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## Comparative analysis for the exposure of workers to vibrations in forestry and agriculture

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**ABSTRACT:** Healthy and safe working conditions are prerequisites for sustainable management of forest and agriculture workers. In practice sustainability can only be ensured by properly instructed and trained workers doing a good job. Long term exposure to either hand-arm or whole-body vibration has been associated with the development of certain musculoskeletal disorders. Many sawmill employees are exposed to vibration on a daily basis. This paper aims to analyze data for safety and protection of workers in forestry and agriculture professions who are exposed on negative effects caused by mechanical vibrations. For reaching this aim, a questionnaire with 8 questions and 34 offered answers was prepared. The survey was conducted randomly and we had 386 respondents from 500 calls. The contacted people who refused to respond were not taken as a parameter in any analysis. Several cities from north, central, south, east and west region of Macedonia were points of interest. The people were contacted telephonically by National phone network of home phone numbers. The results from workers in forestry and agriculture professions were separate in four segments: determination of exposure on vibration by professions, determination the amount of vibrations by systems of transmitting on workers, daily exposure to vibration  $A(8)$  and implemented vibration control measures. In forestry professions we have the biggest percent of workers who are working with powered hand tool followed from the workers who operate special forestry vehicle and the least are workers that working with non-powered tools. When we are talking about how the vibrations are transmitted, professional workers with hand held operating tool are most exposed on vibration system called hand-arm vibration (HAV), the opposite of the workers who are managing forestry vehicles that are mostly exposed to the whole body vibrations. In daily exposure on vibrations  $A(8)$  hand tool operators are exposed in a smaller amount of time to vibrations in contrast of workers who operate forestry vehicles. This trend was also followed in the agriculture professions. In implemented control vibration measures in agriculture all segments had very high percentage of positive responses, while in the forestry companies executives need to work on providing trainings for prevention and purchasing new products that produces less vibrations.

**Keywords:** hand-arm vibrations, control vibration measures, daily exposure  $A(8)$ , forestry and agriculture

### 1 INTRODUCTION

The safety and health of workers are a priority on the list of tasks and challenges of employers or managers in all areas of the economy everywhere in the world. Closely related to the safety and health of employees are the risks of injuries and diseases that are partly or entirely caused by physical hazards at the workplace. The most common physical hazards in the working environment are: noise, vibration, ionizing radiation, non-ionizing radiation, microclimate conditions, brightness and increased and decreased atmospheric pressure. In addition to the basic physical characteristics of vibrations in terms of their frequency, vibratory acceleration is particularly important for the potentially harmful effects of vibration on the health of workers exposed to them. Acceleration represents a change of speed in unit of time and is expressed in  $m/sec^2$ , that is the amount used to determine the allowed exposure time according to the international standard. Mechanical vibrations to which workers are exposed and receiving them through the fingers or hands when using hand-held vibrating tools are called local vibration, and that is representing, hand-arm vibration exposure (HAV). Negative effects on workers' health caused by local hand-arm vibrations are most often due to the interruption of the supply of blood and oxygen to the fingers resulting from long-term vibration exposure and causes damage to the blood vessels and nerve systems that are initially reversible, but with prolonged exposures eventually become irreversible. It takes a lot of time and effort to measure vibration in all economic areas and branches where workers are exposed to the harmful effects of workplace vibrations during the working day [1].

According to [2], generally the exposure to whole body vibrations is commonly associated with transport or in certain industrial processes operating machinery or specialized vehicles, while exposure to local hand-arm vibrations is usually associated with a vibrating machine motor, electric or hand tools [3]. The expected harmful effects on health caused from exposure to vibration at the workplace depend not only on the physical characteristics of the vibration, but also on the specifications of the machines and tools used during the performance of the work, the weather conditions at work, the characteristics of the material what is being done, the individual sensitivity and the position of the body in relation to the spread of vibration [4]. The earliest diagnoses of diseases and injuries caused by mechanical vibrations date back to 1862 [5] and are made by French physicist Dr Maurice Raynaud. A more objective system for determining the stage of injury, that is, giving the possibility of providing special classifications of the stages of injury through the vascular and sensorineural phases, by determining the peripheral, vascular and neurological disorders, was proposed and accepted at a thematic workshop held in Stockholm in 1986 [6]. Most common stage of whole body vibration is so called discomfort which can be defined as unpleasant feeling at the workplace and is the most responsible state for reducing the concentration of the worker. It is caused by vibrational acceleration, and depends on the frequency, direction, location of vibration reception and the duration of vibration exposure [8]. There is no way to measure and limit the vibratory discomfort that is individually determined. The initial conditions caused by occupational exposure to the harmful effects of local vibrations are

dominated by symptoms - tingling, pain, stiffness, and seizures of white fingers. Next, further exposure to mechanical vibration causes muscle and bone disorders, and the possibility of changes in the central nervous system is not excluded. Initial symptoms commonly occur suddenly and in most cases are caused by a combination of exposure to vibration in cold and / or under low temperature conditions. Clinical indication that prejudices peripheral circulation damage is a condition called Raynaud syndrome. When this condition occurs as a consequence of occupational exposure to local vibrations, first pallor is observed only in confined zones, in most cases on the fingertips, which is further followed by a feeling of cold in the hands. Furthermore, with the prolonged exposure to the harmful effects caused by vibration, the pallor expands and penetrates the inside of the affected fingers and the final stage of disease is reached "white fingers". The finger blinking latency period in the white finger disease may range from two to 16 years, the stiffness phase of the disease is varying from 2 to 12 years [9]. The exposure assessment of vibration plays an important role in the safety and proper functioning of the worker at his workplace [10]. With our research we will collect valuable data that will help for increasing safety and reduce injury and health damage to workers caused by exposure to mechanical vibration in the workplace.

## 2 MATERIALS AND METHODS

It was intended to make the poll randomly, and it would be subject to analysis by 386 respondents in several cities in the Republic of Macedonia. In order to achieve this goal, we have taken the task of creating a questionnaire in which, through certain questions, we will get answers, which will be statistically analyzed and graphically visualized in appropriate mathematical software (ANOVA, SPSS, and Excel).

Questionnaire with 8 questions and 34 offered answers was prepared. The survey was conducted randomly and we had 386 respondents from 500 calls. The contacted people who refused to respond were not taken as a parameter in any analysis. Several cities from north, central, south, east and west region of Macedonia were points of interest. The people were contacted telephonically by National phone network of home phone numbers. The survey was conducted for seven months.

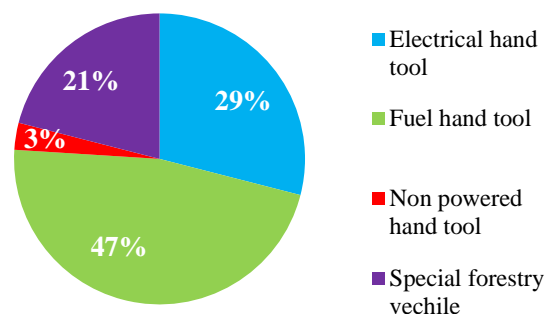
## 3 RESULTS

### 3.1 Determination of exposure to vibrations in forestry professions

Forestry as a commercial branch has a wide range of activities and from here comes the important function that plays in the environment. Forestry professions have a large spectrum, so in our research, based on the responses of the respondents, we analyzed four forestry professions. Answers from the conducted scientific survey are presented on Figure 1.

From presented results on Figure 1 in form of pie, we can conclude that the largest percentage of forestry workers surveyed work on the profession related to the management of a certain hand-held power tool, followed by the workers who manage a professional forestry vehicle and the lowest percent representation is among workers who work with a no powered hand-held tool. These results indicate that the number of workers who in the description

of their working profession have the task of operating with certain hand tools versus those who manage certain off-road forestry vehicles is significantly larger. From this indicator we can further consider improving the working conditions of these workers, increasing safety and reducing the risk during working hours.



**Figure 1:** Total percentage of people exposed to vibration in forestry professions

In addition to the previous analysis of exposure to vibrations of workers in forestry professions, we investigate the percentage of exposure on the basis of which system the vibrations act. The answers from this part of the questionnaire are represented in Table I.

**Table I:** Quantity of exposure to vibrations in a view of acting system in forestry professions

Type of vibration	Forestry jobs			
	Fuel hand tool	Electrical hand tool	Non powered hand tool	Special forestry vehicle
	Percent %			
Hand – arm	93	88	95	2
Whole body	0	3	5	91
Hand – arm and whole body	7	9	0	7

\*Responses in the survey were obtained by sample of 386 respondents

The vibration system is very important indicators since the vibrations of a local character do not have any common features with the vibrations that are received with the whole body (general vibrations). Different properties generate various problems and risks, so a different basis for their reduction and prevention is required. From the results presented above we can determine the expected opinion of this indicator in the professions of the forestry sector, i.e. the strongest action of the vibrations from the hand-arm system we have at forestry professions that in their description have tasks related with a hand tool, while diametrically opposite to them are the workers who manage professional forestry vehicles, here we have 98% acting vibrations that are received through the whole body system versus 0% of workers from this forestry profession who are exposed to vibrations of a local (hand-arm vibration) character.

### 3.1.3 Daily exposure to vibration $A(8)$ in forestry professions

Using the answers from the conducted survey, data on the daily exposure  $A(8)$  in forestry professions were obtained. The mathematical analysis determines the percentage exposure of vibrations in the forest professions presented in the Table II below. The daily exposure was analyzed in quarterly zones, i.e. the respondents were asked to assess whether their exposure to vibrations in eight hour workday is less than two hours, greater than two and less than four, greater than four and less than six and a maximum daily exposure six and eight hours.

