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THE APPLICATION OF SEXUAL DYMORPHISM AND ITS BEARING IN DETERMINING THE POPULATION SEX STRUCTURE OF THE MARITSA BARBEL (*BARBUS CYCLOLEPIS* HECKEL, 1848)

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Abstract

The populations of Maritsa barbel fish (*Barbus cyclolepis* Heckel, 1848) are under increasing anthropogenic pressure, necessitating constant monitoring and assessment of the demographic indicators of this endemic and protected species. The study empirically proves the utility of a hitherto theoretically-defined method of Marinov (1964) for determining the population sex structure. It uses the difference in the height of the anal fin between male and female the Maritsa barbels in order to determine the sex of a fish specimen. The empirical investigation, undertaken in order to test the method, utilized a large sample of 518 fish specimens, caught in the Chepinska River, outside of the spawning seasons, during the time period 2006–2010. The results are then compared with those, obtained from a smaller sample, caught in the same river in the years 2010–2011, during a period in which all mature individuals will have formed gonads. The comparative analysis of the results from the two samples proves the accuracy of the method for determining juvenile fish sex and thus provides a comprehensive representation of the sex structure of Maritsa barbel populations. Empirically proving the utility of the theoretical model entails two important conclusions for assessing the reproductive potential and estimating the stock size of the fish. First, this morphological peculiarity of the Maritsa barbel permits the accurate determination of its population sex structure throughout the year, not only during the spawning season. Consequently, no killing of fish from this endemic species would be necessary in order to monitor the populations.

Key words: age groups, height of the anal fin, sexual dimorphism, sex ratio.

Introduction

Determining the sex of a fish outside of the breeding season is often a very difficult task. In general, data describing the sex structure of the sexually mature segment of the fish population is often obtained by examining the presence of caviar or semen in a fish specimen. Con-

sequently, it is not possible to determine the sex of a juvenile fish – i.e. a fish without fully formed gonads. However, in the case of the Maritsa barbel (*Barbus cyclolepis* Heckel, 1848), the fish's morphological peculiarity may allow determining the overall sex structure of the population.

Marinov (1964) theoretically defined a method for determining the population sex

structure of the Maritsa barbel. It uses the difference in the height of the anal fin between male and female barbels, in order to determine the sex of a fish specimen. Using biometric data, Marinov found a statistically significant difference. According to Marinov (1964, 1989) it is no more than 16.6 % of the small length of the body. On the other hand, the height of the female anal fin is more than 17 % of the body length to the end of the scales cover. This morphological relationship permitted Marinov (1964) to develop a theoretical method, which uses this feature in order to determine the sex of a fish specimen.

Research investigation conducted by Kolev (2013) confirmed Marinov's biometric results and established that the average height of the anal fin of Maritsa barbel males in the Maritsa River basin was 16.3 % of the body length to the end of the scales cover. This method has not yet been applied to the task of empirically determining the population sex structure.

According to Zhivkov (1981) and Zhivkov and Yankov (1987) the average sex ratio of a population depends on the presence and duration of several periods in a fish's live. The percentage of dominance of one sex over the other during different periods, as well as the dynamics of age structure of the population, are also important. Many fish populations have been characterized by four periods, each of them described by a specific sex ratio (Nikolsky 1965; Zhivkov 1999; Yankov 1988a, 1988b; Raikova-Petrova 1992; Hamwi 2005; Rozdina 2009). Initially there are more males among the hatched fish. Therefore, the males predominate during the first period (A). In the second period (B), the number of male and female fish becomes equal. In the third period (C), the female fish predominate because of an earlier dying off of the males, which have

already participated in the reproduction. The last, fourth period (D) is characterized by the survival of only female fish.

A study of barbel fecundity conducted by Kolev (2016) found similar periods in the life cycle of the Maritsa barbel from the Chepinska River. The study found that the male barbels predominate from the time of hatching, up until the fourth year of the life of a generation. The four years old fish however were mostly females, and the five years old fish were only females. The research focus of Kolev's study (2016) did not aim to provide a comprehensive description of the overall sex structure of this Maritsa barbel population. Consequently, up until now the monitoring of its population sex structure has relied on comparatively less precise estimates and by necessity these estimates have also involved the killing of sample specimens.

The present scholarly contribution aims to address this research lacunae, by empirically testing the utility of Marinov's method (1964) for determining the sex of the Maritsa barbel by utilizing the difference in the height of the anal fin of male and female fish.

Study Area, Materials and Methods

The study area includes the Chepinska River, a right tributary of the Maritsa River (Fig. 1).

The Chepinska River is 81.7 km long with a catchment area of 899.6 km².

A total of 518 specimens of the Maritsa barbel were caught by electrofishing. It was performed according to the EN 14011:2004 instruction (Water quality – Sampling of fish with electricity).

The age of the fish was established by counting the annual rounds of fish scales.

The sex of the fish was determined by

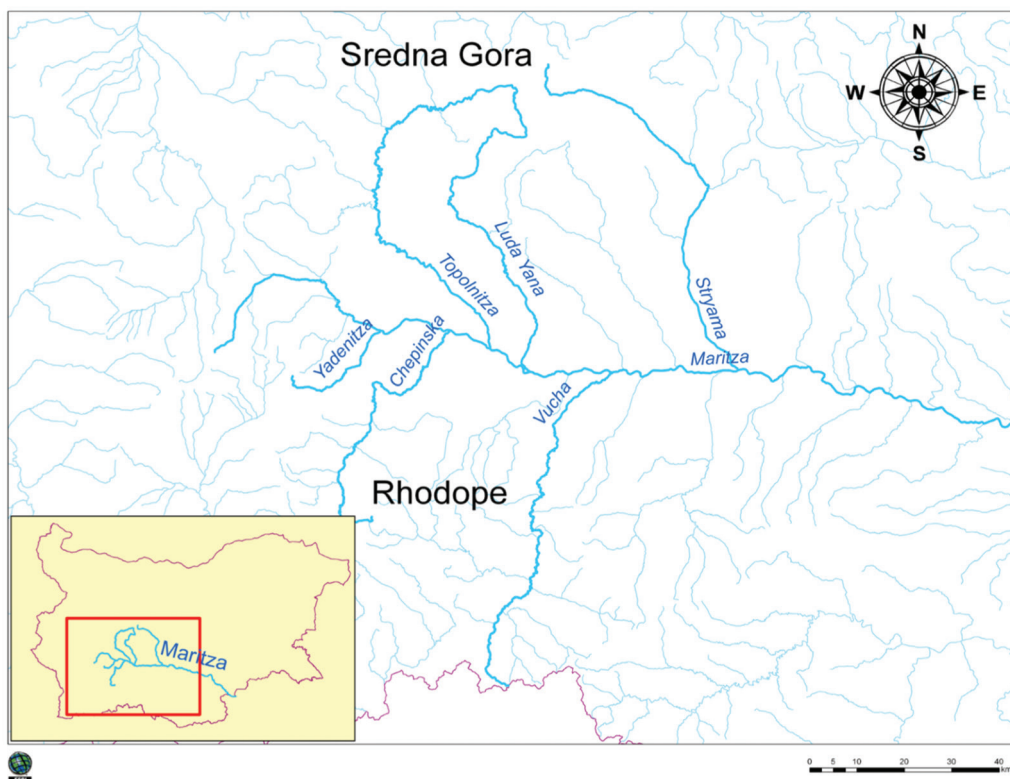


Fig. 1. Location of the Chepinska River, Arc Map 10.0 (ESRI – ArcGIS 2013).

the method proposed by Marinov (1964). Specimen with a height of the anal fin not exceeding 16.6 % of the small body length were identified as males. Specimen with a height of the anal fin equal to or exceeding 16.7 % of the small body length were identified as females.

The statistical interpretation of the results was made by using the χ^2 criterion (Lakin 1973, Grancharova and Hristova 2006). The material was processed using Excel for Windows program.

Results and Discussion

Table 1 presents the results obtained. By the use of the morphological feature, the

sex of the youngest age groups of the Maritsa barbel was determined. These were the juvenile fish.

For the one, two and three years old barbel fish the sex ratio was one to one (B period). The females were more than the males in the group of the four years old fish (C period). In the group of the five years old barbel the predomination of the females was considerable (Table 1).

The average sex ratio calculated using the height of the anal fin, was characterized by the predomination of female fish $\sigma:\phi = 1:1.3$ ($d = 1$; $\chi^2 = 9.5$; $\chi^2_{\text{stand.}} = 3.8$; $P > 0.05$).

The sex ratio in different size classes, obtained with the help of the height of the anal fin, is shown in Table 2. There

Table 1. Sex ratio of the Maritsa barbel population from the Chepinska River.

Age group, years	Females ♀, %	Sex ratio (♂:♀)	<i>d</i>	χ^2	χ^2 stand.	<i>P</i>	<i>n</i>
One-year-olds	49	1:1	1	0.08	3.84	<0.05	109
Two year-olds	50	1:1	1	-	-	-	44
Three-year-olds	52	1:1	1	0.58	3.84	<0.05	246
Four-year-olds	68	1:2.1	1	11.64	3.84	>0.05	88
Five-year-olds	97	1:30	1	27.13	3.84	>0.05	31
Sum							518

Note: *d* – degree of freedom; *n* – number of fish.

Table 2. Sex ratio of the size classes, describing the Maritsa barbel population, established using the percentage of the height of the anal fin of the small body length.

Size class (<i>L</i>), mm	Females ♀, %	Sex ratio (♂:♀)	<i>d</i>	χ^2	χ^2 stand.	<i>P</i>	<i>N</i>
21–30	0	1:0	-	-	-	-	4
31–40	42	1:1	1	0.47	3.84	<0.05	19
41–50	39	1:0.63	1	2.08	3.84	>0.05	39
51–60	66	1:0.82	1	4.12	3.84	>0.05	41
61–70	46	1:1	1	0.31	3.84	<0.05	52
71–80	49	1:1	1	0.04	3.84	<0.05	110
81–90	55	1:1	1	0.85	3.84	<0.05	95
91–100	64	1:1.8	1	6.21	3.84	>0.05	78
101–110	61	1:1.6	1	1.09	3.84	>0.05	23
111–120	83	1:5	1	8.00	3.84	>0.05	18
121–130	89	1:8	1	5.44	3.84	>0.05	9
131–140	86	1:1	1	3.57	3.84	<0.05	7
141–150	100	0:1	-	-	-	-	12
151–210	100	0:1	-	-	-	-	11
Sum							518

were more male fish in the first four size classes 21–60 mm (A period). Fish with the length to the end of the scale cover between 61 mm and 91 mm had a normal sex ratio 1:1 (B period). Female fish dominated the size classes of fish longer than 91 mm (C period). The only exception was the size class 131–140 mm, because the difference between the two sexes was not statistically significant. However, the value of the χ^2 was much closer to the standard value ($\chi^2_{\text{stand.}} = 3.84$) and the uncertainty in this difference was due to the small num-

ber of fish in this size class. There were only female fish in the size class of length greater than 141 mm (D period).

Sex ratio of Maritsa barbel population size classes, established by using the height of the anal fin by an age group, was closer to the results obtained by studying sexually mature fish (Kolev 2016) (Table 3). A study of fecundity by Kolev (2016) determined that the presence of only female fish in the fifth and last age group was due to the small number of fish in the sample.

Table 3. Sex structure of the age groups, describing the Maritsa barbel population, established during the study of fish fecundity (Kolev 2016).

[illegible]

The results of the sex determination of the Maritsa barbel, by using the two methods cited (by the height of the anal fin and by the sex products of the fish) were comparatively evaluated to be very different (Kolev 2016) (tables 2 and 4).

In the material collected for a study of fish fecundity, there were only a few specimens with a body length between 21 mm and 60 mm, because the catch was made in the late autumn, and it was mostly targeting the bigger fish (Kolev 2016) (Table 4). No female fish with formed

caviar and with a body length less than 120 mm were found in the sample. The sex structure was characterized by the presence of only three periods: a period with a presence of only male fish (A period), a period with a normal sex ratio 1:1 (C period) and a period in which only female fish were found (D period).

The sexual dimorphism of the height of the anal fin was very well expressed in the young age groups, unlike the development of gonads (tables 2 and 3). This morphological particularity made it

Table 4. Sex ratio of size classes, describing the Maritsa barbell population, established during the study of its fecundity (Kolev 2016).

[illegible]

possible to obtain a comprehensive representation of the sex structure of Maritsa barbel populations.

The study found only one male fish in the five years old group, so the dominance of the females in this age group was very high (Table 3). It was clear that the males gradually die during this age period. This finding has been confirmed by Rozdina (2009), who found out that the seven and eight years old barbels were only females. Obviously the fourth period (D), when only females survive, can only be identified for older barbels. Although in this sample no fish of such age was identified, such barbels had been recorded by other authors (Dikov and Zhivkov 1985, Vasiliou and Economidis 2005).

The average sex ratio of the Maritsa barbel population from the Chepinska River estimated by this research ($\sigma:\varphi = 1.3:1$) is very different from the value ($\sigma:\varphi = 1:1$) obtained by the study of Maritsa barbel fertility in the same river (Kolev 2016). These results can be explained by the larger sample size, utilized in the present study, as well as by the ability to determine the sex of the juvenile fish.

Conclusions

Based on the empirical analysis and verification, discussed in the body of this article, the study concludes that the method proposed by Marinov (1964), for determining the sex of The Maritsa barbel by using the height of the anal fin, is indeed accurate. Consequently, the method allows including the youngest age groups in describing barbel population sex structure. Determining the sex of the juvenile fishes is indispensable for achieving a more comprehensive understanding of the populations sex structure.

The difference in the height of the anal fin between the male and female of the Maritsa barbels allows utilizing much larger sample sizes, because in this case it will also enable the inclusion of juvenile fish. This, in turn, allows obtaining higher population monitoring accuracy and greater statistical significance of the research analyses. Moreover the method, proposed by Marinov (1964) and empirically verified by the present study, is fast and easy to use.

In conclusion, the main contribution of this publication is that it presents and verifies a method, which allows determining the sex structure of a Maritsa barbel population without killing any fish and even outside the breeding period. Minimizing fish losses is very important, especially since the Maritsa barbel is an endemic species for the Balkan Peninsula and it is also protected by the Bulgarian Biodiversity Conservation Act (applications 2 and 4 of the Law).

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DETERMINING THE SUMATRAN ELEPHANT (*ELEPHAS MAXIMUS SUMATRANUS*) CARRYING CAPACITY IN ELEPHANT TRAINING CENTRE, WAY KAMBAS NATIONAL PARK, INDONESIA

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Abstract

Sumatran elephants are one of the endangered species that are protected, and some of them have been tamed (and trained) to support tourism activities. The purpose of this study was to determine the carrying capacity of elephants in supporting tourism activities at the Elephant Training Centre, Way Kambas National Park. Data obtained through interviews and observations, followed with analysis on the carrying capacity of elephants for various tourist activities, including Elephant Riding, Tracking, Safari, Night Safari, and Full Day. The results showed that the elephant carrying capacity was still maintained, with up to 390 people per day that could be entertained by 23 elephants. The balance between the purpose of protection and elephant tourism can be achieved if the elephant carrying capacity is not exceeded. Intensive promotion and provision of adequate tourism facilities and infrastructure need to be carried out by managers of Elephant Training Centre to increase the number of tourists, moreover on special interest tours; where this will have a significant impact on increasing non-tax state revenues following the elephant carrying capacity.

Key words: conservation area, endangered species, protected area, sumatran elephant.

Introduction

The increasing number of tourists visiting national parks year after year shows how the tourism sector is progressively developing in conservation areas (Marcelina et al. 2018). The driving factor for tourists to visit national parks is for recreation and seeking knowledge, valuing wildlife, and the desire to feel a strong bond to nature (Mutanga et al. 2017). The relationship between wildlife-based tourism and

conservation is not always positive, and there are increasing concerns about the sustainability of tourism environments in protected areas (Grunewald et al. 2016).

One of the endangered species that is protected and some of which have been tamed to support tourism activities is the elephant. The study conducted by Kerley et al. (2003) shows the existence of elephants as one of the key components for attracting and offering tourism experiences that are in protected areas. Ranaweer-

age et al. (2015) argue that monitoring tourist influences on endangered species, such as Asian elephants is the vital matter. Hence appropriate action can be taken to reduce disturbances towards this wildlife. According to Febryano and Rusita (2018), the development of elephant tourism products must have specification, quality and needs to be able to provide education on the importance of maintaining the preservation of elephants, for protection and tourism to be achieved simultaneously.

One of the conservation areas that offers activities of elephants that have been tamed is Elephant Training Centre (Pusat Latihan Gajah/PLG) located in Way Kambas National Park (Taman Nasional Way Kambas/TNWK), Indonesia. Its establishment was initially intended to minimise the conflict between Sumatran elephants (*Elephas maximus sumatranus* (Temminck, 1847)) and humans. Indrawan et al. (2010) explained that IUCN had designated Sumatran elephants with critically endangered status. According to Wahyudi (2016), their population in 2013 was estimated to be only around 1970 elephants; while this figure is much smaller than the elephant population in 1980, which is approximately 5000.

Elephants that have been tamed are then trained to assist in handling elephant conflict with humans, saving animals, security patrols, and transportation equipment to support forest fire control activities. Over time, the PLG was able to attract tourists to take a closer look at the actions of elephants that had been tamed, such as: various elephant attractions, photos with elephants, following mahout (elephant handlers) activities in caring for, feeding and drinking, patrolling and observing the handling of elephant disorders and riding elephants (BTNWK 2012). Elephant Riding is a tourist activity that is in

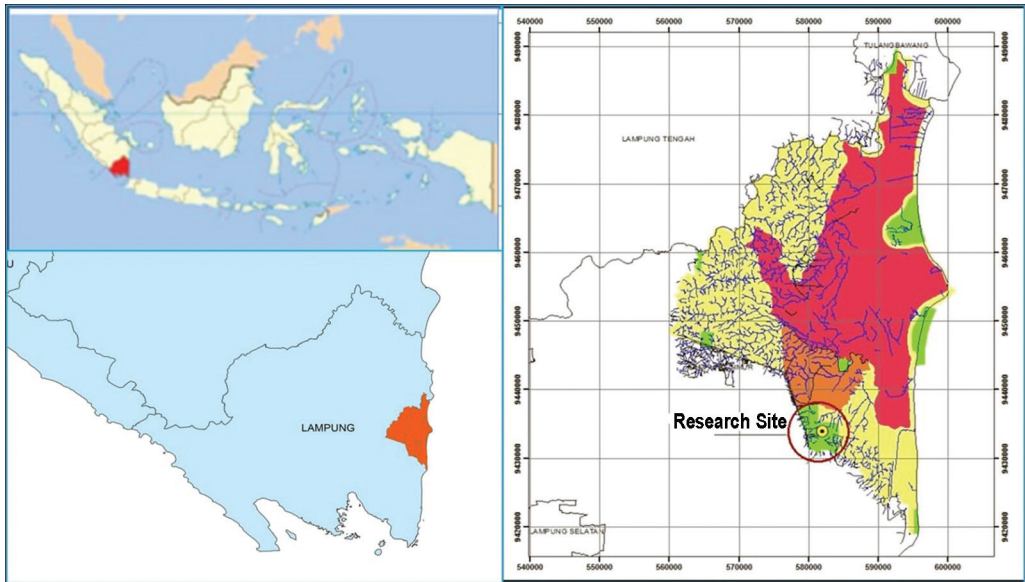
high demand by tourists, but the number of elephants used is limited and must ensure not to exceed the carrying capacity of elephants to be ridden by tourists every day.

Important ethical issues were raised around questions of animal welfare, especially definitions of acceptable and appropriate standards for working animals, along the lines of the development and expansion of elephant riding (Duffy and Moore 2011). Elephants used by humans as a means of tourism activities often experience torture (Dick 2016). The research conducted by WAP (2017) on 3,000 elephants involved in the tourism sector in several countries, namely: Sri Lanka, Nepal, several states in India, Laos, Cambodia, and Thailand in late 2014 to mid-2016 showed how three out of four elephants experience poor living conditions, such as: being chained, lack of ecological encounter, inadequate shelter, lousy food, and stressful interactions with tourists.

Operational hours and elephant mileage are influential variables in understanding the work intensity of elephants in elephant training locations in Northern Thailand (Bansiddhi et al. 2018). To maintain their existence in PLG, the carrying capacity of elephants to entertain tourists in each day must be considered. This consideration is critical, mainly as they are icons of TNWK and Lampung Province which attract tourists, both domestic and international, to visit the region. Therefore, the aim of the study was to determine the carrying capacity of elephants in supporting tourism activities at PLG TNWK.

Methods

This research was conducted at PLG TNWK, East Lampung (Fig. 1) in Jan-



Source: Febryano and Rusita (2018).

Fig. 1. Map of research site.

uary–March 2018. Data collection was done by interviews and observations. Determination of respondents for interviews was conducted by purposive sampling, namely the technique of determining the sample according to the terms or criteria set by the researcher (Arikunto 2010). Respondents were Way Kambas National Park Agency (Balai Taman Nasional Way Kambas/BTNWK) managers of 20 people, consisting of: Head of BTNWK (1 person), Deputy Head of BTNWK (1), BT-

NWK staff (4), Head of PLG TNWK (1), PLG TNWK staff (2), Head of Administration Division PLG TNWK (1), and mahout/elephant trainer (10). The data and information obtained were analysed quantitatively descriptively related to the carrying capacity of elephants used for several tourism activities including Elephant Riding, Tracking, Safari, Night Safari, and Full Day. Data analysis was performed using a modified formula carrying capacity of the Boullon Formula (1985) as follows:

Elephant Carrying Capacity = Number of Elephants × Elephant Capacity (person) (1),

$$\text{Rotation Coefficient} = \frac{\text{Time duration provided by manager}}{\text{Average time duration for 1 activity per person}} \quad (2),$$

Elephant Carrying Capacity per Day = Elephant Carrying Capacity × Rotation Coefficient (person/day) (3).

Results and Discussion

Description of research location

Geographically, TNWK area is located at 4°37'–5°16' S and 105°33'–105°54' E. In government administration, it is in Lampung Province which covers two districts, namely: East Lampung Regency and Central Lampung Regency (BTNWK 2016). The distance of TNWK from the state capital (Jakarta) is 241.6 km that can be reached within 5–6 h drive. When using an aircraft, it can be reached within 45 min from Jakarta to Bandar Lampung (provincial capital); continued with 2–3 h ride.

The TNWK area is stipulated through the Decree of the Minister of Forestry No 670/Kpts-II/1999 dated 26th August 1999. It has an area of approximately 125,631.31 ha and has a role as a natural conservation area to protect its wealth in various wildlife. The existence of these wild animals is still well preserved, especially the big mammals, namely: Sumatran elephant (*Elephas maximus sumatranus* (Temminck, 1847)), Sumatran tiger (*Panthera tigris sumatrae* (Pocock, 1929)), Sumatran rhinoceros (*Dicerorhinus sumatrensis* (Fischer, 1814)), Malay tapir (*Tapirus indicus* (Desmarest, 1819)), and Sun bear (*Helarctos malayanus* (Raffles, 1821)) (BTNWK 2016).

TNWK with its biological and non-biological wealth is a huge potential to be developed as an object of attraction for

tourists, both domestic and international. Some locations have become tourist icons that have been widely known both nationally and internationally, such as the Elephant Training Centre (PLG) with the main assets of tame Sumatran elephants and Sumatran Rhino Asylum (Suaka Rhino Sumatra/SRS) with Sumatran rhinoceros assets (BTNWK 2016). It was established on 27th August 1985, and is the location of elephant taming, training, breeding and conservation. Until now the PLG has trained around 300 elephants that have been distributed throughout the country (BTNWK 2012).

The number of tourists visiting the PLG from data of five years (2013–2017) shows an increase. In 2017 it experienced a visit increase of more than 50 % compared to previous years. The peak occurred in January and July, with an average daily visit of 213 people. The highest number was in July as it coincides with school holidays, but in June there were no tourists from abroad and only 134 people from within the country. The area is usually visited by tourists only on certain days such as Eid al-Fitr, Eid al-Adha, weekends or during festivals.

Direct increase in tourist visits has helped increase the number of non-tax state revenues (Table 1). This increase is the result obtained from tourist entrance tickets, which is IDR15,000 per person. Research by Parida et al. (2017) shows that tourism activities in India play a significant role in increasing state revenues.

Table 1. Number of tourist visits and non-tax revenue during 2013–2017.

No	Year	Domestic	International	Total	Non-tax revenue (IDR)
1	2013	13,299	339	13,638	77,934,500
2	2014	25,363	210	25,573	221,296,000
3	2015	23,405	257	23,662	311,685,000
4	2016	35,627	362	35,989	407,462,000
5	2017	77,550	392	77,942	830,422,500

Note: USD 1 = IDR 14,021.50 (5th February 2019). Source: BTNWK (2018).

Elephant carrying capacity in supporting tourism activities

The elephant is one of the icons that are very important in developing tourism at PLG. Elephant attraction is one of the tourist activities that present elephants and handlers with various skills such as dancing, playing football, and different other. This activity is minimal as it is only performed for one hour each day. Such attractions are only represented by some elephants, and if their posture is already large, they are no longer allowed to do the attractions.

In addition to the elephant attractions stated above, other tourist activities use elephants as mounts, namely the Elephant Riding, Tracking, Safari, Night Safari, and Full Day. Each activity has a different elephant carrying capacity depending on the number of elephants and the time duration provided by the manager (Table 2). There are 46 elephants at PLG TNWK; however only 23 of them are allocated in Elephant Riding activities; while the remaining five are allocated for tourist attractions. The elephant carrying capacity for overall above mentioned tourist activities is up to 390 people.

