen shoots and *T. piniperda* population in the examined stand requires:
    a) establishment of a relationship between the number of damaged shoots fallen onto the ground and the shoots remaining in tree crowns. The studies conducted in the crowns of the cut sample trees show that beetle attacks take place the upper part of the shoots which, due to their low weight, do not fall off or whose identification on the ground is not possible;
    b) estimation of the average number of shoots damaged by individual beetles in the population. The studies carried out in the forest in southern and central Sweden show that beetles can damage one to two shoots during their feeding activity in the crowns;
    c) assessment of the participation of both pine-shoot beetle species in the feeding in pine shoots;
    d) adjustment of the time and frequency of fallen shoot collection to the environmental conditions of the stand. The optimal time of shoot collection in

central Poland is early and late autumn and spring after the disappearance of the snow cover. Limiting the collection of fallen shoots to November only hinders the identification of fallen shoots in late summer and early autumn. In turn, a high seasonal variation in shoot fall dynamics should not prevent spring shoot collection.

2. The transect method based on the damaged shoot collection is the most effective method of forecasting pine-shoot beetle population;
3. A similar number of shoots with two tunnels under the conditions of both high and low population density of pine-shoot beetles makes their use for forecasting purposes ineffective.

The results obtained were published in:

Borkowski A. 2002. A needle fall caused by pine shoot-beetles in the stands in the vicinity of sawmills and wood yards in the Świętokrzyskie Mountains. *Sylwan*, 5: 61–64.

Borkowski A. 2003. Forecasting occurrence of pine shoot-beetles (*Tomicus piniperda* (L.) i *T. minor* Hart.) on the basis of the needle drop. Sylwan, 9: 53–56.

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Borkowski A. 2007. Feeding ecology of pine shoot beetles (*Tomicus* spp.) in tree crowns in Scots pine, *Pinus sylvestris* L., stands under one year outbreak. *Journal of Forest Science*, 10: 445–451.

5.3. The statistical method of estimating the population density of major bark beetle species in conifers

Together with Dr. Rafał Podlaski we have developed a novel method of estimating the total density of infestation of trap trees or windfalls of pine, fir and spruce as well as pine deadwood by major bark beetle species (except for *T. minor*) in the case of which I have developed such a method myself). The counting of egg galleries of a given bark beetle species is very time-consuming because it requires precise debarking of tree stems, while at the same identifying egg galleries. Thus, in the majority of studies, the estimation of the density of egg galleries is restricted to smaller or larger pieces of bark collected from various parts of the stem. Such procedures are not based on statistical methods, as they do not allow the calculation of estimation errors.

The aim of the conducted research was to:

1. To elaborate a method for assessing the total density of stem infestation, allowing to calculate estimation errors for analysed stems with reference to:
   a) wind-fallen fir trees were colonized by *Cryphalus piceae* (Ratz.);
   b) wind-fallen fir trees were colonized by *Pityokteines curvidens* (Germ.);
   c) wind-fallen spruce trees were colonized by *Ips typographus* L.;
   d) wind-fallen spruce trees were colonized by *Pityogenes chalcographus* L.;
   e) pine deadwood was colonized by *Xyloterus lineatus* (Oliv.);
   f) pine tree traps were colonized by *T. piniperda*;
   g) pine tree traps were colonized by *T. minor*.
2. To elaborate a method for estimating the mean total density of infestation of wind-fallen or trap trees in a given area;
3. To verify the proposed methods.

The entomological analyses of pine and spruce trees were conducted by myself, while the analyses of fir trees I made in collaboration with Dr. Rafał Podlaski.

The most important results:

– the linear correlation function was developed between the number of egg galleries of the examined bark-beetle species in 1-metre or 0.5-metre long stem sections and in 0.2-metre long branch sections, and the total density of stem and branch infestation;

– for the strongest correlation (for the above mentioned relationships), the mean relative errors of estimation did not generally exceed 20 per cent (maximum 40 per cent);
– the method of estimating the mean total density of infestation of stems was developed on the basis of unrestricted simple random sampling of windfalls for areas of different sizes (depending on the size of the study area, small-area and large-area variants were distinguished). To estimate the lower and upper limit of the confidence interval for the mean total infestation density of the windfall, a scheme employing the normal distribution was used;
– when verifying the proposed methods used to assess the population density of *I. typographus* in the Świętokrzyskie Mountains in an area of ca 4,000 hectares, the mean total density of infestation of spruce stumps by *I. typographus* was estimated. In 2010, the mean total density of infestation of spruce windfalls was 440.6 egg galleries/m^2 (from 358.7 to 522.6 egg galleries/m^2 at $\alpha = 0.05$; the relative error of estimation was 18.6 per cent).

