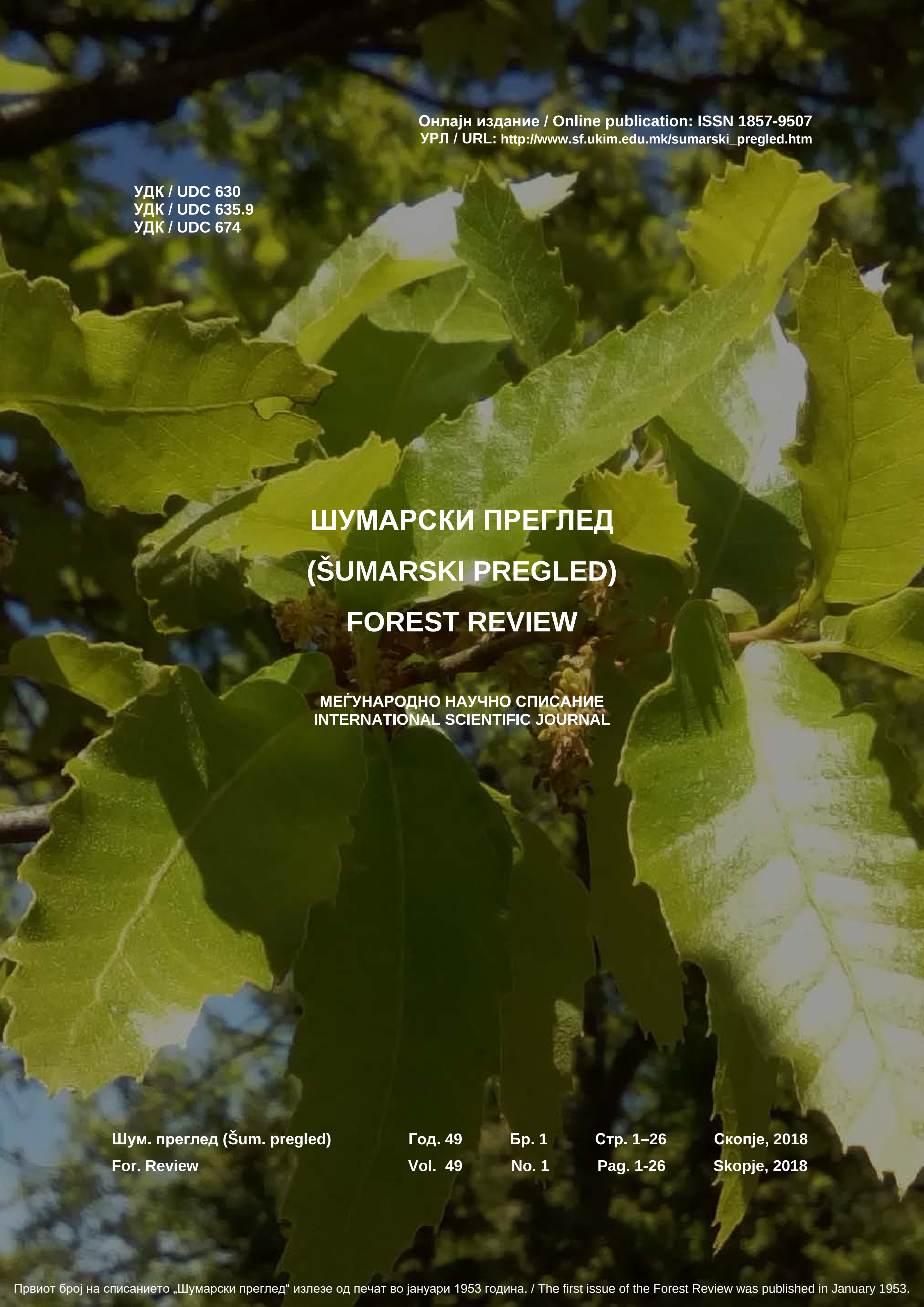

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Forests' health in Maleshevo region