Elephant Riding is an activity for tourist to ride an elephant for 10 min with a relatively short route in the tourist area around PLG office. The capacity of each elephant is a maximum of 2 tourists per one way, therefore in each day, it can accommodate 300 tourists with 30 rotations. Most local tourists visiting at weekends prefer Elephant Riding activities compared to other tourist activities that use elephants for riding offered by PLG managers.

Tracking, Safari, and Night Safari are tourist activities riding elephants entering the roaming area that is the secondary forest around PLG. The time provided for Tracking activities is 30 min per route; while for Safari and Night Safari with a path that is further than Tracking activity the time duration provided per route is 30 min. The carrying capacity of elephants for Tracking activities is 50 people per day with a rotation of 10 times. As regards to Safari and Night Safari, the elephant carrying capacity is for up to 22 people and 13 people respectively, each with 4.5 rotations. In the three abovesaid tourism activities, each elephant is only allowed to carry one tourist and one handler in each route, to ensure the satisfaction and comfort of tourists.

Table 2. Elephant carrying capacity.

No	Type of tourism activities	Number of elephants provided by managers	Capacity of the elephant (person/elephant)	Time duration provided by managers (min)	The average time for one activity per person (min)	Elephant carrying capacity per day (person/day)
		a	b	c	d	(a·b)·(c/d)
1	Elephant Riding	5	2	300	10	300
2	Tracking	5	1	300	30	50
3	Safari	5	1	540	120	22
4	Night Safari	3	1	540	120	13
5	Full Day	5	1	540	540	5
Total						390

The Full Day is a tourist activity following elephant activities with its mahout (elephant handler) starting from morning to evening with a roaming area in the secondary forest around PLG. Various activities followed by tourists include bathing elephants in the morning and evening, feeding them in the morning before being grazed to secondary forests around PLG, and observing the behaviour during herding until walking back to PLG. The elephant carrying capacity in Full Day activity is one tourist; therefore, with five elephants available for this activity, Full Day can only accommodate five tourists with one rotation each day.

At present all tourism activities at PLG TNWK that use elephants for riding are still below the elephant carrying capacity to support these activities. The Elephant Riding itself that is in high demand by local tourists has capacity 300 people per day and is still far above the average number of tourists per day during the peak season in January and July 2017. Marsiglio (2017) states the number of tourists that can be maintained below the elephant carrying capacity significantly will help sustainable tourism management.

The main factor that may influence tourist interest the most to do Elephant Riding activity is the ticket price charged by PLG managers (Table 3). Different from the Elephant Riding activity with ticket price more affordable for local tourist,

which is charged at IDR 20,000 per person; the tourist activities such as Tracking, Safari, Night Safari, and Full Day, are preferred by international tourists despite the more expensive rates, because these four tourist activities offer a longer and further route and roaming time compared to the Elephant Riding activity, and the route has access to the secondary forest areas. Besides, PLG managers also differentiate rates between local and international tourists ranging from IDR 100,000 to IDR 300,000 gap.

The number of tourists visiting PLG TNWK tends to increase every year (Table 1). This is inseparable from manager's role who continues to promote through various media, both print as well as electronic. However, there is a concern if the number of tourists who are interested in doing Elephant Riding activities exceeds the elephant carrying capacity, it will affect the health condition and sustainability of the elephant itself. This condition certainly may have an impact on the balance between elephant conservation and tourism goals. If in the future the elephant carrying capacity is already reached, consequently the manager can limit the number of tourists in relevance with it, or the manager may also increase the ticket price. Ruggerio et al. (2012) explained the environmental impact that may arise due to the number of tourist visits could be minimised by providing alternative tourism activities.

Table 3. Ticket prices of tourism activities.

No	Type of tourism activities	Local tourists (IDR/person)	International tourists (IDR/person)
1	Elephant Riding	20,000	20,000
2	Tracking	150,000	250,000
3	Safari	250,000	350,000
4	Night Safari	500,000	800,000
5	Full Day	750,000	1,000,000

Note: USD 1 = IDR 14,021.50 (5th February 2019). Source: BTNWK (2018).

The tourism activities such as Tracking, Safari, Night Safari, and Full Day, are indeed the alternative tourism activities developed by PLG managers and focus on tourists who have special interests. They are mostly joined by international tourists because the rates are relatively expensive for the market of local ones. The research of Harmony and Pitoyo (2012) shows how tourists no longer pursue or quest for cheap offers for their tourist destinations, in contrary, they are willing to pay a high price for the quality of experience gained from their tour visits.

Current development causes a shift in the interest of tourists from natural tourism to special interest tourism, where the tour guarantees the existence and preservation of natural tourism objects and attractions. The study conducted by Rathnayake and Gunawardena (2013) at Kaudulla National Park shows that diversification of activities is the most appropriate solution. This is useful for improving tourist service and satisfaction towards the activities experienced by tourists with the elephants; so that the variety choice of tourism activities may reduce the frequency of elephant use as a tourist attraction.

The number of tourists who decided to experience in the four tourism activities mentioned above is still far below the carrying capacity of the elephant. However, it is unfortunate that the data is currently not adequately available in PLG, including information on the number of tourists who selected to do Elephant Riding activities. Promotions that have not been optimised by managers, especially for overseas market segments, may reflect in the number of international tourists visiting TNWK that is relatively small (Table 1). Marcelina et al. (2018) in its study at PLG TNWK mentioned several facilities, such as the arena of elephant attractions,

playgrounds, trash bins, and toilets which were poorly maintained and damaged, and that the numbers were still lacking. Besides that, general tourism facilities and infrastructure in Lampung Province, especially around TNWK area and others are also still inadequate. Hence it influences the satisfaction of tourists, especially international ones.

Tourist satisfaction is one of the essential elements in formulating tourism development strategies (Bagri and Kala 2015, Latiff and Imm 2015). Providing relevant information before tourism activities and the impressions tourists may have when visiting a tourist site for first time may increase their satisfaction, so that they may come again in next opportunity (Park et al. 2018). This satisfaction becomes one of the positive promotions to increase the number of tourist visits, especially to participate in some elephant riding activities at PLG.

If all tourist activities involving the elephants mentioned above are managed to be within the elephant carrying capacity, it may result with the potential to contribute significantly to the increase in non-tax state revenues of IDR 41,600,000 per day (Table 4). This is with the assumptions that the Elephant Riding activities are only in demand by local tourists, while the other four tourist activities, namely: Tracking, Safari, Night Safari, and Full Day, are more favoured by international tourists.

The study by Polyapipat and Loh (2015) on the development of elephant tourism in Thailand reveals that the number of visits decreases every year, as people's comprehension of the preservation and concern for elephants is very high. Tourists make their visit to watch elephant attractions only 1–2 times within one year, and other than that they do activities such

as observing elephant behaviour, seeing them bathing, seeing eating, and photographing. The study conducted by Koprina (2016) shows how elephant attraction activities in India are no longer allowed to be carried out through torturing these an-

imals. According to Makecha and Ghosal (2017) conservation education programs have turned out to be effective in encouraging people to get closer to non-human species; it will affect the attitude towards conservation of these animals.

Table 4. The income potential of some elephant riding activities per day following the elephant carrying capacity.

No	Type of tourism activities	Elephant carrying capacity/day (person/day)	Income potential		Total (IDR)
			Local tourists (IDR)	International tourists (IDR)	
1	Elephant Riding	300	6,000,000	0	6,000,000
2	Elephant Tracking	50	0	12,500,000	12,500,000
3	Safari	22	0	7,700,000	7,700,000
4	Night Safari	13	0	10,400,000	10,400,000
5	Full Day	5	0	5,000,000	5,000,000
Total					41,600,000

Note: 1 USD = IDR 14,021.50 (5th February 2019).

Conclusions

The number of tourists visiting the PLG TNWK is still within the elephant carrying capacity to support several tourism activities, such as Elephant Riding, Tracking, Safari, Night Safari, and Full Day, which is up to 390 people per day with 23 elephants. Local tourists' preference dominates Elephant Riding, while international tourists favour in the other four activities. Each activity has a different carrying capacity depending on the limited number of elephants and the time duration provided by the manager. The number of elephants involved in carrying out tourism activities that is suitable with their carrying capacity is an endeavour to achieve a balance between protection and tourism goals. PLG managers need to conduct intensive promotions and provide adequate facilities and infrastructure to increase the number of tourists, mainly on special interest tourism activities with relatively higher prices, such as Tracking, Safari, Night Safari, and

Full Day; hence non-tax state revenues may increase significantly up until these activities have reached their carrying capacity.

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STATE OF FOREST MANAGEMENT CERTIFICATION IN RUSSIA BY THE END OF 2016

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Abstract

Some global markets' demand towards sustainable forest management is contributing to the displacement of national governments as the central source of environmental rule-making authority. Forest Stewardship Council (FSC) is a particularly innovative example of a voluntary non-state market-driven governance mechanism. Hosting the largest proportion of the global forest resources the Russian Federation is particularly important arena for forest certification. A new Russian forest management FSC standard based on International Generic Indicators is planned for approval at the beginning of 2019. It is thus crucial to understand what this voluntary mechanism identifies as barriers to different aspects of sustainable forest management. We assessed the overall state of FSC forest management certification in Russia by analysing quantitative and qualitative variables of non-conformities exhibited regarding (1) regional specifics, (2) size of forest management units of certificate holders, (3) certification bodies and (4) type of evaluation. The current state of FSC forest management certification in Russia is characterized by the dominance of the certified area in the European part of the country, where its density is 3–4 times higher. The geographic location of various certification bodies has been established; in particular, LLC 'Forest certification' dominate in Siberia, 'SGS Qualifor' in Far East, and the rest are operating mainly in the European part. As a result of the analysis, no differences were revealed in the number of non-conformities exposed due to the size of forest management units and their geographical location. In most cases, there is no significant difference between the certification bodies. However, we reliably found a greater number of non-conformities exhibited by LLC 'Forest certification' in comparison with 'NEPCon'. In addition, a significant difference is found between the number of non-conformities and the type of evaluation. Principles 6, 8, and 9 are more problematic, with a higher frequency of non-conformities.

Key words: forest certification, Forest Stewardship Council, non-conformities, Russian Federation, sustainable forestry, map of certified forests.

Introduction

Voluntary certification of forest management (FM) has become a widespread approach toward responsible use of forests (Rotherham 2011, Alves et al. 2011). Created in 1993, Forest Stewardship Council's

(FSC) certification is one of the most commonly adopted schemes worldwide (Araujo et al. 2009), and its application is growing. FSC certification has experienced phenomenal growth across temperate and boreal forest regions. Currently, about 201,000 M ha of forest is FSC

certified and FSC certificate holders (CHs) are based in 86 countries (www.ic.fsc.org). FSC's vision reflects the principles of sustainable development. FSC Principles and Criteria operationalize this vision, setting out social, economic and ecological requirements applicable at a global scale. FSC International approves national FSC standards, which include nationally or regionally adapted indicators.

An important feature of FSC certification is its greater environmental friendliness compared to other certification systems (Garrelts and Flitner 2011, Moore et al. 2012).

Pioneering the approach of certifying socially and environmentally responsible forestry practices, FSC has been replicated across multiple sectors, from agriculture to fisheries and mining.

During recent years, FM practices certified by FSC have provoked considerable public debate and controversy in many countries. A number of well-known environmental NGOs have not withdrawn their support for FSC (e.g., the Swedish Nature Conservation Society in 2011, Greenpeace Russia in 2014).

FSC provides a comprehensive assessment of the sustainability of FM (Merger et al. 2011) and contributes to combating illegal logging (Trishkin et al. 2015). The impact of forest certification on the ecological condition of forests (Cubbage et al. 2010, Johansson et al. 2013, Kalonga et al. 2015, Simonsson et al. 2016, Elbakidze et al. 2016) and social institutions (Maletz and Tysiachniouk 2009, Nysten-Haarala 2013, Miteva et al. 2015) can already be considered proven.

However, limited evidence of tangible and intangible outcomes of FSC certification is a major constraint for both end-consumers and interest groups, such as NGOs, governments, industry and In-

igenous organizations. There is lack of studies that analysed main challenges in implementation of FSC certification on the ground as well as audit process of certified FM is not studied properly.

At the end of 2016, standard FSC-STD-RUS-V6-01-2012 expired. The new Russian FSC FM standard based on International Genetic indicators is planned for approval at the beginning of 2019. During the transition period, version 6.01 continued to operate, but with additions and changes, in particular relating to intact forest landscapes, etc.

The aim of the study is to assess the overall state of FSC FM certification in Russia by analysing quantitative and qualitative variables of the non-conformities (NCs) exhibited, by taking into account (1) regional specifics, (2) size of the FM units of certificate holders (CHs), (3) certification bodies (CBs) and (4) type of evaluation.

Methods and Materials

The study included analysis of the official evaluation reports available on www.info.fsc.org platform. Subject of analysis were all FM certificates issued in Russia till 2016-12-31 to individual companies (single certificates) or group entities (group certificates). All formulated NCs were grouped according to (1) regional specifics, (2) size of the FM units of CHs, (3) CBs and (4) the type of evaluation.

We analysed the public version of evaluation reports (main evaluations and re-evaluations) across European and Asian parts of Russia.

The quantitative and qualitative characteristics of the exhibited NCs compared to the national FM standard by various CBs were also assessed (7 CBs were re-

viewed in total). To quantitative indicators, we attributed the number of NCs, and to qualitative – their nature (social, environmental aspects, etc.).

Analysis of NCs was carried out for all CBs, except for 'Bureau Veritas', 'Control Union Certification' and Certification association 'Russian Register', because each of them has just a few CHs. The premise of it was the fact that the national office of FSC Russia periodically conducts calibration workshops with the participation of CBs representatives on the interpretation of the Russian FM standard. This suggests that CBs have somewhat different opinions on certain issues. To assess these differences, we have identified 10 indicators, which NCs are allotted most often.

The total number of NC reports analyzed (without division into minor and major NCs) was 2209. Considering that during re-evaluations, often the gradations of NCs increase due to their repetition, in the study did not separate them by type.

The number of NCs reports per CBs was as follows: 'NEPCon' – 831, LLC 'Forest certification' – 1043, 'GFA Certification GmbH' – 151, Certification association 'Russian Register' – 29, 'Bureau Veritas' – 15, 'Control Union Certification' – 8, 'SGS Qualifor' – 131.

FSC CHs were divided into 4 categories according to the area of FM units: small (<10,000 ha), medium (10,000–50,000 ha), large (50,000–500,000 ha) and extra-large (>500,000 ha). This separation is based on the standard FSC-STD-20-007 (V3-0) En Forest Management Evaluations. Additionally, we identified a category of extra-large companies. This is done taking into account the internal state of forest industry in Russia.

An analysis of the impact of certification cycles (the main, the 1st re-evaluation,

the 2nd re-evaluation) on the number of NCs exhibited was also carried out. A total of 50 public versions of re-evaluation reports were analyzed, including 7 based on the results of the 2nd re-evaluation.

NCs were recorded in a database, developed in Microsoft Excel, and their distribution was traced and quantified. Statistical differences were calculated by use of STATISTICA 10.0 software. The Mann-Whitney U-test was applied to reveal the differences between two groups, while the differences between several groups were tested using Kruskal-Wallis Analysis of Variance (ANOVA) method, with a transgression probability of $p = 5\%$.

Results

Characteristics of FSC certified forest in Russia

As of December 31, 2016 in Russia, a total of 146 FSC FM certificates were issued for an area of over 40 million ha. The distribution of certified forests across the country is uneven, with 24 M ha (or 60 %) located in the European part, and 16 M ha (or 40 %) in the Asian part (Fig. 1). Taking into account the fact that the area of the European part constitutes 23 % of the total area of Russia, it turns out that the density of certified forests here is 3–4 times higher than in the Asian part. One reason of this difference is that the main markets for FSC-certified wood and products exported from Russia are located in the European Union (EU) and the FSC-certification in the country is driven mainly by demand of a global green market (Trishkin et al. 2014). Most of the forest companies in the Asian part of Russia supply certified products to China, which go further to Japan or Europe.

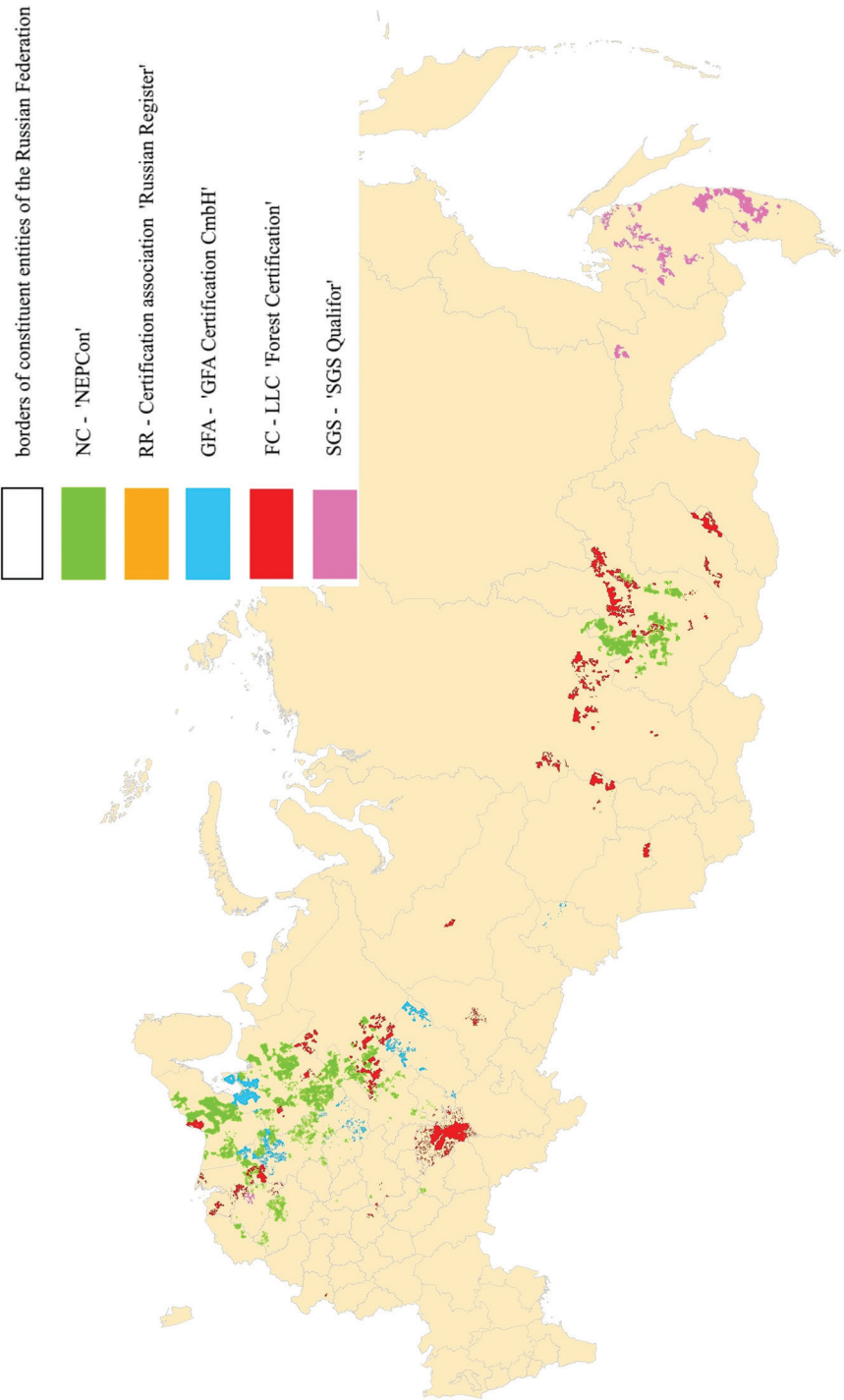


Fig. 1. Certified forests under FSC scheme in February 2016 by CB.

In general, 74 % of FSC certificates were issued for FM units located in the European part of the country, and 26 % for units in the Asian. Areas of single CHs were smaller in the European part than in the Asian. In general large and extra-large timber tenures accounted for 97 % of certified forests in the European part, and for 99 % in the Asian (Fig. 2) due to the reason that mainly large vertically integrated forest companies were motivated to certi-

fy FM in order to export timber products. However, given the relative proximity to the EU, many, in the European part medium- and small enterprises established international business activities successfully as well. The accuracy of differences between the number of NCs between companies from the European and Asian part was not confirmed (Mann-Whitney test $p = 0.3263 > 0.05$).

The dominant type of certificates was issued to single forest companies (88 %). The remaining certificates were issued to group entities (12 %) which meet the requirements of FSC Standard for Group Entities in Forest Management Groups (FSC-STD-30-005 V1-1). A total of 17 group certificates were issued for FM units with a total area of about 4 M ha, which included 65 forest companies. All group certificates were issued to companies located in the European part. In general, the development of group certification is conditioned by the needs of large European companies, such as Stora Enso, which develops this type of certification most actively in the North-West Russia.

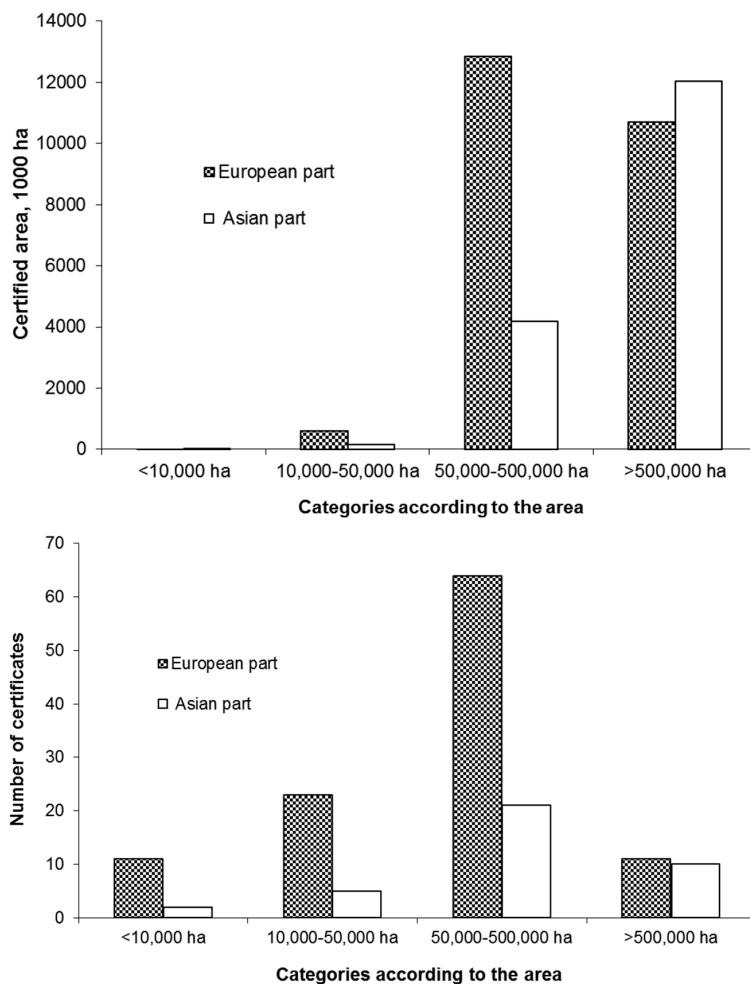


Fig. 2. Area of certified forests (top) and number of certificates in relation to size of FM units.

Approximately half of the certificates were issued to forest companies operating in four regions: Arkhangelsk (20 certificates), Irkutsk (18), Vologda (17) and Leningrad (16). The three regions (Arkhangelsk, Vologda, and Leningrad) are the most forested regions in the European part that are closely located to EU markets. The same applies to Irkutsk region, located in the Asian part in close proximity to China market.

There were five CBs operating in Russia in 2016: 'GFA Certification GmbH' (Germany), 'NEPCon' (Denmark), 'SGS Qualifor' (France), LLC 'Forest certification' (Russia), and Certification association 'Russian Register' (Russia). Based on the number of CHs, 'NEPCon' had been leading for many years, with a market share of 49 %. Another major CB was LLC 'Forest certification', which certified FM in 34 %

of the companies. Other CB account for 17 %, including 'GFA Certification GmbH' (10 %), 'SGS Qualifor' (6 %), and Certification association 'Russian Register' (1 %). 'Bureau Veritas' had lost several of its clients in Russia. The largest group certificates were issued by 'GFA Certification GmbH' and 'NEPCon'.

CBs differed by the geographical location of their CHs. In particular, 68 out of 75 clients of 'NEPCon' were located in the European part, and only 7 companies were located in Siberia. 'GFA Certification GmbH' had about the same situation with

13 CHs located in the European part and 2 CHs based in Siberia. The Certification association 'Russian Register' had been operating only in the European part. Siberia was mainly covered by LLC 'Forest certification', which had 37 % of CHs in that region, and the Far East was represented by 'SGS Qualifor', which operated there exclusively.

The number of FM certificates that were terminated, on average, for the period from 2006 to 2016 is 7 per year (Fig. 3).

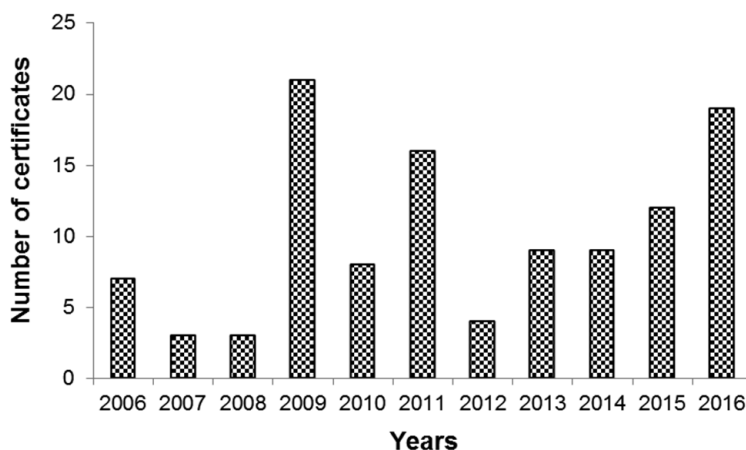


Fig. 3. Dynamics of terminated FSC certificates.

