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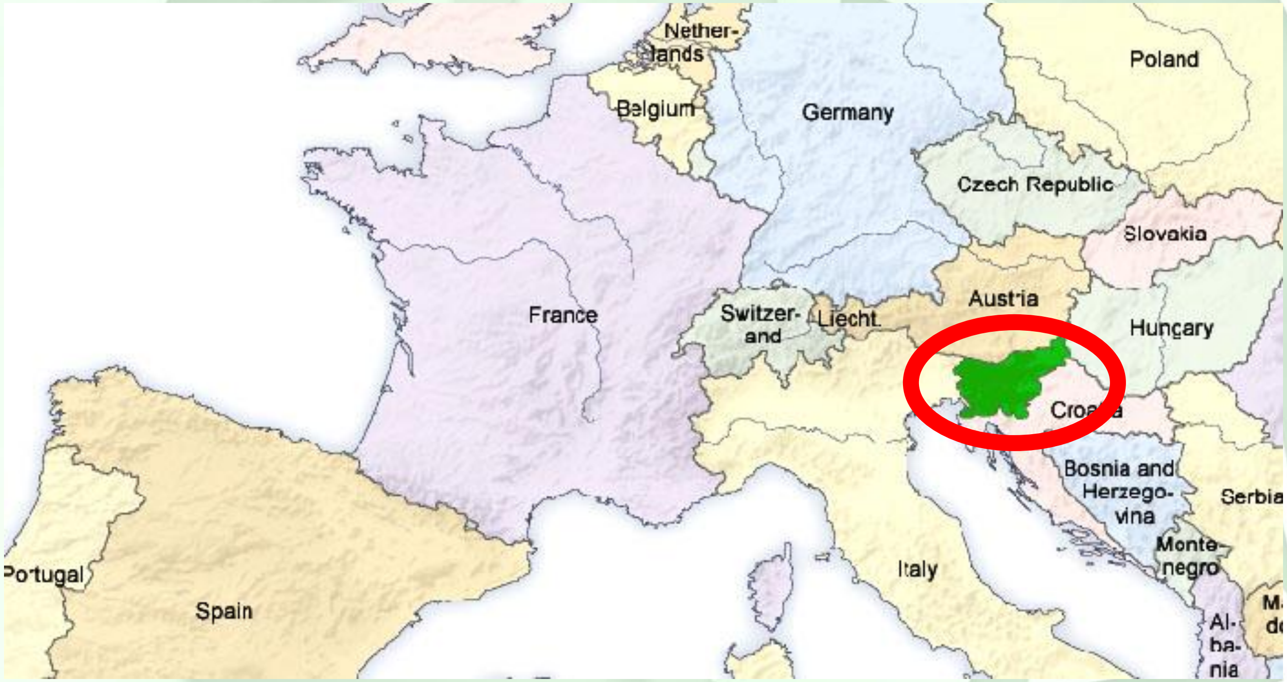
Bark beetle infestation in Slovenia: causes, current state, impacts, lessons learned and perspective

Damjan Oražem, Marija Kolšek (Slovenia Forest Service), Andreja Kavčič, Barbara Piškur, Maarten de Groot, Nikica Ogris (Slovenian Forestry institute)



FORESTS´ FUTURE
Czech Republic 2021

23rd of March, 2021

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Presentation content:

1. Forestry, bark beetles and spruce in Slovenia
2. Causes for bark beetle calamity
3. Past development and current situation
4. Forecasting system and prognosis of infestation
5. Lessons learned

Some basic facts of Slovenian forestry (2020):

Forest area: 1,2 million ha (58%)

Growing stock:

357 million m^3 (304 m^3 /ha)

conifers: 45%, broadleaves: 55 %

Annual increment:

8,8 million m^3 (7,5 m^3 /ha)

Planned (allowable) cut:

6,3 million m^3/year

Annual cut:

3,9 million m^3 in 2011-2013

6,3 million m^3 in 2014

4-6 million m^3 in 2015 - 2020

Type of forest management:
nature friendly, no clear cuts, forests are treated like ecosystems, not like fields of trees

Regeneration: >97% natural

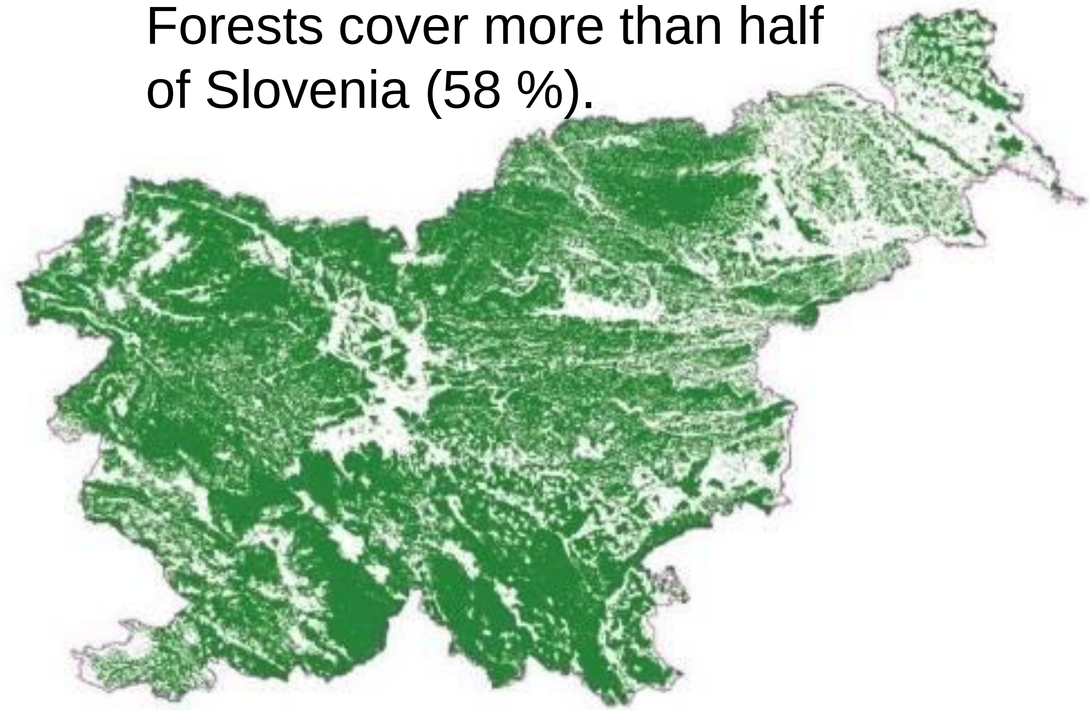
Ownership:

private forests 75%,

state forests 22%

forests of local communities 3%

Number of forest owners: 413.000



Forests cover more than half of Slovenia (58 %).