**Table II:** Daily exposure to vibration  $A(8)$  in forestry professions

Daily exposure $A(8)$	Fuel hand tool	Electrical hand tool	Non powered hand tool	Special forestry vehicle
	Percent %			
exposure < 2h	27	23	15	11
2h < exposure ≤ 4h	41	48	38	19
4h < exposure ≤ 6h	22	17	31	44
6h < exposure ≤ 8h	10	12	16	26

\*Responses in the survey were obtained by sample of 386 respondents

From the mathematical analysis of the daily exposure in forestry professions, the following conclusions can be reached. The highest daily exposure to vibrations over four and over six hours is most common with 44 and 26% in the working profession managing professional forestry vehicles. Contrary to them, the lowest daily exposure is 17% in the quarter showing exposure between 4 and 6 hours at operators with fuel hand tools, and the lowest daily exposure for the quarter from 6 to 8 hours of exposure with 10% we have in the forestry profession which involves working with electrical hand tools. These results are most likely a consequence of the description of the work tasks of certain forest professions, more detailed working tasks had handheld operators and they are intervening, in contrast to the workers who manage forestry vehicles whose profession covers daily continuous tasks.

### 3.1.4 Implemented control measures in the forestry professions

Forestry as an economic branch covers many working professions, which in their description have activities that are carried out on the field, and thus the risk of injury to workers is increased. It is these indicators that give a sign of the enhanced implementation of preventive measures in order to enable workers to work more efficiently and safer.

In the Table III below, the results of our examination are presented.

**Table III:** Measures for protection and control of vibrations in forestry professions

Implemented vibration control measures (multiple answers are allowed)	Number of workers who reported control implemented	% of workers who are exposed to vibrations
Provide gloves	59	98
Use vibration dampeners	8	13
Provide vibration absorbing seats	13	22
Purchase products with less vibration	24	40
Provide training on how to prevent health problems caused by vibration	34	57
No control measures provided	6	10

\*Responses in the survey were obtained by sample of 386 respondents

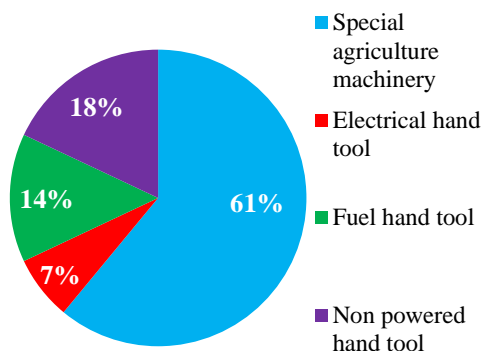
The general picture given by the analyzed data on implemented preventive measures in the forest professions is promising. This fact can be taken from high percentage (57%) of workers who replied that their company organizes trainings for preventing health problems caused by vibration. Also the parameter where workers report that their executives didn't take any control measures for preventing them from the negative effects caused by vibration is very small, only 10%. However, in this segment there is still work that need to be done. The companies must consider the fact that high 40% of workers answer that their companies do not purchase new products that produces less vibration.

### 3.2 Determination of exposure to vibrations in agriculture professions

Following the trends in our research work, a large number of respondents stated that their work tasks belong to the economy branch - agriculture. Based on the answers we defined four professions that will be analyzed in several segments. The percentage of people exposed to vibration in agricultural professions is shown on Figure 2 below.

From the analysis of the presented results in Figure 2 we can summarize that the most represented agricultural profession with 61% of the answers is the management of a particular agricultural professional machine and unlike only 7% of the workers have agreed that their working profession is the management of hand-held electric tools.

The obtained results can be explained by the fact that in agriculture as a branch of industry, profiles of workers of all kinds are needed, but as we can see in our survey, all professions are operational, i.e. they are carried out on the field.



**Figure 2:** Total percentage of people exposed to vibration in forestry professions

### 3.2.1 Determination the amount of vibrations by systemson workers in agriculture professions

As we mentioned above because of the different professions in agriculture we have workers who are exposed to different types of vibration in their work positions. Exposure to vibrations from individual systems in agricultural workers is presented in Table IV.

**Table IV:** Quantity of exposure to vibrations in a view of acting system in agriculture professions

Type of vibration	Agriculture occupations			
	Fuel hand tool	Electrical hand tool	Non powered hand tool	Special agriculture machinery
	Percent %			
Hand – arm	84	89	93	0
Whole body	7	3	0	94
Hand – arm and whole body	9	8	7	6

\*Responses in the survey were obtained by sample of 386 respondents

From the above data we can notice that the system of vibration activity of whole body, i.e. exposure to vibration of a general type, highest percentage over (90%), we have in the working profession that includes management of a professional agricultural machine. This act of vibration that is transmitted to whole body at workers that working with hand held tool no matter if it's powered or not the percent varieties from 0 to around 10%. The act of hand-arm vibration system is highest at the professions, which in their tasks managing hand held tools around 90%. Opposite to them operators of special agriculture, machinery and vehicles have the smallest exposure to hand arm vibrations.

### 3.2.2 Daily exposure to vibration A(8) in agriculture professions

The daily exposure to vibrations A(8) as an indicator tells us about the repeated activity of vibration in a certain profession in one working day. The percentage of daily exposure in agricultural professions is presented in a Table V below.

**Table V:** Daily exposure to vibration A(8) in agriculture professions

Daily exposure A(8)	Fuel hand tool	Electrical hand tool	Non powered hand tool	Special agriculture machinery
	Percent %			
exposure < 2h	24	21	17	12
2h<exposure≤4h	47	44	32	27
4h<exposure≤6h	29	23	37	38
6h<exposure≤8h	10	12	14	23

\* Responses in the survey were obtained by sample of 386 respondents

The analyzed results of indicator A(8) showing that the highest percentage (24%) of exposure less than 2 hours per day is in the profession of working with fuel hand tools, which is approximately the same as with other agricultural professions dealing with hand tools in general, in contrast to a statistically smaller value of 12% in the profession involving the management of an agricultural machine. This trend continues in other quarterly indicators of daily exposure, so the increase in quarterly daily exposure, the percentage of representation in agricultural professions that involve the use of hand tools decreases, in contrast to the professions that include the management of a professional agricultural machine where the percentage of daily exposure increases in proportion to the higher exposure in time.

### 3.2.3 Implemented control measures in the agriculture professions

Agriculture is a widespread economy branch and occupies a large percentage of industry in almost all countries of the world. This fact has been proven in our survey and from here we continue with an analysis in the area of implemented preventive measures in agriculture. In Table VI the results of the analysis are presented.

From the results presented in the Table VI, we can clearly see the high percentage of implemented measures in all segments of agriculture. The most popular measures are the use of protective gloves and vibration absorbing seats. A very significant high percentage of positive answers we have in the indicator - providing new products that are safer for workers, make the work more efficient and easier, and at the same time, they produce fewer



vibrations, reducing the risks of occurrence of diseases caused by exposure to vibration. Also very important indicator is the organization of trainings and training camps that speak about the protection from vibrations for preventing health problems arising from vibrations. In this indicator we have 66% positive responses, so we can say that this is an indicator that shows us a stable developed branch in our country. It is very important in the future to maintain this high trend of positive indicators, so there should be close cooperation with both state institutions and private domestic and foreign investors.

**Table VI:** Measures for protection and control of vibrations in agriculture professions

<b>Implemented vibration control measures (multiple answers are allowed)</b>	<b>Number of workers who reported control implemented</b>	<b>% of workers who are exposed to vibrations</b>
Provide gloves	282	88
Use vibration dampeners	45	14
Provide vibration absorbing seats	234	73
Purchase products with less vibration	196	61
Provide training on how to prevent health problems caused by vibration	212	66
No control measures provided	86	27

\*Responses in the survey were obtained by sample of 386 respondents

#### 4 CONCLUSIONS

Our questionnaire, which was modified for the needs of this scientific research, fulfilled the set goals and tasks. With statistical processing of the received answers we collect data that shows the real image in forestry and agriculture in a view of safety of workers. From obtained results we can reach following conclusions.

In forestry professions we have the biggest percent of workers who working with powered hand tool followed from the workers who operate special forestry vehicle and the least are workers that working with non-powered tools. In the speaking of way how the vibrations are transmitted, professional workers with hand held operating tool are most exposed on vibration system called hand-arm vibration (HAV) opposite of the workers who managing forestry vehicles that are mostly exposed to whole body vibrations. In daily exposure on vibrations A(8) hand tool operators are exposed smaller amount of time to vibrations in contrast of workers who operate forestry vehicles.

In the implemented control measures for protection from vibrations forestry workers stated that in their company's interest for providing training on how to prevent health problems caused by vibration is very small, as for purchasing new products that produces smaller amount of vibrations.

In agriculture professions at the point of view on system of acting of the vibrations and daily exposure on vibrations A(8) the results following the trend that is noticed at the forestry professions.

Speaking of implemented control measures for vibration in agriculture we have high percentage of positive responses in all segments, which can be indicator of one really stable and developed branch in our country.