The calculation excludes 2009 and 2011, as well as 2015 and 2016. In 2009, the CB of LLC 'Europartner' ceased to exist. Almost all companies have moved to another CB LLC 'Forest certification'. Out of 21 terminated certificates in 2009, 11 were clients of LLC 'Europartner'. In 2011, the transfer of 'NEPCon' from co-operation with 'Rainforest Alliance' under 'Smart Wood Program' to its own accreditation began. In connection with this, 13 terminated certificates out of 16 this year were clients of 'Smart Wood'. These sharp spikes in the number in 2009 and 2011

are due to purely technical reasons and are not related to the quality of certification. However, starting from 2015, active cooperation between Accreditation Services International (ASI) and the national office of FSC began to improve the quality of certification in Russia. In addition, a sharp increase in terminated certificates is a vivid confirmation of that. The dynamics of the number increase of terminated certificates is convincing, for the first half of 2017 18 certificates on an area of 2.4 M ha have been suspended.

Main NCs related to regional specifics, size of FM units of CHs, CBs and the type of evaluation

'GFA Certification GmbH' auditors most often found NCs related to compliance with the national legislation and forest exploitation activities (indicator 1.1.2), provision of personal protective equipment to employees (indicator 4.2.10), ensuring a sustainable level of forest exploitation (indicator 5.6.2), execution of the technical documentation for slashing sites (indicator 5.6.5) and the availability of a program for transition from large-scale clear-cutting to selective, gradual and small-scale clear-cutting (indicator 6.3.7). 'SGS Qualifor' found NCs with indicators associated with provision of the employees with personal protective equipment (indicator 4.2.10) and its application (indicator 4.2.11), environmental impact assessment at the landscape level (indicator 6.1.5) and collection, removal from the slashing sites, and disposal of waste (indicators 6.7.5 and 6.7.6). 'NEPCon' auditors most often allot NCs as per indicators related to holding of a special assessment of work conditions (indicator 4.2.5), use of personal protective equipment (indicator 4.2.11), execution of the technical documentation for

slashing sites (indicator 5.6.5), and collection of information on the dynamics of flora and fauna (indicator 8.2.7), as well as on changes in the number of rare species (indicators 8.2.7 and 8.2.8). For LLC 'Forest certification' auditors, the most common indicators are those related to holding of a special assessment of work conditions (indicator 4.2.5), execution of the technical documentation for slashing sites (indicator 5.6.5), as well as those related to the issues of provision for the non-confidential information on the forest management plan (indicator 7.4.1), a summary of the monitoring results (indicator 8.5.1) and the parameters of allocation of high conservation value forests (indicator 9.2.4).

In particular, the auditors of 'GFA Certification GmbH' pay more attention to compliance with the legal requirements in the course of production activities, the issues of transition from large-scale clear-cutting to other types of logging and ensuring sustainable FM; the auditors of 'SGS Qualifor' prioritized the fuels and lubricants and waste handling problem and the impact on the landscape, while 'NEPCon' concentrated mostly on monitoring of flora and fauna, including rare species, and LLC 'Forest certification' – on access to non-confidential information for stakeholders.

During audits of 'GFA Certification GmbH' an average of 10.1 ± 2.4 NCs per 1 main evaluation or re-evaluation was allotted; the same value for 'SGS Qualifor' is 14.6 ± 4.8 NCs, 12.6 ± 1.4 NCs for 'NEPCon', and 21.7 ± 3.6 NCs for LLC 'Forest certification'. Differences in number of exhibited NCs between different CBs were unreliable (Kruskal-Wallis test $p = 0.1699 > 0.05$). However, the pairwise comparison revealed a significant difference between 'NEPCon' and LLC 'Forest certification' (Table 1).

Table 1. Estimation of significance of number of NCs exhibited by CBs (non-parametric Mann – Whitney U-test).

CBs	'GFA Certification GmbH'	'NEPCon'	'SGS Qualifor'	'Forest certification' LLC
'GFA Certification GmbH'	-	0.5114	0.5194	0.0534
'NEPCon'	0.5114	-	0.6990	0.0382*
'SGS Qualifor'	0.5194	0.6990	-	0.3816
'Forest certification' LLC	0.0534	0.0382*	0.3816	-

Note: * – the differences are significant, p -value < 0.05.

An analysis of the number of NCs allotted by the size of certified area showed lack of significant differences (Table 2). The significance of differences between number of NCs and size of FM units has not been confirmed (Kruskal-Wallis test $p = 0.4761 > 0.05$). The pairwise comparison using the Mann-Whitney test also did not confirm the connection.

It was found that the evaluations of small forest landowners exhibited 15.6 ± 3.8 NCs, the most often – as per 7 indicators (4.2.5, 4.2.10, 5.6.5, 6.2.12, 8.2.7, 8.2.8, 9.2.1). For medium forest landowners 12.1 ± 1.7 NCs allotted with 9 most common indicators (4.2.5, 4.2.10, 5.6.5, 6.1.7, 6.3.7, 6.3.15, 8.2.8, 8.5.1, 9.2.4). For large forest landowners 17.4 ± 2.3 NCs allotted with 8 most common indicators (4.2.5, 4.2.11, 5.6.5, 6.3.15, 8.2.7, 8.2.8, 8.5.1,

9.2.4). And for particularly extra-large forest landowners 11.8 ± 3.3 NCs issued with 8 most common indicators (4.2.10, 4.2.11, 6.1.7, 6.3.8, 6.7.3, 6.7.5, 8.2.7, 8.2.14, 9.1.5).

In general, forestry companies of the European part exhibited fewer NCs in comparison with those in the Asian. In the European part the most often issued NCs were associated with 8 indicators (1.6.6, 4.2.5, 4.2.10, 4.2.11, 5.6.5, 8.2.7, 8.2.8, 8.5.1), and for the Asian one these indicators are 4.2.10, 4.2.11, 6.7.3, 6.7.5, 7.4.1, 8.2.7, 8.2.8, and 8.5.1. The CHs based in the European part most often had challenges with knowledge of the national FM standard, and in the Asian there with use and storage of fuels and lubricants, domestic, and industrial wastes, as well as their disposal.

Table 2. Estimation of significance of number of NCs exhibited by CHs with different areas of managed forest units (non-parametric Mann – Whitney U-test).

Size of FM unit	Small	Medium	Large	Extra-large
Small	-	0.7472	0.9258	0.2701
Medium	0.7472	-	0.6899	0.1931
Large	0.9258	0.6899	-	0.1523
Extra-large	0.2701	0.1931	0.1523	-

Note: The differences are insignificant, p -value > 0.05.

We have analyzed impact for the 1st (through the example of 50 companies)

and the 2nd (through the example of 7 companies) re-evaluations. It was found

that in the course of the 1st re-evaluation 11.2±2.5 NCs are allotted with 5 most common indicators (4.2.5, 4.2.11, 5.6.5, 8.2.7, 8.5.1). During the 2nd re-evaluation, 9.7±3.7 NCs are allotted with 7 most common indicators (2.1.1, 4.2.5, 4.2.11, 6.7.1, 8.2.7, 8.2.8, 8.5.1). On average, 15.3±1.5 NCs are allotted throughout Russia during FM evaluations. There was tendency towards reduction in the number of NCs allotted from cycle to cycle. Confirmed the relationship of cycles of certification with a number of NCs (Kruskal-Wallis test $p = 0.0012 < 0.05$). Thus, re-evaluations are conducted with significantly fewer NCs.

Main NCs related to forest functions

The most common problem was the insufficient level of labour protection in enterprises (14 %).

According to the reports of CBs, most of the Russian forest enterprises did not provide their workers with the uniforms and equipment that meet the quality and quantity requirements of the Russian Federation and the International Labour Organization. There was also a problem when employees did not wear the personal protective equipment provided by the employer. Another complaint was that there was no special assessment of working conditions, or it was done improperly.

Additionally, all CHs provided poor personnel training, both in general knowledge of FM standard, and regarding environmental aspects as it was reflected in reports. Largely, this is due to the high turnover of manpower in the forestry sector, which is characterized by low wages.

Most of the enterprises had executed poorly and did not fill in correctly the technological documentation for logging sites. Basically this is due to the fact that

according to the current Russian forestry legislation, the technical chart is an internal document of timber companies. Only the new (end of 2016) 'Rules of logging' feature a unified form of this document. However, most likely, CBs will continue to allot NCs, since this form does not fully meet the requirements of FSC forest certification.

The problem of use of fuel and lubricants, waste collection and disposal is the most inveterate for Russian forestry enterprises. Often times both domestic and industrial garbage is left at the logging sites, and at the best, it is burned or buried. It should also be noted that a situation where this practice takes place regardless of the fact that there is a valid contract for disposal with specialized organizations is not uncommon. In addition, no one is used to dealing with fuel spills.

NCs related to environmental issues total 48 %. One of the main NCs regarding the 8th Principle 'Monitoring and Assessment' was about monitoring of changes in flora and fauna, and also the dynamics of rare species number. Often certified companies did not have reliable data and research organizations were not able to provide this data of proper spatial resolution to forest companies. The second problem, according to the reports, was related to the fact that forest enterprises had to identify key habitats for protection of rare species, however, annual monitoring based on field observation had not been developed and/or applied properly.

The availability of non-confidential information and its communication to the parties concerned is extremely bad. Moreover, cases when certified companies ignore requests for provision of non-confidential information by scientific and public organizations are common. For small and extra-large ones, a weak involvement of

the stakeholders in the process of allocation of the high conservation value forests of social types (HCVF of types 5 and 6).

NCs related to social-cultural functions total 4 %. Issues related to indigenous people also have led to solutions at the state level, and when conducting FM evaluations in case of applicability of the 3rd Principle, close attention is paid to the interaction of the forest company with representatives of indigenous people. However, there have been no precedents when companies in their production activities would use any knowledge of indigenous peoples and they would pay them a compensation for this.

Given the low population density in the well-forested regions, forestry companies are constantly in need of skilled workers, and the local population, as a rule, does not cover these needs. In recent years, there has been a tendency to partially compensate for the staff shortage by involving citizens of China under the quotas approved by the state. As practice shows, they work exclusively on industrial sites, and are not involved in forest work.

In general, there are no discrimination problems. The only example of such issue is indication of gender in job advertisements, when it comes to purely male professions (e.g. a turner), or female ones (e.g. a cleaning woman).

The sustainable use in the long-term are also problematic for Russian enterprises. Again, this is largely a phenomenon of the Soviet past. In the Soviet Union, the annual allowable cut was made, as a rule, for 40–60 years. Also losses of forest resources from various factors (fires, windfalls, outbreaks of insect pests, etc.) were not taken into the total planned annual harvest level. Considering the need to exclude voluntarily protected areas with high conservation values of types 5 and 6,

this problem is typical for the majority of Russian forestry enterprises.

NCs related to economic functions total 14 %. In terms of use of raw materials, there is a tendency according to which larger companies have capacities for deep processing of wood, including low-grade wood and waste, and tend to have orientation toward export. Smaller enterprises manufacture minimally processed products and, as a rule, are oriented toward local or regional markets within the country. However, there are exceptions.

Despite the fact that there were no NCs related with indicator 5.3.4 'Silvicultural operations do not lead to complete or partial destruction of sites of special significance for maintenance and reproduction of other forest resources (recreation, water, soil, fisheries, mushrooms, berries etc.)', potentially there are risks of destruction or damage to areas that support maintenance of various forest resources. For medium forest landowners there is a problem of ensuring sustainable forest exploitation and the lack of programs for the transition from large-scale clear-cutting to small-scale selective or gradual clear-cutting. Extra-large forest landowners face the problem of sustainability of use of forest resources and the abandonment of the key elements, as well as the problem of storage of fuels, lubricants, and waste, and their recycling.

For 29 indicators there were no NCs issued (Table 3). Such indicators are called 'sleeping'. According to FSC principles, their variation is as follows: 1 – 5 %, 2 – 22 %, 3 – 14 %, 4 – 1 %, 5 – 33 %, 6 – 12 %, 7 – 4 %. There are no sleeping indicators only in Principles 8 and 9. The average share of sleeping indicators in Russian FM standard is 11% while their share in FSC Principles 2, 3, 5 and 6 is above that value.

Table 3. List of indicators not addressed in NC reports.

Indicator number	Formulation
1.3.3	The organization shall not use forced labour.
2.3.2	Disputes and grievances consistent with 2.3.1 shall be resolved through communication, negotiation or mediation. Legal procedures are used only if negotiations fail.
2.3.4	There shall be no outstanding disputes of substantial magnitude involving different interests.
3.4.1	Rights of indigenous people for commercial use of their traditional knowledge and skills regarding the use of forest species or management systems in forest shall be recognized and if possible documented.
3.4.2	The organization shall reach an agreement with indigenous people on compensation for commercial application of their traditional knowledge and skills regarding the use of forest species or management systems in forest silvicultural operations.
3.4.3	Indigenous people shall be compensated in consistency with 3.4.2.
4.1.1	The organization shall give employment priority to workers from local people.
4.1.2	Employment of workers from other regions of Russia and other countries shall be justified.
4.1.3	The organization shall not discriminate staff on the basis of their sex, nationality, religion and other characteristics with regard to employment, workplace and human rights issues.
5.2.1	The organization shall seek the best economic use of forest resources, taking into account its financial and technical possibilities.
5.2.2	The organization shall process harvested forest resources or delivers the resources to local or regional wood processing organizations, if this is economically and technically justified.
5.3.2	The organization shall utilize cutting waste (small diameter stems, snags, short cuts, wood dust, etc.) and products of their on site processing (e.g. chips) if it is economically and technically justified and under condition that this does not exert adverse implications on forest productivity, biodiversity, and forest regeneration.
5.3.4	Silvicultural operations do not lead to complete or partial destruction of sites of special significance for maintenance and reproduction of other forest resources (recreation, water, soil, fisheries, mushrooms, berries, etc.).
5.4.1	When planning forest management the organization shall explore technical and financial feasibility of production of a range of forest goods and services.
5.4.2	The organization shall expand the range of goods and services delivered to the market, including those demanded in the local market if economically practical.
5.4.3	The organization shall not prevent the development of different kinds of forest use (e.g. collection of mushrooms and berries, hunting, recreation) within the forest area being certified.
5.5.5	Wetlands shall be drained only if this is required for restoration of their natural hydrological regime.

Indicator number	Formulation
5.6.6	Secondary forest uses of the forest area being certified shall not lead to the depletion of secondary resources.
6.5.7	Construction of forest roads and bridges shall not disturb habitats critical for lifecycles of animals (in particular, by avoiding sensitive areas, restricting number of water crossings, no water-crossing construction during fish breeding period and preserving natural ways of animal migration).
6.7.7	When economically and technically justified, environment friendly fuels and oils shall be used for machinery and equipment.
6.8.1	Organisms (entomophagous insects or biological substances) shall only be used as biological control agents when the inefficiency of other methods of non-chemical pest and disease management is scientifically proved).
6.8.2	Biological control agents shall be used in consistency with applicable administrative regulations.
6.8.3	Genetically modified organisms shall not be used.
6.9.1	The use of exotic plants shall only be allowed for maintenance of man-made stands consisting of introduced species, which are of high historical and cultural value (e.g. larch stands), for urban gardening and in plantations (see Principle 10).
6.9.3	If exotic species consistent with 6.9.2 occur within the forest area being certified, the organization shall undertake measures to prevent their uncontrolled spread.
6.10.1	Conversion of forests to plantations shall only be permitted when it occurs on the very limited portion of the forest management unit being certified. This means that all conditions below are met: a) Conversion does not occur on high conservation value forest areas (see also 6.10.3, 6.10.4), and b) It does not affect a total of more than 5 % of the area of the FMU, and c) It does not exceed 0.5 % of the area of the FMU in any one year, and d) It enables clear, substantial, additional, secure, long-term conservation benefits across the FMU.
6.10.2	Conversion of forest lands to other categories, which function cannot guarantee conservation of forest cover in the long term (except building forest infrastructure and local mineral resource quarries), shall only be permitted when it affects a very limited portion of the forest management unit, corresponds to the area development plans (housing, road construction, etc.) and is approved at the federal, regional or municipal levels and supported by local people. Very limited portion means that all conditions below are met: a) Conversion does not occur on high conservation value forest areas (see also 6.10.3, 6.10.4), and b) It does not affect a total of more than 5 % of the area of the FMU, and c) It does not exceed 0.5 % of the area of the FMU in any one year, and d) It enables clear, substantial, additional, secure, long-term conservation benefits across the FMU.

Indicator number	Formulation
6.10.3	The organization shall not initiate conversion of HCVF to lands of other categories, which function cannot guarantee conservation of forest cover in the long term (except construction of forest infrastructure.
7.1.12	The forest management plan shall describe the system for monitoring of forest increment and dynamics consistent with Principles 6 and 8.

Discussion

In the Russian national FM standard, the number of indicators per Principle varies: from 9 indicators in Principle 2 to 82 indicators in Principle 6. In the remaining Principles, with the exception of Principle 10, which, as a rule, is not applied to evaluations (in Russia, there are no forest plantations created for the purpose of timber growing), there is a more balanced number of indicators – from 20 to 32. At that, judging from Figure 4, Principles 1, 2, 3, 5, and 7 have the frequency of NCs allotment lower than the proportion of their indicators.

Principles 6, 8, and 9 are more problematic (Table 4), with a higher frequen-

cy of NCs allotment. This suggests that, on the one hand, audits reveal mostly the problems associated with the environmental aspects of certification, and on the other hand, Russian forestry enterprises have problems with environmental requirements' implementation. A comparative analysis in five European countries also showed that Principle 6 (Halalisan et al. 2016) is the most problematic. However, number of NCs on Principles 4 and 8 is also high. Gullison (2003) after analyzing the reports of 30 companies from 11 countries showed that 66 % of NCs relate to ecological and environmental aspects.

A similar study conducted in Latin America (Basso et al. 2011) showed that the main NCs were related to environmental and labour legislation.

Normally, number of NCs should not be correlated with certified area (Newsom et al. 2006). Our results confirm this finding, despite the large variation in size of FM units in Russia, reaching several orders of magnitude. However, there are cases when the relationship between the certified area

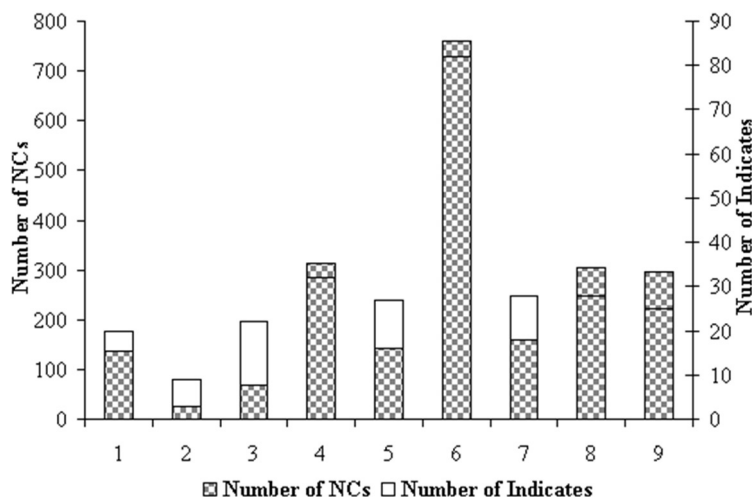


Fig. 4. NC reports per indicators divided into 9 Principles FSC.

and the number of detected NCs is confirmed. E.g. Halalisan et al. (2016) proved that this relationship had a positive correlation (Spearman $r = 0.583$).

Table 4. List of indicators addressed in NC reports (in every 3rd evaluations).

Indicator number	Formulation	Total number of NCs
1.6.6.	The requirements of the Russian National FSC Standard shall be explained to staff.	35 or 25.4 %
4.2.5	The organization shall have certified working places.	44 or 12.5 %
4.2.10	Forest workers shall be provided with personal protective equipment. The requirements of health and safety regulations, including the use of relevant tools and machines, and work clothing and personal protective equipment in accordance with Table 1 of ILO Code of Practice on Safety and Health in Forestry Work (2001) shall be adhered to by the staff.	39 or 12.5 %
4.2.11	The technological map and/or other documents specifying the development of a particular harvest area (lesoseka) shall contain at least the following information: - location, including district forest management unit (lesnichestvo), forest group, numbers of blocks (kvartals), sections (vydels), harvest areas; - type of management operation (use); - type and technique of harvesting or type of resource harvested; - grade of harvested timber; - size of harvest area; - pre-harvest stand composition;	46 or 14.7 %
5.6.5	- area at which young growth shall be retained; - AAC for the leased area in terms of timber and/or other forest resources; - indication which trees shall and shall not be harvested; - timelines for timber harvesting and removal from forest; - non-exploitable areas (NEP), other retention stands/stand elements; - forest protection measures and their timelines; - method for clearing the harvest area; - peculiarities of harvesting techniques; - forest regeneration activities; - bays, industrial and household waste disposal sites; - waste removal/disposal operations.	48 or 33.6 %
6.3.15	Staff shall be familiar with measures aimed at preserving and maintaining ecological functions and conservation values of forest (see 6.3.5–6.3.14) and are trained in their application.	34 or 4.5 %
8.2.7	Information permitting to assess the composition of flora and fauna and its changes in relation with the forest management shall be collected and analyzed.	41 or 13.4 %

Indicator number	Formulation	Total number of NCs
8.2.8	Information shall be collected and analyzed with purpose to monitor changes in the populations of rare, threatened and endangered species of plants, animals and fungi.	40 or 13.1 %
8.5.1	A summary of the monitoring results of parameters consistent with 8.2, except confidential information, shall be available to the public.	44 or 14,4 %
9.2.4	Identification parameters of HC VF as well as mapped HC VF shall be publicly available.	36 or 12.1 %

The share of NCs in labour protection is very high (Table 4). This can be explained by the fact that such NCs are related to the level of country's development and the stability of its economy. The connection between the development of a country and the number of NCs identified in the protection of labour and health of employees of timber industry companies is shown by Newsom and Hewitt (2005) and Hain (2012).

Forest certification positively affected the ecological condition of the surveyed streams, but its effects were only measurable after 5 years of certification (Dias et al. 2015). Our study showed that there is a positive effect of re-evaluations on the number of identified NCs. In the long run, this may also lead to the strengthening of not only ecological, but also social and economic functions. The implementation of forest certification requirements provides a real improvement in the company's management system. This applies to almost all aspects, including the greening of forest exploitation and the rights of workers (Cubbage et al. 2010). The FSC arose with the participation of environmental NGOs and therefore a greater effect should be expected in ecological aspects (Moore et al. 2012).

In conducting evaluations in Russia, auditors give 15.3 ± 1.5 NCs. This data is not different, for example, from the num-

ber of NCs detected on FM evaluations in USA. There, on average, 13.9 NCs are exposed on the main evaluations, and at the 1st re-evaluation only 6.4 NCs (Newsom et al. 2006). Those, as in Russia, the number of NCs in USA decreases from a main evaluation to a 1st re-evaluation.

The results of the study showed that, in general, the number of NCs by different CBs is not significantly different. It meets the requirements of forest certification. However, the difference was established between the two CBs ('NEPCon' and LLC 'Forest certification'). Perhaps this is due to the fact that auditors of different CBs have differences in interpretations of one or another requirements of FM standard (Simonsson et al. 2016). The examples of this were given by Maletz and Tysiachniouk (2009).

The paper (Lukashevich et al. 2016), devoted to the general state of FSC forest certification in Russia, shows that by the end of 2015 the largest share of the market for audit services belongs to 'NEPCon' (more than 40 %). In the second place is LLC 'Forest certification', which has 28 % of CHs. The third place is occupied by 'GFA Certification GmbH' with 11 %. Our characteristic of the distribution of CHs by CBs coincides with this data, but differs in greater detail. This study also states that the most often NCs was fixed in principles 6, 8, and 9.

Conclusions

The current state of FSC FM certification in Russia is characterized by the dominance of the certified area in the European part of the country, where its density is 3–4 times higher. It is there that the leading regions by the number of certificates are located. This is due to more stringent consumer requirements in the European Union countries compared to Asian ones (mainly China). A characteristic feature of certification in Russia is the predominance of large and extra-large forest owners certified according to single schemes. The main CB is 'NEPCon' (Denmark), however LLC 'Forest certification' (Russia), 'GFA Certification GmbH' (Germany) and 'SGS Qualifor' (France) have also significant market shares. The geographic location of various CBs has been clarified; in particular, LLC 'Forest certification' dominates in Siberia, 'SGS Qualifor' in the Far East, and the rest CBs operate mainly in the European part. The dynamics of suspended certificates testifies to the significant role of ASI for improving the quality of certification. As a result of the analysis, no differences were revealed in the number of NCs exposed due to the size of the FM units and their geographical location. In most cases, there is no significant difference between the CBs. However, a greater number of NCs issued by LLC 'Forest certification' in comparison with 'NEPCon' has been found. In addition, a significant difference is found between the number of NCs and the certification cycle. Thus, enterprises undergoing certification for first time receive a greater number of NCs. In general, the development of FSC FM certification in Russia has positive trends and in future, we should expect its moderate growth and quality improvement.