Some basic facts about bark beetles in Slovenia:

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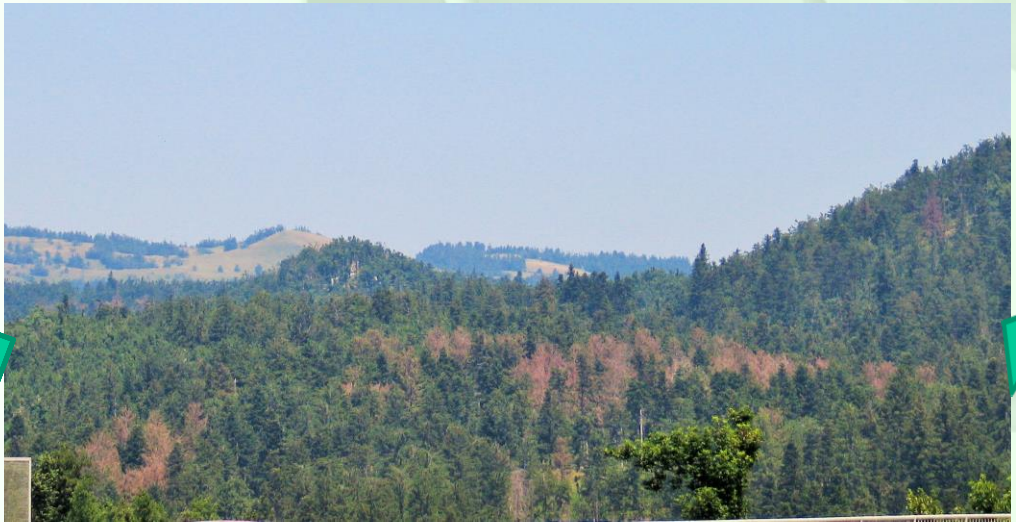
- **Number of bark beetle (Scolytinae) species in Slovenia:** ~ 90
- **Number of „economically" important species:** ~ 5
- > 98% of the bark beetle damage in forests is done by 1 main and one (more or less) accompanying species on one tree species (Norway spruce):

***1. Ips typographus** ((1)2 - 3 gen./Y)*

2. Pityogenes chalcographus



Norway spruce in Slovenia:

Share in growing stock (GS):

- 30,2 % (2020)
- in average 108 m^3 /ha
- sum: 108 $x10^6$ m^3

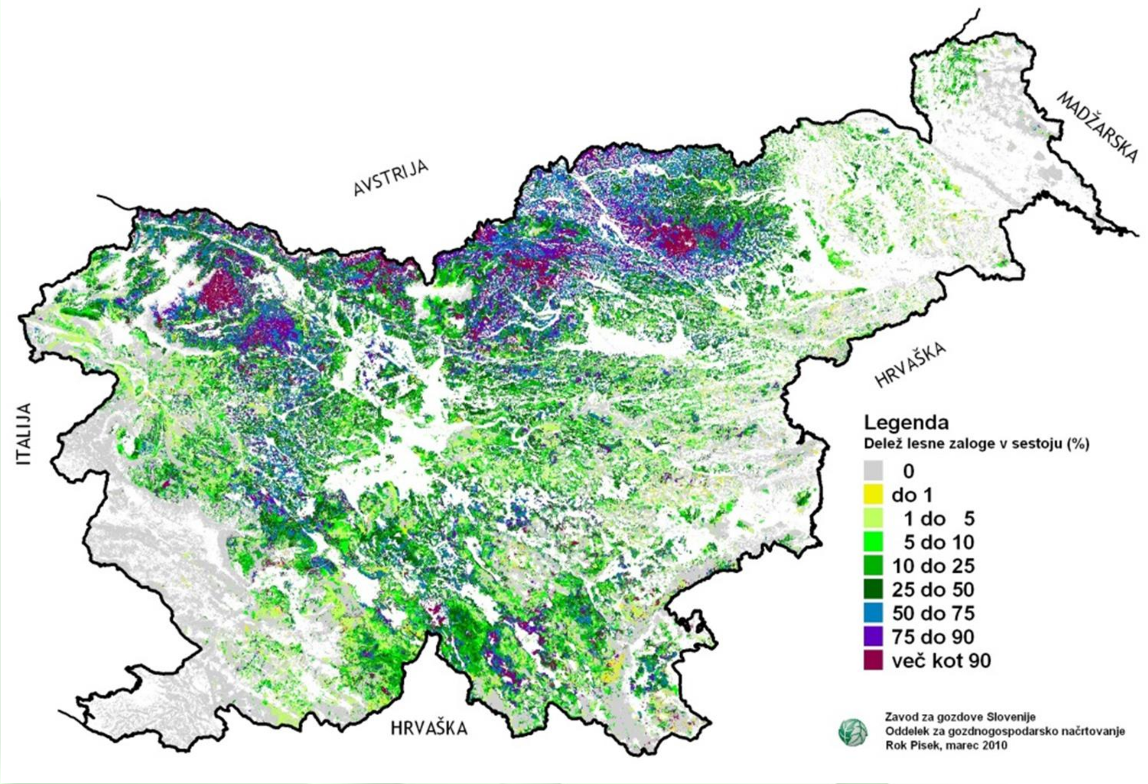
Share in GS in last 2 decades:

- 2000: 32,5%
- 2010: 31,5%
- 2020: 30,2 %

Share „by nature“:

- 8-10%

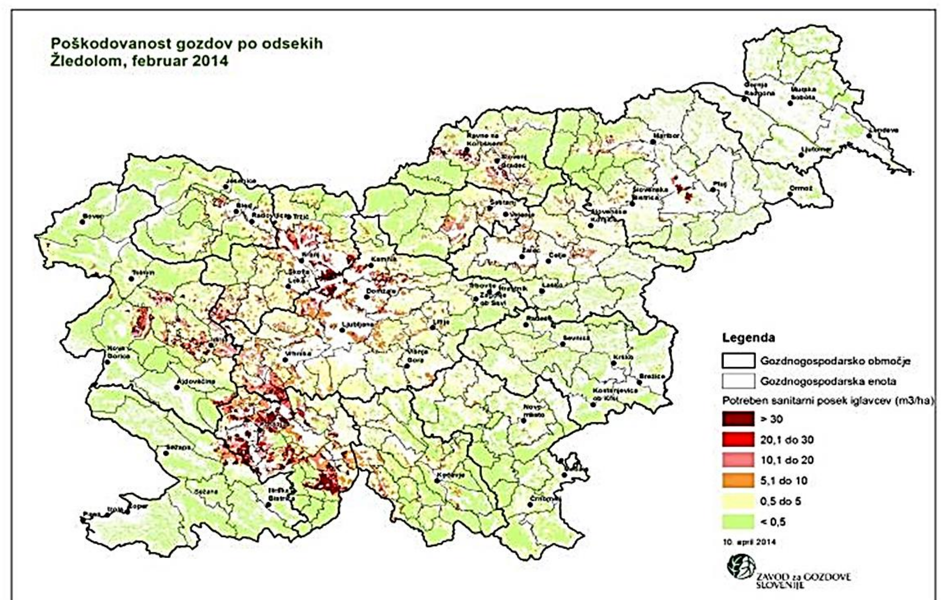
Share of Norway spruce in stock (%) in 2010.



