

Monitoring and Risk Assessment of the Spruce Bark Beetle, *Ips typographus*

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Abstract

A model describing development of the spruce bark beetle, *Ips typographus*, combines topo-climatic aspects of the terrain with eco-physiological aspects of the bark beetle. By correlating air temperature and solar irradiation measured at a reference station, along with topographic data and microclimatic conditions of terrain plots, topo-climatic models of a given research area are established. Within the scope of modeling, GIS is used for data processing and visualization. The model allows a monitoring, retrospective analysis and prognosis of brood development at any site and thus facilitates decision-making in forest management and the identification of hazardous zones.

Introduction

Populations of *Ips typographus*, the most severe forest pest in Central Europe, have expanded and intensified due to favorable climate change and more frequently occurring extreme weather conditions, and may increase in severity in the future. The situation has been aggravated by the fact that, after the Second World War, most of the forest stands in Central Europe were planted mainly with spruce. The total area of such plantations in Austria alone amounts to 1 million hectares. These stands are now approaching a critical age where they are attacked readily by the beetle, therefore an abundance of appropriate brood material is available to support devastating outbreaks of this bark beetle species. Control of *Ips typographus* is hindered by the fact that its outbreaks are not only restricted to secondary planted spruce forests of lowlands. As evidenced in the National Park “Bayerischer Wald” in Germany, where *Ips* infestations killed more than 75% of the spruce trees in an area of about 3,500 ha, considerable damage may occur also in the highland at altitudes from 1100 to 1400 m (Bayerische Landesanstalt für Wald und Forstwirtschaft 1999).

Materials and Methods

We developed a model which provides forest organizations the capability to monitor and forecast outbreaks of *Ips typographus* and which is comprised of the following components:

Aspects related to topo-climatology:

- topographic features such as elevation, slope, and aspect
- intensity of potential and effective solar irradiation
- temperature measurements of the air, phloem of trees (and soil)
- stand structural features such as tree species composition, canopy closure, etc.

Eco-physiological aspects of beetle development including:

- time of swarming and brood initiation
- thermal characteristics of developmental stages, i.e. effective thermal sums needed to complete development of specific instars
- voltinism including the factors inducing and terminating diapause

These parameters constitute the input data-set of a database-management system. Information is stored in the form of separate tables and the relationships needed for the model are analyzed and validated by a linked statistical package via multiple regression analyses. Developmental modeling allows us to assess times of brood initiation and actual stages of brood development at each single