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## Detecting alternative prey of the Balkan lynx using scat analysis

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**ABSTRACT:** The Eurasian lynx (*Lynx lynx* L. 1758) is an ambush predator with preference for medium-sized ungulates. The felid, however, has a varied diet which includes other animals, ranging from lagomorphs and rodents to chiropterans and small carnivores. The paper offers an overview of the alternative diet of the endangered population of the Balkan subspecies (*Lynx lynx* subsp. *balcanicus*) in western Macedonia. Alternative prey detection was done by analysing scat material collected near feeding site or found by chance in the period between 2010 and 2018. A total of 37 scats were retrieved. Of the total scats brought for analysis, only 28 gave conclusive results. Scat samples were analysed for morphological characteristics, undigested parts of the prey item (hairs and bones), also including immunological and serological analysis of the immunoglobulins present. Data reveals a diverse assortment of animal prey species with roe deer, chamois, brown hare, marten, wild boar, rat, mouse, red squirrel, edible dormouse, shrew, and pipistrelle bat. Such dietary shift in this predator may be owing to the unavailability of its principal prey item, namely roe deer, but also chamois. Therefore, anthropogenic pressure on the main prey species presents significant threat to ensuring a healthy and viable Balkan lynx population.

**Keywords:** Balkan lynx, alternative prey, scats, immunoglobulins, hairs

## 1 INTRODUCTION

The Eurasian lynx (*Lynx lynx* L. 1758) is a medium-sized polyphagous carnivore that evolved to live and hunt in the Palearctic forests. Its preferred prey depends on the geographical region that lynx occupies. For example the main prey in Europe are medium-sized ungulates – roe deer (*Capreolus capreolus*) and chamois (*Rupicapra rupicapra*) [15, 30, 31, 33, 25], and in the taigas of North Siberia it is lagomorphs [26]. Throughout its vast area of distribution, the Eurasian lynx is observed to prey also on red deer (*Cervus elaphus*), reindeer (*Rangifer tarandus*), fallow deer (*Dama dama*), muntjac (*Muntiacus* sp.), sika deer (*Cervus nippon*), lagomorphs (brown hare – *Lepus europaeus*), rodents and shrews (dormice, voles, mice, squirrels), birds (tetraonids, passerines), small carnivores (red fox – *Vulpes vulpes*, mustelids, wildcat – *Felis silvestris*, raccoon dog – *Nyctereutes procyonoides*), wild boar (*Sus scrofa*), amphibians and insects [6, 13, 24, 35, 20, 32]. Although rarely, domestic animals, like sheep and goats, enter the lynx diet [19, 32]. Lynx prey variation and selection depends on many factors, but the most important are habitat, prey availability, sex and age, and season [47]. Larger prey is mostly consumed during spring–summer, and predominantly by adult males, while smaller prey, alternative prey included, is more typical of autumn–winter predation in adult females with kittens and in subadults [35]. Alternative prey might be important for the survival of lynx in their early years [35] or of nurturing mothers [17, 22]. It is noted by Jobin *et al.* [17] that lynx prey upon roe deer and chamois according to their abundance. Lynx are quite adaptive to food regime of feast and famine; when enough prey, males on average consume 3.4 kg meat per night [17], but in between two larger kills they can survive several days on minimum or no food at all. Alternative prey becomes important during intermediate periods (between two large kills) or in low availability of main prey, due to poaching, for example. This poses an important issue in view of its hunting strategy—lynx are ambush predators—since its constant presence at a given area tends to alert the prey. Therefore,

lynx require “large and exclusive home ranges to ensure constant hunting success” [4], which necessitates stable and somewhat evenly distributed prey population. Due to the disturbance in the Macedonian forests, mainly from legal or illegal logging, poaching, hunting, stray dogs, etc., lynx main prey (roe deer) is disturbed and vigilant [48, 49, 50]. This makes it hard to kill, so we assume that lynx, up to some extent, are forced to depend on alternative prey. Lynx enlarge their home range when the main prey becomes less available or its population number drops down critically [51]. Okarma *et al.* [35] noted that the decline in roe deer was followed by decline in lynx population. The use of alternative prey often depends on the relative abundance of the preferred prey [9]. Some studies suggested that Eurasian lynx shift their diet to the alternative prey when the preferred prey is greatly reduced [10, 42, 34, 39], while other suggest that the same is happening while the alternative prey is abundant [22].

The conventional cluster analysis derived from radio-telemetry studies are the most common method for analysing Eurasian lynx diet [23]. Smaller prey, however, is much more difficult to encounter, because the procedure for discovering prey items is slower (the time between the kill is made, GPS/GSM locations are received and team visits the potential site) and therefore remains from smaller prey animals are almost impossible to detect. The classical VHF telemetry using homing-in methods to track lynx movements made it possible to encounter certain smaller prey items [17] that could otherwise be omitted. Another method to detect small prey is by snow tracking, but that would require good snow conditions that are not always the case. Nevertheless, the full prey spectrum could be concluded with scat analysis [35].

The Balkan lynx (*Lynx lynx balcanicus*, Buresch, 1941) presents an isolated and autochthonous population of the Eurasian lynx (*Lynx lynx* Linnaeus 1758) that inhabits south-western Balkans. The narrow distribution and limited number of mature individuals, as established by the expert assessment of its combined population at less than 50 adult individuals, earn the Balkan's largest felid the critically endangered (CR) status on the IUCN Red List

of Threatened Species [27]. Hence, the lynx is strictly protected in the countries with confirmed distribution (Macedonia, Albania, Kosovo) and assumed distribution (Montenegro and Greece) [12]. The Balkan lynx diet hasn't been thoroughly studied in the past. Mirić's [29] monography on the Balkan lynx contains one chapter dedicated to diet in which anecdotal information on lynx prey spectrum are published, mostly coming from local hunters and herders. The project "Status, ecology and land tenure system of the critically endangered Balkan lynx *Lynx lynx martinoi* in Macedonia and Albania" [7] through the long-term and ongoing Balkan Lynx Recovery Programme enabled systematic radio-telemetry studies of the Balkan lynx. However, no activities have been dedicated to explore the smaller prey items that can be found in the Balkan lynx diet. Recent analysis conducted on Balkan lynx scats using basic forensic techniques like immunological analysis and identification of species through hair samples [11, 46, 18] suggests that the lynx feeds on a range of animals which pose an alternative prey, albeit some findings, as literature suggests regarding red fox, may hint to intraguild predation [42]. Documenting the alternative prey of an elusive predator such as the Balkan lynx is hard to determine, mostly because of the ecology of this medium-sized cat. Smaller prey is consumed immediately, often without a trace or evidence at the kill site. Additionally, in a habitat with scavenging animals, there are no leftovers to be traced and identified. The aforementioned forensic methods based on the scat analysis might help to discern what is on the feeding menu of the Balkan lynx.

We believe that this study will help shed more light on the feeding habits of this predator with hopes of improving conservation efforts. Thus, the aim of this paper is to get knowledge about Balkan lynx alternative prey represented in its diet.

## 2 STUDY AREA

Balkan lynx distribution is restricted to south-western Balkans, with two main nuclei with confirmed reproduction: Mavrovo National Park and its vicinity, in Macedonia, and Munella Mountain, in Albania [28]. The research presented in the study was performed in the Mavrovo National Park and its southern and eastern surroundings (Fig. 1). The area is typically mountainous with small rivers, steep valleys and an altitudinal range of 600 to 2,200 meters. The vegetation cover is mostly forests, represented by European beech (*Fagus sylvatica*), King Boris fir (*Abies borisii-regis*), various oak species (*Quercus* spp.) and mixed beech-fir forest communities. Besides lynx, two other large carnivores share the landscapes: brown bear (*Ursus arctos*) and grey wolf (*Canis lupus*). Wild ungulates present in the area which are potential food source for the lynx are the roe deer and chamois. The area is sparsely populated, where most of the people have abandoned the high-altitude villages and have settled into the nearby towns or migrated abroad [52].

## 3 METHODS

During a conducted radio-telemetry studies (2010–2018), obtained samples were mostly recovered near the feeding site (covered with litter, dry grass or snow), on trails and in box-traps (set to capture lynx). We used molecular biology technique similar to the DNA-based

technique of species identification, with the advantage of low cost and potential to be performed in the field [53, 54, 55, 56, 57, 58, 59, 60]. DNA-based identification is more reliable and quite accurate, but it requires intensive laboratory work and it is more expensive.

Scat material was collected in the period between 2010 and 2018. Part of the scat was collected opportunistically during fieldwork (Balkan Lynx Field Book), while other is related to the collared Balkan lynx individuals (Fig. 1). In total, five individuals (4 males and 1 female) were captured and fitted with radio-collars. Lynx scats are particularly hard to find, as lynx tend to hide their excrements by covering them with nearby material (soil, dead leaves, snow, etc.). Searching effort to find kills and scats was calculated depending on the number of participants in the search party. Each participant would search the area in the centre of the cluster for one hour. The time was half an hour shorter if more than one participant joined the search party. When a kill was found, the search continued around the kill looking for a peculiar stack where scat is hidden. The scat was collected either in zipper bags or tubes filled with 70% ethanol. The samples were labelled with the following information: date, place, coordinates, lynx ID and habitat. Samples were then brought to the Forensic Department within the Macedonian Ministry of Interior (MoI) for detailed content analysis, including: morphological characteristics, determination of undigested parts of the prey item (hairs and bones), and immunological and serological analysis of the immunoglobulins found in the sample.