Icebreak in Slovenian forests (30th Jan.– 10th Feb. 2014)

Foto: Tonček Jerič

Amount (m^3) of damaged trees/ha – ice sleet 2014



Icebreak of record size was an expected trigger for outbreak of bark beetle infestation …

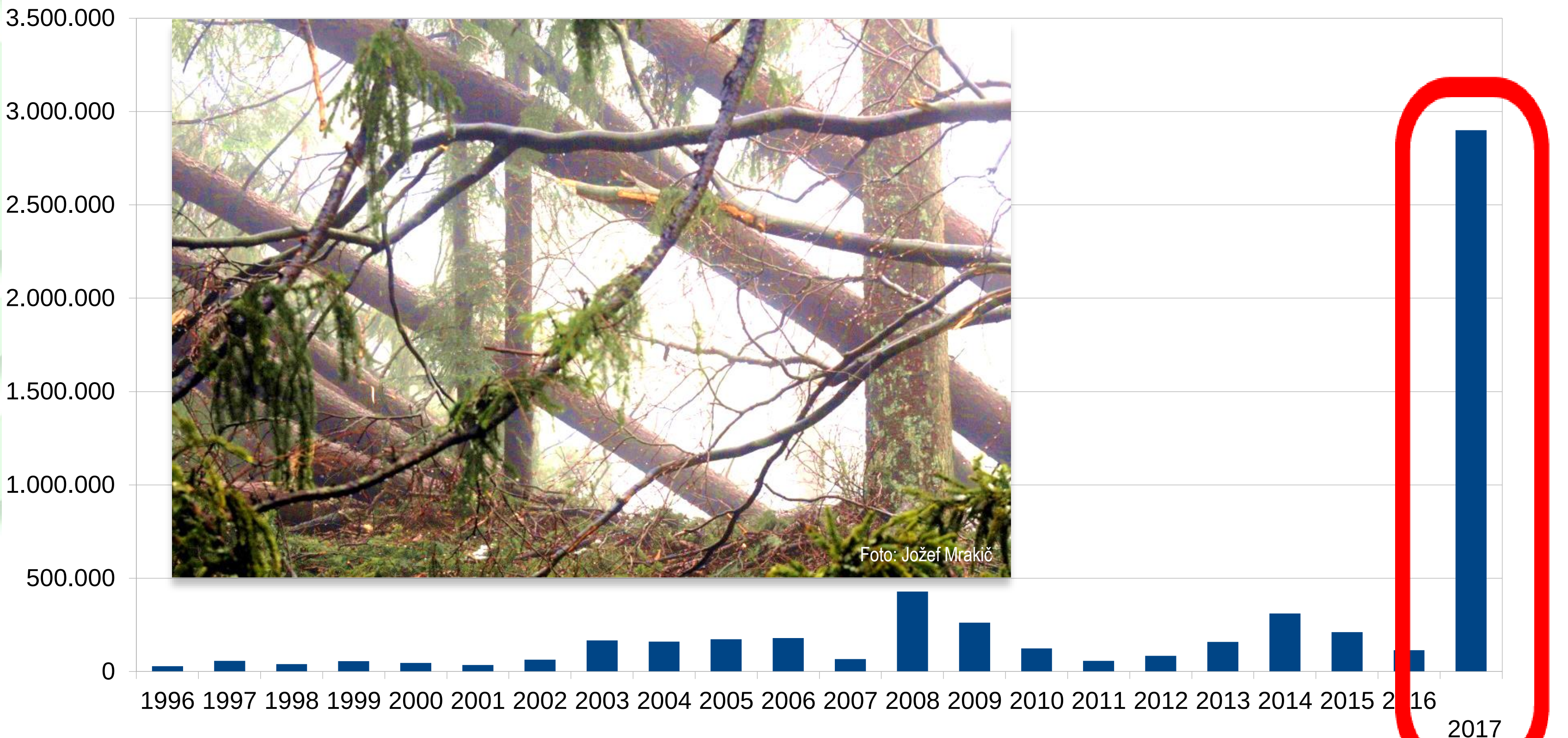
- 602.000 ha (51 %) of forests damaged
- 1/3 conifers, 2/3 broadleaves
- 15.000 km of blocked forest roads
- 14.000 ha need reestablishment of new forest
- 900 ha area to be planted
- 214 mio EUR = financial damage in forests + 214 mio EUR elsewhere

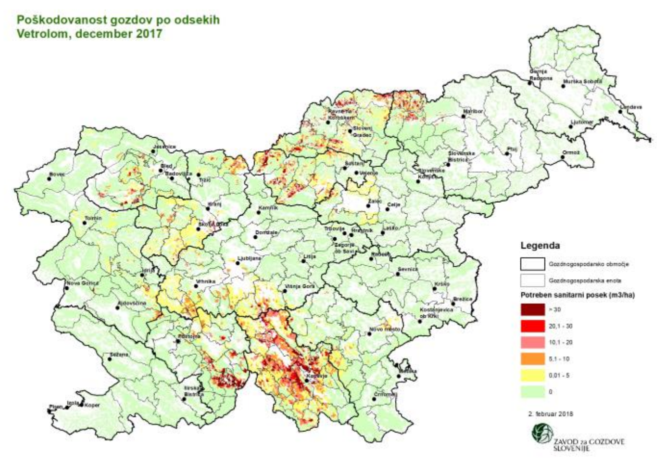
Foto:Borut Debevc

year	10^6 m3
1896	0,5
1953	0,1
1975	0,3
1980	0,7
1985	0,5
1995	0,7
1996	0,9
2014	**9,3**

Wood removed 2014-2018: 75%

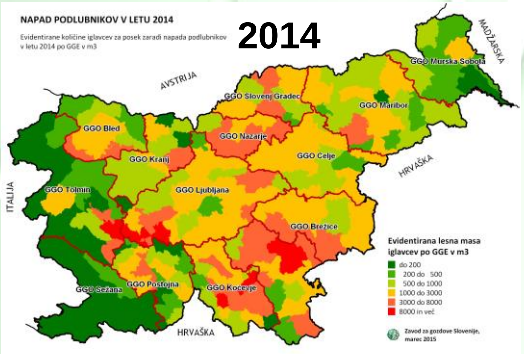
…and a wind-break in December 2017 gave an additional push to bark beetle infestation…