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PAST AND PRESENT SILVICULTURAL SYSTEMS AND TENDING OPERATIONS IN HIMALAYAN MOIST TEMPERATE FORESTS OF PAKISTAN

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Abstract

Himalayan moist temperate forests have the highest contributing values in the forest resources of Pakistan. These forests provide timber for commercial and domestic use, non-wood forest products that are abundantly available for local farmers and the international market. These forests are also source of fresh water to the lowlands. Locals and nomads are highly dependent on these forests for their livestock production. Silvicultural systems and tending operations are important management tools for the optimization and utilization of forest resources. Edaphic and biotic factors are also influenced by these systems for biomass production. There are two different silvicultural systems applied in the management: protection and conservation, i.e. selection system (also including group selection) and clear felling system. The group selection and clear felling system were applied for experimental purpose in the 1980s. At present, only selection system with 3D's (dead, dying and diseased), and damaged trees logging is accepted in different parts of the Himalayan moist temperate forest. Before 1992, 1.9 % and 88.6 % of activities were found for clear felling and selection system, respectively. Tending operations are also inactive in different parts of the forests. Tending activities i.e. weeding 21.1 %, cleaning 88.6 %, thinning 16.1 % and improvement felling 1.43 % average, were recorded to examine the active status in the study area. Studies must be conducted for the protection, conservation and management optimisation of these valuable forest resources.

Key words: afforestation, harvesting system, Himalayan temperate forest, management activities, species composition.

Introduction

Ecologically and biologically Pakistan is one of the richest countries, including high mountains of Himalayan, Karakorum and Hindu Kush and deep Indian ocean with high diversity (Hussain 1984). Forest ecosystems are one of the major parts of the natural richness. Production is one of the key elements of forest resources and their services especially in the conif-

erous forests (Müller et al. 2019). These forests are the major source of palatable plant species (Khan 1985), they also provide fuel-wood and medicinal plants to the local community (Sher and Al-Yemeni 2011). Due to the heavy exploitation, intensive utilization and recreational activities (Rashid et al. 2011) in these valuable ecological niches, the fauna and floristic community become near to extinct (Al-Yemeni and Sher 2010, Sher and Al-Yemeni

2011). Special management is demanded, for wildlife biodiversity maintenance in many cases (Moser et al. 2002).

To get maximum benefits without destroying these forests, foresters need sustainable management rules and integrated plans. Harvesting or silvicultural system is the scientific method to utilize these forests properly. Silvicultural systems are the 'set of silvicultural operations by which forest crops are tended, harvested, and replaced by new crops – this constitutes a Silvicultural Systems' (Troup 1952) for standard definition (Association 1953, Champion et al. 1965b). Availability of environmental resources to establish and create new individuals and survivors are provided by the silvicultural treatments and tending operations (Harper et al. 1965, Lewandowski et al. 2015). According to studies during four decades of span, plant compositions, differences were significantly shifted through the years, the sites were degraded due to reduction (35 %) in species richness, forbs and grasses ratio was increased due to an increase in acidity and change of the soil chemical composition (McGovern et al. 2011). The distribution of natural regeneration, its amount and types are also determined by the interaction of a wide range of overstorey and understorey vegetation with climatic and edaphic factors (Bataineh et al. 2013). The soil have undergone large changes in the past years due to environmental pressure (McGovern et al. 2013), which affects the species composition, structure, and diversity of the forest stands. That ultimately influenced the choice of silvicultural systems and tending operations in the mountainous forest with scattered vegetation.

Outdoor recreation is the key eco-commercial service of these mountainous forests. Flora and fauna are highly diversi-

fied in its nature, great importance for protection and scientific management is required, for forest resources conservation and sustainability. Silvicultural systems and tending operations are important management tools for the optimization and utilization of forest resources. The present study is focused on identifying management activities and status of forest for conservation, protection and production level.

Material and Methodology

Moist temperate forest of Pakistan – Ecological consideration: Forests in Pakistan cover about 6.6 % of the country area (5,832,506 ha), where Himalayan moist temperate forests cover about 0.7 % (572,508 ha) of the total country area. These forests are found in Khyber Pakhtunkhwa (P), Punjab (P) and Azad Jammu and Kashmir (S) (Province (P), State (S)) at high altitudes (900–3500 m) (Bukhari et al. 2012) (Fig. 1). Typically represented by conifers, vertically on the down from these forests subtropical pine forests and on top sub-alpine and alpine pastures are found (Champion et al. 1965a). Dry temperate forests are found while moving horizontally from these ones which are surrounded by great mountainous ranges of Asia, recorded rainfall in the area is 635 mm to 1524 mm (detail is given in Table. 1).

The Himalayan moist temperate forest is further classified for more precise and accurate research work as shown in Table 2 and Figure 2 (Champion et al. 1965a). The geological formations of Himalayan moist temperate forest areas are mainly occurring on gneisses and schists (Shah and Moon 2004), also extended over shales, conglomerates, limestone, granites and quartzites (Champion et al.

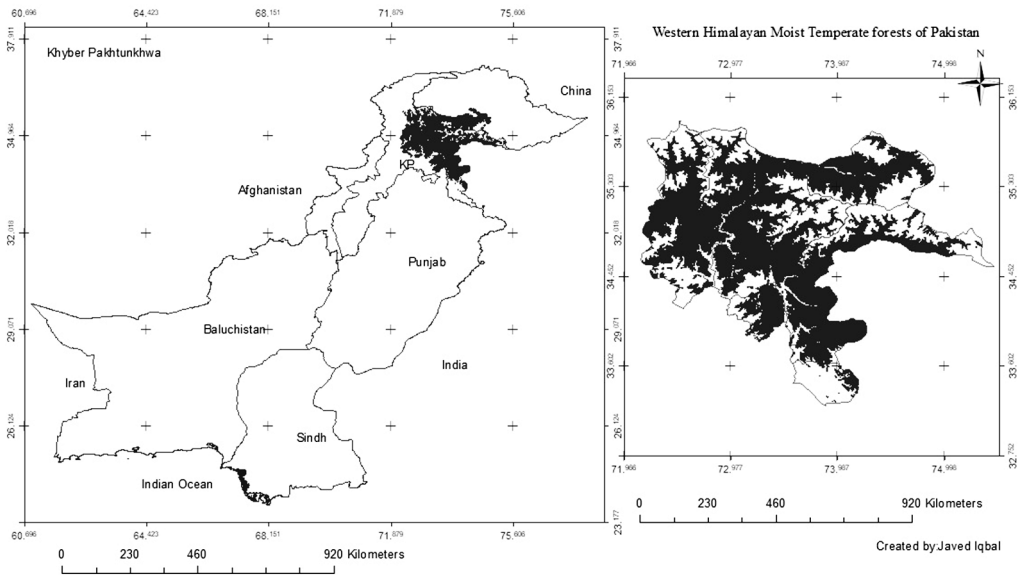


Fig. 1. Study area (ArcGIS 10.6 Academic version).

1965a). Loamy soils are predominant in the area showing a wide range of distribution and accumulation of acid humus of a considerable depth likewise those found in the spruce forest (Taylor and Hoon 1934). According to the forest working plan of Himalayan moist temperate forest these forest stands fall in site quality II (moderate) for vegetation growth and rarely sites are with site quality I (high) (Lughmani 1961, Shah 1967, Yusuf 1955).

Data collection and analysis

Data were based on working/management plan of the forest divisions. The data were categorized into management activities (cultural operation, tending operation, and silvicultural system) along vegetation type and stand density shown in Table 1. Data was collected through random selection of forest division. For statistical analysis, frequency distribution and percentage for activities were examined. Thirty forest divi-

sions were examined for past and present management practices; due to variation in the area of forest, percentages of different activities were recorded. Rstudio, Sigma-plot and PAST statistical packages were used. Data were representing through bar chart, histogram and line graph.

Problems of the area

Due to limited access to the study area (April to September) and also limited growing season (June to August), the research activities need extensive planning. Due to the high influence and pressure of tourist activities (infrastructure), the study area is exposed to degradation during the summer season. Population pressure (encroachment, shifting cultivation, grazing, extensive fodder and medicinal plant collection) also plays its negative role in the degradation of the forest cover, enhancing the erosion activities (Saeed 2003). Terrain and topography also affect the

Table 1. Description of the research areas.

Description	Khyber Pakhtunkhwa	Azad Jammu and Kashmir	Punjab
Area, ha	391,769	161,842	17,249
Soil/topography	Steep Northwestern slope on limestone shales, Lower on clod northern slopes	On a moderate slope with Northern aspect, Steep northern aspect on coarse granite,	Moderately steep sheltered North-western aspect on limestone,
Climate	MAR 1600 mm, MAT 3.2 °C	MAR 660 mm, MAT 2.1 °C	MAR 1506 mm, MAT 4.9 °C
No of plots for Selection System/area	25/2.5 ha	25/2.5 ha	25/2.5 ha
No of a plot for Clear-cut system/area	2 ha (Full enumeration of the plot)	1 ha (Full enumeration of the plot)	Nil
No of a plot for Group selection system/area	1 ha (Full enumeration of the plot)	Nil	Nil

Note: Mean Annual Temperature (MAT), Mean Annual Rainfall (MAR). Source: Champion et al. (1965a).

Table 2. Distribution and floristic composition of Himalayan moist temperate forest of Pakistan (Champion et al. 1965a, Efloras 2008).

Forest subdivision	Localities / Altitude	Species
A Lower Western Himalayan Temperate forests		
i Low-level blue pine forest (<i>Pinus wallichiana</i> Jackson)	Loon Bagla, Jhelum division, Kashmir / A.B. 1982–2134 m	<i>Pinus wallichiana</i> , <i>Quercus dilatata</i> Royle, <i>Taxus baccata</i> L., <i>Viburnum nervosum</i> D. Don, <i>Indigofera heterantha</i> Wall., <i>Paeonia emodi</i> Wall.
ii Moist deodar forest (<i>Cedrus deodara</i> Roxb.)	Malkandi Compartment 1/2, Shogran, Kagan Valley / 2286 m Ashkot Compartment 13, Keran division, Lower Nilam valley, Kashmir / 1676–1982 m	<i>Cedrus deodara</i> , <i>Pinus wallichiana</i> , <i>Picea smithiana</i> Wall., <i>Abies pindrow</i> Royle, <i>Quercus dilatata</i> , <i>Quercus ilex</i> L., <i>Aesculus indica</i> Wall., <i>Prunus cornuta</i> Wall., <i>Acer caesium</i> Wall., <i>Viburnum nervosum</i> , <i>Rosa macrophylla</i> Lindl., <i>Berberis lycium</i> Royle in Trans., <i>Hedera nepalensis</i> K. Koch, <i>Clematis monnana</i> Buch.-Ham.

iii	Western mixed coniferous forest	Ashkot, Lower Nilam valley, Kashmir / 2286–2438 m Shogran, Kagan valley / 2362 m Dungagali water catchment, Murree Hills / 2438–2591 m	<i>Cedrus deodara</i> , <i>Pinus wallichiana</i> , <i>Picea smithiana</i> , <i>Abies pindrow</i> , <i>Taxus baccata</i> , <i>Aesculus indica</i> , <i>Prunus padas</i> L., <i>Juglans regia</i> L., <i>Ulmus wallichiana</i> Planch., <i>Populus ciliata</i> Wall., <i>Acer caesium</i> , <i>Viburnum nervosum</i> , <i>Anemone obtusiloba</i> D. Don, <i>Actaea spicata</i> L., <i>Hedera nepalensis</i> , <i>Rosa moschata</i> Herrm.
iv	Ban oak forest (<i>Quercus incana</i> Roxb.)	Sehri Bari Reserve Forest compartment 58, Ghoragali, Murree Hills / 1829 m Loon Bagla (near Chakar), Muzaf-farabad forest division, Swat, Abbottabad / 1646 m	<i>Quercus incana</i> Roxb., <i>Cornus macrophylla</i> Wall., <i>Pistacia integerrima</i> J. L. Stewart, <i>Quercus dilatata</i> , <i>Pinus wallichiana</i> , <i>Pyrus pashia</i> Buch.-Ham., <i>Diospyros lotus</i> L., <i>Ficus palmata</i> Forsk., <i>Pinus roxburghii</i> Sargent, <i>Prunus padas</i> , <i>Indigofera heterantha</i> , <i>Rhamnus virgata</i> Roxb., <i>Viburnum grandiflorum</i> Wall. ex DC., <i>Hedera nepalensis</i> , <i>Quercus glauca</i> Thunb., <i>Olea glandulifera</i> Wall.
v	Moru oak forest (<i>Quercus dilatata</i> Royle)	Loon Bagla compartment 3, Muzaf-farabad division, Kashmir / 1829–2134 m Near Dungagali, Murree Hills / 2438 m	<i>Quercus dilatata</i> , <i>Pinus wallichiana</i> , <i>Populus ciliata</i> , <i>Ulmus wallichiana</i> , <i>Abies pindrow</i> , <i>Taxus baccata</i> , <i>Prunus cornuta</i> , <i>Juglans regia</i> , <i>Cornus macrophylla</i> , <i>Viburnum nervosum</i> , <i>Berberis lycium</i> , <i>Fragaria nubicola</i> (Hook.f.) Lindl., <i>Viola kashmiriana</i> W. Becker, <i>Hedera nepalensis</i> , <i>Euphorbia wallichii</i> Hook. f.
B Upper West Himalayan fir and mixed broadleaved forest			
i	Upper West Himalayan fir and mixed broadleaved forest	Upper Mushkin, Astor Valley, Gilgit / 3200 m	<i>Abies pindrow</i> , <i>Pinus wallichiana</i> , <i>Picea smithiana</i> , <i>Betula utilis</i> D. Don, <i>Sorbus aucuparia</i> L., <i>Salix flabellaris</i> Andersson in Kung., <i>Lonicera webbia</i> Wall., <i>Fragaria nubicola</i> .
ii	Kharsu oak forest (<i>Quercus semecarpifolia</i> Smith in Rees)	Keran division, Upper Nilam Valley, Kashmir / 2900 m Swat / 2896–3200 m Kagan division, Hazara / 3200 m	<i>Quercus semecarpifolia</i> Smith in Rees, <i>Abies pindrow</i> .
C Edaphic, seral and Degraded type of Himalayan moist temperate forests			
i	Moist temperate deciduous forest	Pahlgam, Lidder Valley, Kashmir / 2134 m Makanai Forest, Shogran, Kagan division / 2591 m Dungagali, Murree Hills / 2438 m	<i>Padus cornuta</i> Wall. ex Royle, <i>Aesculus indica</i> , <i>Juglans regia</i> , <i>Acer caesium</i> Wall. ex Brandis, <i>Ulmus wallichiana</i> , <i>Corylus colurna</i> L., <i>Viburnum grandiflorum</i> , <i>Acer pictum</i> auct., <i>Parrotia persica</i> (DC.) C.A.Mey., <i>Salix flabellaris</i> , <i>Hedera nepalensis</i> , <i>Rosa moschata</i> , <i>Populus ciliata</i> , <i>Ulmus wallichiana</i> , <i>Quercus dilatata</i> , <i>Clematis montana</i> Buch.-Ham., <i>Fragaria nubicola</i> .

ii	Populus-Salix flabellaris Andersson in Kung. forest	Upper part of moist temperate forest / 2743 m	<i>Populus ciliata</i> , <i>Salix flabellaris</i> Andersson in Kung. <i>Pinus wallichiana</i> .
iii	Alder forest	Kagan, Siran Valley Dir and Swat / 915–1829 m	<i>Alnus nitida</i> (Spach) Endl. Gen., <i>Salix flabellaris</i> Andersson in Kung. <i>Populus ciliata</i> .
iv	Riverain blue pine forest	Extended into the dry zone, recorded in Kagan, Dir and Nilam Valley / 1524–3048 m	<i>Pinus wallichiana</i> , <i>Alnus nitida</i> (Spach) Endl. Gen., <i>Populus ciliata</i> , <i>Salix flabellaris</i> . Some <i>Cedrus</i> and <i>Picea</i> on a higher level and on lower <i>Pinus roxburghii</i> .
v	High-level blue forest	Upper Mushkin Forest, Astor Valley, Gilgit / 2743 m	<i>Pinus wallichiana</i> , <i>Picea smithiana</i> , <i>Rosa webbiana</i> Wall., <i>Berberis lycium</i> , <i>Lonicera webbiana</i> , <i>Rubus armeniacus</i> Focke., <i>Ribes himalayense</i> Decne. <i>Populus alba</i> L., <i>Betula utilis</i> , <i>Salix flabellaris</i> .
vi	Secondary blue pine forest (<i>Pinus wallichiana</i> A.B. Jackson)	Paryai Reserve Forest, Siran division / 1981 m Shinkiani-Kund ridge, Siran division / 1829 m Miandam Forest, Swat / 2073 m Ghoradnaka, Murree Hills / 2286 m Loon Bagla, Muzaffarabad division, Kashmir / 1981–2133 m	<i>Pinus wallichiana</i> , <i>Cedrus deodara</i> , <i>Populus ciliata</i> , <i>Quercus dilatata</i> , <i>Rhododendron arboreum</i> Sm., <i>Prunus cornuta</i> Wall., <i>Viburnum nervosum</i> , <i>Berberis lycium</i> , <i>Rubus armeniacus</i> , <i>Viburnum kashmiriana</i> , <i>Hedera nepalensis</i> , <i>Quercus incana</i> , <i>Indigofera heterantha</i> , <i>Fragaria nubicola</i> . <i>Diospyros lotus</i> , <i>Aesculus indica</i> , <i>Ulmus wallichiana</i> , <i>Taxus baccata</i> , <i>Cornus macrophylla</i> .
vii	Himalayan moist temperate scrub	Lower Jhelum Valley or areas where trees are eliminated through biotic agencies / 1238 m	<i>Plectranthus barbatus</i> Andrews, <i>Berberis lycium</i> , <i>Indigofera heterantha</i> , <i>Cotoneaster humilis</i> Dunn, <i>Sarcococca saligna</i> (D. Don) Muell.-Arg.
viii	Pohu Scrub (<i>Parrotia persica</i> (DC.) C.A. Mey.)	Kashmir in the valley to the north of Jhelum, Swat Valley and Kagan / 1828–2438 m	<i>Parrotia persica</i>
ix	Himalayan temperate parkland	Middle and higher elevations Kagan Valley and Kashmir valley / 2286 m	Coniferous and broadleaved mostly forbs and grasses.
x	Himalayan temperate pastures	Last stage of degradation of the original broadleaved and coniferous forests. Better-drained slight banks between the flatter trampled ground / 2145–2655 m	<i>Pinus wallichiana</i> , and mostly forbs.

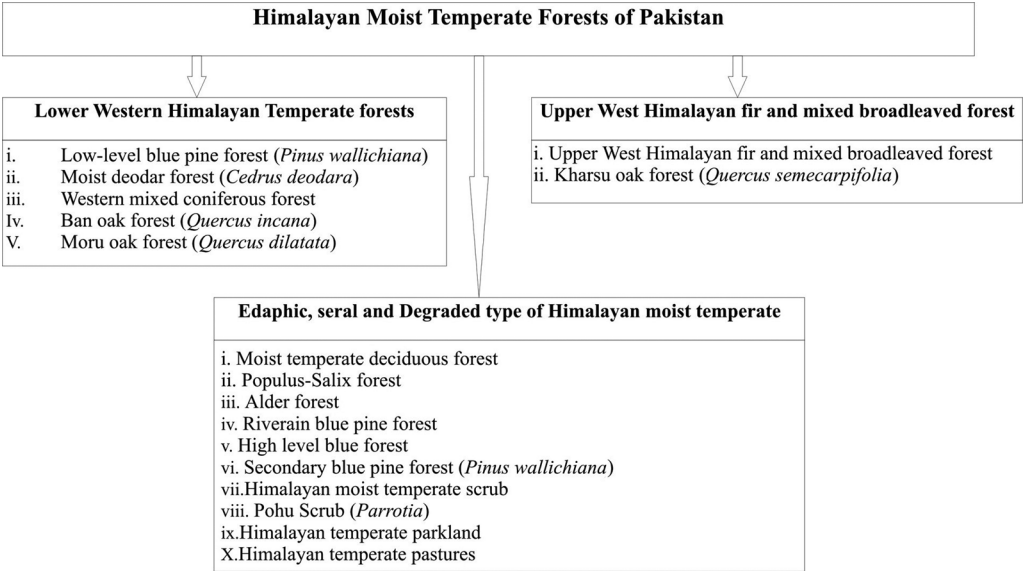


Fig. 2. Structure of forest types in Himalayan moist temperate forests of Pakistan (Champion et al. 1965a).

research activities in the area for the purpose of improvement and development of forest stands (Champion et al. 1965b).

Results and Discussion

Past and present silvicultural or harvesting systems: Due to the limited forest resources and less intense vegetation cover in Himalayan moist temperate forests, the silvicultural (harvesting) systems have very limited application. In the past (1947–1992) these forests were harvested under proper silvicultural system, i.e. selection system (this system is applied due to low vegetation cover, steep terrain and also due to recreational activities in the area). In the 1980s one-hectare plot were harvested for research purposes under group selection system, and one-hectare plot were clear felled under clear felling system. Besides that, strip clear-felling were also observed in Kund

forest in the 1980s. Since 1993 until present, green felling were banned, only 3D (dead, dying and diseased), wind fallen, top/half broken and snow damaged trees are harvested under prescribed selection system. The presentation of the research plots is given in Table 1.

The period before 1992 shows clear indication in Fig. 3 of scientific and management activities in the study area (average of percentage is about 1.9 % in clear felling area, whereas an average of 88.6 % activities was found in the selection system). After 1992 there is a clear indication of less management activities in the study area shown in Fig. 4 (no evidence of clear felling system were found, whereas selection system was partially working after 1999 by the government and average 14.56 % activities were active). The comparison between the periods is also illustrated on Fig. 5, which graphically represents the activities before and after 1992.

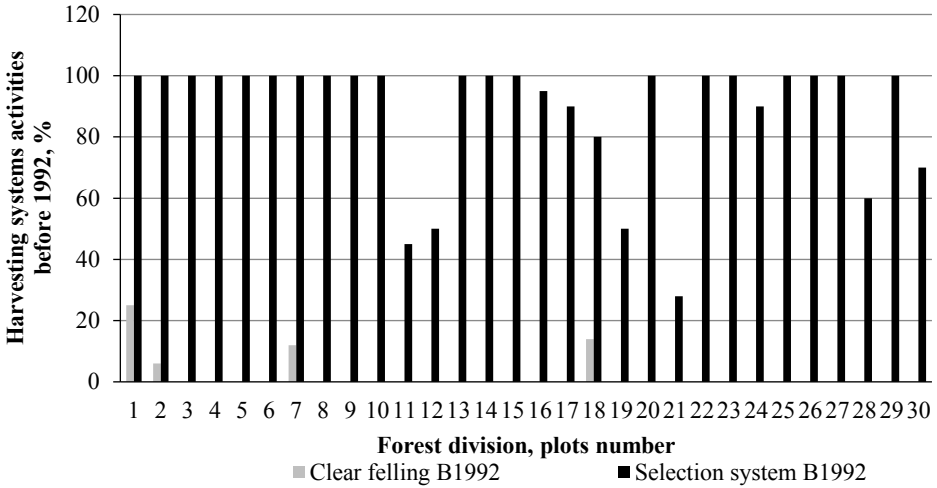


Fig. 3. Silvicultural system (Harvesting system) – past.

Note: X-axis – Forest division as plots (administrative zones for forest management), Y-axis – harvesting system share of activities, %.

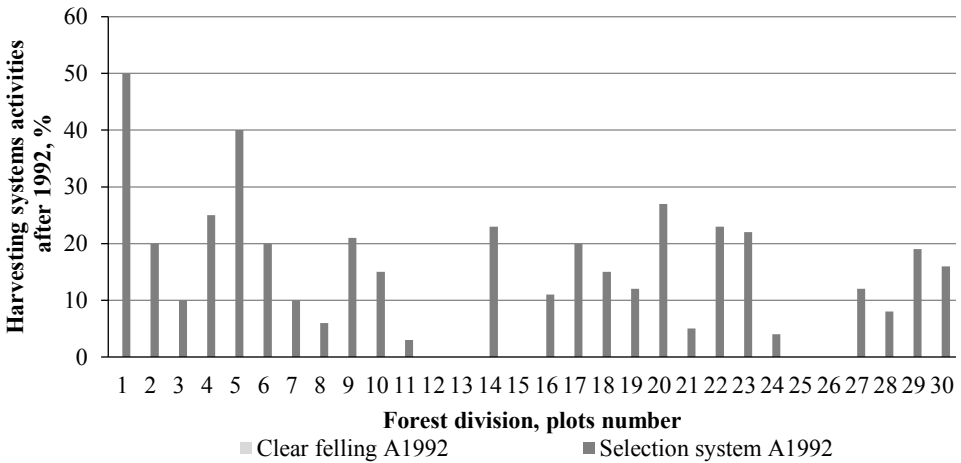


Fig. 4. Silvicultural system (harvesting system) – present.