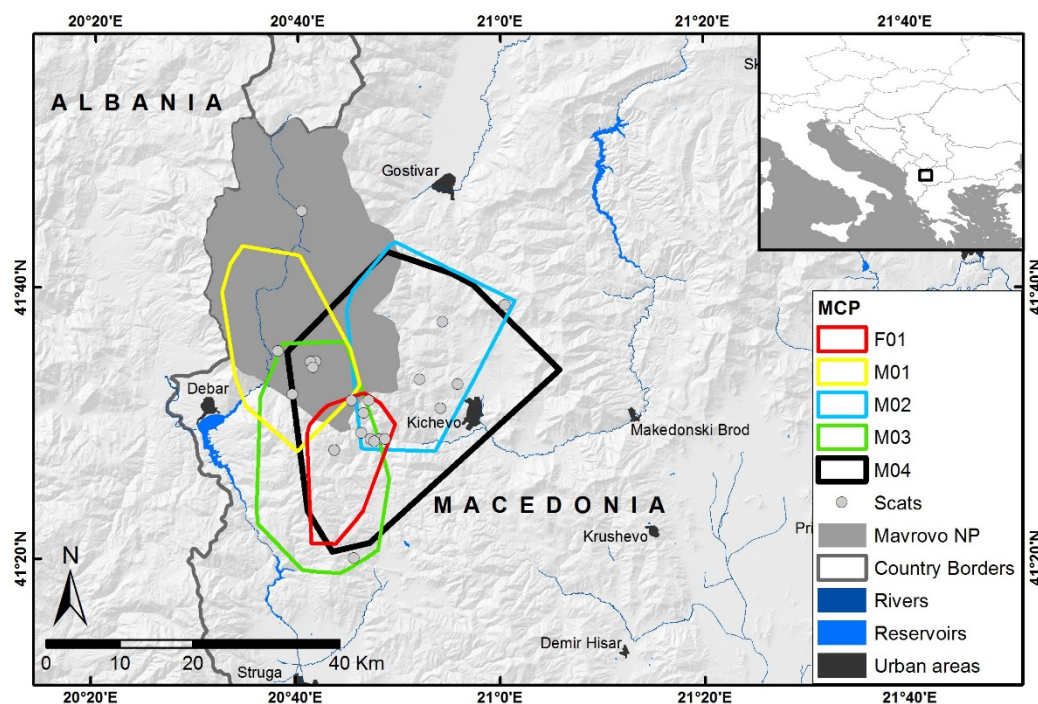
With the morphological analysis of the scat we could identify the species that produced the scat, i.e. whether it comes from a carnivore or a herbivore. Moreover, if the original morphology is preserved, the genus is identified as well. As regards detection of carnivores and brown hare in the sample, we proceeded with separation of the hairs from the rest of the sample content. Following physical separation, hairs were submerged in a physiological solvent for further cleaning. The final stage was rinsing the hair material in Xylene® (106.17 g/mol, Alkaloid). From the selection of treated hair samples, slides for oil immersion microscopy were produced using Canada balsam, dried on room temperature for 24 hours. Determination of origin of hair samples was made by comparison with hair material obtained with previously identified museum specimens from the mammal collection of the Macedonian Museum of Natural History in Skopje.

Possible protein residues from the faecal samples were diluted with 5% ammonium hydroxide solution (Sigma Aldrich®). This solvent was proved as most effective for extraction of old and denatured samples and that does not interfere with further testing [61, 62, 63]. Small piece of the samples, approximately 0.5 cm, was placed in 25 ml polypropylene screw cap tubes, together with 4.0 ml from the 5% ammonium hydroxide solution. During the first phase of dilution, the samples were placed on orbital mixer for a period of 1–3 hours, while later for the final dilution, sample tubes were transferred into the water bath with ultra sound in the duration of 2–3 minutes. The diluted sample was then transferred to a Petri dish and put in the airflow laminar until full evaporation. The evaporation leftover was then diluted in 200 µl sterile phosphate-buffered saline® (PBS, Sigma). Detection of residual proteins was performed in agar gel with pH 8.6. Wells with a diameter of 0.5 cm were arranged in a circular way into the agar gel plates, whereas the well in the centre



was intended for the unknown test sample, and the wells for the specific antiserum were arranged in four directions goat and/or rabbit against bear, bovine, cat, hen, turkey, deer, dog, fox, human, rabbit, rat, mouse, sheep, horse and donkey. All antisera were obtained in lyophilised form from MP Biomedical. The samples (unknown solvent) and specific antiserum were applied using Pasteur pipette into the designated wells and properly marked. Afterwards the

at a distance of 0.5–0.7 cm. Used antisera are whole serum polyclonal unconjugated primary antibodies developed in agar gel plates with the samples were placed in a moist chamber where the immunodiffusion took place. The solvents diffused radially in the plate, and wherever there was a precipitation line on the touching surface between the tested sample and appropriate antiserum the analysis was considered positive.



**Figure 1:** Study area. Grey dots are locations where scat samples were found. Rectangle polygons represent the home range of collared Balkan lynx

#### 4 RESULTS

Until July 2018, a total of 149 field visits for finding prey on GPS clusters were performed. During these visits, 106 prey remains were found. Around the kills we were able to locate 24 scats. Furthermore, 13 lynx scats were found by chance. These scats could, in fact, belong to some of the radio-collared individuals. However, our analysis cannot confirm this. Of the total of 37 scats brought to the MoI laboratory, only 28 gave a positive result (Tab. I, Fig. 1). In total, 12 different prey animal species were detected in the scat remains: roe deer, chamois, brown hare, marten (*Martes* sp.), wild boar, rat (*Rattus* sp.), mouse (*Apodemus* sp.), edible dormouse (*Glis glis*), red squirrel (*Sciurus vulgaris*), shrews (*Neomys* sp., *Crocidura* sp.) and pipistrelle bat (*Pipistrellus* sp.).

The comparison of lynx diet among samples collected at kill sites (radio-tracking) and those collected randomly (by chance) revealed different results. For example, roe deer appears twice more (66.7%) in scat found at kill sites than in scat found by chance (33.3%). Furthermore, some prey species, like marten, edible dormouse, red squirrel, shrews and pipistrelle bat, are only found in scat collected at kill sites, while other (chamois, wild boar, rat and mouse) only in scat collected by chance. When it comes to

prey detection per sample (scat), with radio-telemetry we could detect 1.3 prey sp. per sample compared to 1.2 sp. per sample with the scat found by chance, suggesting no significant difference. However, we should note that roe deer is the most present prey species in the scat (50%) collected. The previous relates to the fact that most scat is found at roe deer kills, which correlates to roe deer having the biggest share in the Balkan lynx diet (approximately 65%).

Concerning the lab methodology for prey detection in scat, hair analysis gave better results (39 prey items) in detecting prey species compared to the protein analysis (12 prey items). Additionally, hair analysis detected prey species in all 28 scats (100%), while protein analysis, in 13 (40%). This is due to the fact that proteins are more prone to degradation beyond detectability than hairs (Janevski, R. *personal communication*).

We did additional calculations to discover the frequency of occurrence (F%) showing the percentage of scats containing different food types relative to the total number of analysed samples; and level of significance (Fr%) – the frequency of occurrence in relation to the total occurrence of the food type. Results from that analysis is presented in Tab. II.



**Table I:** Results from the scat analysis of the Balkan lynx

No.	Date	Region	Animals confirmed		Scat retrieval
			Residual proteins	Hairs found	
1	No data	Mavrovo NP	Lynx*, chamois, rat, roe deer	Chamois, rat, roe deer	By chance
2	10.04.2010	Mavrovo NP	Lynx, roe deer, Brown hare, chamois	Brown hare, chamois	By chance
3	10.04.2010	Mavrovo NP	Lynx, roe deer	Roe deer	By chance
4	10.04.2010	Mavrovo NP	Lynx	Wild boar	By chance
5	24.02.2012	Kichevo region	Lynx	Roe deer	Radio-tracking
6	25.02.2012	Mavrovo NP	Lynx	Roe deer, brown hare	By chance
7	25.02.2012	Mavrovo NP	Lynx	Roe deer, mouse	By chance
8	07.03.2012	Kichevo region	Lynx, roe deer	Lynx, roe deer	Radio-tracking
9	14.03.2012	Kichevo region	Lynx	Lynx, roe deer, brown hare	Radio-tracking
10	11.04.2012	Kichevo region	No data	Roe deer	Radio-tracking
11	14.09.2012	Kichevo region	No data	Stone marten	Radio-tracking
12	27.09.2012	Mavrovo NP	No data	Brown hare	By chance
13	10.10.2012	Kichevo region	No data	Brown hare, roe deer	Radio-tracking
14	11.10.2012	Kichevo region	No data	Roe deer, marten	Radio-tracking
15	24.04.2015	Kichevo region	No data	Mouse	By chance
16	27.05.2015	Ohrid region	No data	Roe deer	Radio-tracking
17	19.03.2015	Kichevo region	No data	Lynx	By chance
18	15.03.2015	Mavrovo NP	No data	Roe deer	By chance
19	27.02.2015	Kichevo region	No data	Roe deer	By chance
20	24.01.2015	No data	No data	Roe deer, wild boar	By chance
21	10.04.2016	Kichevo region	No data	Edible dormouse	Radio-tracking
22	10.04.2016	Kichevo region	No data	Edible dormouse, pipistrelle bat	Radio-tracking
23	28.04.2016	Kichevo region	Brown hare	Brown hare, <i>Sciurus</i> sp.	No data
24	28.04.2017	Kichevo region	Brown hare	Brown hare, <i>Sciurus</i> sp.	Radio-tracking
25	23.11.2017	Kichevo region	No data	Roe deer, <i>Crocidura</i> sp., <i>Neomys</i> sp.	Radio-tracking
26	09.02.2018	Kichevo region	No data	Roe deer	Radio-tracking
27	01.05.2018	Mavrovo NP	Lynx, roe deer	Lynx, roe deer	Radio-tracking
28	No data	No data	Lynx, roe deer	Lynx, roe deer	Radio-tracking