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ABSTRACT: The aim of this research was to assess the current health condition of the forests in the Maleshevo region, to examine the influence of different factors and if possible, to identify future threats to the health of the forests. The main focus of research were insect pests, as the most common negative influence in the forests of this region recorded in recent past. The research was done by collecting data and its analysis on six square – shaped sample plots with surface area of 625 m^2 each. The research was done in the course of five months, from July to November 2018. Samples were also taken to the entomological laboratory of the Faculty of Forestry in Skopje for further analysis. The presented results show the qualitative and quantitative states of each of the noted factors that influence the health of the forest. The number of determined species of insect pests was 13, of which the most influential are the bark beetles and the pine processionary moth. However, if the abundance of these species is compared to the research done in 2003 and in 2009 respectively, the situation can be considered as improved. Based on these results, recommended measures are also given in order to improve the level of forests' health in this region.
Keywords: forests' health, Maleshevo, pests, bark beetles, sample plots, wood samples

1 INTRODUCTION

The Maleshevo region (Figure 1) is one of the richest in the Republic of Macedonia in terms of forests and forest products. As they are, the forests in this region are an integral part of the regional economy. For that reason, maintaining the health of these forests should be a priority. One way of predicting and stopping the threats before they appear is to analyze the current influence of different factors to the forest ecosystem.

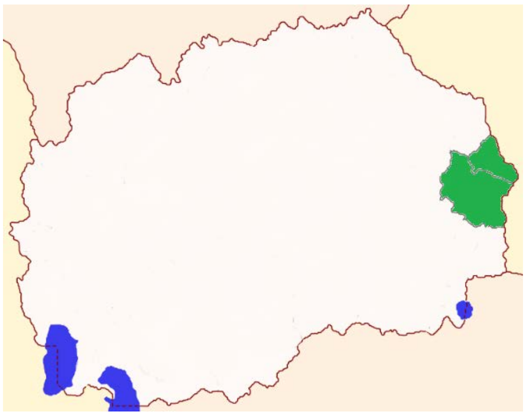

Figure 1: Location of the Maleshevo region in the Republic of Macedonia

In the past, there has been a number of recorded issues concerning the forests' health in the Maleshevo region. The causes for the problems are different and diverse. However, in many cases it has been proven that the insects' influence has been the deciding factor [1-4]. An especially serious problem are the secondary pests, which are always present in these forests. The importance of these insects as pests is connected to other factors that reduce the trees' natural resistance [5]. Such factors are: extreme weather conditions, forest fires, negative human impact on the forest, previous infestations by other species of insects, etc.

In order to get a clear picture of the threats that the insect pests pose to the forests' health in this region, it is necessary to have annual reports of their abundance and population dynamics. However, that is not the case. The only available analyses were carried out with an interval of over five years between them. That is why it was necessary for this research to provide an in depth analysis of the negative influence of the insect pests, and for some other harmful factors as well.

2 MATERIALS AND METHODS

2.1 Research area

The research was carried out in the forests managed by the two subsidiaries of PE "Macedonian Forests" based in the Maleshevo region. More precisely, "Maleshevo" and "Ravna Reka" based in Berovo and Pehchevo respectively.

For the needs of this research, six stationary sample plots were marked in different parts of the Maleshevo region (Figure 2). Each of them square – shaped with an area of 625 m^2 (25 m x 25 m).

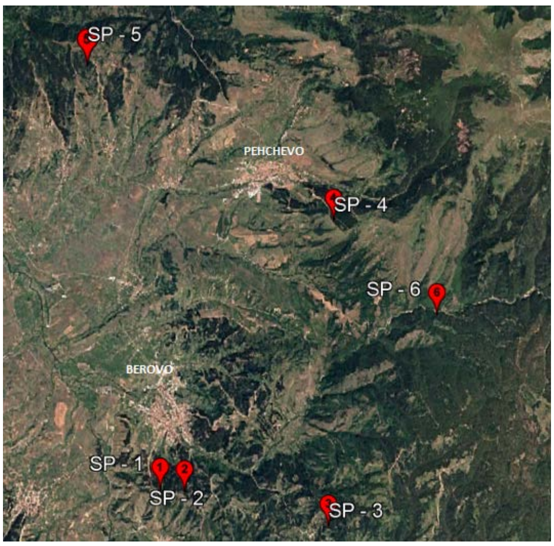

Figure 2: Location of the sample plots in the Maleshevo region

2.2 Description of sample plots

The sample plots were placed in stands where the most economically important tree species of the region are dominant. Those species are the following: Austrian pine, Scots pine and European beech (Table I) [6-9]. All of the sample plots were at an altitude between 1,000 and 1,200 meters above sea level.