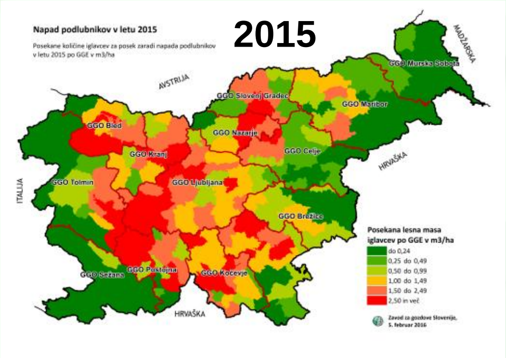


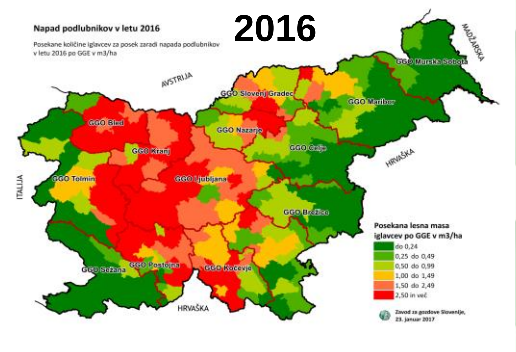


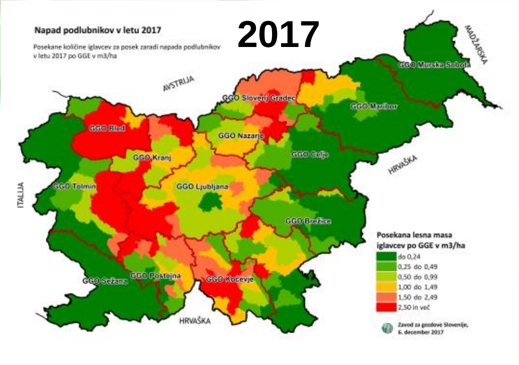
Damage: 2,9 mio m3
Financial damage: 48 mio €
<u>Wood removed in 2018:</u> ~ 100%:

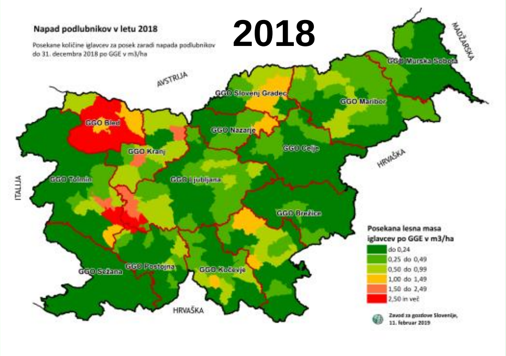
Bark-beetle outbreak in 2014-2020

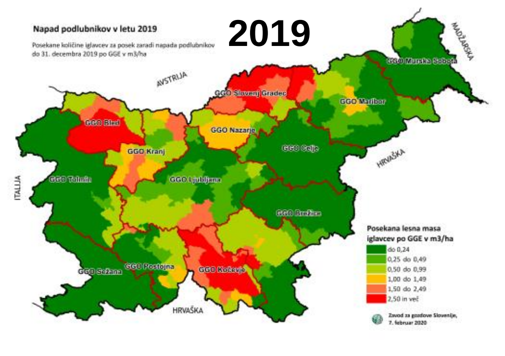


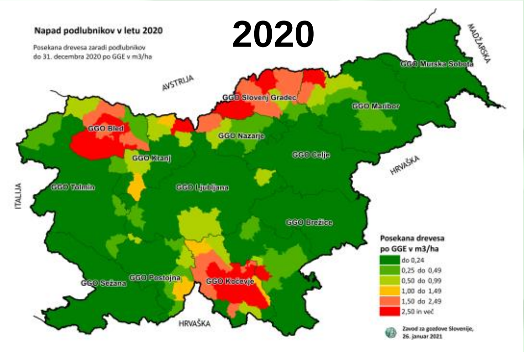












Summary of bark-beetle outbreak in 2014 – 2020

2014: 420.000 m^3

2015: 2.150.000 m^3

2016: 2.210.000 m^3

2017: 1.720.000 m^3

2018: 700.000 m^3

2019: 1.330.000 m^3

2020: 760.000 m^3

SUM 2014 - 2020: 9,3 mio m^3

160 mio EUR = financial damage

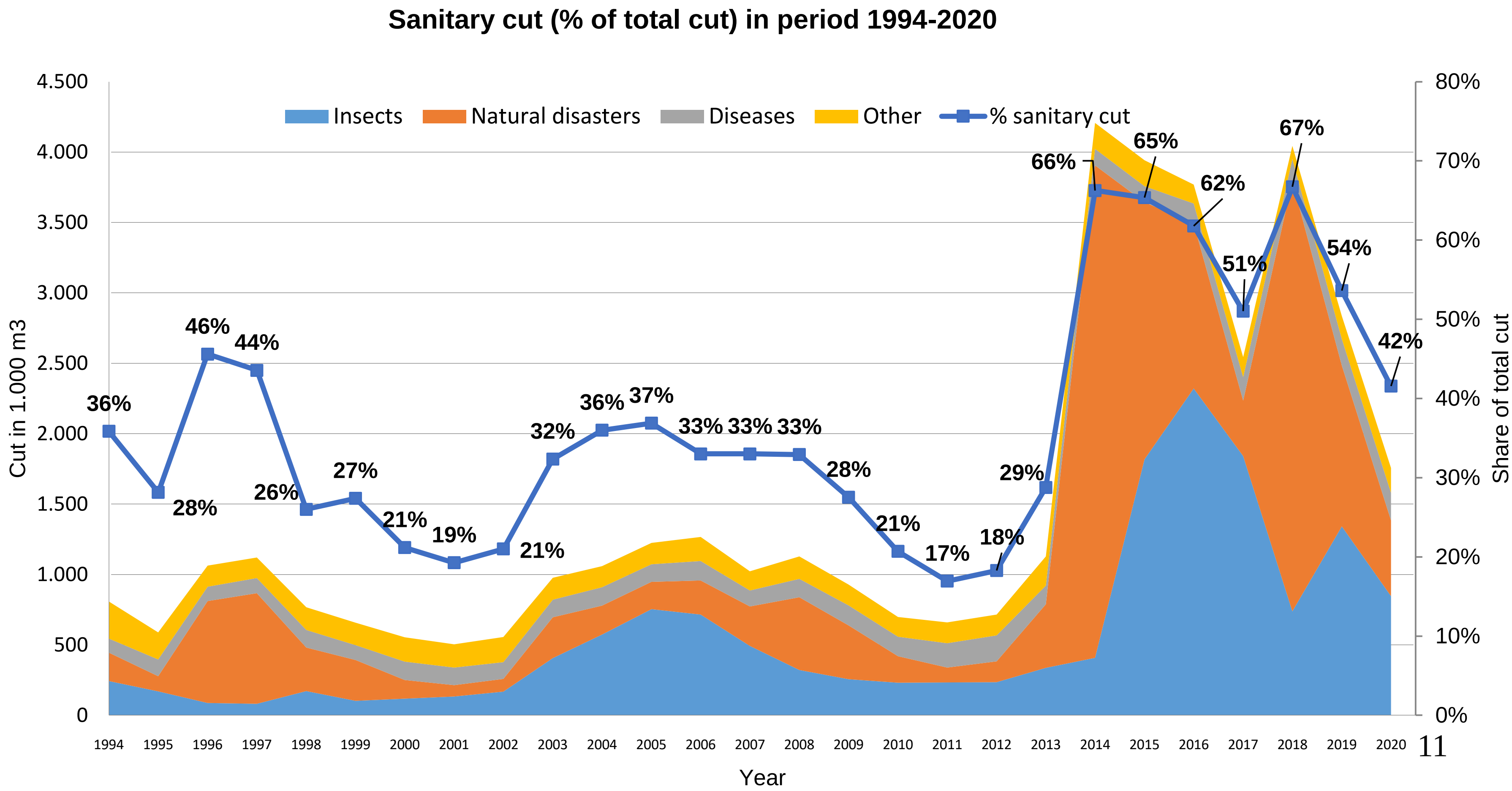
SUM of ice-break + windthrow + bark beetle (2014-2020):