The results obtained were published in:

Borkowski A. 2010. A method of estimation of the total density of infestation of Scots pine stems by the lesser pine shoot beetle (*Tomicus minor* Hart.). *Electronic Journal of Polish Agricultural Universities*, Vol. 13, Issue 4.

Borkowski A., Podlaski R. 2005. A method of estimation of the total density of infestation of Scots pine stems by the larger pine shoot beetle (*Tomicus piniperda* L.). *Folia Forestalia Polonica*, Series A-Forestry, Number 47: 26–32.

Borkowski A., Podlaski R. 2011. Statistical evaluation of *Ips typographus* (L.) population density: a useful tool in protected areas and conservation-oriented forestry. *Biodiversity and conservation*, 20: 2933–2951 (**IF=2,238**).

Borkowski A., Podlaski R. 2012. Statistical method for estimating *Pityogenes chalcographus* (L.) population density on Norway spruce *Picea abies* (L.) Karst. windfalls. *Sylwan*, 2: 137–146 (**IF=0,159**).

Borkowski A., Podlaski R. 2012. Statistical method for estimating *Xyloterus lineatus* (Oliv.) population density on Scots pine *Pinus sylvestris* L. *Acta Agraria et Silvestria ser. Silvestris*, 1: 59–68.

Podlaski R., Borkowski A: 1993. A statistical method for evaluating the abundance and colonization density of the pine beetle (*Tomicus piniperda* L.) on trap trees in Poland. *Anzeiger für Schädlingskunde Pflanzenschutz, Umweltschutz – Journal of Pest Science*, 66: 107–108.

Podlaski R., Borkowski A. 2009. Method for estimating density of *Cryphalus piceae* (Ratz.) brood galleries using a regression model. *Journal of Applied Entomology*, 5: 402–409 (**IF=1,436**).

Podlaski R., Borkowski A. 2009. Estimating stem infestation density of *Pityokteines curvidens* (Germ.) on windfalls: a statistical approach. *Journal of Pest Science*, 82: 357–365(**IF=0,818**).

5.4. Colonization of spruce windfalls by the selected cambiophagous and xylophagous insect species

The outbreaks of *I. typographus* was observed in all central and northern European countries for a long time. Recent outbreaks of *I. typographus* in Poland have covered large areas of spruce stands both in managed forests and those placed under the conservation status. In the forests of the Świętokrzyskie Mountains, no significant threat to spruce stands from *I. typographus* was noted except for the interwar period. 2007 saw an increase in the population of this species in the forest with the share of spruce. In addition to the colonization of wind-damaged trees, the bark beetles attacked healthy trees causing a decline of spruce forests over a large area.

In the years 2007-2009, I carried out research under this project in the stands with an admixture of spruce where no mass incidence of *I. typographus* was observed.

The aim of the research was to:

a) evaluate the density of cambiophagous and xylophagous insects developing in the trees damaged by the wind;
b) determine the sex structure in the populations of *I. typographus* and *P. chalcographus* colonizing spruce windfalls.

The most important results:

– *Ips typographus* infested all sample trees, colonizing them along the entire stem length except for the stem section of the current and last year's high growth. The infestation density indicators in 2008-2009 expressed as the number of egg galleries/m^2 amounted to 466 (oscillating between 99 and1071 egg galleries) and 455 (oscillating between 115 and 935 egg galleries);

– *Ips typographus* together with *P. chalcographus* infested, first of all, the examined spruce trees (frequency 82-84 per cent), their mean infestation density in both investigated seasons was similar and amounted to 68-71 egg galleries/m^2. Other species found in the examined trees, mainly *H. palliatus*, *Dryocetes autographus* (Ratz.) and *X. lineatus* were characterized by a low (less than 1 per cent of all egg galleries in stems) density. Egg galleries of *Ips amitinus* Eichh. were occasionally found on thicker branches in the lower part of crowns;

– the sex structure in the population of *I. typographus* in both investigated seasons indicated an almost twofold higher number of females (67-67.5 per cent). Egg galleries with two tunnels dominated, their share was threefold higher than the egg galleries with one and three tunnels. Egg galleries on the stems with five tunnels occurred sporadically;

– The spatial distribution of *I. typographus* egg galleries indicates a balanced density of insects of this species along the entire lengths of the examined stems (F = 0.7953, p = 0.6211). The observed lower value of this parameter in the thicker part of the analyzed windfalls was the result of the lower infestation level in the butt-end of the stems (F = 6.0765 , p = 0.0009). The population of *P. chalcographus* shows a similar infestation pattern of the windfalls. The exception is the lower density of egg galleries in the first 10 per cent of the stem section (F = 4.5055 , p < 0.0001). The entomological analysis of the top part of the crowns shows that the upper limit of the infestation density of stems for *I. typographus* is a two-year and for *P. chalcographus* a one-year height growth section. The results of the correlation analysis show a statistically significant linear correlation between the diameter of the 0.5-meter stem section and the infestation density of stems by *P. chalcographus* (r = -0.3043, p < 0.0001), while they do not show such dependency for *I. typographus* (r = -0.0447, p = 0.3126).