Table I: General information about the forest stands in which the sample plots were placed

Sample plot	Dominant species	Mean DBH (cm)	Age (years)	Tree density / ha
SP – 1	*Pinus nigra*	20	50	700
SP – 2	*P. sylvestris / P. nigra*	18	50	700
SP – 3	*P. sylvestris*	16	70	950
SP – 4	*P. sylvestris / P. nigra*	23	50	310
SP – 5	*P. sylvestris*	12	20	3000
SP – 6	*F. sylvatica*	/	/	/

Sample plots from 1 to 5 were placed in even aged, planted forests. On the other hand, sample plot 6 was placed in an uneven aged natural forest.

2.3 Field research

The first step in the field research was recording the values of several visual indicators for the stand health. The following indicators were observed:

- Number of dead trees;
- Number of dying trees;
- Percentage of defoliation;
- Percentage of yellowing leaves.

After evaluating the previously mentioned symptoms for every sample plot, we used different methods to determine the presence and abundance of every important species of insect pest [10].

Primarily, the abundance of the pine processionary moth (*Thaumetopoea pityocampa*), an ever present pest in the pine forests in Macedonia, was to be determined [11]. At the time of the beginning of this research (in July 2018), the insect was in its imaginal stage. Because of that, we used a method that is based on the number of present adults during the species mating season. In order to determine the abundance of the insect, we used pheromone traps that attract the males. The traps, in which the pheromone was placed, were of the type "Delta trap" (Figure 3). We placed the prepared traps on the south side of the Austrian pine trees, approximately at 1/3 of the tree height. Attracted males would stick to the glue placed inside the trap.

Figure 3: Sketch of a Delta trap

Besides the data concerning the caught males of *Thaumetopoea pityocampa*, at the end of the research period (November 2018), another method was used to show the information about the abundance of this insect. This method consists of counting the caterpillar nests that appear at that time of the year (Figure 4). The data is shown as number of caterpillar nests per hectare.

Figure 4: Nest with living caterpillars, Sample plot 2

After placing the pheromone traps, the following phase of this research consisted of collecting wood samples from the sample plots. These samples would later be used in the laboratory analysis as a way of determining the presence and abundance of wood boring insects. Most notably, bark beetles (Coleoptera; Scolytidae) and longhorn beetles (Coleoptera; Cerambycidae). The nature, as well as previous occurrences of these two groups of insects in the region suggest that they are most common on the Scots pine [12]. Consequently, wood samples were taken only from the sample plots where this species of pine is present (SP from 2 to 5). For collecting samples, one dead and one dying tree from each of these sample plots were cut. The length of the colected wood samples was 1 meter (Figure 5). They were taken from the base, the middle and the top of each of the felled trees.

Figure 5: Collected wood samples

Apart from cutting trees for the purpose of collecting samples for laboratory analysis, one tree on each of the same sample plots was cut to be placed as a "bait" tree for bark beetles (Figure 6). The fallen trees, whose resistance to infestation becomes weakened, serve to attract the adults of the different species of bark beetles during their mating season. The trees that were used as baits were selected from those that were not showing any obvious injury or disease. The bait trees were left on the sample plots for the duration of the entire research period. During this time, they were examined periodically every 3 weeks. Their examination was conducted in such manner that the bark was removed as ring around the trunk. This was done at the base, the middle and the top of the fallen tree.

No wood samples were taken from the sample plot in the beech forest. Instead, from this sample plot, living branches with leaves were collected. This is the case because in this region, the main pests recorded on the beech are *Rhynchaenus fagi* and *Mikiola fagi*. Both of these species of insect are known as pests that damage the leaves of the tree. All of the collected branches were carefully herbarised for further analysis.

2.4 Laboratory analysis

All of the samples collected from the field were taken to the entomological laboratory at the Faculty of Forestry in Skopje for further analysis. The collected wood was sorted acording to location and left undisturbed until mid September 2018. This gave time for the insects that had already inhabited the wood to complete their galleries and their metamorphosis. This was done to ease the determination of the present species of insect. Meanwhile, the collected adults and larvae from the field were identified to which species they belong. This was done by using binocular microscope "Carlzeis – Jena" and multiple identification keys [13-15].