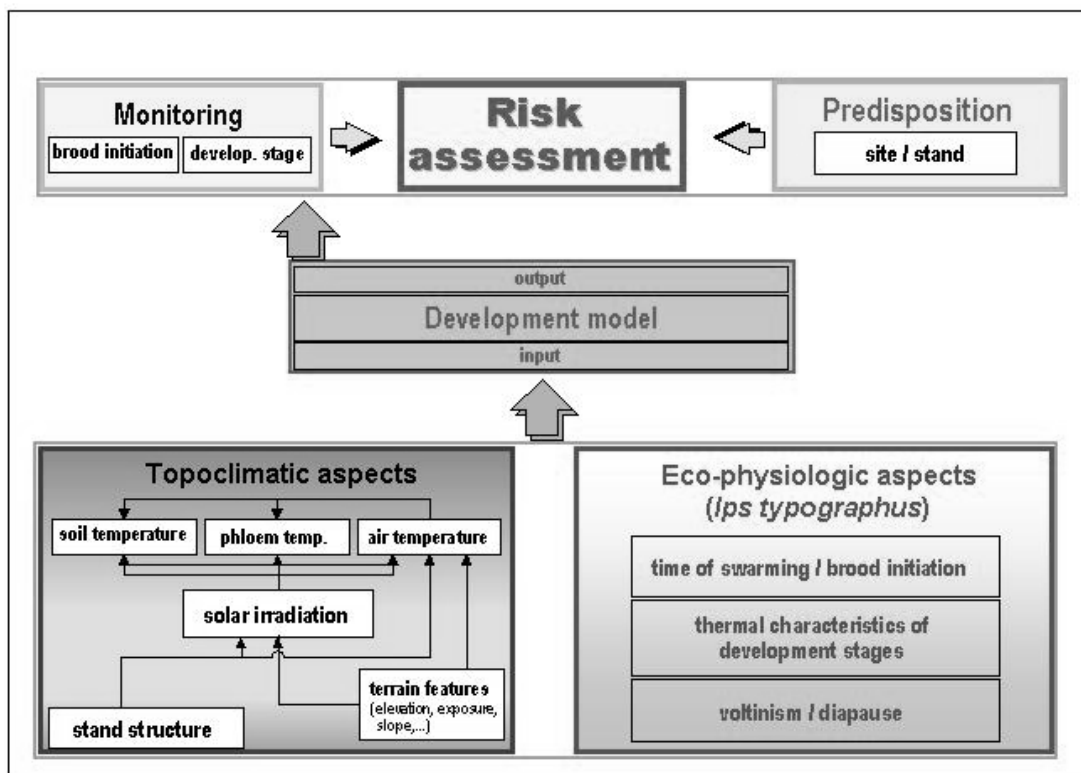


Figure 1.—Components of a model to monitor bark beetle development and to assess the risk of an outbreak.

point of the study terrain and for each time of the season. When combined with data concerning the predisposition of forest stands to bark beetle attack, this model provides managers with a comprehensive tool for risk assessment (Fig.1).

Requirement for the topo-climatic model include the following:

1. Installation of a base station (or reference station) to measure air temperature and solar irradiation
2. Installation of gauging-stations to measure air temperature at various locations in the terrain
3. Deduction of the topographic parameters (elevation, exposure, and slope) from a digital elevation model
4. Multivariate regression analysis of the data recorded at the base station, the gauging-stations, and topographic parameters

By means of resulting correlations, “close to ground” air temperature can be extrapolated for any location of the terrain (without the aspect of vegetation), based on data from the reference station.

A realistic estimation of bark beetle development requires the assessment of microclimatic conditions for the bark beetle, i.e. calculation of mean daily phloem temperatures at various aspects of felled trees and density conditions of the stand. Consequently, relations between phloem temperatures of a spruce tree, air temperature and solar irradiation were deduced (comp. Pennerstorfer 2000) from data at the gauging-stations that were established at an experimental site and by different indices of canopy closure (Fig. 2).

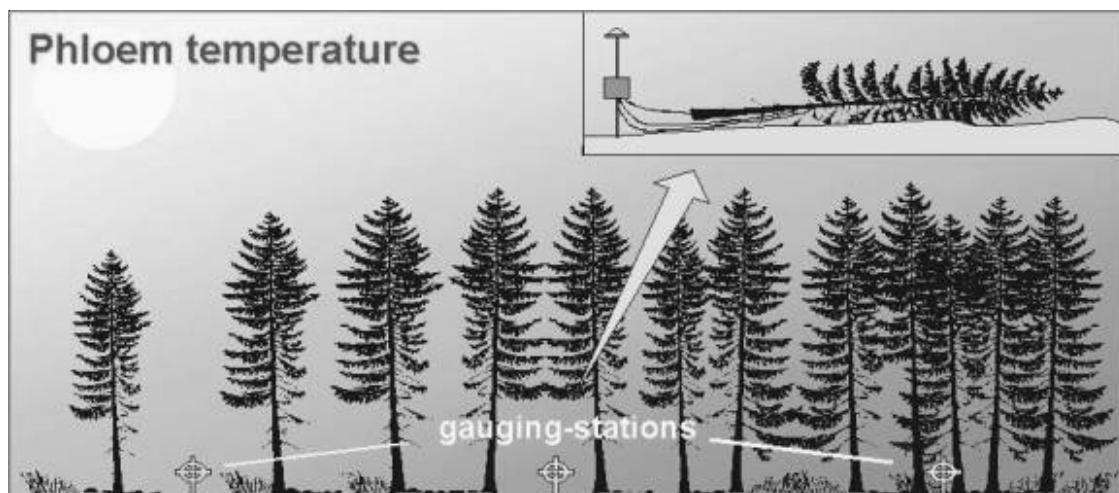


Fig.2.—Experimental design for deducing the correlation of phloem temperature at various positions on felled spruce trees and air temperature as well as solar irradiation (modified by the degree of canopy closure).