The results obtained were published in:

Borkowski A. 2011. Occurrence of the European spruce bark beetle *Ips typographus* (L.) and six-toothed spruce bark *Pityogenes chalcographus* (L.) in spruce stands damaged by wind in the Świętokrzyskie Mountains. *Leśne Prace Badawcze*, 72 (1): 31–36.

5.5. Colonization of traps made of cut pine and fir stems by selected cambiophagous and xylophagous insect species

The tree-trap method is the oldest and still used for reducing the population density of secondary pests of conifers (Instruction on Forest Protection 1988, 2004, 2012). Thus, the studies on the effectiveness of the method is especially useful in silvicultural and protection procedures against these insect species and in the areas under the conservation status where wind-damaged trees used as traps are actually the only method of forecasting and reducing bark beetle population density.

In the years 1990-1994, I carried out research under this project in the surroundings of the Suchedniów-Oblęgorek Landscape Park on my own, and in research teams (mainly in cooperation with Dr. Rafał Podlaski) in the Świętokrzyskie Mountains.

The aim of the conducted works was:

a) quantitative and qualitative evaluate n of bark beetles infestation of the reproduction material;
b) evaluation of the effect of the selected environmental factors on the density of infestation of trap trees by *T. piniperda* and *C. piceae*.

The most important results:

– 12 major bark beetle species were identified on trap trees made of cut stems of wind-damaged pine and fir trees including tree stumps;
– the density of infestation of trap trees by *T. piniperda* mainly depended on degree of their insolation on the sites with windfalls, while the height of trap tree location above ground level was not significant. The infestation density was the highest in the traps located in forest gaps (high insolation). With the increase in the diameter of trap trees, the number of egg galleries increases while the infestation density of traps remains unchanged;

– insolation intensity had a significant effect on the density of infestation of trap trees by *C. Piceae*, the infestation density was the highest in the lower part of the fir trees in shaded locations, but without additional shelter from the undergrowth, shrubs and tall herbs (low insolation).

The results obtained were published in:

Borkowski A. 1994. Biology and ecology of some Scolytidae species of the coniferous trees in the protection zone of the Suchedniowsko – Oblęgorski Landscape Park. *Studia Kieleckie*, 4: 115–119.

Borkowski A. 2001. Colonisation of trap trees by pine shoot-beetles *Tomicus piniperda* (L.) i *T. minor* (Hart.) in the stands surroundings the sawmill and wood yards. *Sylwan*, 11: 81–84.

Borkowski A., Podlaski R. 1992. Influence of chosen ecological factors on the density of colonization of trap trees by the larger pine-shoot beetle (*Tomicus piniperda* L.). *Sylwan*, 7: 67–71.

Borkowski A., Podlaski R., Wojdan D. 1994. Impact of insolation degree on the *Tomicus piniperda* colonization density in tree traps. *Sylwan*, 5: 61–64.

Podlaski R., Wojdan D., Borkowski A., Wypiórkiewicz J. 1999. The impact of insolation intensity on the density of colonising trap trees by *Cryphalus piceae* (Ratz.) (Coleoptera, Scolytidae) in the Świętokrzyski National Park. *Sylwan*, 12: 59–65.

5.6. Dynamics of the numbers of fir budworms in the Świętokrzyski National Park

The silver fir (*Abies alba* Mill.) forests in Central Europe are in regress. The weakened fir stands are affected by various abiotic and anthropogenic factors such as the persistent occurrence of fir budworms: *Choristoneura murinana* Hb., *Epinotia nigricana* H.S. and *Zeiraphera rufimitrana* H.S. In the second half of the past century, the outbreaks of these budworms species in Poland occurred primarily in the Świętokrzyskie Mountains area, where fir is not only close to the border of its natural range but also under the impact of the lowland climate and industrial emissions.

By the end of the past century, this process had been largely intensified after the outbreaks of budworms species in the 1970s. Due to the ever persistent threat to fir forests from fir budworms, the permanent monitoring of the population dynamics of these species is especially required. In the 1990s, I carried out research on forecasting budworms populations in team research teams, mainly in cooperation with Dr. Rafał Podlaski and Dr. Dariusz Wojdan.

The following analyses were made during the implementation of this project, *inter alia*:

a) species composition and population numbers of fir budworms on the basis of hibernating larvae;
b) the level of threat posed to fir stands by fir budworms.