Figure 6: Bait tree placed on sample plot 4

After enabling the wood boring insects to complete their galleries, detailed analysis of the wood samples followed. At first, the surface of the bark was examined for any injuries visible to the naked eye. The most important of those injuries being the openings made by the young bark beetle adults flying out of the wood. These openings were also counted on each of the wood samples. For comparison of results, their number is shown on 100 cm^2 (10 cm x 10 cm) of bark surface.

Following the examination of the surface, the bark of the wood was removed. The underside of the bark was checked for any present insects, either adults or larvae. The methods for their identification remain the same.

The presence of pests on beech, and their abundance, was determined by examining the already collected leaves. The abundance of *Rhynchaenus fagi* was measured by the number of mines carved by its larvae on the leaves. On the other hand, the abundance of *Mikiola fagi* was measured by counting number of galls made by this insect on the beech leaves. The information about the abundance of both of the species is shown per 1,000 leaves. This is done by using the following formula:

$$A = \frac{Bm}{Bl}\ x\ 1{,}000$$

in which:

A – Abundance

Bm – Total number of counted mines / galls

Bl – Total number of collected leaves

3 RESULTS AND DISCUSSION

3.1 Visual indicators

As it can be seen from Table II, no number is given for sample plot no. 5. This is so because this stand had an unusually high density, which made it practically non-feasible to count the number of dead or dying trees, which were fairly common on the sample plot. For this case, we decided to use a visual estimate for this information. According to that, about 40% of the total number of standing trees were dead. Additionally, another 20% were showing signs of dying out.

Table II: Number of dead and dying trees per sample plot

Sample plot	No. of dead trees	No. of dying trees
SP – 1	0	1
SP – 2	0	0
SP – 3	2	3
SP – 4	4	1
SP – 5	/	/
SP – 6	0	0

Another visual indicator of the health condition of the stand is the percentage of defoliation, as well as the percentage of yellowing of leaves (Table III).

Table III: Estimated percentage of defoliation and yellowing of leaves per sample plot

Sample plot	Defoliation (%)	Yellowing of leaves (%)
SP – 1	0	0
SP – 2	10	10
SP – 3	10	20
SP – 4	10	20
SP – 5	30	40
SP – 6	0	0

3.2 Identified insect pests

Following all of the identification methods, the presence of thirteen different species insects listed as pests in forestry was confirmed. Their presence per sample plot is listed in Table IV. As it can be seen here, the presence of every species is in close correlation to the natural characteristics of the specific forest stand. Namely, the species *Rhynchaenus fagi* and *Mikiola fagi* are only found in the stand where beech is present [16]. On the other hand, the pine processionary moth (*Thaumetopoea pityocampa*) is present on every other sample plot except that one. However, there is also difference between the different sample plots placed in pine forests depending on the mixture of the two present species of pine.

Table IV: Identified species of insect per sample plot

Species	SP - 1	SP – 2	SP - 3	SP - 4	SP - 5	SP - 6
***Ips sexdentatus* Boern.**		+	+	+	+	
***Ips acuminatus* Gyll.**		+	+	+	+	
***Ips mansfieldi* Barrenillos.**			+	+		
***Acanthocinus griseus* Fabricius.**				+		
***Monochamus galloprovincialis* Olivier.**		+		+	+	
***Hylastes ater* Payk.**					+	
***Pissodes notatus* F.**		+	+	+	+	
***Orchestes fagi* L.**						+
***Mikiola fagi* Htg.**						+
***Thaumetopoea pityocampa* Schiff.**	+	+	+	+	+	
***Phaenops cyanea* Fabricius.**					+	
***Rhyacionia buoliana* Den. *et* Schifft.**		+	+		+	
***Xyloterus lineatus* Olivier.**					+	

An example of this is the presence of the locally occurring species of bark beetles (*Ips sexdentatus, Ips acuminatus, Ips mansfieldi* and *Hylastes ater*). Even though the possibility exist for them to build their galleries on either Austrian pine or Scots pine trees, they usually prefer the Scots pine. The same goes for the identified species of longhorn beetles [17].

3.3 Abundance of *T. pityocampa*

The most frequent pest of all of the detected was *Thaumetopoea pityocampa*. This came as no surprise as this species is constantly present in the pine forests in the region. However, the impact it has on the forest depends on the weather conditions for the current year. In warmer and dryer years, the damage done can be devastating for the pine trees [18, 19].