- 65 % of forests affected
- 400+ MIO € damage
- 30.000 ha to be renewed, of which 1.700 ha by planting (23 species)
- Increment, stock: „survived“

Damaged trees removed 2014-2020: ~ 100%

Previous year record bark-beetle outbreak in last 100 years: 750.000 m^3 (2005)

Who decides about cutting – nature or a forester?



We faced all possible „troubles“ and did the best what our profession can deliver at such occasion.
How was it with cost effectiveness of recovery & prevented damage?

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A big difference in the costs and effects of recovery when it is:

a) **Spontaneous:**
- timber markets & value ⬇
- unpredictable course of actions
- bigger risk of secondary damage
- later finnished or uncomplete recovery
- more casualties
- stagnation or regression of the forestry profession
- small-scale owners are mostly not able to take care of the forest
- bottlenecks / blocades

b) **Smartly guided:**
- timber markets & value ↓
- professional guidance
- overwiev of the sitution
- lower costs (plans, seedlings etc.)
- support of state, public, media
- more prevented secondary damage
- faster restauration
- collected useful experience for related cases and future events
- mostly avoided bottlenecks
- balancing the expectations (of all) with the real possibilities

Has it any sense to „chase“ the bark-beetles?

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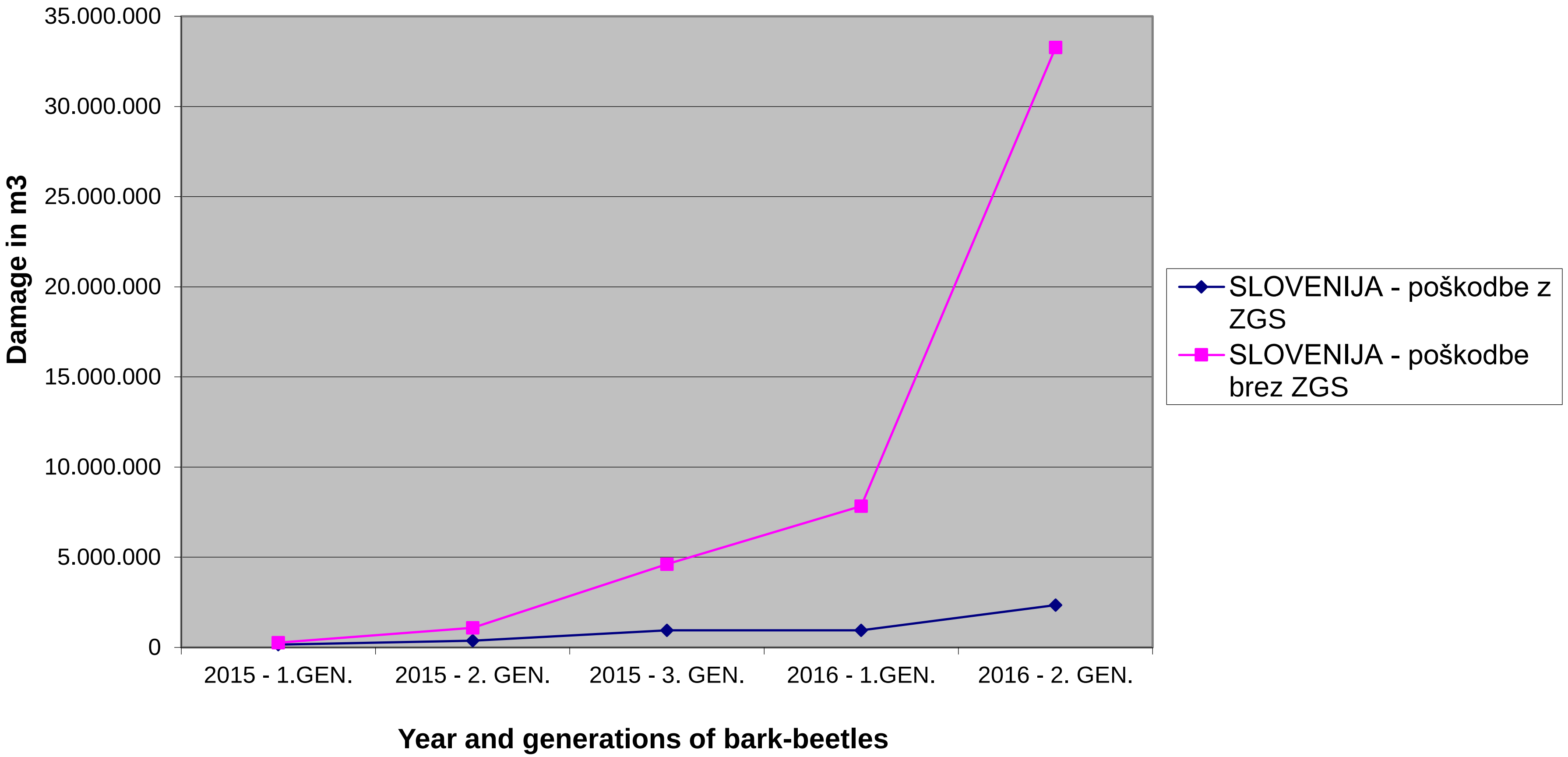
Theoretical calculation of the increase in damage due to bark beetles with (in blue) and without (in pink) the influence of Slovenia Forest Service on the process of sanitary logging



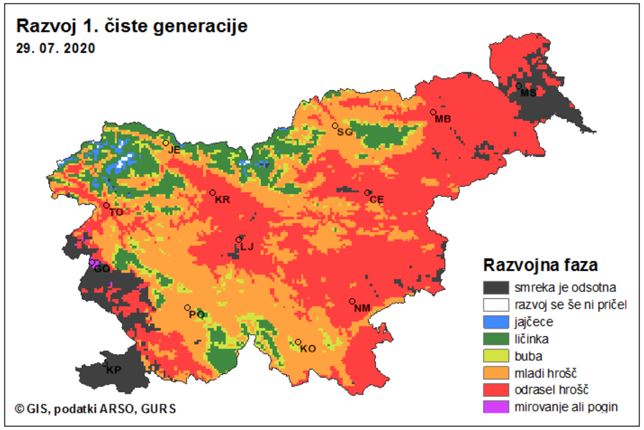
Improvement of the bark beetle monitoring system

