Insect pests in the forests of Bulgaria and their economic importance

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Abstract: Based on the forest-pathological inventories for the last 30 years, the economic importance of the insect pests in the Bulgarian forests and its dynamics for the periods 1990–2002 and 2003–2018 were determined. Insect pest attacks have declined sharply in the last sixteen years- in coniferous forests they have decreased three times and in deciduous ones - almost six times. Generally, the health status of the forests, with regard to pest status, after 2003 is improving, and this is more clearly expressed in the deciduous forests. As a result of this development, the pest control measures areas gradually shifted from deciduous to coniferous forests. Since 2003, deterioration in the health status of ageing coniferous plantations has been identified, however, with the attacks of two major groups of pests escalating- pine sawflies and bark beetles.

Key words: strong attacks, pest control measures, forest-pathological forecasts

Introduction

Forests in Bulgaria are part of the European and global forest wealth. For decades the total area of forest territories in Bulgaria has been steadily increasing, in the period 1965–2008 it has increased from 3.612 mill. ha to 4.114 mill. ha, or 37.06% of the country's territory. By the end of 2008, the growing stock of Bulgarian forests was 591.162 mill. m³, with an annual increment of about 14 mill. m³. The forests' average age is 51. Deciduous forests predominate (69.8%), and coniferous forests occupy 30.2% of the forest area. The coniferous forests consist mainly of Scots pine (52%), Austrian black pine (26%) and Norway spruce (15%). Their composition is dominated by pine plantations (85%). The deciduous forests consist mainly of beech (48%) and oak (30%) (EFA 2015).

However, the condition of the forests is an issue of concern. In recent years, under the influence of climate change, the forests in the lowlands have been showing signs of decline. These processes are clearly expressed in pine plantations and coppice oak forests. Most of the pine plantations in Bulgaria were created in the 1960s and 1970s at altitudes below 800 m, i.e. outside their natural range, where they are short lived (Popov et al. 2015). Their natural regeneration by seed is a rare exception, and in times of economic hardship, artificial reforestation is also very limited (Popov et al. 2018a). Coppice forests in Bulgaria occupy 1 998 033 ha or 48% of the forest territories of the country. They are represented mainly by oaks (60% of the area), of which the Turkey oak is particularly sensitive to decline (Popov et al. 2018b).

Apart from the main factor, the global warming, various other abiotic and biotic factors can also influence on forest health, e.g. insects, pathogens, weather, pollution, wind, etc. Of these, insect attacks can be a serious threat to forest ecosystems. The economic importance of the species is determined by the amount of damage inflicted and the necessary costs to control it. In practice, the economic importance of a particular species is determined by the area of pest control measures to counter its attacks. Other possible criteria are the attacked area, which is divided into heavily and slightly attacked, the spent resources for pest control and the damage (the loss of increment and growing stock, valued in cubic meters or money).

Analyses based on the area of necessary control measures against pests outbreaks in
Bulgaria have been made in studies of Mirchev et al. (2003) and Zaemdzhikova et al. (2019a). According to Mirchev (2003), attacks by 61 different insect species have been reported in the forests of Bulgaria in 1990–2002. The necessary control measures have been taken only against 12 species, i.e. only 20% of the insect pests caused economically significant damage to the country's forests. The area of the necessary pest control measures was 630 000 ha (48 500 ha per year), of which 77% was in deciduous forests and only 23% in coniferous forests. Almost all forest protection measures (99%) were directed against leaf-eating insects. No control against wood-boring pests was reported during the period.

For the period 2003–2018, in a study by Zaemdzhikova et al. (2019a), strong attacks by 23 species or taxonomic groups of insects have been reported in coniferous forests, and by 33 species in deciduous ones. The necessary control measures have been taken against 40 species of insects. The sum of the heavily attacked areas for the period amounts to 225 000 ha (14 062 ha per year). The necessary control measures area is 178 244 ha (11 140 ha per year), of which 60% is in deciduous forests and only 40% in coniferous forests.

The purpose of this work is to outline the trends in forest health and the forest-pathological situation in Bulgaria on the basis of official professional data on the size of the attacks of insect pests in the periods 1990–2002 and 2003–2018.

Material and methods

Data on insect pest attacks and protection measures areas against them are based on archive data and the information system of the Executive Forest Agency (EFA). The main source of information were the annual "Forest-pathological forecasts" for the period 2003–2018 (the results of the pest inventory), published on the website of EFA (http://www.iag.bg/docs/lang/1/cat/6/index) and earlier publications (Mirchev et al. 2003, Zaemdzhikova et al. 2019a).