Results and Discussion

The terms resulting from the regression analyses allow us to extrapolate the phloem temperature of trees from air temperature and solar irradiation measured at the reference station, and from indices of canopy closure at the stand level. As expected, phloem temperature of the sun-exposed side of a tree is much higher than the air temperature in an open stand, while in a closed stand, the exposure of the log has no influence on cambial temperature (Fig. 3a-b).

Microclimatic conditions may differ significantly at short distances within a stand; this was shown by recordings at forest sites in the High Tatras National Park (Tanap, Slovakia) in 2001 (Netherer et al. 2002). Beetles developing in a sun-exposed tree situated at the forest edge at an elevation of 1000 m were able to complete two generations successfully, with offspring emerging up until August. Nearby in a shaded tree, offspring reached only the larval stage of the second generation within the same period of time.

Thus an estimation of the developmental progress of bark beetles within a tree must be related to “effective phloem temperature sums,” which is the heat sum above the lower developmental threshold needed for stage completion. The instar specific thresholds were determined in laboratory experiments by using the “sandwich” technique (comp. Coeln et al. 1996, Wermelinger & Seifert 1998). Based on times and rates of larval development at different temperatures, lower threshold values were derived for each stage by extrapolation and the corresponding thermal sum in day degrees was calculated.

A realistic monitoring system for the development of *Ips typographus* requires further knowledge about the following:

- Determination of voltinism, i.e. the proportion of uni-voltine and multi-voltine individuals within a population
- number of sister broods and times of brood establishment by the parental beetles
- factors regulating induction and termination of diapause
- frost resistance of hibernating stages
- thermal thresholds that induce spring flight