Silviculture or tending operations:

Silviculture or tending operation tends toward the improvement of the forest crop (Short and Radford 2008) by providing species selection and reducing the canopy, as well as the intensity of damages. The tending operation may be defined

as ‘any treatment or tending designed to enhance growth, quality, vigour, and composition of the stand after establishment or regeneration and prior to final harvest’ (Helms 1998). According to the species composition, the operations were carried out in the forest area. Weeding is not com-

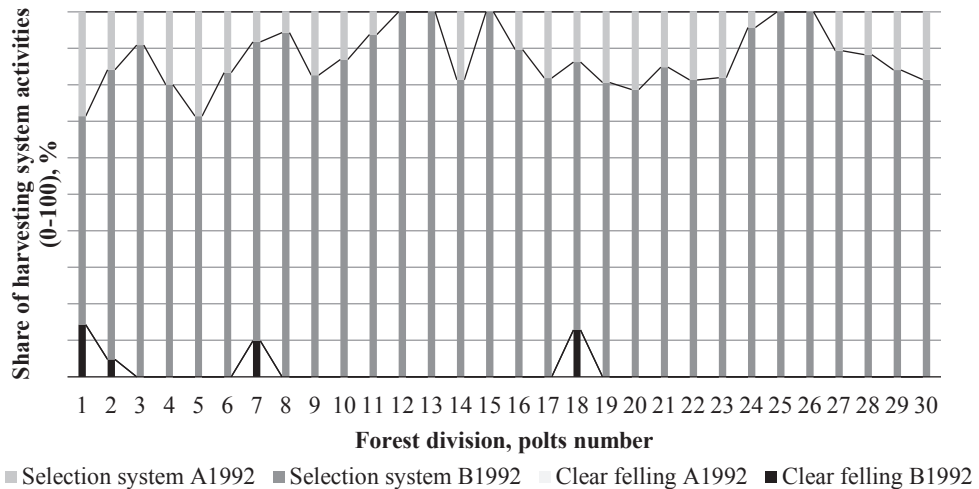


Fig. 5. Combined representation of harvesting data in the research area.

Note: X-axis shows forest division as research plots as administrative zones, Y-axis shows the share of harvesting activities in the region before and after green felling ban.

pulsory because weeds are very rare in the area and mostly highly nutritional and palatable plant species were found due to favourable growth condition. Cleanings was done just before the plantation or afforestation activities. Due to the low density and cover in the study area, thinning operation is very limited except for some special treatment. Pruning was also done during summer and before winter for fuel-wood collection and also for seed collection (Lughmani 1961, Shah 1967, Yusuf 1955).

Combine representation of tending operation before 1992, whereas the activities after green felling ban were discounted in the research area. Weeding (WD) activities were about 21.1 % on average, cleaning (C) activities are higher in number but they are not clearly categorized by the department (88.6 % average), thinning (T) and improvement felling (IF) were found 16.1 % and 1.43 % average, respectively shown in Fig. 6.

Conclusions

The discussion for conclusion is based on the available literature and past history of silvicultural operation in the mountainous region. Mountain forests show many problems worldwide (Borůvka et al. 2005). Due to the high recreational (tourism), conservation (wildlife), commercial (timber, medicinal plants and livestock), protection (watershed) and historical/geological (Himalayas) values of the Himalayan moist temperate forests, sustainable management of the forest must be focused for the future development of the area, as well as of the rest of the country (Champion et al. 1965a). For the sustainable development of these mountainous forests, developmental indicators must be defined before aim towards strategic and operational activities (Golusin and Ivanović 2009). The socio-economic condition and livelihood of communities living in or adjacent to these forests are completely dependent

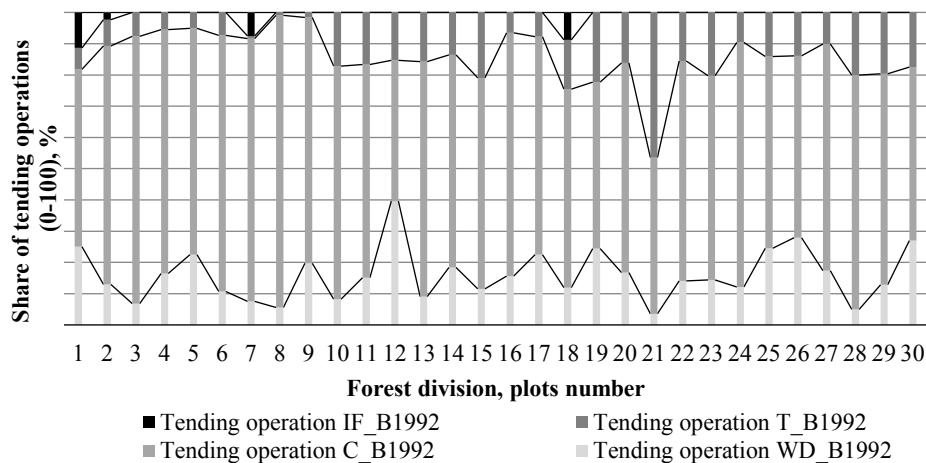


Fig. 6. Tending operations or silviculture practices in the research area.

on these forests (De Sousa et al. 2015). These forests have high potential as a watershed for the water reservoirs (Tarbela and Mangla) and also a source of fresh water to all reservoirs of Pakistan. Study areas are highly productive for the fodder collection, livestock grazing and high value of medicinal plants, which are affected by the lack of research (Abbasi et al. 2012). Present and past harvesting system and management systems in the area are only focused on trees (main crop), very little importance was given to the understorey vegetation or undergrowth.

Impacts of harvesting or silvicultural systems: Organizationally, as well as technically, timber harvesting or silvicultural systems are complex systems due to the advancement in the technology (Shegelman et al. 2015). These systems exposed the area for many environmental, biological and social factors, research study related to the impact of harvesting system on the undergrowth, site index and site quality, growth of the regeneration, composition, yield production, tree growth, diversity, and economic consid-

eration must be taken into account for the sustainable management of the area (Chaudhary et al. 2016). These areas are very sensitive to erosion, to reduce the rate of erosion or its control, vegetation cover plays a vital role for the protection and conservation of these watersheds (Bataineh et al. 2013).

Impact of silviculture/tending operations: Tending operations also plays an important role in the growth and establishment of forest stands (Novák et al. 2015, Short and Radford 2008). Impacts of these operations affect the growth of the main crop, regeneration establishment, growth, space to the undergrowth, biomass production, and soil potential for the growth and also for supply fuel-wood. Tending operations will also help the livelihood and socio-economic conditions of the local communities. Studies aimed in the future will also provide a good understanding of the management of these forests, to reduce the high flood risk, land destabilization, sustainable eco-tourism, and ecological diversity. The integrated management plan for the optimum production and

contribution to climate change, mitigation/adaptation, and carbon sequestration is also required for future management and development of forest resources (Kumar et al. 2016).

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FIRST RESEARCH AND RESULTS FROM SEMI NATURAL REARING OF ROCK PARTRIDGE (*ALECTORIS GRAECA GRAECA* (MEISNER, 1804)) IN BULGARIA

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Abstract

The aim of the study is to establish the breeding success of Rock partridge (*Alectoris graeca graeca* Meisner, 1804), rearing in semi natural conditions. In 2014, in the western part of Stara Planina Mountain, we built light demountable aviary for raising Rock partridge. The location of the cage falls within the natural range of the Rock partridge. They were placed in typical of the species habitats. In each aviary with an area as about 300 square meters 4 males and 4–5 females were settled. Of a total of 73 nests surveyed for the entire study period in 22 (30.1 %) of cases nesting was unsuccessful. In 54 cases, the bird chose artificial nests or built nests around the facilities of the aviary. In 19 cases they chose natural places to build nests. The average clutch size during the experimental period 2014–2017 was 8.4 ± 2.9 (2–13) (mean $\pm$ sd. min–max). The hatchability was $74.3 \% \pm 10.3 \%$ (60–88.9 %) ($n=11$). The survival rate of fledglings to 90 days was 64.4 %. The breeding success was similar for wild Rock partridges. The average hatchability was higher than that recorded in captivity, but lower than in the wild.

Key words: clutch size, hatchability, hatchlings.

Introduction

Farmed birds released in the wild are killed within few weeks and the main reason for this is predation (Burger 1964, Hessler et al. 1970, Krauss et al. 1987, Robertson 1989, Parish and Sotherton 2007). Some authors explain the high losses in farmed birds with ethological, physiological and anatomical constraints that reduce their fitness compared to wild populations (Csermely et al. 1984, Paganin and Meneguz 1992, Putaala and Hissa 1995, Amici et al. 2017). The daily mortality rate of hand reared Rock partridges (*Alectoris graeca*

(Meisner, 1804)) directly put into the wild is 3–8 % of the released, with 52–84 % of the released birds dying within 21 days (Dessi-Fulgheri et al. 2001). A study performed on Gray partridges (*Perdix perdix* Linnaeus 1758) reported 50 % reduction in hatching in released birds compared to those from wild populations (Rands and Hayward 1987). Hand reared birds show losses in laying performances and eggs hatchability, due to ethological changes on the farm (Rands and Hayward 1987, Putaala and Hissa 1998, Parish and Sotherton 2007). In addition, the generation of farmed birds has higher losses and

less breeding potential than those in wild populations (Hill and Robertson 1988, Leif 1994, Brittas et al. 1992, Sage et al. 2003, Woodburn 2001, Meriggi et al. 2007). Hand reared Grey partridges showed higher mortality rate than those semi naturally reared or in the wild (Dowell 1990a, b; Buner and Schaub 2008). In partridge, it has been found that the birds breeding in semi natural conditions, tested with anti-predator techniques, have much higher levels of survival than farm ones (Slaugh et al. 1992, Alonso et al. 2005, Gaudioso et al. 2011, Sánchez-García et al. 2016). For Red-legged partridge (*Alectoris rufa* Linnaeus, 1758) Pérez et al. (2004) highlighted that its reintroduction is really difficult to perform starting from hand reared birds. The results of reintroduction of galliform birds, by release of hand reared into the wild, are with very various success. They usually associated with many long-term efforts that the release of a large number farmed birds (Ellis and Anderson 1963, Starling 1991, Panek 1988, Melin and Damange 2002, Meriggi et al. 2007). Many authors claim that the release of hand reared birds is not good practice to restore or increase wild populations of galliform (Sexson and Norman 1972, Roseberry et al. 1987, Panek 1988, Hill and Robertson 1988, Dowell 1990a, Brittas et al. 1992, Slaugh et al. 1992, Thaler 1986, Perez et al. 2004, Alonso et al. 2005).

In Bulgaria, attempts to hand rear Rock partridges started in the late 1960s but results consisted in low clutch size (6–8 eggs per hen) and hatchability (Dilovski and Chavdarov 1974, Bubarsky and Todorov 1988). In the 70s and 80s a crossbreeding between the two species of genus *Alectoris* (*chukar* and *gracca*) started with no particular success in clutch size and hatchability (Dilovski and Chavdarov 1974). All such attempts to

raise Rock partridges and their hybrids in farms ended in the middle of 1990s due to low hatching and high bird mortality.

The aim of the study is to evaluate the breeding success of Rock partridge, reared in semi natural conditions.

Materials and Methods

The experimental breeding program and four aviaries of 300 square meters were built in sites included in the natural distribution range of the species. Each aviary was circular, 1.6 m high at the edges and 4.5 m in the center. The sites of each aviary were consistent with the characteristics of the habitats according to Simeonov et al. (1990) and the significant environmental factors (Amici et al. 2009) as far as possible. Around the aviaries, wild Rock partridges have been observed. The purpose was the aviary conditions to be close to those in the wild. All aviaries were in the same conditions of the weather and habitat, located alongside and with west exposure. In each aviary, rocks occupy 15–30 % of the area and there were natural shelters (20 %) offering nesting sites. In addition, 2 artificial shelters and 4 nests were built in each aviary to increase the supply of nesting places. The nests were classified according to the place in the aviary in artificial, and shelters and natural nests built in different parts of the aviaries. In 2015 was built another aviary, identical to the previous ones. In each aviary, 2 males and 3 females were placed at density of 1 bird/60 m². After 2015 we put 4 males and 5 females at density of 1 bird/33 m².

Mating birds came from two farms in Central and Northern Greece. They were taken at the age of 5 months in September 2013 and transferred to the aviaries.

In 2015, 3 male Rock partridges captured from wild population, integrated into the stock of mating birds of Vrachanski Balkan Nature Park.

The nest success was determined as a number of clutches that produce young to the total number of clutches (Murray 2000). The clutch size was determined as the mean number of eggs from nests with brood females. There were not included nests with 1–3 eggs subsequently abandoned. The hatchability was calculated as a percentage of hatched eggs to the total number of eggs laid. The survival rate of fledglings was determinate as a percentage of number of 90 days young birds to the number of fledglings.

Eggs from abandoned nests and nestling out were collected and measured. The maximum length and width was measured with caliper, and weigh with a scale accuracy of 0.01 g.

Results

For the entire study period, 29 artificial nests were used, in 25 cases the birds built nests under the sheds of the feeders. There were also 19 nests in different parts of the aviary: 6 nests in rock crevices; 7 under bushes and 6 in high grass vegetation, most commonly under the Hellebores (*Helleborus odoratus* Linnaeus, 1753).

The Rock partridge preferred artificial nests and facilities for building them accordingly, nesting success was higher than with the nests in other places of the aviary ($\chi^2=3$, $p=0.04$) (Fig. 1).

The results for all studied nests are shown in Table 1.

Of a total of 73 nests observed, during the study period, 22 (30.1 %) of the cases were with unsuccessful nesting. Six nests (27.3 %, $n=22$) were destroyed by reptiles; 6 nests (27.3 %, $n=22$) were de-

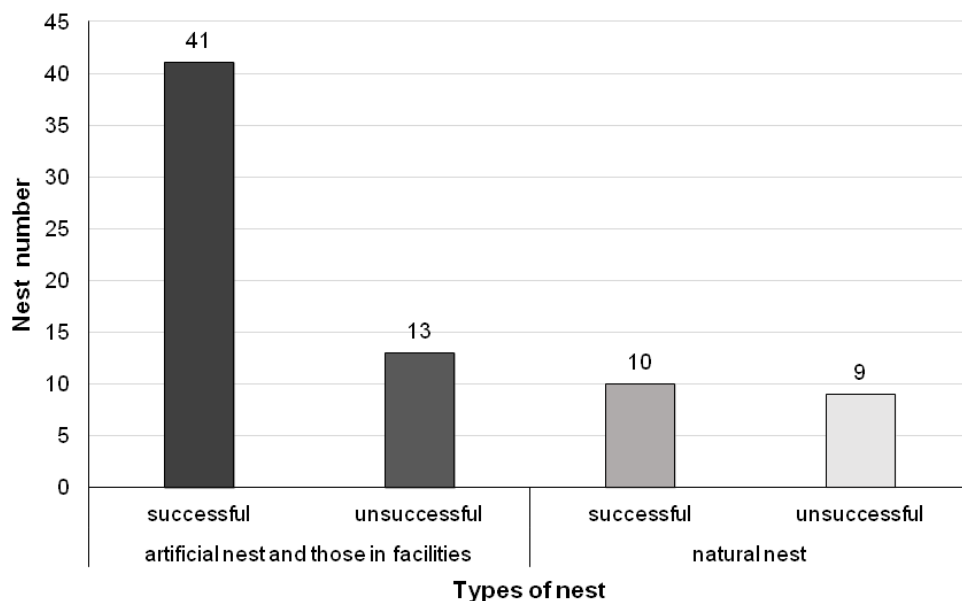


Fig. 1. Nests by place and success of nesting.

stroyed by strong storms and in 10 cases (45.4 %, $n=22$) we were unable to establish the reasons for abandonment of the nests, but all 10 were with 1 to 3 eggs. We had 51 successful nesting's for the survey period and nesting success was 69.9 %.

Table 1. Observed nests and causes for destroying.

Year	All number of nests	De-stroyed, number	Reptilian	Abandoned nest
2014	6	3	1	2
2015	22	11	2	9
2016	21	4	1	3
2017	24	4	2	2
Total	73	22	6	16

The first laid eggs were observed from the second half of April to the beginning of May (07.05.2014, 09.05.2015, 01.05.2016, 19.04.2017). The laying period was about 20 days, one egg in 1–3 days. The incubation period was 25–27 days.

The average length of eggs was 41.06 ± 1.57 (37.54–45.16) mm; the width 30.76 ± 1.08 (28.64–33.11) mm; weight 21.19 ± 1.88 (17.4–25.5) g ($n=113$).

The mean clutch size was 8.4 ± 2.9 (2–13) eggs (mean $\pm$ std.; min–max). One clutch was with 16 eggs, but 2 females were found in it. The first hatchlings were observed on June 2, 2014 at 9:30 am from a nest of 8 eggs (6 hatchlings). In the following years, the first hatchlings were observed on 08.06.2015, 16.06.2016 and 09.06.2017. The average hatchability was $74.3 \% \pm 10.3 \%$ (60–88.9 %) ($n=11$). Mean survival rate of fledglings, up to 90 days was 64.4 ± 4.3 (60–70 %).

Discussion

In this study, Rock partridges use more often artificial nests and those in facilities than natural vegetation and rocks. Figure 1 shows the larger number of observed nests in facilities than the other parts of the cages. Perhaps one of the reasons for this could be the lack of sufficiently suitable natural nesting sites in the aviaries. Successful nesting was found in 69.9 %. These data are similar that reported by some authors for wild populations (Vavalekas et al. 1993, Bernard-Laurent et al. 2017). In some cases, the cause of losses was reptiles and storms. Vavalekas et al. (1993) also reported similar observations in wild populations. The last authors also point out the abandoned nests, for which the reason was obscure have a small number of eggs. The rainfall rate in the second half of July is the significant factor after the average temperature in the first half of June for the nesting success of Rock partridge in the Alps (Giordano et al. 2013). The aviaries in which the birds are bred are 1233 m a.s.l. and often in the spring there are extreme temperatures and heavy rains. We believe that one of the reasons of the recorded losses should be the extreme conditions at certain days during the incubation period. In case of lower altitude aviary with predominance of southern and southeast slopes, the results would probably be better.

The mean clutch size found in this study was slightly lower than the one known in wild populations. About Bulgaria Simeonov et al. (1990) reported an average number of eggs 12–15, for northern Greece authors indicated 12–18

(Vavalekas et al. 1993) and 7–14 for the Alps (Bernard-Lauren et al. 2017). The lower clutch size is probably due to differences in environmental factors or the effect of aviary and breeding density.

The average hatching rate in the present study was 74.3 % and is slightly higher than that of the farm ones (Kirikci et al. 2004) but is lower than that reported for the native population in Northern Greece – 90.8 % (70.6–100 %) (Vavalekas et al. 1993) and in Southern French Alps – 91–92 % (Bernard-Lauren et al. 2017). Egg sizes and weights measured in this study overlapped with known for Rock partridge (Simeonov et al. 1990, Vavalekas et al. 1993, Kirikci et al. 1999, Kirikci et al. 2004). The present study found higher hatchability compared to hand reared Rock partridges.

Conclusion

In this study, Rock partridges used more often artificial nests and those in facilities than natural vegetation and rocks. One of the reasons for this could be the lack of sufficiently suitable natural nesting sites in the aviaries. The mean clutch size and hatching rate was lower than that reported for the native population but the nest success is similar to the wild. Probable cause is the effect of aviary or density of the birds. This study showed an alternative way of breeding Rock partridges compared to farming but further research is needed.

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FOOD SPECTRUM AND PREDOMINANT PREY IN THE DIET OF THE EAGLE OWL *BUBO BUBO* POPULATION IN SOUTHEASTERN BULGARIA

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Abstract

Food spectrum was based on 62,314 prey specimens belonging to 367 taxa collected between 1994 and 2013. The diet included 40.9 % new taxa for the Eagle owl food in Bulgaria. Mammals and birds were most hunted, while reptiles, amphibians, fishes and arthropods were negligible with total 7.8 % by number and 0.8 % by biomass. Voles (*Microtus* spp.) 18.2 %, true mice (*Mus* spp.) 8.2 % and Northern white-breasted hedgehog (*Erinaceus roumanicus*) 5.9 % were the most numerous prey. The staple prey for food biomass were Northern white-breasted hedgehogs 22.9 %, European hares (*Lepus europaeus*) 8.9 %, Norway rats (*Rattus norvegicus*) 6.5 % and Common moorhens (*Gallinula chloropus*) 5.5 %. The individual diets of successful pairs were dominated most often by the same taxa. The present study reports increasing shares of small prey in total diet and first records of dominance in individual diets by a number of passerines, amphibians and arthropods. Hunting on predatory birds and mammals accounted for 11.4 % by biomass. Dominance by a carnivorous mammal, Red fox (*Vulpes vulpes*) – only young individuals, of the biomass of three individual diets is first reported for the country. The large share of small unusual prey and more predators in the diets were most likely the Eagle owl adaptation to local unfavourable food supply.

Key words: feeding ecology, food stress, pellet analysis, threatened owl.

Introduction

The Eagle owl (*Bubo bubo*) is an adaptive top predator which diet includes prey from all vertebrate classes, large invertebrates and occasionally carrion (Glutz von Blotzheim and Bauer 1994, Milchev and Spassov 2017, Penteriani and Delgado 2016). It prefers mammals and birds with a mass between 200 and 2000 g, but the habitat diversity in hunting territories with different local food supplies and prey ac-

cessibility may strongly influence the local food spectrum (Dalbeck 2003, Demay et al. 2015, Milchev and Gruychev 2015, 2016, Obuch and Karaska 2010, Schweiger and Lipp 2011, Shin et al. 2013, Tobajas et al. 2015). Several studies of Eagle owl's food in Bulgaria indicated a predominance of Northern white-breasted hedgehogs (*Erinaceus roumanicus*), European ground squirrels (*Spermophilus citellus*), hamsters, rats, European hares (*Lepus europaeus*) and voles (*Microtus*

spp.) among mammals and gallinaceous birds, corvids, pigeons and waterbirds among the avian prey (Simeonov et al. 1990). The populations of several main prey species have decreased and these species were included in Bulgarian Red Data Book: European ground squirrel and hamsters as 'vulnerable', European hare as 'near threatened' (Golemanski 2015). The national population of Eagle owl with a total 450–550 pairs was categorized as 'endangered' (BirdLife International 2015, Golemanski 2015). The structure of the Eagle owl's diet is crucial both for the management of the predator populations as well to sustain favourable status of the prey communities.

The present long-term study of the Eagle owl's diet aims to (i) complete and update the list of prey species; (ii) to characterize the dominant structure of the diet.

Material and Methods

The study area covers approximately 10,000 km² with mostly hilly and plain landscape. Its borders are the Black Sea coast to the east, Bulgarian-Turkish border to the south, Maritza and Sazliyka Rivers to the west, and the northern foots of St. Iliyski, Bakadzhitsite and Hisar hills to the north. Deciduous forests dominated by oaks (*Quercus* spp.) predominate mainly along the state border with Turkey. Open habitats dominated by arable lands cover most of the central and northern parts of the area (see also Milchev and Menzel 2017).

Food remains (intact and disintegrated pellets, parts of carcasses, feathers, etc.) were collected from occupied rocky complexes in 53 Eagle owl localities between 1994 and 2013 ($n = 1,050$ samples). Localities with successful pairs raising at

least one nestling to the age of 40–45 days (Glutz von Blotzheim and Bauer 1994, Penteriani and Delgado 2008) were visited three times during the breeding period: 1) end of April – beginning of May; 2) end of May – beginning of June; and 3) end of August – beginning of September. Food remains from the nests with later clutches were collected starting with the second visit and additionally once again in late June – mid-July. Sometimes, we could not visit the new difficult-to-reach nest places in the first visit. Other factors such as the proximity of people and human activities or unfavourable weather prevented us from accessing the nest sites for a complete collection of food remains. The collected food remains in such cases were combined with the materials from the following visit into one sample. Localities without breeding attempts or with destroyed clutches/broods were not visited subsequently due to the low amount of food remains in such situations (pers. obs.).

Prey species were identified using the specialized anatomical literature for the respective prey group, comparative material from the National Museum of Natural History, Sofia, and the authors' own comparative collection. The species identification relied mainly on: 1) fragments of crania and mandibles, pelvic and limb bones for mammals and birds, including also pectoral girdles and feathers of birds; 2) fragments of crania and mandibles, pelvic girdles for other vertebrates, including also squamae for reptiles and fish; 3) fragments of head, prothorax, wing cases and mandibles for invertebrates. In case of difficulty to distinguish a species to another, e.g. *Apodemus sylvaticus* and *A. flavicollis*, *Microtus arvalis* and *M. levis*, as well as *Mus macedonicus*, and *M. musculus*, the identification was made

only to the genus level, where the genus appellation refers to just these respective species pairs. Minimum number of individuals was estimated following the procedures by Frey (1973). Bird feathers identified to species were compared to the list of bone determinations from the same sample, and the missing species from bone samples were added to the species list. The biomass was calculated based on Glutz von Blotzheim and Bauer (1994), and Peshev et al. (2004) with the following additions: 1) the young specimens of 11 mammalian and bird species (Appendix 1) were added with reduced mass from one half to one tenth of the mass of an adult specimen based on the comparison of bone remains; 2) the biomass of young Eagle owls consumed due to cannibalism was after Penteriani et al. (2005); 3) indeterminate Passeriformes were size-split into two groups of 10 g and of 20 g; and 4) fish biologists determined fish biomass for individual specimens by species. The difference in frequencies of new taxa in the main prey classes in Eagle owl diet was tested with chi-square test.

Results

The current diet analysis is based on 62,314 prey specimens from 367 taxa with prevalence of mammals (14.4 % by taxa, 53.1 % by number (% N), 50.4 % by biomass (% B) and birds (64.0 % by taxa, 39.1 % N, 48.8 % B) (Appendix 1). Overall, reptiles, amphibians, fishes and arthropods were negligible with a total of 7.8 % N and 0.8 % B. The cumulative total of all prey specimens of previous Eagle owl diet studies in Bulgaria accounts to only 8.9 % of the present study (Table 1). Respectively the present study includes 40.9 % new taxa ($n = 367$) for the Eagle owl's diet in the country. The new prey taxa presented 39.0 % ± 7.9 (range 25.0–47.9 %) in the six main taxonomic groups. The individual frequencies of the new taxa in these six groups differed insignificantly ($\chi^2_5 = 4.65$, $p > 0.05$). Bats increased the number of new mammalian taxa the most (60.9 %, $n = 23$), while orthopterans increased the number of invertebrates (42.9 %, $n = 21$). Passage migrants and vagrants increased the list

Table 1. Number of prey taxa and specimens in Eagle owl *Bubo bubo* diets in Bulgarian studies.