The most important results:

– The research revealed the occurrence of a group of fir budworms including *Choristoneura murinana* Hb and *Epinotia nigricana* H.S *Choristoneura murinana* was the most frequent species in pure fir stands, usually with one-storey structure. Less numerous was *Epinotia nigricana* occurring frequently in the forests of Forest Sub-districts where *Choristoneura murinana* was not detected

- In 1991-1996, the detected number of hibernating larvae of fir budworms was similar and no risk of their outbreak in the Świętokrzyski National Park was envisaged.

The results obtained were published in:

Wojdan D., Podlaski R., Wypiórkiewicz J, Borkowski A. 1998. Obervations of fir budworms (Lepidoptera, Tortricidae) in the Świętokrzyski National Park. *Rocznik Świętokrzyski Ser. B – Nauki Przyrodnicze* 25: 23–32.

5.7. The assessment of hazards to forest ecosystems in the area of industrial emissions

Industrial emissions are one of the main causes of degradation of forest ecosystems. Most studies on this issue cover the period after the emissions have appeared. The lack of comparable data prior to the appearance of emissions, prevents a fully objective studies of changes to forest ecosystems. Together with Dr. Rafał Podlaski we have developed a comprehensive research methodology aimed at:

– assessment of the effect of industrial emissions of the planned Kielce Power Plant on the selected elements of forest ecosystems: soil, stands and certain groups of insects.

On the basis of an expert's opinion on the projected mean values of SO^2 and fly ash concentrations used in the research, the following was developed:

a) distribution pattern of study plots;
b) methods of measurement of atmospheric and soil pollution;
c) detailed research methodology for forest stands and entomological analyses.

Methodological assumptions were published in:

Podlaski R., Borkowski A. 1995. Threats resulting from the start-up of the Kielce Power Plant and the methods of determining their impact on forest ecosystems. *Kieleckie Studia Bilogiczne*, 8: 221–231.

Synthetic summary of the scientific achievements

PUBLICATIONS

1. In journals from the **Journal Citation Reports base**

- number of articles: **7**;
- total Impact Factor, according to the year of publication: **5,497**;
- total Impact Factor (on 31st December 2012): **10,833**;

2. In journals whose titles are in the **Journal Citation Reports** base, while a given article was published in the year when the journal did not have the Impact Factor yet:

- number of articles: **10**;

3. In journals not being in the **Journal Citation Reports** base:

- number of articles: **16** (including 6 popularising articles);

Among the post-doctoral research articles (22 publications), the majority (15) are my own original articles, six in cooperation with one co-author and one with more than one co-author.

Total number of articles: 33 (including 6 popularising articles**)** and one monograph;

total number of points according to the list of the MNiSW (dated 20th December 2012)**: 380**;

NUMBER OF QUOTATIONS according to the **Web of Science base**

(on 31st December 2012): **15**;

HIRSCHA INDEKS according to the **Web of Science base**

(on 31st December 2012): **2**.

PUBLICATIONS	Before PhD	After PhD	**Total**
journals from the **Journal Citation Reports base**	1	6	**7**
In journals whose titles are in the **Journal Citation Reports** base, while a given article was published in the year when the journal did not have the Impact Factor yet:	2	10	**12**
In journals not being in the **Journal Citation Reports** base	3	12[a]	**15[a]**
Total	**6**	**28[a]**	**34[a]**

[a] — including 6 popularising articles

My participation is detailed in appendix 6, with each publication. I participated in the realisation 6 projects an at present I am a person doing the project of 1 university grant. I am an author of 7 papers presented during international and state scientific conferences.

Detailed list of my scientific achievements (with the author's share) can be found in appendix 6.

Popularizing and teaching activities

I popularized knowledge by conducting educational workshops in the framework of the Festival of Science in Kielce 2001-2010 (6th edition).

Regarding my didactic activities I delivered lectures on: general ecology (lab and field classes), animal ecology (lab and field classes), environment protection (lectures, lab and field classes), environmental protection (field classes).

I supervised 15 undergraduate dissertations and 14 graduate dissertations as well as I reviewed 22 undergraduate and graduate dissertations.

Achievements in the field of organizational activity

1. 1999 - I served as Secretary of the Institute's Recruitment Committee for Part-time Extra-mural Studies;
2. 1999-2004 - Tutor for students;
3. 2000 - Chairman of the Faculty Electoral Commission for elections to the Teams of the State Committee for Scientific Research;
4. 2000 - Member of the Faculty Electoral Commission;

5. 2011-2013 - Member of the Council of the Faculty of Mathematics and Natural Sciences, the Jan Kochanowski University in Kielce;

6. Since 2012 - Member of the Faculty Committee for Academic Staff Evaluation;

7. 2013 - Member of the Institute's Committee for Interviewing Candidates for Full-Time Graduate Courses

A detailed list of my achievements in the fields of education and poplarisation as well as a summary of my co-operation with scientific institutions and organisations can be found in appendix 9.

Kielce, 25/10/2013

Andrzej Borkowski

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Signature of the Petitioner