\*Lynx hairs and residual proteins belong to the same individual from which the scat was retrieved

**Table II:** Frequency of occurrence and level of significance results of different food type found in the collected Balkan lynx scat

Species	Frequency of occurrence (F%)	Level of significance (Fr%)
Roe deer	64%	44%
Chamois	7%	5%
Brown hare	25%	17%
Marten	7%	5%
Wild boar	7%	5%
Rat	4%	2%
Mouse	7%	5%

Edible dormouse	7%	5%
Red squirrel	7%	5%
Shrews	7%	5%
Pipistrelle bat	4%	2%
<b>Total</b>		<b>100%</b>

## 5 DISCUSSION

The chosen method of double immune diffusion on agar gel is a quick and cheap method for identification of antibodies such as immune globulins [64]. The method is called "double" for the fact that in this procedure, the antigen and the antibody are allowed to migrate towards each other in a gel and a line of precipitation is formed where the two reactants meet. The positive side of the

precipitation reaction is its high specificity. The method is widespread and used regularly when working on diagnosis or protein detection, or when comparing antigens or antisera. The negative side of the method is its low sensitivity [1]. The considerable potential for prey identification was key to choosing this method although we targeted proteins of the most probable prey items known from previous ecological studies. While insufficient material was rare, negative results were obtained from samples that were more degraded or predominantly consistent of hairs. For these samples, adding the microscopic identification of hair significantly raises the chance of prey species identification. The macro- and microscopic structure of mammal hair is amazingly diverse and therefore easily discernible for species, genera or higher taxa. Mammal identification through hair morphology requires time and practice, and so this method is underproportioned in the era of molecular investigations. At the same time, hair is the most frequent and often the only life sign of mammals in the field. Moreover, the most recent biodiversity and conservation biology studies prefer the use of non-invasive methods, including hair-trapping, bird-nest analysis, and the identification of the hairs as remnants of prey taxa [43]. We recommend using both methods (hair and protein analysis) because they provide best results when combined, although hair analysis seems to be the more reliable method.

In view of the results presented above, roe deer is evidently the principal prey of the Balkan lynx, with a significant diet contribution found in 18 scats. This is in line with diet studies conducted in other regions of the nominal taxon's distribution, namely, the Norwegian [34], Swiss [8] and Dinaric populations [22]. In the Balkans however, the negative anthropogenic pressure on roe deer population within the home range of the Balkan lynx manifests in various forms: logging (either legal or illegal), hunting, poaching, and presence of stray dogs. Such occurrences, in turn, cause population decline and distress in the prey species consequently reducing the lynx's prey availability. Therefore, although larger than its Spanish and North American counterparts, the Balkan lynx might alternatively feed on small mammals. In that respect, lagomorphs become main prey whenever roe deer availability is reduced, and in our study they were found in seven analysed scats. Thus, main prey lows make the brown hare a significant food source for the lynx, especially in exploited forests [15]. Moreover, prey selection in lynx, as already pointed out, also hinges on age and sex. Brown hare seems to be the main prey species of subadult individuals, whereas adult males tend to hunt larger preys than females [38, 35]. Chamois also participates into the lynx prey base (twice found in the scats), albeit to a lesser degree than the previous two prey items. This may be due to the restricted distribution range of this bovid and its modest population size [2]. The additional prey data reflects the opportunistic predatory nature of the Balkan lynx. This is seen in the contribution of marten into its prey base (found in two scats). Lynx predation upon wild boar is low, whereby our scat analysis shows that suids are found in two scat samples. This may suggest either predation upon juvenile individuals or scavenging – the latter is rarely seen in lynx [3, 36, 41, 34, 5, 22]. Furthermore, scarcity of the main and the preferred alternative prey provokes the lynx to hunt shrews and rodents [15, 45, 34, 22], despite their low nutritional value.

Our results confirm this and reveal that the Balkan lynx predated upon mouse (found in 2 scats), shrew (2), squirrel (2) rat (1), and dormouse (2). In fact, edible dormouse presents an important alternative prey for the Dinaric population of Eurasian lynx, particularly for females and subadults [22]. An increase in the frequency of finding hares and rodents may be seasonal and more research is needed to have a clear picture. As far as opportunism goes, one peculiarity of behaviour the Balkan lynx displays is predation of bats. Scat analysis confirms the presence of pipistrelle bat (found in one scat analysis) in the lynx diet. This novel finding is the first ever to indicate such behaviour in the Balkan lynx, although some literature suggests that bats can become occasional lynx prey [14] (Jędrezejewska & Jędrezejewski 1998). Since rats and, to a great extent, pipistrelle bats are readily associated with human habitation (mostly low-activity or derelict buildings), the finding implies that lynx might approach man-made infrastructure. This is further supported by the fact that the Eurasian lynx uses conspicuous human objects in its natural surroundings for scent-marking [40, 21]. But ventures into human settlements are sometimes prey-motivated, as seen in the attacks on livestock, which are mainly due to the reduced availability of roe deer [34]. Still, despite the anecdotal evidence of such behaviour in our study area, scat analysis reveals no traces of livestock animals. However, another point to consider in this respect is scat sample size. Trites and Joy [44], for example, recommend that a minimum of 59 scats should be analysed to identify prey species occurring in scat at a frequency below 5%. Contrary to numerous bird findings in Eurasian lynx diet [16, 38, 42, 45, 34, 22], our investigation does not show presence of this prey item. This may be owing to the relatively small sample size (28 scats that gave results). In that respect, Pires *et al.* [37] warn against underestimating avian prey when poorly represented in scat, especially if the scat contains mammalian prey vestiges.

## 6 CONCLUSIONS

The paper makes an initial attempt to elucidate the full prey spectrum of the Balkan lynx diet. The variety and the frequency of consumption of alternative prey can be considered as an indicator of the principal prey availability in disturbed habitats. The methods we used for scat analysis can help detect the smaller alternative prey in the Balkan lynx diet that is impossible to discover with the field search using lynx telemetry locations. Described methods (immunological and hair sample analysis) are reliable and precise, they are cheaper than DNA analysis, but still require laboratory work. Future application of these methods will be crucial to establish their relevance in such investigation and validate results gained. Having information on the whole lynx prey spectrum can help in understanding the predator-prey relationship, competition and prey availability which then can be used for sustainable management of main prey species as an important precondition for the survival and recovery of the Balkan lynx.

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## Use of modern geomatic techniques for creating and updating a green cadastre of urban trees and shrubs: a case study of Kumanovo city river bank

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**ABSTRACT:** The goal of this paper is to implement modern, up-to-date, geomatics technique and technologies in the environment. The base is made in GIS software, a GPS device is used to record detailed points on the field and for recording and preparing a new orthophoto was used a modern sophisticated drone DJI Mavic Pro. QGIS (Quantum Geographic Information System), as a key software, was used for computer data processing and recordings obtained from the field research, and other utility programs were used to perform the tasks. The subject of the article is the Kumanovo city promenade in Macedonia, which is a convenient place to try to implement this data processing method. The results obtained give us a map of the entire urban dendroflora on the river bank in the city of Kumanovo. In fact, an inventory of all trees and shrubs was carried out, 4 projections were prepared with the help of modern applications, and as the ultimate goal, and a web digital map of the riverbank was prepared. This method can be applied in forestry, agriculture, water management, geodesy, space planning, sustainable development and environmental protection.

**Keywords:** QGIS and GPS, drone, urban dendroflora inventory, geomatic techniques, remote sensing, Kumanovo

### 1 INTRODUCTION

The good appearance and preservation of nature is a wealth that needs to be passed on from generation to generation. The care for the environment and the overall natural environment becomes a moral responsibility of the whole community. With the great advances in the technologies in all spheres, as well as in forestry and urban areas, new transparent databases are created that will make it easier, more effective and safer to manage the environment [1]. In Finland, the City of Helsinki's Street and Park Division maintains a digital tree register (approximately 40,000 trees) that includes trees that are situated at road sides and some of the trees in the parks. The tree-register data includes information on the species, height, diameter-at-breast height (DBH), and geo-location. The tree-register data are used in urban and environmental planning, in locating old trees that are hazardous (for citizens), and in biodiversity monitoring [11]. A GNSS (GPS) or global navigation satellite systems is a very precise way to display the desired location. The accuracy depends on the device itself, or data available on the base station, and of course the number of available satellites in the sky when the data is collected [2]. In recent decades, remote sensing (RS) techniques applied in forestry have been given an increased attention, which leads to the ability of extracting important information for forest planning and sustainable management [7]. There is also a method of collecting data on the exact location of the trees with the so-called Total Station. Today it is an indispensable instrument for geodesists, in fact, this instrument uses infrared rays to measure distance and automatically record and store it in its base. After the collecting of data is completed with this device it can be directly downloaded into a computer and entered into geographic information system (GIS). GIS gradually but surely becomes a valuable tool for demonstrating how natural and human-produced components communicate with one another. In many countries, GIS software is used as the main tool in many departments and sectors, in particular in (urban) forestry.

### 2 MATERIALS AND METHODS

#### 2.1 Investigation area

The riverbank is located 1 km from Kumanovo city centre. This specific location is the subject of investigation because it is a great place with quite dense vegetation, and unique green space for implementation some new methodologies of work in urban areas. It extends over an area of 45,000 square meters and represents a new city infrastructure built in 2007 (Figure 1) with coordinates North 42.13573, 21.72777 and 42.13579, 21.72853. On the South, the coordinates are 42.12597, 21.73119 and 42.12616, 21.73225.