Figure 7: Number of *T. pityocampa* males caught using the pheromone traps, per sample plot

Table V: Number of caterpillar nests on sample plots

Sample plot	Number of caterpillar nests	Number of caterpillar nests per hectare
SP – 1	2	32
SP – 2	5	80
SP – 3	1	16
SP – 4	2	32
SP – 5	1	16
SP – 6	0	0

As we can see from the information shown in Figure 7 and Table V, sample plot 2 has the highest abundance of *T. pityocampa*, measured by both number of adult males (in June) and number of caterpillar nests (in November). The second highest abundance is present at sample plot 1. This outcome is consistent with the known biology of this insect because these two sample plots have a higher number of *P. nigra* stems compared to the rest. Even though 80 nests per hectare may seem a lot, when compared to one of the highest recorded numbers in the R. of Macedonia of 20,400/ha, this can be classified as a weak infestation. The data concerning the collected male adults using pheromone traps can be compared to the same type of information acquired in 2009 about the same region [20]. This comparison is shown in Figure 8 as the average number of collected adults per forestry subsidiary (Berovo and Pehchevo). As we can see here, the abundance has decreased. Even though this reduction can be attributed to multiple factors, one likely reason is the extreme weather conditions during the winter of 2016/2017 [21]. It was not uncommon for the air temperature during that winter to go lower than -20ºC. Concequently, the following year there was no recorded infestation caused by *T. pityocampa*.

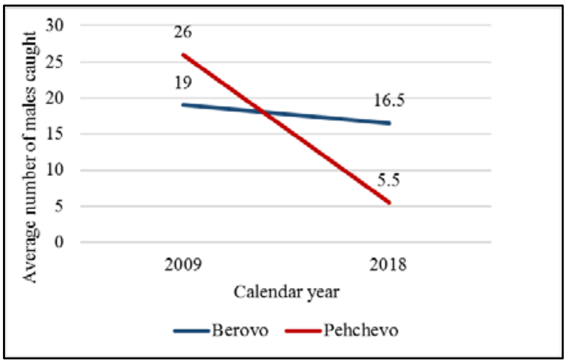

Figure 8: Comparison of the average number of collected *T. pityocampa* adults per forestry subsidiary between 2009 and 2018

3.4 Abundance of bark beetles

During this research, four species belonging to the family of bark beetles (Scolytidae) were identified. Two of which can greatly influence the health of the forest ecosystem. Those are *Ips acuminatus* and *Ips sexdentatus* [22]. It is not uncommon for these two species to inhabit the same tree. The former builds its galleries on the higher parts of the stem, while the later inhabits the lower parts with thicker bark (Figure 9) [17]. These two species were present on all of cut trees from which wood samples were taken. The only exception here is that *I. sexdentatus* was not present on the healthy trees that were placed as baits.

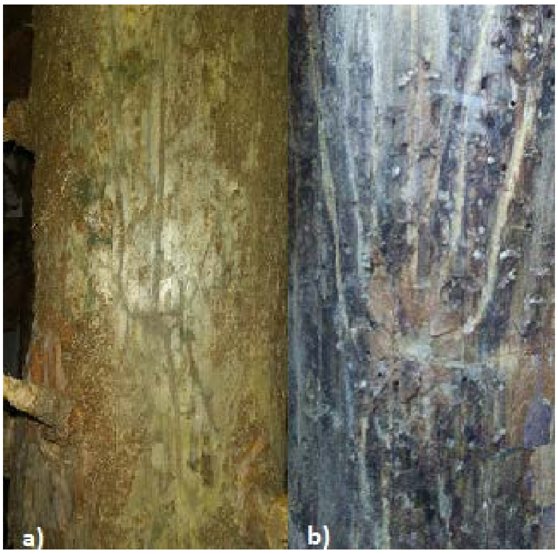

Figure 9: Galleries in wood made by bark beetles
a) *I. sexdentatus* b) *I. acuminatus*