Two criteria for the magnitude of the attacks and the pest’s economic importance - the area of strong attacks and the area of necessary control measures against them are used. Both are parameters of planning. The difference is in the details - the attacks of some species are usually not treated. We prefer the heavily attacked area, but also cite the necessary measures area for the compatibility with older publications. The area of weak attacks, which is also registered and known, was not taken into account, since it is less important and less certain.

Results

The area of necessary control measures during the period 1990–2018 is shown in Table 1. The extent of attacks during the period 2003–2018 is represented by the heavily attacked area, which usually coincides with the area of measures.

The distribution of the area of necessary pest control measures during the two periods is presented on Fig. 1. The data in Table 1 and Fig. 1 show, that since 2003 the serious attacks have decreased almost 5 times, with the decrease being stronger in deciduous forests (6 times), and less in coniferous forests (2.5 times).

From Fig. 1 it can be concluded that the health of the forests, in regard to pest status, after 2003 is improving, which is more clearly expressed in the deciduous forests. As a result of this development, the focus of the pest control activities gradually shifted to coniferous forests.

In the period 1990–2018, in Bulgaria's coniferous forests, control measures have been applied against 17 species or taxonomic groups of insects, and in the deciduous forests against 25 species (Table 1). For the period 2003–2018 from the data in Table 1 it can be estimated that 87.5% of the strong attacks in all forests are caused by leaf-eating pests - gypsy moths (37.9%), pine processi...
Table 1. Heavily attacked area by pests and necessary control measures area during the period 1990–2018.

| Insect pest | Necessary control measures area, [ha per year] | Heavily attacked area, [ha per year] |
|-------------|-----------------------------------------------|-------------------------------------|
|             | 1990–2002 | 2003–2018 | 2003–2018 |

**Coniferous forests**

**LEAF-EATING INSECTS**

| Insect pest | 1990–2002 | 2003–2018 | 2003–2018 |
|-------------|-----------|-----------|-----------|
| Thaumetopoea pityocampa (Denis & Schiffermüller, 1775) | 9 710.5 | 2 773.4 | 2 649.2 |
| Neodiprion sertifer (Geoffroy, 1785) | 1 465.8 | 1 174.1 |
| Diprion pini (Linnaeus, 1758) | 121.6 | 129.3 |
| Acantholyda hieroglyphica (Christ, 1791) | 5.8 | 1.5 |
| Diprionidae spp. Pamphiliidae spp. | 1 299.7 | 0.5 | 0.3 |

**WOOD-BORING INSECTS**

| Insect pest | 1990–2002 | 2003–2018 | 2003–2018 |
|-------------|-----------|-----------|-----------|
| Scolytinae spp. | 20.8 | 1 233.3 |
| Ips acuminatus (Gyllenhal, 1827) | 6.0 | 213.6 |
| Ips sexdentatus (Börner, 1776) | 1.0 | 27.0 |
| Ips typographus (Linnaeus, 1758) | 0.3 | 6.7 |
| Tomicus piniperda (Linnaeus, 1758) | 2.0 | 160.5 |
| Pityogenes bidentatus (Herbst, 1784) | 0.03 | 0.1 |
| Pityogenes chalcographus (Linnaeus, 1761) | 0.0 | 0.2 |
| Pityogenes quadridentis (Hartig, 1834) | 0.0 | 2.2 |
| Hyllobius abietis (Linnaeus, 1758) | 21.5 | 0.1 |
| Pissodes castaneus (De Geer, 1775) | 0.2 | 0.1 |
| Cerambycidae spp. | 0.0 | 6.0 |
| Buprestidae spp. | 0.0 | 1.0 |

**SUCKING INSECT PEASTS**

| Insect pest | 1990–2002 | 2003–2018 | 2003–2018 |
|-------------|-----------|-----------|-----------|
| Aphididae spp. | 6.5 | 7.5 |
| Diaspididae spp. | 0.0 | 0.2 |
| Adelgidae spp. | 0.0 | 0.2 |

**ROOT PESTS**

| Insect pest | 1990–2002 | 2003–2018 | 2003–2018 |
|-------------|-----------|-----------|-----------|
| Melolonthidae spp. | 2.4 | 2.3 |
| Otiorhynchus ovatus (Linnaeus, 1758) | 1.3 | 0.1 |

**PESTS ON BUDS**

| Insect pest | 1990–2002 | 2003–2018 | 2003–2018 |
|-------------|-----------|-----------|-----------|
| Rhyacionia buoliana (Denis & Schiffermüller, 1775) | 22.1 | 0.2 | 1.1 |