**Figure 1:** Satellite image of the Kumanovo city river bank (Google Maps, 2018)

#### 2.2 Methods

This study started in August 2018, and the entire geo data base was developed in GIS software. GPS device was used to record detailed points on the ground, as well as for recording and for making a new orthophoto image from DJI Mavic Pro drone. First, the collection of field data using a GPS device as well as a collection of

attributes (species, diameter, height, canopy, damage, leaning) as detailed points, in this case, trees, was done. The collected data was processed into Excel table and used in QGIS software. Drone was used to record the entire space occupying the river bank in a pre-made map, using DroneDeploy® application (Figure 2). With the help of the drone, 2D and 3D models were made, as well as DEM (Digital Elevation Model) and health condition of trees and shrubs. Special layers displayed in GIS format were created and processed. As previously mentioned, drone is an unmanned aircraft that is driven from the ground. Controlling and using of the drone can be manual or automatically with a pre-made flight plan, or with the help of various applications that give the opportunity to create a map or route for the drone to fly. First step for using this application is to install it into a device (smartphone) that will be connected later with the drone controller. Creation of profile on DroneDeploy® gives the opportunity at any time to plan and edit new or old maps and flight plans [9].



**Figure 2:** Flight plan for drone created on DroneDeploy® application

In this case, the aerial image was taken on altitude of 100 meters with a pixel size of 3 cm, overlap of images of 70% and a maximum flight speed of 54.7 kilometres per hour. Recording of the imagery lasted 21 minutes and 241 photos were taken. In addition to the orthophoto, the application also offers a 3D projection of the marked space as well as elevation model and pictures showing the state of the urban dendroflora.

The processing of data collected from the field was carried out in the QGIS (Quantum Geographic Information System) platform version 2.18.25. Geo-referencing of footage, processing of collected GPS points (Waypoints), processing of excel tables; moving of GPS points was performed. Geo-referencing is most easily achieved with time-stamped GPS data recorded during the flight. It is typical uses of photogrammetry techniques to create a large and complete image [10].

Geo-referencing created orthophoto that is appropriately placed in the space, but since the footage uses a plain GPS system, the accuracy varies from 10 to 15 meters and the orthophoto recording is not absolutely precise and presented in the space. To correct this error, the orthophoto recording should be geo-referenced with a more accurate existing satellite image.

Excel spreadsheet processing is designed to simplify collection of data from the field. These are the attributes of woody species recognized with their scientific name, diameter in certain categories e.g. 0-5, 6-10, 11-20, 21-30 meter, etc. Category 'Damage' is created to obtain data

on injuries, damages and other diseases, whether from the abiotic or biotic origin. There are four types defined: 'Trunk damage', 'Canopy damage', 'Fully damaged' and 'No damage'.

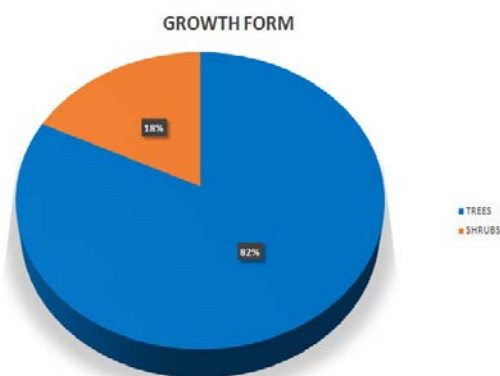
'Height' category coincides with the column 'Canopy' and here the parameters are taken in meters but in this table refer to the height of the tree itself. Prepared Excel file of inventory of our study is entered in the QGIS. Next step in QGIS software is moving GPS collected points of the field because each point make a certain "error" depending on the characteristics of the GPS device itself. The GPS device used to collect our data is with good positioning encounters of 2-meter error. With the processing of points, inserting them, as well as inserting a photo from the drone into the GIS software, the incomplete match of these two important elements has come to an end. Specifically, the GPS device for each point, in this case, the tree deviates for a certain distance. In order to complete this operation and processing, the GIS software offers the opportunity to move these points or move them to the desired position.

For woody plant identification species features and growth forms, certain literature for (urban) dendrology is used [14, 15, 16, 17, 18], and for recent nomenclature and taxonomy of the woody species, the plant database of World Flora Online [19] and The Plant List [20]. In addition, for the lower (hort.) taxa and the English common names the online Internet database of the Royal Horticulture Society [21] is consulted.

### 3 RESULTS AND DISCUSSION

#### 3.1 Inventory of the urban dendroflora of the Kumanovo city river bank

With the inventory carried out in this area, 27 taxa of woody plants were identified, represented in 637 individuals. The list of the taxa and the number of individuals (where applicable) is presented in Table I, ordered alphabetically by species' scientific name.



**Figure 3:** Growth form of the urban dendroflora of the Kumanovo city river bank

#### 3.2 Analysis of the urban dendroflora of the Kumanovo city river bank

Analysing the Table I, there are 5 species that are dominant in this area. The most prevalent is *Fraxinus americana* L. (170 trees), which is distinctive for parks of this kind that require avenues near river. Also, a large percentage are willows: *Salix babylonica* L. (32), as well as *Salix babylonica* var. *pekinensis* 'Tortuosa' (f) (53),

which also form an avenue along the banks of the Kumanovka River. A good percentage of representation is found in the species *Catalpa bignonioides* Walter, *Platycladus orientalis* (L.) Franco, and *Cupressus arizonica* Greene. These quantitative and qualitative results are very important step in any inventory. In fact, that information or the inventory itself gives us the knowledge of what we actually have in the green area and what measures in the future should be implemented, in order to maintained urban green areas

**Table I:** Inventory of the urban dendroflora of the Kumanovo city river bank

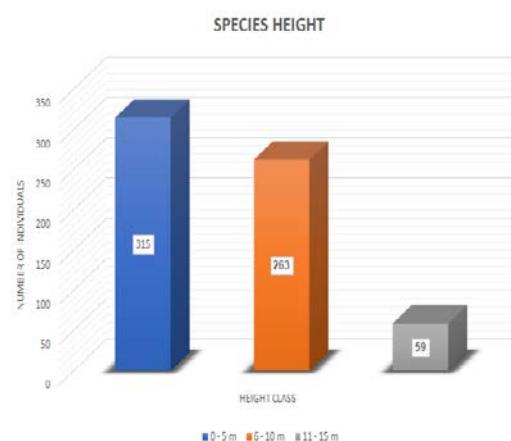
Scientific name	Number of individuals
<i>Acer negundo</i> L.	1
<i>Acer platanoides</i> L.	7
<i>Acer saccharinum</i> L.	7
<i>Catalpa bignonioides</i> Walter	79
<i>Cedrus atlantica</i> (Endl.) Manetti ex Carrière	11
<i>Cedrus deodara</i> (Roxb. ex D.Don ) G.Don	10
<i>Celtis australis</i> L.	5
<i>Cupressus</i> × <i>leylandii</i> A.B.Jacks. & Dallim.	22
<i>Cupressus arizonica</i> Greene	53
<i>Cupressus sempervirens</i> L.	1
<i>Fraxinus americana</i> L.	170
<i>Juglans regia</i> L.	1
<i>Juniperus horizontalis</i> Moench	1
<i>Koeleruteria paniculata</i> Laxm.	3
<i>Morus alba</i> L.	6
<i>Picea abies</i> (L.) H.Karst.	37
<i>Picea pungens</i> Engelm.	11
<i>Pinus wallichiana</i> A.B.Jacks.	5
<i>Platycladus orientalis</i> (L.) Franco	78
<i>Prunus cerassifera</i> 'Nigra'	7
<i>Quercus frainetto</i> Ten.	2
<i>Salix babylonica</i> L.	32
<i>Salix babylonica</i> var. <i>pekinensis</i> 'Tortuosa' (f)	53
<i>Thuja occidentalis</i> 'Smaragd'	7
<i>Thuja occidentalis</i> L.	19
<i>Thuja plicata</i> Donn ex D.Don	3
<i>Tilia tomentosa</i> Moench	6
Total:	637

After realized collection of attributes and inventory phase, the next phase is processing the same input into the GIS software, as well as the production of statistical data that will give a detailed picture of what kind of green area is about. In few photos will be presented some statistical data obtained from the inventory.

On Figure 3 it is given the percentage of trees represented in comparison with the shrubs. Given the shape and surface area of investigated area as well as the obtained data from Table I, we can conclude that there is

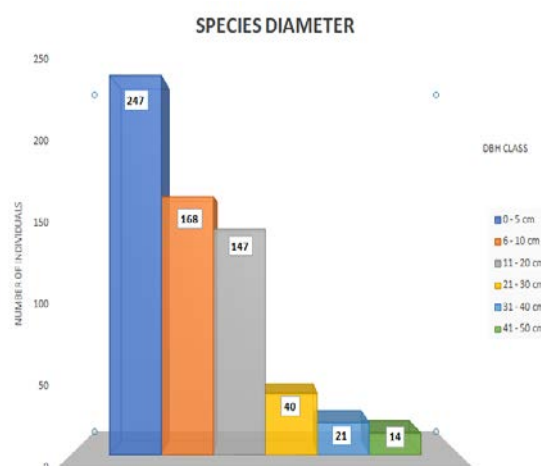
a large representation of trees, as much as 82%, comparing to shrubs with 18%. This is due to the observed two avenues, i.e., *Salix* species along the bank of the riverbed, as well as the avenue of *Fraxinus americana*, which follows Oktomvirska Revolucija Blvd. in length.