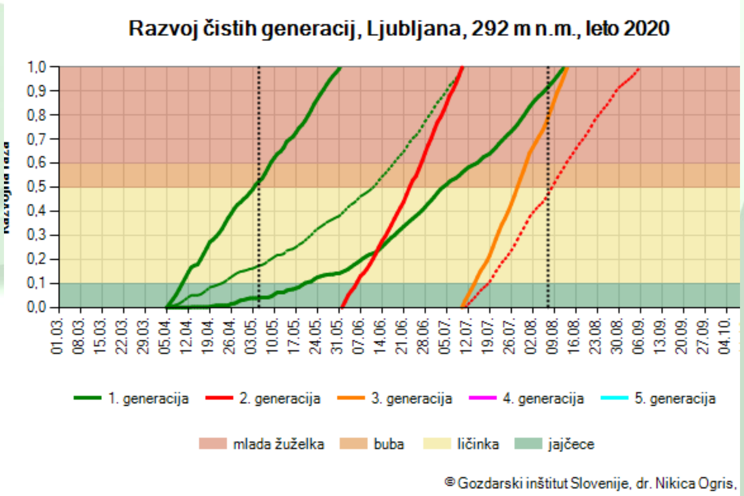
Phenological models that simulate the development of *Ips typographus* (**RITY model**) and *Pityogenes chalcographus* (**CHAPY model**) based on local conditions were developed.

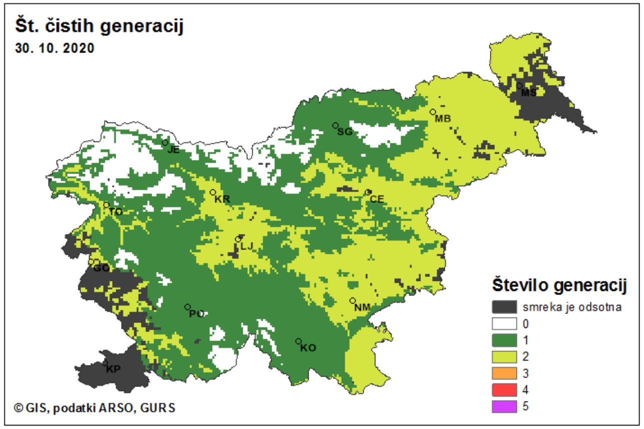
RITY and CHAPY models are based on PHENIPS phenological model.

They are used for:

- **optimization of the trapping system**,
- **short term prognoses** of bark beetle outbreaks,
- setting the **deadlines for sanitary feelings** of attacked spruce trees.







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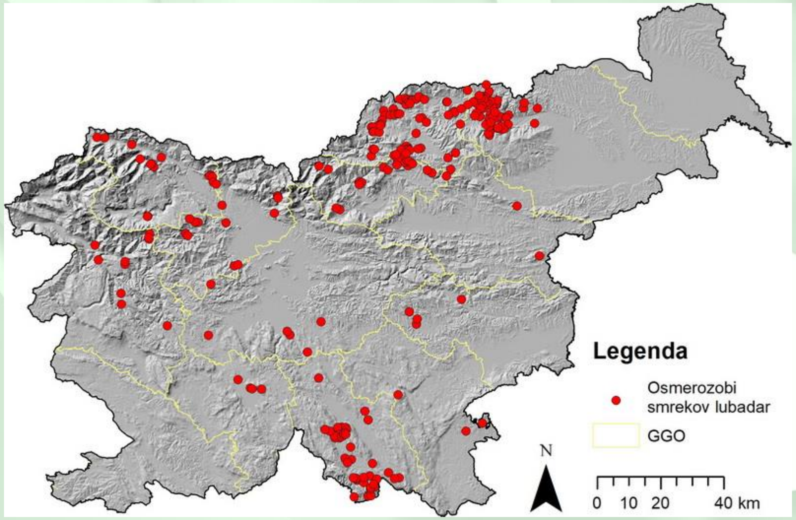
Outputs of RITY & CHAPY models

- Development through time.
- Onset of swarming, infestation.
- Number of generations (filial, sister).
- Suggesting a deadline for sanitary felling.
- Short term prognoses for bark beetle outbreaks.



Locations of pheromone traps where the threshold of 9,000 specimens of *Ips typographus* was exceeded in 2020, indicating the outbreak

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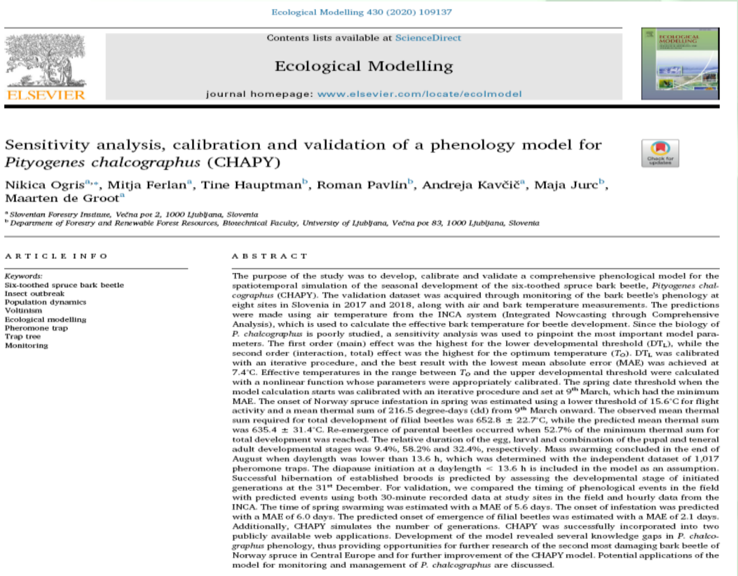
RITY & CHAPY additional info

- Ogris, N., Ferlan, M., Hauptman, T., Pavlin, R., Kavčič, A., Jurc, M., De Groot, M., 2019. RITY – **A phenology model of *Ips typographus* as a tool for optimization of its monitoring.** Ecol. Model. 410, 108775.
- Ogris, N., Ferlan, M., Hauptman, T., Pavlin, R., Kavčič, A., Jurc, M., De Groot, M., 2020. **Sensitivity analysis, calibration and validation of a phenology model for *Pityogenes chalcographus* (CHAPY)**. Ecol. Model. 430, 109137.
- **https://www.zdravgozd.si/**



Ecological Modelling 430 (2020) 109137

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Sensitivity analysis, calibration and validation of a phenology model for *Pityogenes chalcographus* (CHAPY)

Nikica Ogris[a,*], Mitja Ferlan[a], Tine Hauptman[b], Roman Pavlin[b], Andreja Kavčič[a], Maja Jurc[b], Maarten de Groot[a]