**TOTAL**

| 11 032.3 | 4 429.4 | 5 616.6 |

**Deciduous forests**

**LEAF-EATING INSECTS**

| Insect pest | 1990–2002 | 2003–2018 | 2003–2018 |
|-------------|-----------|-----------|-----------|
| Lymantria dispar (Linnaeus, 1758) | 25 167.6 | 5 350.6 | 5 330.0 |
| Tortricidae spp., Geometridae spp. | 9 289.3 | 842.7 | 2 508.8 |
| Orchestes fagi (Linnaeus, 1758) | 0.0 | 197.4 |
| Chrysomela populi Linnaeus, 1758 | 5.2 | 275.1 | 135.2 |
| Euprostis chrysorrhoea (Linnaeus, 1758) | 2 690.7 | 30.1 | 48.1 |
| Stereonychus fraxini (De Geer, 1775) | 0.0 | 40.4 |
| Byctiscus populi (Linnaeus, 1758) | 11.6 | 47.6 | 26.1 |
| Thaumetopoea processionea (Linnaeus, 1758) | 181.2 | 3.3 | 24.4 |
| Altica quercetorum Foudras, 1860 | 0.0 | 12.6 |
| Chrysomela vigintipunctata Scopoli, 1763 | 3.6 | 3.6 |
| Leucoma salicis (Linnaeus, 1758) | 4.6 | 5.9 | 3.0 |
| Nyctea asiatica (Krulikovsky, 1904) | 1.8 | 2.9 |
| Clastera anastomosis (Linnaeus, 1758) | 0.0 | 2.0 |
| Phyllonorycter populifoliella (Treitschke, 1833) | 2.0 | 1.7 |
| Hyphantria cunea (Drury, 1773) | 38.5 | 0.0 | 1.5 |
| Cladius spp. | 1.5 | 1.5 |
Byctiscus betulae (Linnaeus, 1758) | 0.8 | 0.9  
Yponomeuta spp. | 0.0 | 1.2  
Noctuidae spp. | 0.0 | 0.8  
Yponomeuta mahalebella Guenée, 1845 | 1.4 | 0.8  
Gracillariidae spp. | 0.1 | 0.0  

**WOOD-BORING INSECTS**

Paranthrene tabaniformis (Rottemburg, 1775) | 79.2 | 51.8  
Saperda populnea (Linnaeus, 1758) | 35.9 | 23.4  
Trachypteris picta (Pallas, 1773) | 13.1 | 5.2  
Lamia textor (Linnaeus, 1758) | 1.6 | 2.9  
Saperda carcharias (Linnaeus, 1758) | 1.2 | 1.2  
Sesia apiformis (Clerck, 1759) | 1.1 | 1.1  

**SUCKING INSECT PESTS**

Aphididae spp. | 0.0 | 3.0  

**FRUIT PESTS**

Etiella zinckenella (Treitschke, 1832) | 5.7 | 0.9  
Curculio nucum Linnaeus, 1758 | 0.1 | 0.1  

**GALL FORMING INSECTS**

Dryomyia circinans (Giraud, 1861) | 0.0 | 0.1  

**OMNIVORES**

Dociostaurus maroccanus (Thunberg, 1815) | 9.2 | 0.0 | 0.0  
Tettigonia viridissima (Linnaeus, 1758) | 0.9 | 1.4  
Tettigoniidae spp. | 5.8 | 1.3  

**TOTAL** | 37397.9 | 6710.9 | 8435.3  

**TOTAL (Coniferous and Deciduous forests)** | 48430.2 | 11140.3 | 14051.9  

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**Fig. 1.** Necessary control measures area during the period 1990–2018.
Fig. 2. Distribution of the areas of the pest attacks and necessary control measures in 2003–2018.

Fig. 3. Distribution of the necessary control measures area by insect pest species and periods.
Insect attacks and control measures against them for the period 2003–2018 (Zaemdzhikova et al. 2019a) differ from the data by Mirchev et al. (2003) for the period 1990–2002. During the current period 2003–2018, there was a pronounced reduction of the area of necessary control measures and, at the same time, a twofold increase in the number of pest species.
against which they are planned. The area of necessary control measures has decreased almost five times, from 48,000 ha per year to almost 11,000 ha per year. A possible reason for this is that the beginning of the period 2003–2018 coincides with the end of the droughts in 1992–2005 (Rosnev et al. 2006), and at the same time it coincides with the success in the fight against the gypsy moth (Georgiev et al. 2014a). There is no such breakthrough in coniferous forests, due to which the share of insect attacks in them has relatively increased.

The poor health of conifers is related to the ageing pine plantations (Mirchev et al. 2016, Popov et al. 2018a). Additional factors are insufficient tending of plantations and periodic droughts that impair their physiological condition. The lack of modern sanitary measures, especially after damage by abiotic factors is a prerequisite for mass outbreaks of highly aggressive bark beetles and other xylophages.