Prey	1		2		3		4		5		6		Present study		
	T	N	T	N	T	N	T	N	T	N	T	N	T	NT	N
Mammals	14	400	16	378	26	732	21	219	16	1087	18	183	53	21	33073
Birds	41	234	71	457	53	482	42	76	68	499	50	249	236	96	24345
Reptilia					5	39	1	4	7	3	1	1	12	5	105
Amphibians	1	33	1	15	4	86	2	10	1	10	1	4	6	2	2283
Fishes					8	19	1	1	2	28			12	3	75
Invertebrates	9	32	5	37	12	79	1	1	9	102	3	6	48	23	2433
Total	65	699	93	887	108	1449	68	311	103	1729	73	443	367	150	62314

Abbreviations and symbols: 1 – Baumgart et al. (1973), 2 – Baumgart (1975), 3 – Simeonov and Boev (1988), 4 – Obuch and Benda (1995), 5 – Simeonov et al. (1998), 6 – Milchev and Gruychev (2015); T – number of taxa; N – number of specimens; NT – number of new taxa.

of new bird taxa, independent of their taxonomy (passerines 42.7 %, $n = 96$, but passage migrants and vagrants 49.0 %). Among all avian taxa, passage migrants and vagrants made up a quarter (26.9 %, $n = 236$ taxa) but composed a small part of bird diet (3.8 % N, 4.2 % B).

Eagle owls hunted mostly rodents (43.0 % N) and passerine birds (15.6 % N). These two orders contributed together to more than the half of all prey specimens. Insectivorous mammals (Eulipotyphla), including mainly Northern white-breasted hedgehogs, together with rodents and rails (Gruiformes: Rallidae) composed half of the prey biomass (Fig. 1).

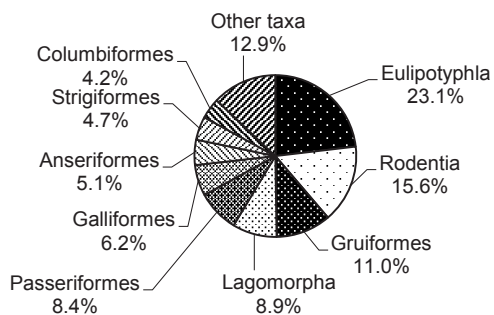


Fig. 1. Main orders for the food biomass of Eagle owls *Bubo bubo* in SE Bulgaria, 1994–2013.

Only three prey exceeded 5 % by total number (voles *Microtus* spp. 18.2 %, true mice *Mus* spp. 8.2 % and Northern white-breasted hedgehog 5.9 %) and contributed to 32.3 % N. Northern

white-breasted hedgehogs (22.9 % B) with three other prey species exceeded 5 % B (European hare 8.9 %, Norway rat *Rattus norvegicus* 6.5 % and Common moorhen *Gallinula chloropus* 5.5 %) and made up together 43.8 % B.

The individual diets of successful pairs were dominated by 26 taxa (mostly mammals and birds, Table 2). The prey with highest occurrence as dominant by number (voles, Northern white-breasted hedgehogs and Norway rats) were the most numerous in 62.0 % of the individual diets ($n = 226$). The most dominant prey in terms of biomass was Northern white-breasted hedgehogs (69.5 %) and that together with Norway rats dominated 82.3 % of the diets. There was only one diet (0.4 %) of a successful pair without any hedgehogs, relying on voles (55.3 % N, 23.7 % B) and rats (5.6 % N, 20.3 % B) as the main prey. The predominant value varied within wide limits (range 6.2–70.4 % N, 11.4–72 % B). Black rats (*Rattus rattus*) attained the highest numerical dominance and Northern white-breasted hedgehogs attained the greatest prey biomass. The second positions by number and biomass in the diets were variously occupied by 37 taxa including the majority of dominant prey. Among the nine taxa with over 5 % occurrence, the food significance of European hares, Common moorhens, young Red foxes (*Vulpes vulpes*) and true mice increased as important subdominant prey (Table 2).

Table 2. The most important prey in diets ($n = 226$) of successful Eagle owl *Bubo bubo* pairs in SE Bulgaria, 1994–2013.

Prey	Dominant by number		Dominant by biomass	
	% occurrence as dominant prey	% N AM $\pm$ SD, min–max	% occurrence as dominant prey	% B AM $\pm$ SD, min–max
<i>Erinaceus roumanicus</i>	17.3	17.4 $\pm$ 7.5, 6.2–42.1	69.5	29.2 $\pm$ 10.8, 11.4–72.0
<i>Lepus europaeus</i>			4.0	19.7 $\pm$ 5.3, 11.4–28.9
<i>Glis glis</i>	3.5	19.6 $\pm$ 7.3, 11.4–35.0		
<i>Microtus</i> spp.	30.1	30.0 $\pm$ 15.5, 8.7–65.7	2.2	19.9 $\pm$ 3.5, 16.3–23.7
<i>Microtus guentheri</i>	0.9	22.0–31.6		
<i>Arvicola amphibius</i>	4.4	19.2 $\pm$ 4.6, 13.6–28.2	0.4	13.6
<i>Apodemus</i> spp.	3.5	16.7 $\pm$ 6.9, 8.0–29.5		
<i>Rattus rattus</i>	1.3	38.0 $\pm$ 28.6, 16.2–70.4	0.9	35.7, 58.7
<i>Rattus norvegicus</i>	14.6	26.7 $\pm$ 12.5, 9.0–60.7	12.8	32.6 $\pm$ 13.9, 14.6–62.8
<i>Mus</i> spp.	8.4	22.7 $\pm$ 11.6, 6.8–50.9		
<i>Vulpes vulpes</i>			1.3	19.3 $\pm$ 3.2, 15.9–22.3
<i>Coturnix coturnix</i>	0.4	10.2		
<i>Alectoris chukar</i>	0.4	12.5		
<i>Spatula querquedula</i>	0.4	8.7	0.4	11.5
<i>Tachymarpis melba</i>	0.4	15.4		
<i>Gallinula chloropus</i>	8.8	14.9 $\pm$ 6.4, 7.0–34.6	4.4	20.5 $\pm$ 6.2, 14.6–34.4
<i>Fulica atra</i>			3.1	17.8 $\pm$ 4.8, 12.7–27.3
<i>Garrulus glandarius</i>	0.4	10.9		
<i>Corvus frugilegus</i>			0.4	20.9
<i>Corvus corone</i>	0.4	11.4		
<i>Melanocorypha calandra</i>	0.4	9.3		
<i>Turdus merula</i>	3.1	14.8 $\pm$ 6.9, 10.4–29.6		
<i>Pelobates syriacus</i>	2.7	14.8 $\pm$ 4.0, 9.3–21.1		
<i>Cyprinus carpio</i>			0.4	23.2
<i>Potamon ibericum</i>	1.3	18.5 $\pm$ 5.5, 12.6–23.4		
<i>Decticus albifrons</i>	0.4	27.1		
	Subdominant by number (only prey with > 5 % occurrence)		Subdominant by biomass (only prey with > 5 % occurrence)	
<i>Erinaceus roumanicus</i>	16.8	10.1 $\pm$ 3.0, 4.3–16.0	17.7	16.0 $\pm$ 5.0, 7.0–28.1
<i>Lepus europaeus</i>			26.5	14.1 $\pm$ 4.1, 6.4–23.3
<i>Microtus</i> spp.	19.0	12.5 $\pm$ 5.0, 5.8–29.3		
<i>Arvicola amphibius</i>	5.3	12.1 $\pm$ 5.2, 7.9–26.3		
<i>Apodemus</i> spp.	7.1	11.2 $\pm$ 3.5, 6.8–19.2		
<i>Rattus norvegicus</i>			8.0	16.9 $\pm$ 7.6, 7.6–35.6
<i>Mus</i> spp.	12.8	11.9 $\pm$ 3.9, 5.4–19.6		
<i>Vulpes vulpes</i>			5.3	13.8 $\pm$ 6.0, 7.4–28.7
<i>Gallinula chloropus</i>	8.8	8.1 $\pm$ 1.9, 4.7–12.1	11.1	12.3 $\pm$ 4.2, 6.2–19.8

Abbreviations and symbols: % N – percent by number in individual diets; % B – percent by biomass in individual diets; AM $\pm$ SD – arithmetic mean $\pm$ standard deviation; min–max – minimum – maximum value.

Discussion

The highly diverse food spectrum of Eagle owls in SE Bulgaria reflects their opportunistic hunting on prey of different sizes, taxonomic groups and preferred habitats (Marks et al. 1999, Mebs and Scherzinger 2008). The number of new taxa in the food did not present any preference for prey of a particular class compared to the known prey list in Bulgaria. Differences in the number of new species were within classes due to larger catches of mostly small species such as bats, passerines and orthopterans. The western Black Sea flyway passes over the study area. This explained the greater number of passage migrants and vagrants as new bird species in owls' food. Despite the great variety of species, these birds contribute very little to the diet biomass.

Mammals and birds were the main Eagle owl prey, as characteristic for this species (Mebs and Scherzinger 2008, Penteriani and Delgado 2016), but their distribution among these taxa was subject to local conditions. The Eagle owls in SE Bulgaria have hunted more on smaller prey as rodents and passerines. The true mice *Mus* spp. with two species, one being wild (*Mus macedonicus*; Peshev et al. 2004), became a frequent Eagle owl prey in Bulgaria for first time. Similar importance of true mice was found for Eagle owls in Northern Spain but with different wild species (*Mus spretus*, Lataste, 1883; Donazar 1989, Serrano 1998). The high availability of true mice was indirectly confirmed by their high frequency in Barn owl (*Tyto alba*) diets in SE Bulgaria, a smaller owl that alike the Eagle owl prefers also opportunistic hunting in open habitats (Milchev 2016). Several other small animals dominated by number a few annual diets of different pairs as exceptions:

Eastern spadefoot (*Pelobates syriacus*), Freshwater crab (*Potamon ibericum*) and Mediterranean wart-biter (*Decticus albifrons*). Günther's voles (*Microtus guentheri*) and Mediterranean wart-biters were the only new species in the present study, which Eagle owls hunted more often and were the dominant prey. Calandra larks (*Melanocorypha calandra*), an endangered passerine bird according to the Bulgarian Red Data Book (Golemanski 2015) dominated an Eagle owl diet. The increased hunting on this species was probably due to its locally numerous breeding population in Sakar Mountain.

The main prey for diet biomass, such as Northern white-breasted hedgehogs, rats, European hares and rails, was consistent with the results of most studies on the Balkan Peninsula (Mihelič 2002, Milchev and Gruychev 2015, Papageorgiou et al. 1993, Sándor and Ionescu 2009, Simeonov et al. 1990). The rare occurrences for the Eagle owl diet were the dominance for diet biomass of European carps (*Cyprinus carpio*) in a breeding season and young Red foxes three times in different localities. Fish is a rare additional prey of Eagle owls (Glutz von Blotzheim and Bauer 1994). Simeonov et al. (1998) reported a diet where fish composed 12.5 % B as an exception in Bulgaria. It formed 27.1 % B in the diet predominated by European carps in the present study.

The share of predatory birds and mammals (Accipitriformes, Strigiformes, Falconiformes and Carnivora) in Eagle owls diets is indicative for the level of food stress (Lourenço et al. 2011, 2018). The contribution of predators to food biomass in this study (11.4 % B) was among the high values in Europe (6.0 % $\pm$ 4.7 B, Lourenço et al. 2011). The main prey for food biomass was the predatory mammal for first time. Superpredation in the three localities with

high hunting on young Red foxes in south-eastern Bulgaria was comparable only to the recent data from the Eagle owl food in Kazanlak Valley, Central Bulgaria (superpredation 20.4 % B, Milchev and Gruychev 2015). The level of superpredation and the prevalence of small prey in diets most likely demonstrate the adaptation of the Eagle owls to the unfavourable food supply in some breeding places of south-eastern Bulgaria.

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Appendix 1. Prey of Eagle owl *Bubo bubo* in SE Bulgaria, 1994–2013.

Prey	% O	Number	% N	% B
<i>Talpa europaea</i> , Linnaeus, 1758	100	238	0.4	0.1
<i>Crocidura leucodon</i> (Hermann, 1780)	100	199	0.3	tr.
<i>Crocidura suaveolens</i> (Pallas, 1811)	95	159	0.3	tr.
<i>Erinaceus roumanicus</i> , Barrett-Hamilton, 1900	100	3695	5.9	22.9
<i>Lepus europaeus</i> , Pallas, 1778; 1474 juv.	100	1549	2.5	8.9
<i>Spermophilus citellus</i> (Linnaeus, 1766)	90	120	0.2	0.3
<i>Glis glis</i> (Linnaeus, 1766)	100	698	1.1	0.7
<i>Microtus arvalis</i> (Pallas, 1779)/ <i>M. levis</i> , Miller, 1908	100	11324	18.2	2.8
<i>Microtus guentheri</i> (Danford and Alston, 1880)	80	374	0.6	0.2
<i>Arvicola amphibius</i> (Linnaeus, 1758)	100	1707	2.7	1.4
<i>Apodemus flavicollis</i> (Melchior, 1834)/ <i>A. sylvaticus</i> (Linnaeus, 1766)	100	3018	4.8	0.7
<i>Rattus rattus</i> (Linnaeus, 1758)	100	1135	1.8	1.9
<i>Rattus norvegicus</i> , Berkenhout, 1769)	100	3036	4.9	6.5
<i>Mus musculus</i> , Linnaeus, 1766/ <i>M. macedonicus</i> , Petrov and Ruzic, 1983	100	5136	8.2	0.8
<i>Nannospalax leucodon</i> (Nordmann, 1840)	95	92	0.1	0.2
<i>Vulpes vulpes</i> (Linnaeus, 1758) all juv.	95	124	0.2	2.5
<i>Mustela nivalis</i> , Linnaeus, 1766	100	196	0.3	0.2
<i>Felis catus</i> , Linnaeus, 1758	20	6	tr.	0.2
Mammalia subtotal	100	33072	53.1	50.5
<i>Coturnix coturnix</i> (Linnaeus, 1758)	100	1052	1.7	0.8
<i>Alectoris chukar</i> (J. E. Gray, 1830)	80	96	0.2	0.4
<i>Phasianus colchicus</i> , Linnaeus, 1758	60	61	0.1	0.6
<i>Perdix perdix</i> (Linnaeus, 1758); 3 juv.	100	1183	1.9	3.7
<i>Gallus gallus dom.</i> , Linnaeus, 1758; 2 juv.	85	68	0.1	0.7
<i>Spatula querquedula</i> (Linnaeus, 1758)	100	327	0.5	1.1
<i>Anas platyrhynchos</i> , Linnaeus, 1758; 116 juv.	100	378	0.6	2.6
<i>Anas crecca</i> , Linnaeus, 1758	60	42	0.1	0.1
<i>Anas crecca</i> / <i>Spatula querquedula</i>	100	80	0.1	0.2
<i>Anas</i> sp.	95	70	0.1	0.5
<i>Tachybaptus ruficollis</i> (Pallas, 1764)	100	523	0.8	0.9
<i>Podiceps cristatus</i> (Linnaeus, 1758)	65	30	tr.	0.3
<i>Columba livia f. dom.</i> , Gmelin, 1789	100	583	0.9	1.6
<i>Columba palumbus</i> , Linnaeus, 1758	100	450	0.7	1.8
<i>Streptopelia turtur</i> (Linnaeus, 1758)	100	274	0.4	0.3
<i>Streptopelia decaocto</i> (Frivaldszky, 1838)	100	271	0.4	0.4
<i>Tachymarpis melba</i> (Linnaeus, 1758)	25	32	0.1	tr.
<i>Cuculus canorus</i> , Linnaeus, 1758	95	79	0.1	0.1
<i>Rallus aquaticus</i> , Linnaeus, 1758	100	279	0.4	0.3

Prey	% O	Number	% N	% B
<i>Crex crex</i> (Linnaeus, 1758)	100	582	0.9	0.8
<i>Porzana porzana</i> (Linnaeus, 1766)	95	99	0.2	0.1
<i>Porzana parva</i> (Scopoli, 1769)	85	99	0.2	tr.
<i>Gallinula chloropus</i> (Linnaeus, 1758); 2 juv.	100	2369	3.8	5.5
<i>Fulica atra</i> , Linnaeus, 1758	100	675	1.1	4.4
<i>Ixobrychus minutus</i> (Linnaeus, 1766)	100	388	0.6	0.5
<i>Nycticorax nycticorax</i> (Linnaeus, 1758)	100	183	0.3	1.1
<i>Ardea purpurea</i> , Linnaeus, 1766	45	12	tr.	0.1
<i>Microcarbo pygmaeus</i> (Pallas, 1773)	70	31	tr.	0.2
<i>Burhinus oedicnemus</i> (Linnaeus, 1758)	95	62	0.1	0.2
<i>Vanellus vanellus</i> (Linnaeus, 1758)	85	74	0.1	0.1
<i>Scolopax rusticola</i> , Linnaeus, 1758	100	316	0.5	0.7
<i>Larus cachinnans</i> , Pallas, 1811/ <i>L. michahellis</i> , J. F. Naumann, 1840; 7 juv.	75	35	0.1	0.2
<i>Tyto alba</i> (Scopoli, 1769)	100	449	0.7	1.1
<i>Athene noctua</i> (Scopoli, 1769)	100	329	0.5	0.5
<i>Otus scops</i> (Linnaeus, 1758)	95	213	0.3	0.2
<i>Asio otus</i> (Linnaeus, 1758)	100	896	1.4	2.0
<i>Asio flammeus</i> (Pontoppidan, 1763)	85	90	0.1	0.3
<i>Strix aluco</i> , Linnaeus, 1758	90	103	0.2	0.4
<i>Bubo bubo</i> (Linnaeus, 1758); all juv.	75	32	0.1	0.2
<i>Accipiter nisus</i> (Linnaeus, 1758)	95	82	0.1	0.1
<i>Accipiter gentilis</i> (Linnaeus, 1758)	90	45	0.1	0.3
<i>Buteo buteo</i> (Linnaeus, 1758); 5 juv.	100	384	0.6	2.5
<i>Falco tinnunculus</i> , Linnaeus, 1758	100	262	0.4	0.4
<i>Lanius collurio</i> , Linnaeus, 1758	100	483	0.8	0.1
<i>Garrulus glandarius</i> (Linnaeus, 1758)	100	717	1.2	0.9
<i>Pica pica</i> (Linnaeus, 1758)	100	478	0.8	0.8
<i>Corvus monedula</i> , Linnaeus, 1758	90	76	0.1	0.1
<i>Corvus frugilegus</i> , Linnaeus, 1758; 17 juv.	45	103	0.2	0.4
<i>Corvus corone</i> , Linnaeus, 1758	100	478	0.8	2.0
<i>Corvus corax</i> , Linnaeus, 1758	55	21	tr.	0.2
<i>Melanocorypha calandra</i> (Linnaeus, 1766)	80	89	0.1	tr.
<i>Calandrella brachydactyla</i> (Leisler, 1814)	90	106	0.2	tr.
<i>Galerida cristata</i> (Linnaeus, 1758)	95	76	0.1	tr.
<i>Lullula arborea</i> (Linnaeus, 1758)	100	132	0.2	tr.
<i>Alauda arvensis</i> , Linnaeus, 1758	100	403	0.6	0.1
<i>Sturnus vulgaris</i> , Linnaeus, 1758	100	662	1.1	0.4
<i>Pastor roseus</i> (Linnaeus, 1758)	20	48	0.1	tr.
<i>Turdus merula</i> , Linnaeus, 1758	100	1970	3.2	1.4
<i>Turdus pilaris</i> , Linnaeus, 1758	95	99	0.2	0.1

Prey	% O	Number	% N	% B
<i>Turdus iliacus</i> , Linnaeus, 1758	80	66	0.1	tr.
<i>Turdus philomelos</i> , Brehm, 1831	100	1488	2.4	0.8
<i>Turdus viscivorus</i> , Linnaeus, 1758	100	183	0.3	0.2
<i>Turdus</i> sp.	100	250	0.4	0.2
<i>Luscinia megarhynchos</i> , C. L. Brehm, 1831	80	67	0.1	tr.
<i>Passer domesticus</i> (Linnaeus, 1758)	90	80	0.1	tr.
<i>Coccothraustes coccothraustes</i> (Linnaeus, 1758)	100	121	0.2	0.1
<i>Emberiza calandra</i> , Linnaeus, 1758.	100	282	0.5	0.1
<i>Emberiza</i> sp.	95	80	0.1	tr.
Passeriformes indet.	100	239	0.4	tr.
Non-passerines indet.	100	75	0.1	0.1
Aves subtotal	100	24345	39.1	48.8
Reptilia subtotal	100	105	0.2	tr.
<i>Pelobates syriacus</i> , Boettger, 1889	100	1689	2.7	0.2
<i>Pelophylax ridibundus</i> (Pallas, 1771)	100	581	0.9	0.1
Amphibia subtotal	100	2283	3.7	0.3
<i>Cyprinus carpio</i> , Linnaeus, 1758	35	22	tr.	0.2
Actinopterygii subtotal	70	75	0.1	0.3
<i>Potamon ibericum</i> (Bieberstein)	100	526	0.8	tr.
<i>Decticus albifrons</i> (Fabricius, 1775)	45	419	0.7	tr.
<i>Decticus albifrons/verrucivorus</i>	80	298	0.5	tr.
<i>Tettigonia</i> sp.	35	70	0.1	tr.
<i>Gryllotalpa</i> cf. <i>stepposa</i> , Zhantiev, 1991	90	119	0.2	tr.
<i>Copris hispanus</i> (Linnaeus, 1764)	45	82	0.1	tr.
<i>Cerambyx cerdo</i> , Linnaeus, 1758	40	71	0.1	tr.
<i>Cerambyx</i> sp.	45	131	0.2	tr.
<i>Lucanus cervus</i> (Linnaeus, 1758)	100	411	0.7	tr.
Arthropoda subtotal	100	2433	3.9	0.1

Abbreviations and symbols: % O – % occurrence in 20 annual diets; % N – % by 62,314 specimens; % B – % by biomass (12,083,399.0 kg); tr. – traces (<0.1 %); juv. – number of juveniles added with reduced mass; ¹prey with less than 0.1 % N and % B, number of specimens.

¹Mammalia: *Talpa martinorum*, Krystufek, 2018 – 43; *Talpa* sp. – 12; *Sorex araneus* Linnaeus, 1758 – 3; *Sorex minutus* Linnaeus, 1766 – 1; *Neomys anomalus*, Cabrera, 1907 – 12; *Suncus etruscus* (Savi, 1822) – 3; *Rhinolophus ferrumequinum* (Schreber, 1774) – 4; *Eptesicus serotinus* (Schreber, 1774) – 4; *Myotis blythii* (Tomes, 1857) – 2; *Myotis daubentonii* (Kuhl, 1817) – 1; *Myotis*

capaccinii (Bonaparte, 1837) – 1; *Myotis myotis* (Borkhausen, 1797) – 1; *Myotis* sp. – 1; *Plecotus austriacus* (J. Fischer, 1829) – 1; *Pipistrellus pipistrellus* (Schreber, 1774) – 1; *Pipistrellus nathusii* (Keyserling and Blasius, 1839) – 1; *Nyctalus lasiopterus* (Schreber, 1780) – 1; *Nyctalus noctula* (Schreber, 1774) – 3; Vespertilionidae gen. – 9; *Miniopterus schreibersii* (Kuhl, 1817) – 3; *Sciurus vulgaris*, Linnaeus,

1758 – 12; *Myocastor coypus* (Molina, 1782) – 1 juv.; ?*Myocastor coypus* – 1 juv.; *Cricetulus migratorius* (Pallas, 1773) – 2; *Mesocricetus newtoni* (Nehring, 1898) – 1; *Dryomys nitedula* (Pallas, 1778) – 38; *Myomimus roachi* (Bate, 1937) – 9; *Microtus subterraneus* (Selys-Longchamps, 1836) – 51; *Micromys minutus* (Pallas, 1771) – 14; *Apodemus agrarius* (Pallas, 1771) – 24; *Sus scrofa* dom., Linnaeus, 1758 (carriion) – 1; *Dama dama* (Linnaeus, 1758) (carriion) – 1; *Ovis aries/Carpa hircus* (carriion) – 1; *Mustela putorius*, Linnaeus, 1758 – 1; *Martes foina* (Erxleben, 1777) – 2; *Vormela peregusna* (Güldenstädt, 1770) – 1.