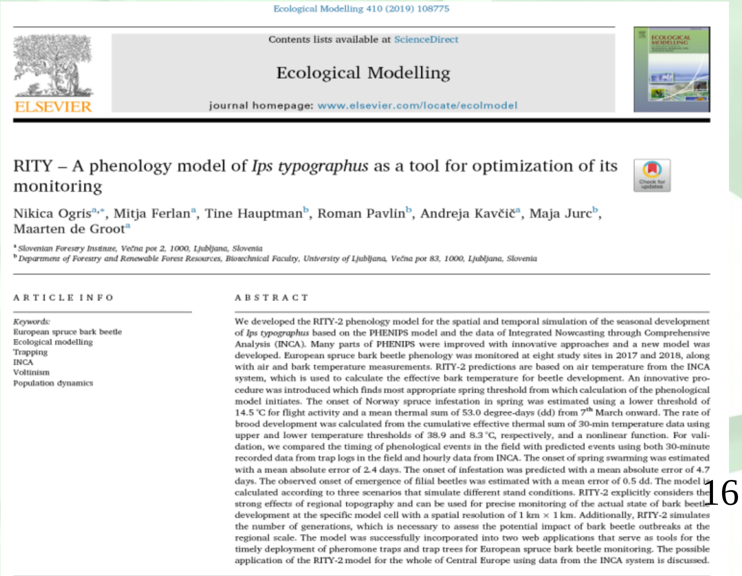
[a] Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, Slovenia
[b] Department of Forestry and Renewable Forest Resources, Biotechnical Faculty, University of Ljubljana, Večna pot 83, 1000 Ljubljana, Slovenia

ARTICLE INFO

Keywords:
Six-toothed spruce bark beetle
Insect outbreak
Population dynamics
Voltinism
Ecological modelling
Pheromone trap
Trap tree
Monitoring

ABSTRACT

The purpose of the study was to develop, calibrate and validate a comprehensive phenological model for the spatiotemporal simulation of the seasonal development of the six-toothed spruce bark beetle, *Pityogenes chalcographus* (CHAPY). The validation dataset was acquired through monitoring of the bark beetle's phenology at eight sites in Slovenia in 2017 and 2018, along with air and bark temperature measurements. The predictions were made using air temperature from the INCA system (Integrated Nowcasting through Comprehensive Analysis), which is used to calculate the effective bark temperature for beetle development. Since the biology of *P. chalcographus* is poorly studied, a sensitivity analysis was used to pinpoint the most important model parameters. The first order (main) effect was the highest for the lower developmental threshold (DT_L), while the second order (interaction, total) effect was the highest for the optimum temperature (T_O). DT_L was calibrated with an iterative procedure, and the best result with the lowest mean absolute error (MAE) was achieved at 7.4°C. Effective temperatures in the range between T_O and the upper developmental threshold were calculated with a nonlinear function whose parameters were appropriately calibrated. The spring date threshold when the model calculation starts was calibrated with an iterative procedure and set at 9th March, which had the minimum MAE. The onset of Norway spruce infestation in spring was estimated using a lower threshold of 15.6°C for flight activity and a mean thermal sum of 216.5 degree-days (dd) from 9th March onward. The observed mean thermal sum required for total development of filial beetles was 652.8 ± 22.7°C, while the predicted mean thermal sum was 635.4 ± 31.4°C. Re-emergence of parental beetles occurred when 52.7% of the minimum thermal sum for total development was reached. The relative duration of the egg, larval and combination of the pupal and teneral adult developmental stages was 9.4%, 58.2% and 32.4%, respectively. Mass swarming concluded in the end of August when daylength was lower than 13.6 h, which was determined with the independent dataset of 1,017 pheromone traps. The diapause initiation at a daylength < 13.6 h is included in the model as an assumption. Successful hibernation of established broods is predicted by assessing the developmental stage of initiated generations at the 31st December. For validation, we compared the timing of phenological events in the field with predicted events using both 30-minute recorded data at study sites in the field and hourly data from the INCA. The time of spring swarming was estimated with a MAE of 5.6 days. The onset of infestation was predicted with a MAE of 6.0 days. The predicted onset of emergence of filial beetles was estimated with a MAE of 2.1 days. Additionally, CHAPY simulates the number of generations. CHAPY was successfully incorporated into two publicly available web applications. Development of the model revealed several knowledge gaps in *P. chalcographus* phenology, thus providing opportunities for further research of the second most damaging bark beetle of Norway spruce in Central Europe and for further improvement of the CHAPY model. Potential applications of the model for monitoring and management of *P. chalcographus* are discussed.



Ecological Modelling 410 (2019) 108775

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Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

RITY – A phenology model of *Ips typographus* as a tool for optimization of its monitoring

Nikica Ogris[a,*], Mitja Ferlan[a], Tine Hauptman[b], Roman Pavlin[b], Andreja Kavčič[a], Maja Jurc[b], Maarten de Groot[a]

[a] Slovenian Forestry Institute, Večna pot 2, 1000, Ljubljana, Slovenia
[b] Department of Forestry and Renewable Forest Resources, Biotechnical Faculty, University of Ljubljana, Večna pot 83, 1000, Ljubljana, Slovenia

ARTICLE INFO

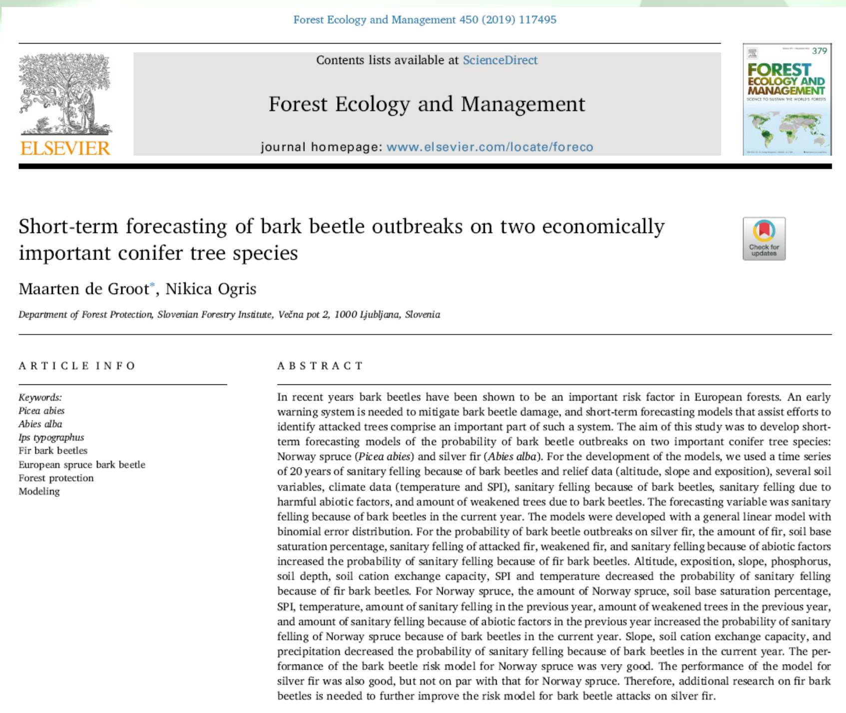
Keywords:
European spruce bark beetle
Ecological modelling
Trapping
INCA
Voltinism
Population dynamics