One of the important attributes of each inventory is the height of the species that are subjects of this type of work. In the investigated area, the results are shown on the Figure 4.



**Figure 4:** Species height of the urban dendroflora of the Kumanovo city river bank

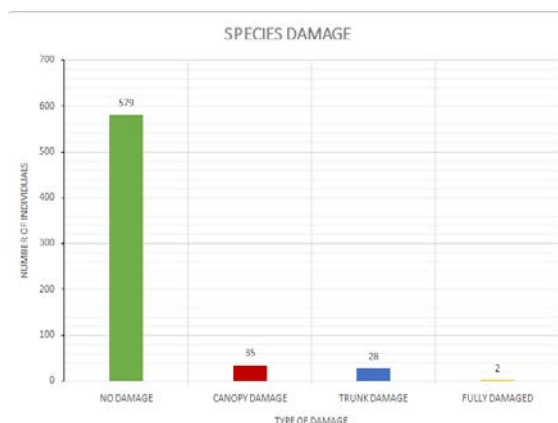
As can be seen, this is a relatively new green area, i.e., 315 woody plants are at a height of 0-5 m, 263 individuals are at a height of 6-10 m, and 59 individuals are at a height of 11-15 m.



**Figure 5:** Species diameter of the urban dendroflora of the Kumanovo city riverbank

Along with height and diameter, we actually get a picture of what kind of individual is about So, Figure 5 presents the current state concerning the diameter of the identified woody plants in the investigated area. A good percentage of dendroflora has a diameter of 0-5 cm in 253 representatives, diameter of 6-10 cm in 168 representatives, and a diameter of 11-15 cm in 147 representatives.





**Figure 5:** Species damage of the urban dendroflora of the Kumanovo city river bank

Significant importance for each plant is the state of health and vitality. By applying modern geomatic techniques and the use of modern devices to monitor the environment, we can fully discover the condition of all of them. On the Figure 6 it is observed that the whole area in large percentage is in healthy and good vital condition, in fact 88% of the total number of trees and shrubs on the investigated area. We have analysed a slight percentage of damage in damage of the canopy and damage of the main stem (trunk), and fully damaged are only 2 individuals (which are actually the consequence of anthropogenic factor).

Overall, main aspects and functions of the plant design [22] of the Kumanovo city riverbank are met.

### 3.3 Obtained projections in DroneDeploy® application

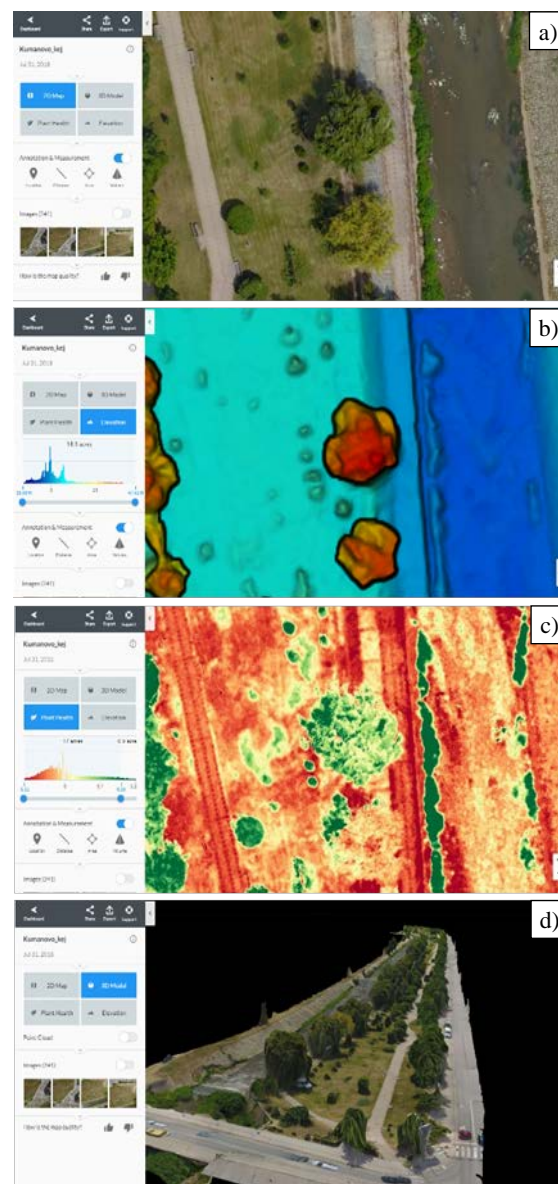
As previously stated, the filming of the investigated area lasted 21 minutes and 241 drone images were prepared. By processing them in the DroneDeploy® web platform and application, 4 projections were provided that represent a powerful tool and a preview image of the correct data for the objects investigated. First projection (Figure 7a) is orthophoto with excellent picture quality and resolution with 3cm pixels. In aerial photogrammetry the sensor is on a drone and is usually pointed vertically down toward the ground. When the sensor is pointed straight down it is referred to as vertical or nadir imagery. Multiple overlapping images are collected as the sensor flies along a flight path.

The second projection (Figure 7b) represents a projection that gives us accurate data on the height of the area concerned (Digital Elevation Model DEM). DEM represents a very important geospatial data type in the analysis and modelling of different hydrological and ecological phenomena, which are required in preserving our immediate environment. DEMs are typically used to represent terrain relief [10].

The third projection (Figure 7c) give us information on the state of the trees themselves, in particular, the state of the health of the urban dendroflora. 'Plant Health' is a tool specifically targeted towards agriculture. The main purpose of the 'Plant Health' projection is to allow you to explore your data even more deeply. You can adjust the contrast to highlight variability within any field.

Once you have identified the relevant plant health ranges, the thresholding tool lets you quantify damage and predict yields by showing the area within a specific range [8].

The last projection (Figure 7d) shows the three dimensional model of the entire research area. This demonstration of the desired area is one of the state-of-the-art projections in geomatic techniques in the last decade. For the complete picture of the entire area, you can check the link in the References chapter [13].

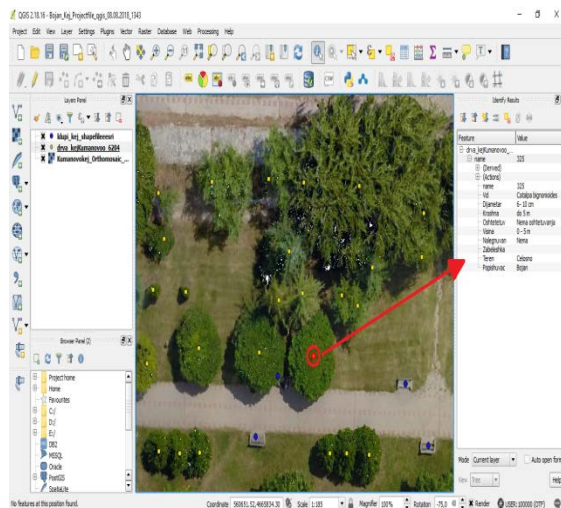


**Figure 6:** Projections of the urban dendroflora of the Kumanovo city river bank in the application DroneDeploy®

### 3.4 Uses of QGIS Cloud in GIS software

The use of GIS software in environmental management gives us numerous benefits and opportunities for easier and transparent work of the editors. QGIS Cloud plug-in that is found in the QGIS's software is a powerful tool for publishing pre-arranged data collected from the field. In fact, this plug-in gives us the opportunity to create a free webpage, in this case, creating a web-digital map of the Kumanovo city riverbank [5]. Figure 8 represents the GPS location of all points (marked yellow) and by clicking on it, a window on the right is opened, where all the attributes of the

identified woody species are given. The scientific name, height, diameter, canopy width, damage, and leaning are entered here, which were previously presented. The prepared database is attached to a free online domain that is automatically processed on a pre-created account. For the complete review of the study area, you can check the link in References chapter [5].



**Figure 7:** Fully processed data of the urban dendroflora of the Kumanovo city river bank in GIS-aided software

#### 4 DISCUSSION

Unmanned aerial vehicle (UAV) can create many different types of maps such as geographically accurate orthorectified two-dimensional maps, elevation models, thermal maps, and 3D maps or models. Digital mapping and digital photogrammetry is a new practice, i.e., practitioners throughout the world are already intensively using these drones for a variety of mappings and for various purposes. The materials used in the methodology itself in this article greatly demonstrate the ability of these drones to be used in an urban environment, as well as mapping the urban dendroflora and urban city greenery. Although the performed inventory represents only one part of the overall operation, we must know that it is an important segment in creating a cadastre on green areas [12]. Advances in the fields of UAV technology and data processing have broadened the horizons of remote sensing in (urban) forestry, and made the acquisition of high-resolution imagery and 3D data more easily available and affordable. In fact, UAVs can be obtained at reasonable costs and can be perceived as a (urban) forester's eye in the sky, capable of performing (urban) forest inventory and analysis on a periodic basis. With the availability of a wide range of sensors, these UAVs allow the end users to define the spatial resolutions, thereby opening new opportunities to forest and urban green areas [4]. The collected data with the inventory as well as the collected data from drone processed in the software (in our case QGIS) gave us as a product digital map of the entire urban greenery of the study area. GIS is an invaluable tool for applying efficient practices to a large-scale environment. These spatial analyses and inventories provide current, comprehensive information vital to open-space decision-making and identify opportunities for a coordinated effort

to guide urban development in a manner that will take advantage of all the social and ecological functions available from the urban forest [6]. The idea of the cadastre of urban greenery would not have the desired quality and usability if the data are not updated regularly and accurately. Only the updated data provides a permanent value for the green cadastre.