Aves: *Pasianus/Gallus* – 2; *Branta ruficollis* (Pallas, 1769) – 1; *Anser anser f. dom.* (Linnaeus, 1758) – 4; *Anser albifrons* (Scopoli, 1769) – 1; *Mergus albellus*, Linnaeus, 1758 – 1; *Tadorna tadorna* (Linnaeus, 1758) – 4; *Tadorna* sp. – 1; *Netta rufina* (Pallas, 1773) – 1; *Aythya ferina* (Linnaeus, 1758) – 14; *Aythya nyroca* (Güldenstädt, 1770) – 9; *Aythya fuligula* (Linnaeus, 1758) – 1; *Aythya* sp. – 3; *Spatula clypeata* (Linnaeus, 1758) – 15; *Mareca penelope* (Linnaeus, 1758) – 3; *Mareca strepera* (Linnaeus, 1758) – 11; *Anas acuta*, Linnaeus, 1758 – 6; *Cairina moschata* dom. (Linnaeus, 1758) – 1; *Podiceps grisegena* (Boddaert, 1783) – 5; *Podiceps nigricollis*, Brehm, 1831 – 22; *Columba oenas*, Linnaeus, 1758 – 6; *Columba* sp. – 4; *Caprimulgus europaeus*, Linnaeus, 1758 – 28; *Apus apus* (Linnaeus, 1758) – 15; *Porzana pusilla* (Pallas, 1776) – 9; *Porzana parva/pusilla* – 9; *Puffinus yelkouan* (Acerbi, 1827) – 1; *Botaurus stellaris* (Linnaeus, 1758) – 8; *Ardeola ralloides* (Scopoli, 1769) – 14; *Ardea cinerea*, Linnaeus, 1758 – 1; *Ardea alba*, Linnaeus, 1758 – 2; *Egretta garzetta* (Linnaeus, 1766) – 18; *Phalacrocorax aristotelis* (Linnaeus, 1761) – 1;

Haematopus ostralegus, Linnaeus, 1758 – 6; *Recurvirostra avosetta*, Linnaeus, 1758 – 8; *Himantopus himantopus* (Linnaeus, 1758) – 11; *Pluvialis apricaria* (Linnaeus, 1758) – 16; *Pluvialis* sp. – 2; Charadriidae gen. – 6; *Numenius arquata* (Linnaeus, 1758) – 1; *Limosa limosa* (Linnaeus, 1758) – 2; *Numenius/Limosa* – 2; *Calidris pugnax* (Linnaeus, 1758) – 8; *Calidris ferruginea* (Pontoppidan, 1763) – 1; *Calidris temminckii* (Leisler, 1812) – 1; *Calidris alpina* (Linnaeus, 1758) – 3; *Calidris minuta* (Leisler, 1812) – 9; *Calidris minuta/temminckii* – 2; *Gallinago media* (Latham, 1787) – 6; *Gallinago gallinago* (Linnaeus, 1758) – 32; *Lymnocyptes minimus* (Brunnich, 1764) – 1; *Actitis hypoleucos* (Linnaeus, 1758) – 3; *Tringa ochropus*, Linnaeus, 1758 – 11; *Tringa erythropus* (Pallas, 1764) – 1; *Tringa totanus* (Linnaeus, 1758) – 1; *Tringa glareola*, Linnaeus, 1758 – 7; *Tringa* sp. – 10; Scolopacidae gen. – 21; *Hydrocoloeus minutus* (Pallas, 1776) – 3; *Larus genei*, Breme, 1839 – 1; *Larus melanocephalus*, Temminck, 1820 – 1; *Larus ridibundus*, Linnaeus, 1766 – 23; *Larus* sp. – 7; *Chlidonias hybrida* (Pallas, 1811) – 3; *Chlidonias leucopterus* (Temminck, 1815) – 3; *Chlidonias niger* (Linnaeus, 1758) – 6; *Chlidonias* sp. – 3; *Sterna hirundo*, Linnaeus, 1758 – 11; *Thalasseus sandvicensis* (Latham, 1787) – 3; *Aegolius funereus* (Linnaeus, 1758) – 1; *Pernis apivorus* (Linnaeus, 1758) – 11; *Clanga pomarina* (Brehm, 1831) – 3; *Hieraaetus pennatus* (Gmelin, 1788) – 8; *Circus aeruginosus* (Linnaeus, 1758) – 14; *Circus cyaneus* (Linnaeus, 1766) – 9; *Circus macrourus* (S. G. Gmelin, 1770) – 5; *Circus pygargus* (Linnaeus, 1758) – 28; *Circus* sp. – 10; *Accipiter nisus/brevipes* – 4; *Buteo lagopus* (Pontoppidan, 1763) – 1; *Buteo rufinus* (Cretzschmar, 1829) – 4, 2 juv.; *Merops apiaster*, Linnaeus,

1758 – 19; *Coracias garrulus*, Linnaeus, 1758 – 24; *Alcedo atthis* (Linnaeus, 1758) – 7; *Alcedinidae* gen. – 1; *Upupa epops*, Linnaeus, 1758 – 52; *Jynx torquilla*, Linnaeus, 1758 – 10; *Picus viridis*, Linnaeus, 1758 – 46; *Picus canus*, Gmelin, 1788 – 3; *Dryocopus martius* (Linnaeus, 1758) – 3; *Leiopicus medius* (Linnaeus, 1758) – 9; *Dryobates minor* (Linnaeus, 1758) – 3; *Dendrocopos leucotos* (Bechstein, 1802) – 1; *Dendrocopos major* (Linnaeus, 1758) – 33; *Dendrocopos syriacus* (Hemprich, Ehrenberg, 1833) – 8; *Dendrocopos major/syriacus* – 26; *Falco naumanni*, Fleischer, 1818 – 1; *Falco tinnunculus/naumani* – 1; *Falco vespertinus*, Linnaeus, 1766 – 11; *Falco columbarius*, Linnaeus, 1758 – 2; *Falco subbuteo*, Linnaeus, 1758 – 21; *Falco cherrug*, J. E. Gray, 1834 – 3; *Falco peregrinus*, Tunstall, 1771 – 2; *Lanius senator*, Linnaeus, 1758 – 41; *Lanius minor*, Gmelin, 1788 – 8; *Lanius rubicus*, Lichtenstein, 1823 – 2; *Oriolus oriolus*, Linnaeus, 1758 – 37; *Poecile palustris*, Linnaeus, 1758 – 1; *Parus major*, Linnaeus, 1758 – 5; *Cyanistes caeruleus* (Linnaeus, 1758) – 5; *Parus* sp. – 4; *Hirundo rustica*, Linnaeus, 1758 – 44; *Cecropis daurica* (Laxmann, 1769) – 1; *Delichon urbicum* (Linnaeus, 1758) – 21; *Aegithalos caudatus* (Linnaeus, 1758) – 1; *Calandrella* sp. – 7; *Eremophila alpestris* (Linnaeus, 1758) – 4; *Alaudidae* gen. – 3; *Locustella* sp. – 11; *Acrocephalus arundinaceus* (Linnaeus, 1758) – 41; *Acrocephalus schoenobaenus* (Linnaeus, 1758) – 1; *Acrocephalus scirpaceus* (Hermann, 1804) – 3; *Acrocephalus* sp. – 39; *Hippolais* sp. – 1; *Phylloscopus collybita* (Vieillot, 1817) – 1; *Phylloscopus* sp. – 7; *Sylvia atricapilla* (Linnaeus, 1758) – 34; *Sylvia borin* (Boddaert, 1783) – 1; *Sylvia communis*, Latham, 1787 – 3; *Sylvia curruca* (Linnaeus, 1758) – 2; *Sylvia crassirostris*, Cretzschmar, 1830 –

4; *Sylvia nisoria* (Bechstein, 1792) – 38; *Sylvia* sp. – 43; *Sylviidae* gen. – 66; *Sitta europaea*, Linnaeus, 1758 – 1; *Turdus torquatus*, Linnaeus, 1758 – 2; *Turdus naumanni*, Temminck, 1820 – 1; *Erithacus rubecula* (Linnaeus, 1758) – 43; *Luscinia luscinia* (Linnaeus, 1758) – 1; *Luscinia* sp. – 15; *Phoenicurus ochruros* (S. G. Gmelin, 1774) – 2; *Phoenicurus phoenicurus* (Linnaeus, 1758) – 2; *Phoenicurus* sp. – 4; *Saxicola torquata* (Linnaeus, 1766) – 9; *Saxicola* sp. – 1; *Oenanthe isabellina* (Temminck, 1829) – 4; *Oenanthe oenanthe* (Linnaeus, 1758) – 56; *Oenanthe* sp. – 41; *Ficedula hypoleuca* (Pallas, 1764) – 1; *Muscicapidae* gen. – 54; *Passer hispaniolensis* (Temminck, 1820) – 7; *Passer montanus* (Linnaeus, 1758) – 11; *Passer* sp. – 1; *Motacilla alba*, Linnaeus, 1758 – 4; *Motacilla flava*, Linnaeus, 1758 – 19; *Anthus trivialis* (Linnaeus, 1758) – 1; *Anthus pratensis/cervinus* – 1; *Anthus* sp. – 14; *Fringilla coelebs*, Linnaeus, 1758 – 41; *Chloris chloris* (Linnaeus, 1758) – 25; *Spinus spinus* (Linnaeus, 1758) – 1; *Carduelis carduelis* (Linnaeus, 1758) – 22; *Linaria cannabina* (Linnaeus, 1758) – 4; *Fringillidae* gen. – 4; *Emberiza citrinella*, Linnaeus, 1758 – 21; *Emberiza cirrus*, Linnaeus, 1766 – 7; *Emberiza hortulana*, Linnaeus, 1758 – 12; *Emberiza melanocephala*, Scopoli, 1769 – 35.

Reptilia: *Testudo graeca*, Boulenger, 1889 – 1; *Ablepharus kitaibelii* (Bibron, Bory St-vincent, 1833) – 1; *Lacerta viridis* (Laurenti, 1768) – 18; *Lacerta trilineata*, Bedriaga, 1886 – 12; *Lacerta* sp. – 28; *Dolichophis caspius* (Gmelin, 1789) – 8; *Zamenis longissimus* (Laurenti, 1768) – 2; *Elaphe sauromates* (Pallas, 1811) – 1; *Natrix tessellata* (Laurenti, 1768) – 6; *Natrix natrix* (Linnaeus, 1758) – 16; *Natrix* sp. – 10; *Serpentes* indet. – 2.

Amphibia: *Triturus ivanbureschi*, Arntzen and Wielstra, 2013 – 2; *Bufo bufo*

(Linnaeus, 1758) – 8; *Bufo* sp. – 1; *Rana dalmatina*, Fitzinger in Bonaparte, 1839 – 2.

Actinopterygii: *Anguilla anguilla* (Linnaeus, 1758) – 1; *Rutilus rutilus* (Linnaeus, 1758) – 1; *Vimba vimba* (Linnaeus, 1758) – 4; *Barbus bergi*, Boulenger, 1911 – 2; *Scardinius erythrophthalmus* (Linnaeus, 1758) – 1; *Squalius cephalus* (Linnaeus, 1758) – 10; *Carassius gibelio* (Bloch, 1782) – 20; Ciprinidae gen. – 10; Cypriniformes – 1; *Sander lucioperca* (Linnaeus, 1758) – 1; *Perca fluviatilis*, Linnaeus, 1758 – 2.

Arthropoda: *Scolopendra* sp. – 16; *Bradyporus dasypus* (Illiger, 1800) – 5; *Bradyporus macrogaster* (Lefebvre, 1831) – 11; *Bucephaloptera bucephala* (Brunner von Wattenwyl, 1882) – 8; *Decticus verrucivorus* (Linnaeus, 1758) – 4; *Pholidoptera brevipes*, Ramme, 1939 – 1; *Platycleis affinis*, Fieber, 1853 – 2; *Platycleis escalerae*, Bolívar, l., 1899 – 1; *Platycleis intermedia* (Serville 1838) – 1; *Platycleis* sp. – 50; *Saga*

natoliae, Serville, 1838 – 2; *Tettigonia viridissima* (Linnaeus, 1758) – 3; *Tettigonia* cf. *caudata* (Charpentier, 1845) – 15; *Anacridium aegyptium* (Linnaeus, 1764) – 3; *Calliptamus italicus* (Linnaeus, 1758) – 1; *Mantis religiosa* (Linnaeus, 1758) – 11; *Lethocerus patruelis* (Stål, 1854) – 1; *Calosoma inquisitor* (Linnaeus, 1758) – 3; *Calosoma sycophanta* (Linnaeus, 1758) – 1; *Carabus scabriusculus* G.A.Olivier, 1795 – 1; *Carabus graecus* (Dejean, 1829) – 1; *Carabus coriaceus*, Géhin, 1885 – 2; Carabidae gen. – 8; *Ophonus* sp. – 1; *Harpalus* sp. – 2; *Morimus asper* (Sulzer, 1776) – 2; *Prionus besikanus*, Fairmaire, 1855 – 1; Cerambycidae gen. – 24; *Hydrophilus* sp. – 1; *Copris lunaris* (Linnaeus, 1758) – 15; *Copris* sp. – 24; *Geotrupes vernalis* (Linnaeus, 1758) – 1; *Cetonia aurata* (Linnaeus, 1761) – 1; *Dorcus parallelipipedus* (Linnaeus, 1758) – 3; *Oryctes nasicornis* (Linnaeus, 1758) – 59; *Scarabaeus* sp. – 3; Scarabaeoidea – 6; Tenebrionidae gen. – 5; Coleoptera – 7.

THE IMPACT OF HETEROBASIDION ROOT ROT ON THE DENSITY, GROWING STOCK VOLUME, AND HEALTH CONDITION OF SCOTS PINE AND SILVER BIRCH STANDS IN VOLYN POLISSYA ZONE, UKRAINE

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Abstract

The study was carried out in Scots pine (*Pinus sylvestris* L.) forests in Gorodotske and Manevtske Forest Enterprises, which are situated in the Manevtsko-Volodymyrets'kyi physiographic region of the Volyn Polissya zone in Ukraine. The aim of the study was to investigate the characteristics and health condition of Scots pine stands, infected by annosum root rot (*Heterobasidion annosum* (Fr.) Bref.), in the disease centres and in the part of the stands outside the centres (the control areas), as well as of silver birch (*Betula pendula* Roth) stands in Volyn Polissya. We have found that the density of planted 43–75-year-old stands of Scots pine, established on formerly arable lands, was 32–66 % lower in the centres of the root rot disease than in the control areas. The growing stock volume was 20–62 % lower, respectively. The health index of the stands varied from 1.7 (weakened trees) to 3.2 (severely weakened trees) in the disease centres and from 1.3 (healthy trees) to 1.6 (weakened trees) outside them. We revealed that birch stands established on formerly arable lands were more resistant to annosum root rot and had better health status compared to pine stands. A set of factors was found to cause the root rot of Scots pine stands on abandoned agricultural lands, some of which were growing overstocked pure stands and their untimely (late) thinning.

Key words: annosum root rot, health condition, *Heterobasidion annosum*, *Pinus sylvestris*, planted pine stands.

Introduction

Scots pine (*Pinus sylvestris* L.) is the main forest forming species in Polissya zone; it occupies about 60 % of the area covered with forest vegetation (Terentjev 2015). Pine stands in Polissya, especially pure pine plantations, established on abandoned agricultural lands in the middle of

the 20th century, suffer great losses due to the root rot caused by the fungus *Heterobasidion annosum* (Fr.) Bref. (Negrutskiy 1986, Woodward et al. 1998).

The root rot reduces the productivity of forest stands, causes their early dieback, provokes massive pest outbreaks, increases fire hazard, worsens the soil-protective, water-conservation and sanitary

functions of a forest. In addition, root rot affected trees are vulnerable to wind storms (Alekseev 1974, Vollbrecht et al. 1994, Brandtberg et al. 1996, Bendz-Hellgren et al. 1999, Volchenkova et al. 2012, Garbelotto and Gonthier 2013, Lapitan et al. 2013, Zvyagintsev and Volchenkova 2014, Lyamtsev 2015, Musienko et al. 2018).

The proportion of the area of conifers infected by root rot in Ukraine is 13–16 % of the total area of the coniferous stands in which pathological processes are detected (Utsky et al. 2010). According to Chudak (2014), the basic infection level in the forests of Polissya in Ukraine is now provided by permanent foci of forest diseases. In recent years, there has been a negative dynamics: since 2007 the area of the foci of forest diseases has increased by 30 % from 90.9 to 117.3 thousand hectares. In the general structure of the stands, in which pathological processes are detected, 72 % of the area (84.7 thousand hectares) is occupied by pine forests infected by root rot. The largest centres of this disease are concentrated in Chernihiv (28.7 thousand hectares), Zhytomyr (14.2 thousand hectares), Kyiv (14.8 thousand hectares), Volyn (11.9 thousand hectares) and Rivne (11.1 thousand hectares) regions.

Annosum root rot occurs in all countries of Europe (Vasiliauskas et al. 2002, Wang 2012, Mead 2013, Sierota 2013), North America (Harrington et al. 1989, Woodward et al. 1998), Central America (Lewis 2002, Mead 2013), some regions of Australia (Mead 2013), Asia (Parmasto 1986, Dai et al. 2003) and Africa (Morocco) (Mead 2013).

The cause of the wide geographic and ecological range of root rot is a variety of ways of reproduction and infection (basidiospores, conidiospores or mycelium).

Primary infections of trees occur via basidiospores and conidia of the fungus. Basidiospores are formed in the fruiting bodies, and conidia, throughout the growing season, on the mycelium where rotting is on the surface of infected stumps or roots (Negrutskiy 1986, Woodward et al. 1998).

The problem of emergence and spread of this disease in Ukraine arose in the middle of the 20th century since pine forest plantations have been established on considerable areas of abandoned agricultural lands, pastures, and wastelands, where soils had lost their forest properties. The association of root rot disease centres with planting on formerly arable lands has been indicated by a number of investigations (Ladeyshchikova et al. 1974, Sierota 1997, Kuznetsov 2005, Bilous 2009, Sierota 2013). The initiation and spread of this disease are attributed by most researchers to the presence of the upper arable layer of soil, the depth of which is limited to a densified layer often referred to as the 'plow-pan'. The presence of such a layer prevents the roots to penetrate into the lower horizons of the soil that causes a decrease in the growth of the above-ground part of a tree and significantly weakens it (Ladeyshchikova et al. 1974, Negrutskiy 1986, Vasiliauskas 1989, Raspopina et al. 2013). Establishing plantations in areas after clear sanitary felling of the stands affected by annosum root rot increases the risk of the infection significantly (Negrutskiy 1986, Bilous 2009, Volchenkova et al. 2012).

A number of researchers (Vorontsov 1978, Artyukhovskiy 1998) assign an important role in spreading of the pathogen to stem pests, which are carriers of fungal spores, causing the infection. A high density (i.e. the number of living trees per hectare) of pure pine plantations, and therefore root contacts, leads to a de-

crease in their resistance to the root rot disease and group dying off (Vasiliauskas 1989, Volchenkova et al. 2012, Raspopina et al. 2013). Ladeyshchikova et al. (1974) and Raspopina et al. (2013), who conducted studies in Eastern Polissya region on sod-podzolic soils of formerly arable lands, showed that the initiation and spread of root rot were associated with the water-physical properties of the soils.

In order to increase the resistance of a stand against annosum root rot in formerly arable land, it was necessary to create mixed forest plantations involving deciduous species. The following species may be used to mix with Scots pine in fresh fairly infertile pine sites: silver birch (*Betula pendula* Roth), Red oak (*Quercus rubra* L.), English oak (*Quercus robur* L.), Grey alder (*Alnus incana* (L.) Moench). Their proportion must be at least 30 % in these conditions (Alekseev 1974, Negrutskiy 1986, Bilous 2009).

Biological methods of protecting plants from the root rot infection with the fungus *Phlebiopsis gigantea* (Fr.) Jülich have considerable advantages and in some conditions are the most effective tools for limiting the harmfulness of the disease. Rishbeth (1963) proved that *Phlebiopsis gigantea*, colonizing stumps, contributed to the inhibition of the pathogen in the roots, and suggested the use of this fungus for the biological control of *Heterobasidion annosum*. Rotstop biofungicide containing spores of *Phlebiopsis gigantea* fungus is widely used in Great Britain, Norway, Switzerland, Finland, Poland, Latvia, and Belarus (Sierota 2001, Kenigshalde et al. 2011, Volchenkova and Zvygantsev 2011, Sierota 2013, Kenigshalde et al. 2016, Kenigshalde et al. 2017).

The antagonistic influence of local strains of this fungus on root rot and the possibility of its use for preventive purpose

in the Left-Bank Forest-steppe of Ukraine were studied at the Donetsk National University. As a result of the research, a regulation was developed for the preparation of the biologic agent Penioflorin based on a spore suspension of selected *P. gigantea* strains, and an instruction for use was prepared (Demchenko and Sukhomlin 2000). However, this preparation (Boiko et al. 2001) has not been introduced in Ukraine, mainly for economic reasons.

It should be noted that in conditions of the forest-steppe in Ukraine, the fruiting bodies of *Heterobasidion annosum* in pine forests are formed very rarely in wet years. Therefore spore infection of the pathogen in such conditions plays a minor role, and the main way to control the disease is forest management, mainly sanitation felling, the effectiveness of which is insignificant. During the felling, all the dead trees in the disease centre and strips of unaffected stands on the perimeter of the centre are removed. Rather than protecting stands from the infection, this method of forest improvement also causes economic losses to the forestry industry, as high-quality green pine wood is progressively changed in deadwood in this case (Vasiliauskas 1989, Kuznetsov 2005, Zvyagintsev et al. 2013).

To reduce the annosum root rot infection level and to form a natural composition of soil microbiota, a number of investigators (Alekseev 1974, Peri et al. 1990, Ladeyshchikova et al. 2001, Lygis et al. 2004b) proposed to establish plantations of silver birch as a pine forecrop on former agricultural land in fresh and moist fairly infertile pine site types. However, a study by Lygis et al. (2004a) in Eastern Lithuania in 25-year-old *B. pendula* stands replanted in the *H. annosum* disease centres in *Pinus sylvestris* stands, which were clear-felled, indicated a low productivity

(45.0–76.1 m³·ha⁻¹), high mortality rates, and comparatively low vigour of the trees due to a strong impact of root rot.

The influence of root rot on stands' features and health condition of Scots pine and silver birch in Volyn Polissya of Ukraine have not been sufficiently studied. Therefore, the identification of factors contributing to the root rot damage of pine stands and the study of their characteristics and health status, as well as the development of preventive and control measures for this disease, are extremely relevant.

The aim of the study was to analyse and compare forest mensurational characteristics and health condition of Scots pine stands infected by annosum root rot and healthy silver birch stands, which

were growing on formerly arable lands, to investigate the possibility of replacing diseased pine stands with birch ones, which are more resistant to this fungus.

Material and Methods

An evaluation of stand characteristics was carried out in June and July 2017, using the methods of forest mensuration described by Neretin et al. (2006) and Hrom (2007). The study was performed in planted Scots pine forests on abandoned agricultural lands of two state forest enterprises: Gorodotske Forest Enterprise and Manevtske Forest Enterprise, which are located in Volyn Polissya zone of Ukraine (Fig. 1) and are representative for this

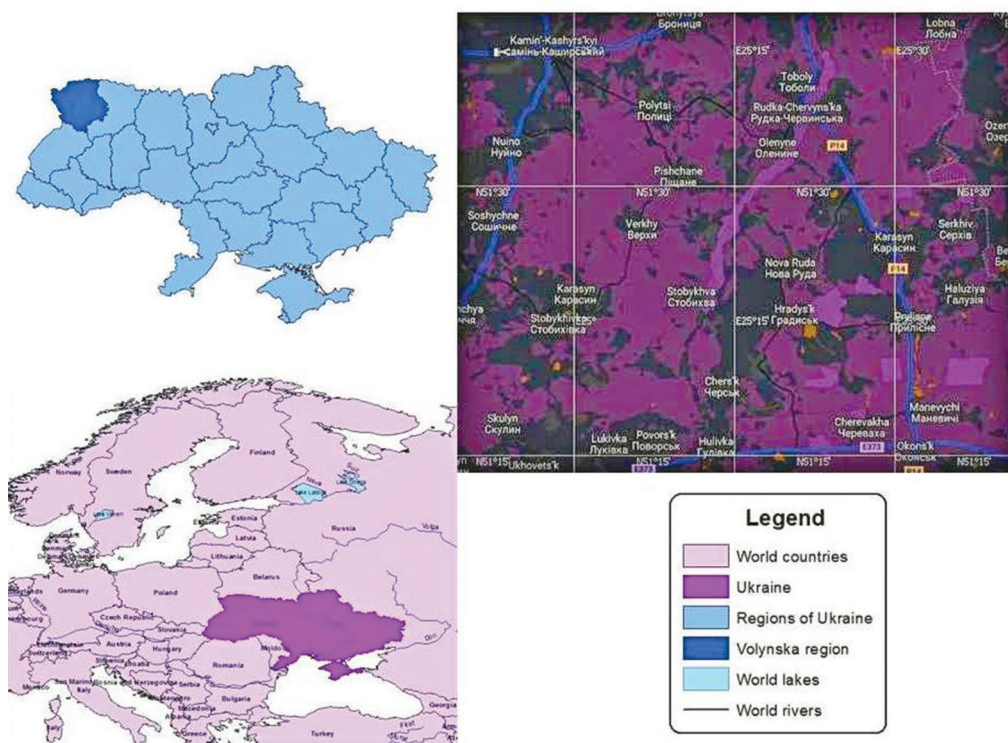


Fig. 1. Location of the study site.

Sam- ple plot	Age, years	Part of the stand	Compo- sition	Part of the trees	Stand density, stems·ha ⁻¹	Average diameter, cm	Average height, m	Growing stock volume, m ³ ·ha ⁻¹	Relative density of stock- ing	λ
10	51	all stand	9Sb	living	724	20.2	22.0	234.5	0.76	—
				dead	21	15.6	19.6	3.5	0.01	
			1Sp	living	76	20.5	22.1	25.7	0.06	
8-DC	56	disease centre	10Sp	living	528	23	20.2	211.7	0.49	3.92
				dead	56	18.2	17.3	11.7	0.03	
8-C	56	control	10Sp	living	800	23	23.1	367.6	0.72	3.92
				dead	14	14.3	19.1	2.1	0.01	
6-DC	61	disease centre	10Sp	living	458	27.7	24.6	306.8	0.58	5.37
				dead	132	25.3	24.1	72.1	0.14	
6-C	61	control	10Sp	living	799	27	26	541.3	0.97	5.37
				dead	73	18.6	22.6	20.8	0.04	
3	62	all stand	10Sb	living	437	26.5	23.2	258.5	0.78	—
				dead	16	16.0	18.9	2.9	0.01	
4-DC	75	disease centre	10Sp	living	167	37.6	25.8	228.9	0.39	6.86
				dead	80	34.6	25	85.5	0.16	
4-C	75	control	10Sp	living	491	35	26.3	561.4	0.98	6.86
				dead	5	22.6	22	2.1	0	

Note: Sp – Scots pine; Sb – Silver birch; single – single trees.