In Bulgaria, major damage in Scots pine plantations is caused by Ips acuminatus, which accounts for up to 80% of the total damage done by bark beetles (Mirchev et al. 2016). In the early 2000s, I. acuminatus has been classified as one of the ten most important wood-boring pests in Europe. It has been rated as particularly harmful in Germany, Slovakia, Switzerland, Romania and Spain, in the Swiss and the Italian Alps (Grégoire & Evans 2004, Wermelinger et al. 2008, Colombari et al. 2013). Often engraver beetle attacks are accompanied by other bark beetle attacks I. sexdentatus, T. minor and T. piniperda (Sitonen 2014), which are noticeably present in the attacked areas in Bulgaria as well.

Concerning leaf-eating pests, serious attacks by the T. pityocampa and pine sawflies have been recorded. The pine processionary moth is considered to be the most dangerous defoliator eating pest in pine ecosystems, due to the strong attacks and the respective significant area of the forest protection measures. As a result of climate change, an expansion of the species has been observed in recent decades in Central Bulgaria (Mirchev et al. 2017, Zaemdzhi kova et al. 2019b). A likely cause is climate warming, which has been identified at national and global levels (Raev et al. 2011, IPCC 2007).

Based on the area of forest protection measures and strong attacks, pine sawflies are identified as the „second” serious group of leaf-eating pests in Bulgaria’s forests. In addition to the costs of pest control, there are also significant economic losses, which a certain species can cause as a result of strong attacks, especially if they are in consecutive years. An essential part of the monetary value of this damage is the combination of growing stock and increment losses. Other countries’ experience shows serious loss of annual increment and growing stock caused by strong attacks of pine processionary moths and pine sawflies, of which the economic significance of the European pine sawfly is of primary importance (Neodiprion sertifer (Geoffroy, 1785)) (CABI 2020).

Currently there is no known estimate for the country’s losses of increment and growing stock caused by the attacks of the two economically most significant species, T. pityocampa and pine sawflies. For this reason, the scientific community’s assessment of the most important needle-eating pest remains a bit subjective. If the conclusion is based solely on area (attacked area or necessary treatment area), such a pest is likely to be the pine processionary moth. For the last sixteen years the area of necessary control measures against T. pityocampa has been twice larger than the ones against pine sawflies. However, if the degree of defoliation and the resulting loss of increment and growing stock are estimated, it is possible that the group of the pine sawflies may prevail.

In deciduous forests, the gypsy moth and the „Tortricidae-Geometridae” group have caused serious attacks over the years. Since 2003, gypsy moth attacks have been greatly reduced to less than 5,500 ha a year.
(Zaemzhikova et al. 2019). In comparison, in the past, its attacks amounting to 50–100 thousand ha repeated every 8–12 years (Georgiev et al. 2013, Georgiev 2018). The main reason for the sharp decrease in attacks is the introduction of the entomopathogenic fungus Entomophaga maimaiga Humber, Shimazu & R.S. Soper (1988) in Bulgaria in 1999, which has proved to be a powerful pest regulator (Georgiev et al. 2013, Georgiev et al. 2014 a, b, Pilarska et al. 2006, 2016, Zúbrik et al. 2016). The „Tortricidae-Geometridae” group is perceived as a secondary pest in our country, and for this reason there is no pest control against it.

In addition to the insect pests already discussed, there is also a perceptible presence of species in the forests, whose attacks are not recorded in the signal sheets. In deciduous forests such are the invasive species Corythucha arcuata (Say, 1832), nutritionally connected to Quercus spp., Corythucha ciliatae (Say, 1832) to Platanus occidentalis L., and Aproceros leucopoda (Takeuchi, 1939) trophically connected to Ulmus spp. (Dobreva et al. 2013, Simov et al. 2012). The gall-forming species Dryomyia circinans (Giraud, 1861) causes damage on the Turkey oak (Georgieva et al. 2019). The damage done by these insects results in loss of increment (CABI 2020), but so far we do not have a quantitative measure of this damage.

Conclusions

Forests’ health is strongly influenced by climate change, which necessitates their adaptation to changing environmental conditions. This requires the development and testing of forestry systems for their management. Deteriorating health and lack of timely forestry measures lead to the physiological weakening of the aging pine plantations, which is a prerequisite for insect pest attacks. In coniferous forests, strong attacks by bark beetles are an example. Unlike bark beetles, the attacks of leaf-eating insects, such as the pine processionary moth and pine sawflies, are rather due to climate change. In deciduous forests, especially in oak coppices, insect attacks prove to be an insignificant factor as compared to the urgent need for forestry systems that enable the coppice oak forests to be successfully converted to high forest issued from seed.

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