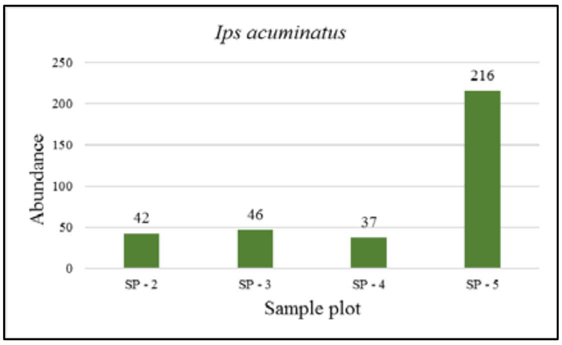

Figure 10: Abundance of *I. acuminatus* per sample plot

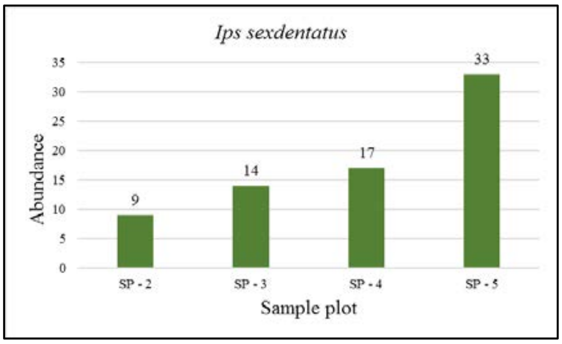

Figure 11: Abundance of *I. sexdentatus* per sample plot

As we can see from Figures 10 and 11, on sample plots from 2 to 4 the abundance is fairly equal and is on a level on which the forests' health is not threatened. However, on sample plot 5 the abundance for both species is several times higher than that of the other plots. This is due to the absence of forest maintenance of that particular stand.

The data gathered about the abundance of these two important species of bark beetles can be compared to those from the period of 2001-2003 (Figures 12 and 13) [23]. The comparison gives us mostly encouraging results. Namely, the abundance for the year of 2018 is generally lower than those calculated for the earlier years. The only obvious exception is the abundance of *I. acuminatus* for the forestry subsidiary of Pehchevo. However, this fact is mostly due to the unusually high abundance calculated on sample plot 5. The stand conditions on that location are perfect for the development of this species of insect. The same does not apply for all of the forests in the region.

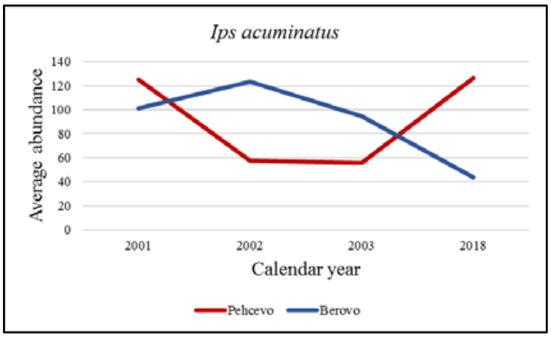

Figure 12: Comparison of the average abundance of *I. acuminatus* for the period 2001-2003 and 2018

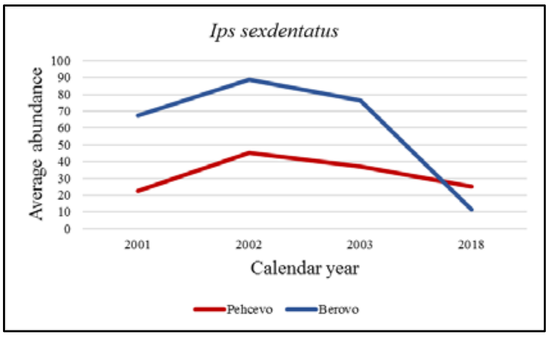

Figure 13: Comparison of the average abundance of *I. sexdentatus* for the period 2001-2003 and 2018

3.5 Impact of longhorn beetles (Cerambycidae)

Two species of longhorn beetles were identified during this research, those being *Monochamus galloprovincialis* and *Acanthocinus griseus*. Both species have a similar impact on the health of the forest. In the case of this study, the longhorn beetles were found only on the wood samples taken from dead trees. This is nonetheless a positive outcome, meaning that their populations are not high enough to endanger living trees. However, as the larvae of these species bore relatively deep into the wood, they can significantly reduce its value. That means that dead trees that are left standing can become practically worthless if they are not cut on time. The same applies for harvested wood not taken out of the forest for an extended period. For this reason, in the forests where these insects are present, the wood harvest should be done meticulously.

3.6 Abundance of pests on *F. sylvatica*

The most important pest in beech forests in Macedonia is *Rhynchaenus fagi.* Its larvae feed on beech leaves and on occasions can cause defoliations of entire beech stands. One larva of this species is capable of consuming up to 1/3 of the leaf surface. During massive infestations, more than one larva per leaf can be present.