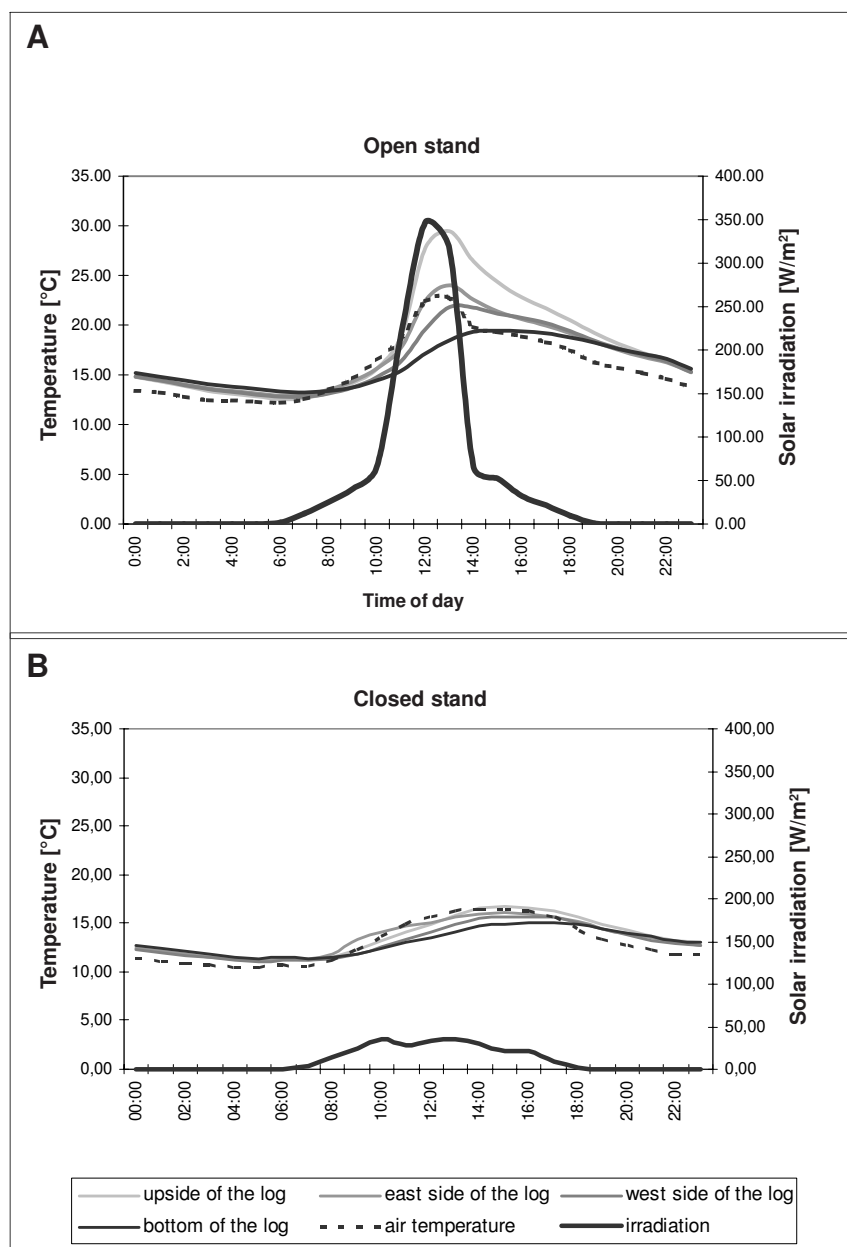


Figure 3a – b.—Phloem temperature measured on felled logs in open (A) and closed (B) stands.

The thermal values ascertained in the lab studies combined with the microclimatic conditions of studied terrain allows us to evaluate and visualize the progress of a population's development at any time of the season and for any site within the research area. The mode of representation is variable and may be realized in the form of tables, maps, or GIS supported 3-dimensional figures (Fig. 4).

The model may be implemented for various purposes which may include:

- Monitoring of insect development in general
- Modeling of scenarios to forecast insect development and to support decision-making regarding modifications and adaptations of forest management in view of climate change
- Indicating the delineation of zones of risk in forest reservations and national parks.
- Retrospective analysis of population dynamics of insects that may provide new insights in population ecology

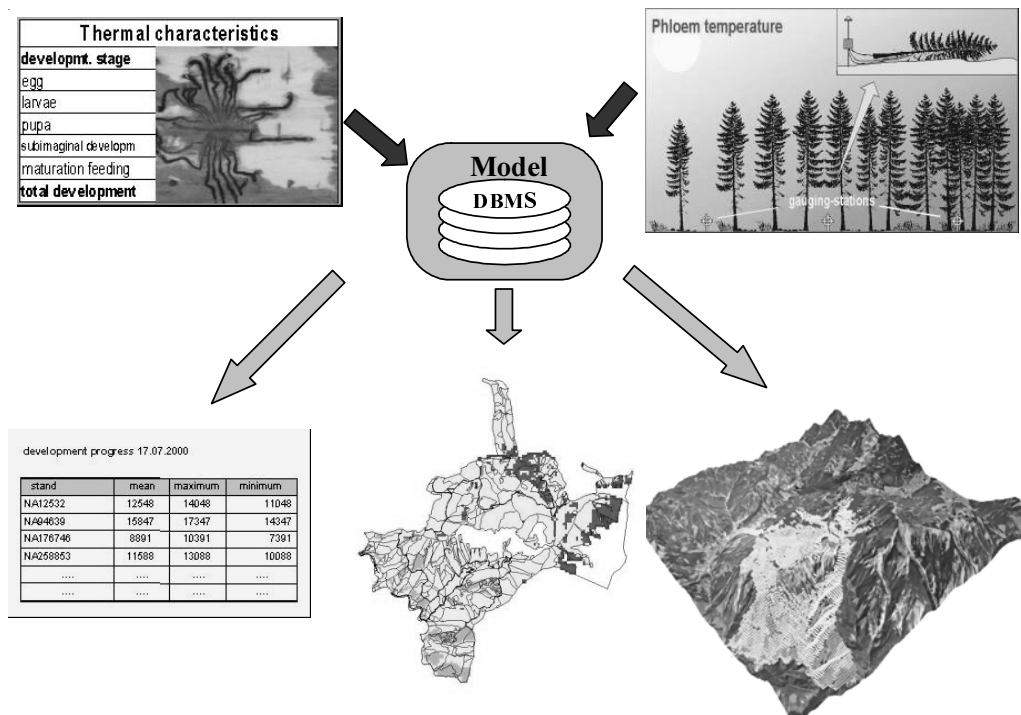


Figure 4.—Data input and examples of outputs.

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