ABSTRACT

We developed the RITY-2 phenology model for the spatial and temporal simulation of the seasonal development of *Ips typographus* based on the PHENIPS model and the data of Integrated Nowcasting through Comprehensive Analysis (INCA). Many parts of PHENIPS were improved with innovative approaches and a new model was developed. European spruce bark beetle phenology was monitored at eight study sites in 2017 and 2018, along with air and bark temperature measurements. RITY-2 predictions are based on air temperature from the INCA system, which is used to calculate the effective bark temperature for beetle development. An innovative procedure was introduced which finds most appropriate spring threshold from which calculation of the phenological model initiates. The onset of Norway spruce infestation in spring was estimated using a lower threshold of 14.5 °C for flight activity and a mean thermal sum of 53.0 degree-days (dd) from 7th March onward. The rate of brood development was calculated from the cumulative effective thermal sum of 30-min temperature data using upper and lower temperature thresholds of 38.9 and 8.3 °C, respectively, and a nonlinear function. For validation, we compared the timing of phenological events in the field with predicted events using both 30-minute recorded data from trap logs in the field and hourly data from INCA. The onset of spring swarming was estimated with a mean absolute error of 2.4 days. The onset of infestation was predicted with a mean absolute error of 4.7 days. The observed onset of emergence of filial beetles was estimated with a mean error of 0.5 dd. The model is calculated according to three scenarios that simulate different stand conditions. RITY-2 explicitly considers the strong effects of regional topography and can be used for precise monitoring of the actual state of bark beetle development at the specific model cell with a spatial resolution of 1 km × 1 km. Additionally, RITY-2 simulates the number of generations, which is necessary to assess the potential impact of bark beetle outbreaks at the regional scale. The model was successfully incorporated into two web applications that serve as tools for the timely deployment of pheromone traps and trap trees for European spruce bark beetle monitoring. The possible application of the RITY-2 model for the whole of Central Europe using data from the INCA system is discussed.

Short term prognosis for sanitary felling of spruce due to bark beetles

- Model based prediction.
- Reliable probability of sanitary felling (AUC=0.89).
- Prognosis made each year in spring for current year.



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ELSEVIER

Short-term forecasting of bark beetle outbreaks on two economically important conifer tree species

Maarten de Groot*, Nikica Ogris

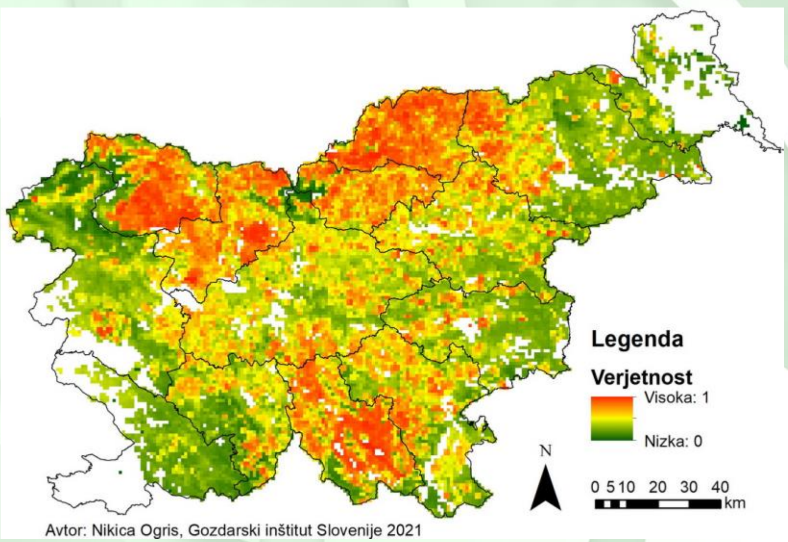
Department of Forest Protection, Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, Slovenia

ARTICLE INFO

Keywords:
Picea abies
Abies alba
Ips typographus
Fir bark beetles
European spruce bark beetle
Forest protection
Modeling

ABSTRACT

In recent years bark beetles have been shown to be an important risk factor in European forests. An early warning system is needed to mitigate bark beetle damage, and short-term forecasting models that assist efforts to identify attacked trees comprise an important part of such a system. The aim of this study was to develop short-term forecasting models of the probability of bark beetle outbreaks on two important conifer tree species: Norway spruce (*Picea abies*) and silver fir (*Abies alba*). For the development of the models, we used a time series of 20 years of sanitary felling because of bark beetles and relief data (altitude, slope and exposition), several soil variables, climate data (temperature and SPI), sanitary felling because of bark beetles, sanitary felling due to harmful abiotic factors, and amount of weakened trees due to bark beetles. The forecasting variable was sanitary felling because of bark beetles in the current year. The models were developed with a general linear model with binomial error distribution. For the probability of bark beetle outbreaks on silver fir, the amount of fir, soil base saturation percentage, sanitary felling of attacked fir, weakened fir, and sanitary felling because of abiotic factors increased the probability of sanitary felling because of fir bark beetles. Altitude, exposition, slope, phosphorus, soil depth, soil cation exchange capacity, SPI and temperature decreased the probability of sanitary felling because of fir bark beetles. For Norway spruce, the amount of Norway spruce, soil base saturation percentage, SPI, temperature, amount of sanitary felling in the previous year, amount of weakened trees in the previous year, and amount of sanitary felling because of abiotic factors in the previous year increased the probability of sanitary felling of Norway spruce because of bark beetles in the current year. Slope, soil cation exchange capacity, and precipitation decreased the probability of sanitary felling because of bark beetles in the current year. The performance of the bark beetle risk model for Norway spruce was very good. The performance of the model for silver fir was also good, but not on par with that for Norway spruce. Therefore, additional research on fir bark beetles is needed to further improve the risk model for bark beetle attacks on silver fir.



Prognosis for sanitary felling of spruce for 2021

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Lessons learned are integrated into forest management

Seen from the perspective of Earth's history of the last 500 million years: humanity and spruce will have a hard time surviving the next few 100 million years. But, we are also here to make sure that the forests are given to our grandchildren in a suitable form, so we need to take care of them here and now. From the Slovenian perspective, the following is clear:

1. **Mixed forest of habitat-adapted tree species and natural regeneration as a part of close-to-nature forest management are in long term the basis for successful and cost-effective multifunctional forestry and damage reduction** (inclusive bark-beetle infestation).
2. **Monocultures, especially of spruce, are due to climate changes a forestry system with huge probability to fail.**
3. **No forestry system can survive without reducing the populations of large herbivores to a sustainable level.**
4. The goal should not always be only the highest timber quality / production. **Stability of the trees and stands and genetic diversity** are also very or even more important.
5. Also NATURA 2000 has to be modernized and has to admit that there are climate changes and evolution going on.

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