#### 5 CONCLUSION

In this research, with the help of new geomatics techniques and the technology for remote management and monitoring itself, we made an inventory of the urban greenery that is located on the riverbank itself, as well as the creation of 5 maps, and at the same time a digital map of the whole river bank with all the attributes. The use of the drone in this investigation showed us all the good sides of this relatively new technology that in the last decade made a big step. One of the great advantages of this technology is the large 4K resolution ( $4096 \times 2160$ ) of the recordings made by the drone, in this case, it has reached 3 cm pixel, at a height of 100 meters. In brief, with a higher height you get a larger pixel, and vice-versa, the lower the height the smaller pixel it is and at the same time the better the quality of the photo recording and more details. Also, the advantage of this technology is that devices are not expensive, and it does not require special training for operating with the drones. It is visually very difficult to follow such areas covered with greenery and therefore the aspiration is aimed at spreading of various maps and digitizing them for the purpose of easier and more efficient management of public green areas. Publishing the thematic map, i.e., preparing a website on the collected attributes, is of great importance, primarily because this result is the final part of the research where the scientific community or the citizens will have an insight into the overall dendroflora that is located on the riverbank. Modern geomatics techniques and at the same time all the technology for remote monitoring and environmental management, whether big or small, can be introduced and applied in all areas of (urban) forestry.

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## Forests' health in Maleshevo region

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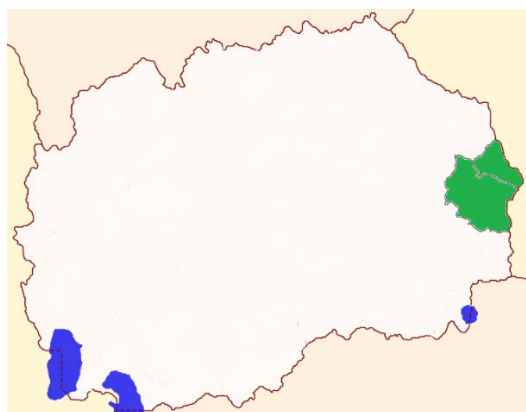
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**ABSTRACT:** The aim of this research was to assess the current health condition of the forests in the Maleshevo region, to examine the influence of different factors and if possible, to identify future threats to the health of the forests. The main 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<sup>2</sup> 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

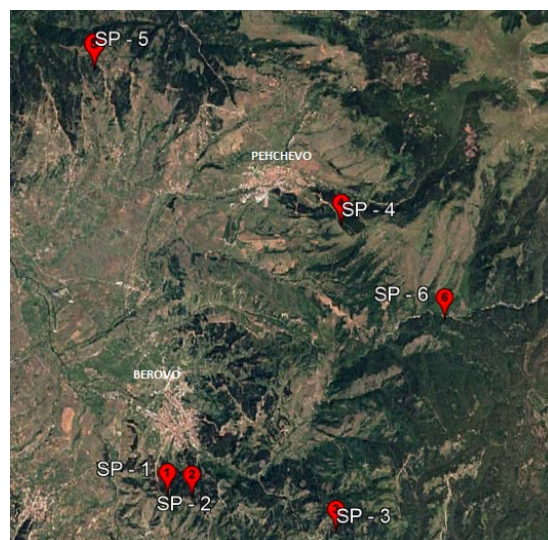
population dynamics. However, that is not the case. The only available analyses were carried out with an interval of over five years between them. That is why it was necessary for this research to provide an in depth analysis of the negative influence of the insect pests, and for some other harmful factors 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<sup>2</sup> (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	<i>Pinus nigra</i>	20	50	700
SP – 2	<i>P. sylvestris</i> / <i>P. nigra</i>	18	50	700
SP – 3	<i>P. sylvestris</i>	16	70	950
SP – 4	<i>P. sylvestris</i> / <i>P. nigra</i>	23	50	310
SP – 5	<i>P. sylvestris</i>	12	20	3000
SP – 6	<i>F. sylvatica</i>	/	/	/

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 collected 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 according 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<sup>2</sup> (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:

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

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.

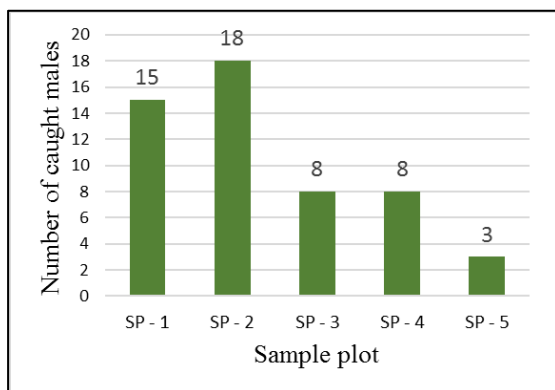
**Table IV:** Identified species of insect per sample plot

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

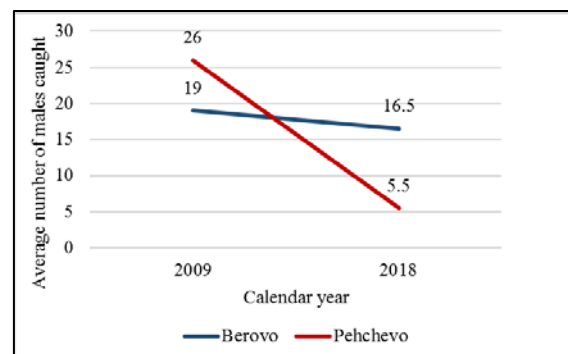
### 3.3 Abundance of *T. pityocampa*

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 -20°C. Consequently, the following year there was no recorded infestation caused by *T. pityocampa*.

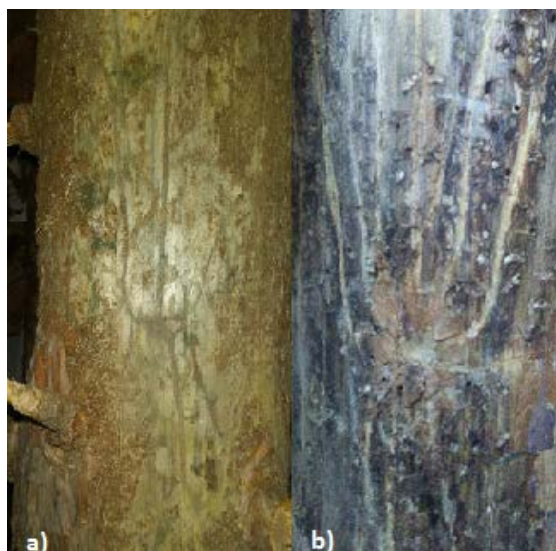
**Figure 8:** Comparison of the average number of collected *T. pityocampa* adults per forestry subsidiary between 2009 and 2018

### 3.4 Abundance of bark beetles

During this research, four species belonging to the family of bark beetles (Scolytidae) were identified. Two of



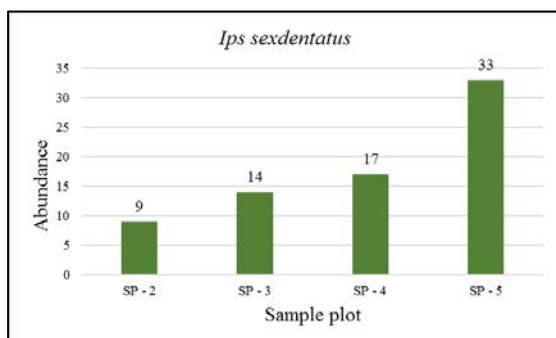
which can greatly influence the health of the forest ecosystem. Those are *Ips acuminatus* and *Ips sexdentatus* [22]. It is not uncommon for these two species to inhabit the same tree. The former builds its galleries on the higher parts of the stem, while the later inhabits the lower parts with thicker 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

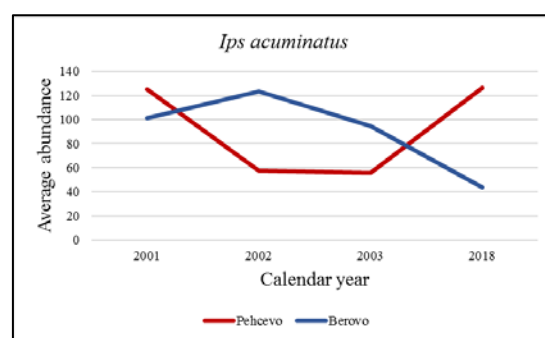


**Figure 11:** Abundance of *I. sexdentatus* per sample plot

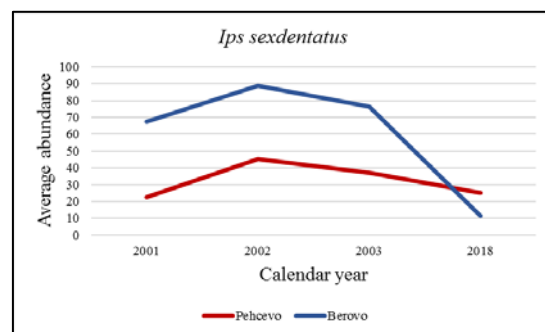
As we can see from Figures 10 and 11, on sample plots from 2 to 4 the abundance is fairly equal and is on a level

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 development of natural pest regulation in the forests where it was originally 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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