After processing the collected beech leaves from sample plot 6, the following results were obtained:

- The abundance of the larvae of this insect was 12 per 1,000 leaves;
- The maximum number of mines per leaf was just one;
- Holes on the leaves made by the adults of this species were common. However, knowing that one individual can make multiple holes, this information cannot be used as a way to determine the actual population density.

Another pest on beech that was identified during this research was *Mikiola fagi*. The impact of this species on the health of the forest is not as important as the previous one. Nonetheless, if a massive occurrence of this insect happens, the damage done to the forest should not be neglected. The density of the galls made by *M. fagi* (Figure 14**)** on sample plot 6 is 72 per 1,000 leaves. According to literature, this insect causes problems when the density of the galls is 5,000 per 1,000 leaves. When compared to that, the current infestation on the sample plot can be classified as a very weak one. In addition, the maximum number of galls per leaf is two, which is also too low to cause real problems to the forest stand's health [14].

Figure 14: Galls made by *M. fagi.*

3.7 Identified beneficial species of insects

Besides the insect species that are considered forest pests, two species that serve a beneficial role in the forest ecosystem were identified during this study. Those species are *Clerus formicarius* L (Coleoptera; Cleridae) and *Nemosoma elongatum* Reitter (Coleoptera; Ostomidae). These two species are bark beetle predators and act as natural regulators of their populations. Considering that the sample plots where these species were confirmed (SP - 4 and SP - 5, respectively) were placed in planted forests, their presence is a positive outcome. This indicates a developement of natural pest regulation in the forests where it was originaly missing.

3.8 Damage done by weather

During the survey of the sample plots, the only visible direct damage done by weather conditions was noticed on sample plots 4 and 5. Here, the presence of bent pine trees as a result of heavy snowfall was observed (Figure 15). Even though snow is the direct cause for the bending of these trees, the primary reason can be traced back to the pest infestations. Namely, because of the dying out of larger groups of trees caused by insects, authorities were compelled to remove them. This in turn, made the abruptly thinned forest stands more susceptible to unpleasant weather [24].

Figure 15: Bent trees on Sample plot 5

3.9 Recommended measures for improving the forests' health.

Based on the indisputable threats to the health of the forests in this region, forest protection measures should be carried out.

According to the current abundance of *T. pityocampa* populations, no immediate suppression measures are required. Still, annual monitoring of its population density and infested area must be carried out. Manual removal of caterpillar nests during the regular forest activities in autumn can help keeping its populations in check with low additional costs. If population density of this pest reaches high levels, the only viable solution is using insecticide. In the Republic of Macedonia, in recent past this has been done by spraying insecticide with an airplane [25]. For this method, it is advisable for bio – insecticides to be used.

For protection against bark beetles, continuous activities are necessary. This encompasses removal of dead and dying trees, as well as not leaving deadwood in the forest. If the removal of cut wood from the forest is not possible then debarking is a second option. The infested stems should be removed as soon as the first symptoms appear. Additionally, neighboring trees should also be removed as a precaution. Forest authorities in the region already carry out these practices, but the frequency of sanitation cutting must be increased. As an additional method of reducing the population of bark beetles, bait trees can also be used. These same methods are also effective against longhorn beetles.

No suppression activities are necessary for the pests infesting the beech forests at the moment.

Additionally, the following common preventive measures have to be carried out:

- Raising mixed forests;
- Regular and appropriate thinning;
- Choosing the species for planting according to

site conditions;
- Control of seedling before planting;
- Maintaining the appropriate forest density.

4 CONCLUSIONS

The following conclusions can be reached from this research:

- Insect pests cause the most common problems concerning the health of the forests in the Maleshevo region.
- The most important pests are the pine processionary moth and the bark beetles.
- Even though they are still present, the abundance of the above-mentioned species is lower than the one measured in 2009 for the pine processionary moth and in 2003 for the bark beetles.
- The presence of some species of insect pests is closely connected with previous infestations of other species, as well as other factors that can contribute to the disturbances in the forest ecosystem.
- The beech forests have significantly more resilience against pests and other harmful factors than the pine forests in the region.
- Planted forests are more susceptible to infestations than natural forests.
- Correctly executed preventive measures play an integral role in forest protection

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