In fresh infertile pine site, four sample plots were laid out in Gorodotske Forest Enterprise: in 43-year-old mixed pine stand (sample plots 5-DC and 5-C) in Borove forestry and in 56-year-old pure pine stand (sample plots 8-DC and 8-C) in Lyshnivske forestry. The planting pine stand in 5-DC and 5-C was established on abandoned agricultural land using mixing pattern of 8 rows of Scots pine and 2 rows of silver birch. The pine stand in 8-DC and 8-C was linearly thinned in 2000 with continuous removal of trees in every 4th row. The thinning was carried out in winter without the use of biological or chemical preparations.

In the site type that is intermediate between fresh fairly infertile and fresh fairly fertile one, two sample plots, 9-DC and 9-C, were established in 47-year-old pure pine stand in Manevyske Forest Enterprise, Okonske forestry.

In fresh fairly infertile pine site, eight

sample plots were laid out in pure pine stands in Gorodotske Forest Enterprise as follows: sample plots 2-DC and 2-C in 50-year-old stand (Gorodotske forestry), sample plots 7-DC and 7-C in 51-year-old stand and sample plots 6-DC and 6-C in 61-year-old pine stand (Novorudske forestry), and sample plots 4-DC and 4-C in 75-year-old pine stand (Borove forestry).

In almost all studied sample plots, stands were created with 2.0 × 0.5 m spacing of planting sites. The exceptions were 8-DC and 8-C where stands were planted using 1.5 × 0.5 m pattern. The soil was cultivated using PKL-70 plow. There were a few silver birch trees of natural origin in some of the plots (Table 1).

The studied sample plots were square shaped. The area of the sample plots ranged from 0.3 ha to 0.57 ha depending on the age of the stand (Table 2) and the number of the dominant trees was at least 200 stems on each plot. The tree diame-

ter (DBH) was measured with a tree caliper at 1.3 m above ground level within the accuracy of 0.1 cm. The average diameter was calculated using the average basal area. The tree height was determined by hypsometer ИУ–1М for 35–45 trees in

each sample plot under field conditions. The average height was estimated using a graph of height variance depending on the diameter of the specific stand that corresponds to the average DBH (Hrom 2007).

Table 2. Area of the sample plots and health condition of the investigated stands.

Sample plot number	Age, years	Composition	Area of the sample plot, ha	Health index I_c
5-DC	43	10Sp	0.32	2.6
		single Sb		1.9
5-C		10Sp	0.32	1.4
		single Sb		1.8
9-DC	47	10Sp	0.33	1.7
9-C		10Sp	0.31	1.4
2-DC	50	10Sp	0.34	2.6
2-C		10Sp	0.30	1.5
7-DC	51	8Sp	0.36	3.2
		2Sb		1.5
7-C		10Sp	0.32	1.4
		single Sb		1.2
10	51	9Sb	0.40	1.5
		1Sp		1.5
8-DC	56	10Sp	0.35	2.3
8-C		10Sp	0.32	1.4
6-DC	61	10Sp	0.43	2.3
6-C		10Sp	0.39	1.6
3	62	10Sb	0.45	1.5
4-DC	75	10Sp	0.57	2.9
4-C		10Sp	0.51	1.3

Note: Sp – Scots pine; Sb – Silver birch; single – single trees.

The site class of the stands is the indicator of their productivity depending on the soil fertility or site conditions. It was determined using the Orlov's site class scales developed on the basis of height, age and origin of stands (Hrom 2007). Stand basal area was found as the sum of the basal area of all live trees in a stand per hectare ($\text{m}^2 \cdot \text{ha}^{-1}$). The relative density of stocking of a stand was calculated as the ratio of the stand basal area to the

basal area of the 'normal' stand (Shvydenko 1987). Growing stock volume was defined as the volume of all living trees per unit area ($\text{m}^3 \cdot \text{ha}^{-1}$), and the density of a stand as the number of living trees per unit area ($\text{stems} \cdot \text{ha}^{-1}$) (Hrom 2007).

The health condition of the trees was estimated using 6 categories, namely: the 1st – trees without signs of damage, the 2nd – weakened trees, the 3rd – severely weakened trees, the 4th – dying trees,

the 5th – standing dead trees died over the present year, and the 6th – standing dead trees died over recent years (Table 3). The degree of stand damage was characterized by the health condition index I_c that was calculated as follows (Sanitary Forests Regulations in Ukraine 2016):

$$I_c = \frac{K_1 n_1 + K_2 n_2 + \dots + K_6 n_6}{N}, \quad (1)$$

where: $K_1, \dots, K_6$ – the category of the health condition of the trees; $n_1, \dots, n_6$ – the number of trees of the given health condition category; N – the total number of recorded trees in the sample plot.

Table 3. Scale used in determination of health status of Scots pine trees.

Category of health condition	Health condition index range	Canopy openness	Degree of needle development		Part of needles with chlorosis or necrosis	Needle colour
			%	Distribution of needles over shoots		
1 st – without signs of damage	1.00–1.50	dense canopy	90–100	no signs of deterioration	0	green
2 nd – weakened	1.51–2.50	open canopy	66–90	no signs of deterioration	up to 1/3	green, light-green
3 rd – severely weakened	2.51–3.50	much open canopy	33–66	concentrated	1/3–2/3	light-green
4 th – dying	3.51–4.50	much open canopy	33	concentrated	2/3	yellowish or yellow-green
5 th – standing dead trees died over the present year	4.51–6.00	–	0	no living needles	1	grey, yellow or reddish-brown
6 th – standing dead trees died over recent years	4.51–6.00	–	0	no living needles	1	–

The root rot disease centre is an area occupied by a group of severely weakened and dying trees of 3rd and 4th categories of health condition, including gaps resulting from the sanitary cutting of the trees affected by annosum root rot (Fig. 2a). The area outside the disease centres (control) is a healthy part of the stand, not disturbed by the pathogenic loss of trees (Fig. 2b). The disease-produced loss of forest consists of severely weakened and dying trees and fresh and old standing dead trees, i.e. the

trees of the 3rd, 4th, 5th and 6th health condition categories (Sanitary Forests Regulations in Ukraine 2016).

We identified the damage of pine stands, caused by annosum root rot, both visually (Ladeyshchikova et al. 2001) and by performing the experiment to stimulate the formation of fruiting bodies of annosum root rot (Negrutskiy 1986). The experiment was carried out both inside and outside a disease centre for trees of different categories of health condition. At a dis-



**Fig. 2. Planted 61-year-old pine stands: a – in the root rot disease centre (6-DC);
b – in the area outside the disease centre (6-C).**

tance of 0.5 m from the tree, we dug pits up to 1 m long, 20–30 cm wide and 40 cm deep and cut the roots of the tree. The pits were covered with planks and moss. After three weeks fruiting bodies of the fungus have developed in cut roots. The fungus was identified by characteristic features, guided by the data of the special literature (Negrutskiy 1986). This provided the opportunity to observe that it was *Heterobasidion annosum* that caused the disease of the investigated pine stands. The formation of the fruiting bodies of annosum root rot did not occur in the areas outside the disease centres within affected pine forests and in birch stands. In the foci of root rot disease, fruiting bodies were not found in the roots of visually healthy trees (the 1st category of health condition) but they appeared en masse in the roots of

the trees of the 3rd–5th health condition categories (Fig. 3).

During the study of stand characteristics, the non-parametric Kolmogorov-Smirnov goodness-of-fit test (λ) (Massey 1951) was used. For this purpose, two series of empirical distributions of tree diameters in paired sample plots (inside and outside root rot disease centres) in pine stands affected by annosum root rot were compared and their belonging to one general population was assessed according to the formula (2):

$$\lambda = d_{\max} \sqrt{\frac{n_1 \cdot n_2}{n_1 + n_2}}, \quad (2)$$

where: $d_{\max}$ – the maximum difference between the values of the first and second series of cumulative frequencies; n_1 , n_2 – the sums of all variants of the population.



Fig. 3. Fruiting bodies of *Heterobasidion annosum* in pine roots: *a* – a tree of the 3rd category of health condition; *b* – a tree of the 5th category of health condition.

In this case, for the calculation of d_{max} formula (3) was used:

$$d_{max} = \sqrt{\frac{p_1}{n_1}} - \sqrt{\frac{p_2}{n_2}}, \quad (3)$$

where: $\sqrt{\frac{p_1}{n_1}}$ and $\sqrt{\frac{p_2}{n_2}}$ – the values of

the first and the second series of cumulative frequencies; p_1 and p_2 – the frequencies (ratios of number of trees of a certain degree of thickness to the total number of trees in the sample plot).

The boundary value of the λ test, which depends on the confidence level, was calculated using the formula (4):

$$\lambda = \sqrt{\frac{1}{2} \ln \frac{2}{P}}, \quad (4)$$

where: P – the corresponding confidence level – 0.95; 0.99; 0.999.

The boundary values of the λ test were 1.36, 1.63 and 1.95 respectively.

All calculations were done using statistical software package MinitabTM (Minitab

Inc., State College, USA) and PAST: Paleontological Statistics Software Package for Education and Data Analysis (Hammer et al. 2011).

Results

The analysis of λ value indicates that the compared populations of the trunk distribution by DBH categories, depending on the average diameter of the stands in the disease centres and in the controls, belong to different general populations and are described by different curves ($\lambda = 3.92...6.86$, $\lambda > 1.95$), that is, the probability of differences exceeds 99 % level (Table 1).

At the time of the study, in the 43-year-old pine stand (sample plots 5-DC and 5-C), only single birch trees remained at the stand due to the discrepancy between the site conditions and bioecological features of this species. As a result of a prolonged disease-producing loss of trees, the number of living trees per hectare in

the pine stand was 33 % less and the average height was 2 % lower in the root rot disease centre (5-DC) as compared to those outside it (5-C). The average diameter, on the contrary, was greater by 6 % because the sparse stand and a large number of openings contribute to the increase of radial increment of trees (Table 1).

In the birch part of the stand in root rot disease centre, the number of living trees per hectare was 11 % less than in the control. The average diameter of the birch trees was 6 % less and the height was 11 % lower in the disease centre than outside the centre.

Due to the mortality and slow growth, growing stock of the stand was 29 % less in the disease centre than in the control. The total relative density of stocking in annosum root rot centre was significantly less than in the healthy part of the stand, 0.54 vs. 0.71 (Table 2). The health condition of the stand in the disease centre was severely weakened (the health condition index I_c was 2.6) due to a significant amount of dead standing trees (24.5 %) and the predominance of trees of the 2nd health category (35 %). Considering that the number of dead pine trees in the part of the stand outside the disease centre was only 1 % and the number and stock were dominated by trees of the 1st health category (70 %), the condition of the stand was assessed as healthy ($I_c = 1.4$). The birch stand was weakened both in the affected and in the healthy part of the stand (the health condition index was 1.9 and 1.8 respectively) because this forest site was unfavourable for silver birch growth (Table 2).

In the 47-year-old pure pine stand, the stand density in the root rot disease centre in 9-DC (456 stems ha⁻¹) was 32 % lower than in the control (9-C) (Table 1)

resulting from the intensive mortality. Due to the less dense stand in the centre of the disease than outside the centre, the stock here was reduced by 20 %. The average diameter of the healthy part of the stand was 7 % less than that of the infected part but the average height was almost the same. Outside the disease centre, the share of healthy trees reached 72 % and the plantation was assessed as healthy ($I_c = 1.4$). In the centre of the disease, the share of trees of the 1st category of health condition accounted for 52 % and the stand was weakened ($I_c = 1.7$).

The results of the study indicated that in the disease centre of the 50-year-old stand (sample plot 2-DC), the stand density was 44 % less and the relative density of stocking was 0.37 less in comparison with the control (2-C) as a result of a prolonged disease-induced loss of trees and thinning. The growing stock volume was 39 % higher in the control than in the centre of the root rot disease. The average diameter of the tree stand was 5 % larger in the disease centre due to the low stand density. However, the average height here was somewhat lower – by 2 % – compared with the part of the stand outside the disease centre (Table 1). The proportion of dead trees (21 %) was four times greater in the centre than outside (5 %) because of the disease impact. In annosum root rot disease centre, the health condition of the stand was severely weakened ($I_c = 2.6$). This was due to the presence of a significant amount of standing dead trees, as well as to the pattern of trees distribution by categories of health condition. Thus, the proportion of trees of the 2nd category reached 39 %, and the share of trees of the 1st category accounted for only 32 %. The part of the stand outside the disease centre was assessed as healthy ($I_c = 1.5$); the trees of the 1st and 2nd categories of

health condition dominated: 68 % and 26 % respectively.

The density of the pine part of the 51-year-old stand was 55 % less in the root rot disease centre (7-DC) than in the area outside the centre (7-C). The slow growth of pine stand in the centre of the disease was indicated by the average diameter and height that were 3 % and 9 % less, respectively, than those for the control. The growing stock volume of the pine stand was 62 % less in the centre of annosum root rot disease as compared with the stock outside it due to the disease-induced loss and slowing growth of the trees (Table 1). In contrast to the pine part of the stand, the density of the birch part in the disease centre was 31 % higher as compared with the control. The initial number of birch trees per hectare inside and outside the disease centre was the same. However, due to the high density of the stand outside the disease centre, birch was mostly removed during the thinning as less productive species compared to Scots pine (Table 1). In the root rot focus, the birch was not removed since the number of living healthy pine trees here was already insignificant. This suggests that birch trees are more resistant to annosum root rot affection than Scots pine ones. Due to the low stand density and relative density of stocking in the centre of the disease, the average diameter of the birch trees was 6 % higher and the average height was 4 % less. Outside the disease centre, the stand was highly dense, and its total relative density of stocking (1.08) was double than in the disease centre (0.52) (Table 1).

In the affected part of the stand, the proportion of dead standing trees was 38 % of the total number of trees in the sample plot. Accordingly, the health status of the stand inside the disease centre

was severely weakened ($I_c = 3.2$), and the part of the stand in the control was healthy ($I_c = 1.4$). The birch trees in both parts of the plantation were assessed as healthy.

The spread of annosum root rot in 56-year-old Scots pine stand (sample plots 8-DC and 8-C) was scattering. In the disease centre, the natural seed reproduction of pine, oak (*Quercus robur* L.) and birch have been found, but it was poor.

Inside the disease centre (sample plot 8-DC), the density of the stand was 34 % less and the relative density of stocking was 0.23 below the control 8-C (Table 1) due to the disease-induced loss of trees and thinning. The growing stock volume was 42 % higher in the unaffected part of the stand than inside the disease centre. The average diameter of the stand in the root rot disease centre was almost identical to that in the control. However, outside the centre, the height of the stand was 13 % greater and the yield class was better (1st) than inside the disease centre (2nd).

The pine trees inside the disease centre belonged to the category of weakened ones ($I_c = 2.3$), unlike the part of the stand outside the centre, the health condition of which was much better: it was assessed as healthy ($I_c = 1.4$). The share of trees of the 1st health condition category was 68 % in the control and only 30 % in the centre of the disease.

The results of the studies on sample plots 6-DC and 6-C indicated that in the root rot disease centre (6-DC) the density of the 61-year-old planted stand and the growing stock volume were 43 % less, the average height was 5 % lower, and the relative density of stocking was 0.4 less as compared with the part of the stand outside the disease centre (6-C). Instead, the average diameter of the stand was

3 % larger in the disease centre due to the low relative density of stocking (Table 1). Pine stand was dense in the control and needed to be thinned.

The proportion of dead pine trees of the 5th and 6th health condition categories was 23 % in the disease centre and only 8 % outside of it. The stand was assessed as weakened, but in the control its condition was better ($I_c = 1.6$) as compared with the centre ($I_c = 2.3$).

In the centre of the annosum root rot disease, the density of living part of the 75-year-old plantation (sample plot 4-DC) was 167 stems ha^{-1} , which was 66 % less than outside the disease centre (sample plot 4-C) (Table 1). Accordingly, the relative density of stocking of the stand in the disease centre was also very low (0.39), in contrast to the fully-stocked stand in the control (0.98). The average diameter of the stand in the centre of the disease exceeded that of the healthy part of the stand by 7 % but the height of the stand outside the centres was slightly higher, by 2 %. In the control, the stock of the stand was 59 % larger than that in the root rot disease centre. In the part of the stand inside the disease centre, the share of trees of the 5th and 6th health condition categories reached one third of all trees in the sample plot (32 %), and therefore the condition of the stand was estimated as severely weakened ($I_c = 2.9$). In the control, the number of dead standing trees did not exceed 1 % and the condition of this part of the stand was healthy ($I_c = 1.3$).

The data of Table 1 show that the density of 51-year-old mixed birch stand of natural seed origin was 800 stems ha^{-1} , of which 724 stems (90 %) were silver birch trees and 76 stems (10 %) were Scots pine trees. The average diameter and average height of birch and pine trees were almost the same. The yield class of

the mixed stand was I^a, the growing stock amounted to 360.2 $\text{m}^3 \cdot \text{ha}^{-1}$ and the relative density of stocking was 0.82.

The mixed stand was estimated to be healthy. The average index of the health condition of birch and pine trees was 1.5, that is, at the border of the weakened one. The 1st category of the health condition included 62 % of birch trees and 59 % of pine trees; 34 % of birch trees and 32 % of pine trees were assigned to the 2nd one, and 1 % and 9 %, respectively, to the 3rd health category. The proportion of dead birch trees was insignificant (3 %).

The planted 62-year-old birch stand had the following mensurational characteristics: the density 437 stems $\cdot \text{ha}^{-1}$, the average diameter 26.5 cm, the average height 23.2 m, the relative density of stocking 0.78, and growing stock volume 258.5 $\text{m}^3 \cdot \text{ha}^{-1}$. There were 68 % of healthy trees, 27 % of weakened ones, 2 % of very weakened and dying ones and 3 % of dead standing trees in its composition. The average diameter and height of the dead standing trees were considerably below those of the living trees: by 40 % and 19 % respectively. The stand was healthy ($I_c = 1.5$).

According to our study, the average height of pine stands on the sample plots inside the disease centres was typically 0–13 % less than outside the centres. The average diameter in the disease centres was 0–7 % over that in the control (Fig. 4) since larger feeding area and living space resulting from the stand thinning contribute an increasing diameter increment. This difference is insignificant and depends on a combination of some factors, such as the intensity of the mortality, the intensity and timing of thinning or sanitary felling, the stage and duration of development of the disease centre, etc.

In the disease centres, the pine stand

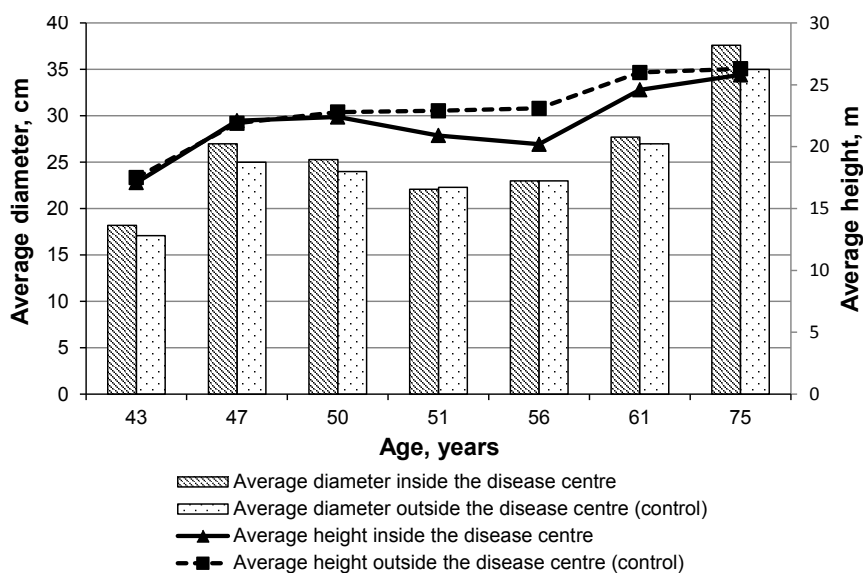


Fig. 4. The average diameter and the average height of pine stands of different age inside and outside root rot disease centres.

density and growing stock volume were significantly less, by 32–66 % and 20–62 % respectively, due to disease-induced loss (Fig. 5). The growing stock volume in the control areas gradually increased with aging (Fig. 5). The only exception was

56-year-old pine stand (sample plot 8-C), which grew in poorer forest site conditions (fresh infertile pine site type). The growing stock volume of the pine part of the stand inside the disease centre depended on the progression of the disease.

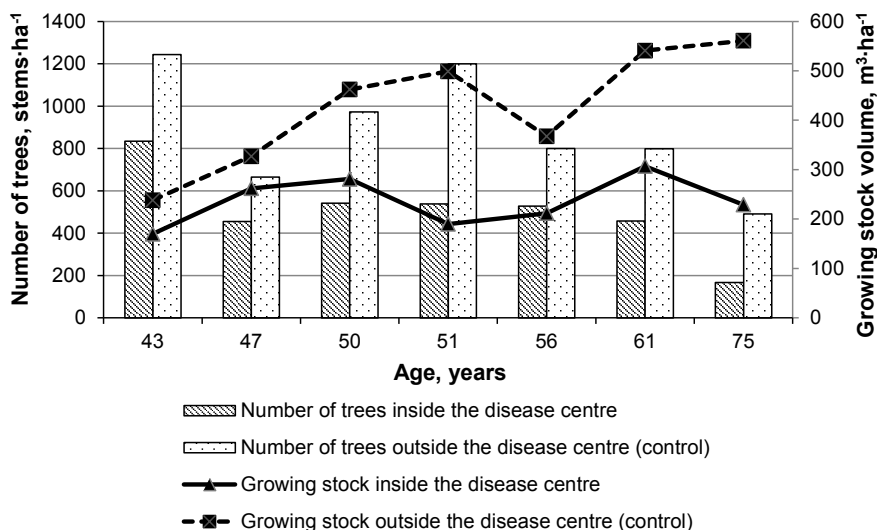


Fig. 5. The number of trees and growing stock volume of pine stands of different age inside and outside root rot disease centres.

In root rot disease centres, mortality was attributable to thicker (by 14–42 %) trees as compared to the control. In disease centres, the average diameter of living trees was 0–23 % larger than that of the dead ones. In the control areas (outside the centres), this difference increased up to 19–42 % (Fig. 6).

Health condition index ranged from 1.7 (weakened trees) to 3.2 (severely weakened trees) for the part of the stands inside the disease centre and from 1.3 (healthy trees) to 1.6 (weakened trees) in control areas (Fig. 7). Birch stands established on formerly arable lands were healthy ($I_c = 1.5$).

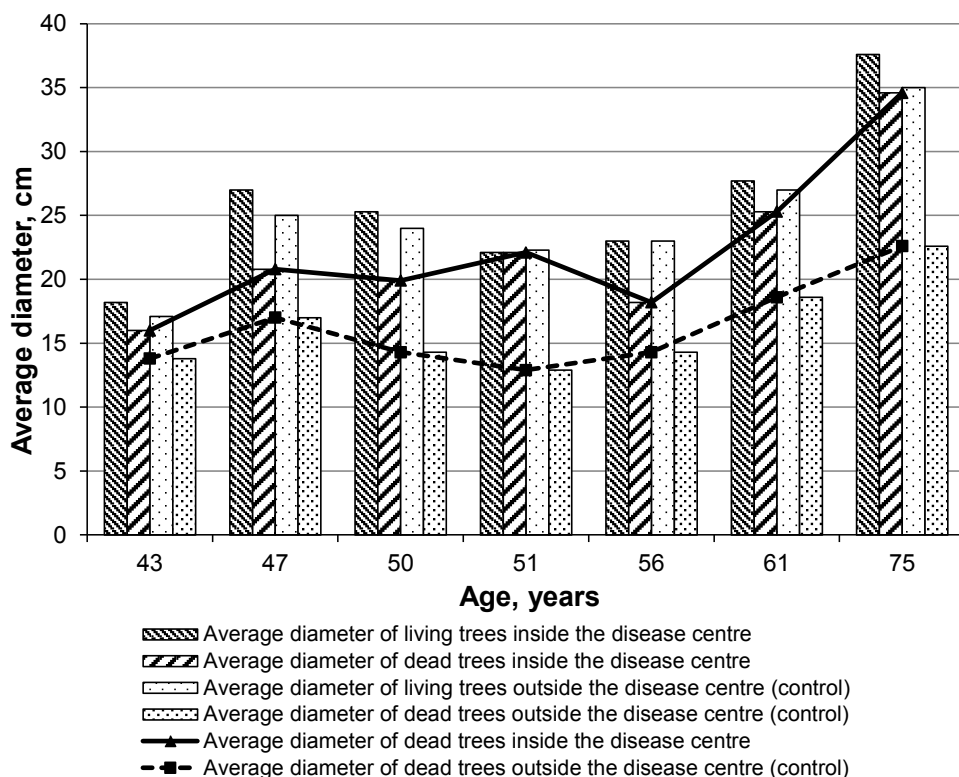


Fig. 6. The average diameter of dead and living trees inside and outside root rot disease centres for pine stands of different age.

Discussion

Our studies on stands' characteristics and health condition of Scots pine stands on formerly arable lands confirm the primary emergence of centres of annosum root rot disease in pure pine stands (or having a small percentage of silver birch trees) with high relative density of stocking

(0.8–1.0). This is also consistent with the findings of other researchers who stated that dense pure pine stands without timely thinning create an environment conducive to spreading annosum root rot due to the increase in number of root contacts of closely-spaced trees (Ladeyshchikova et al. 1974, Vasiliauskas 1989, Volchenkova et al. 2012, Raspopina et al. 2013).

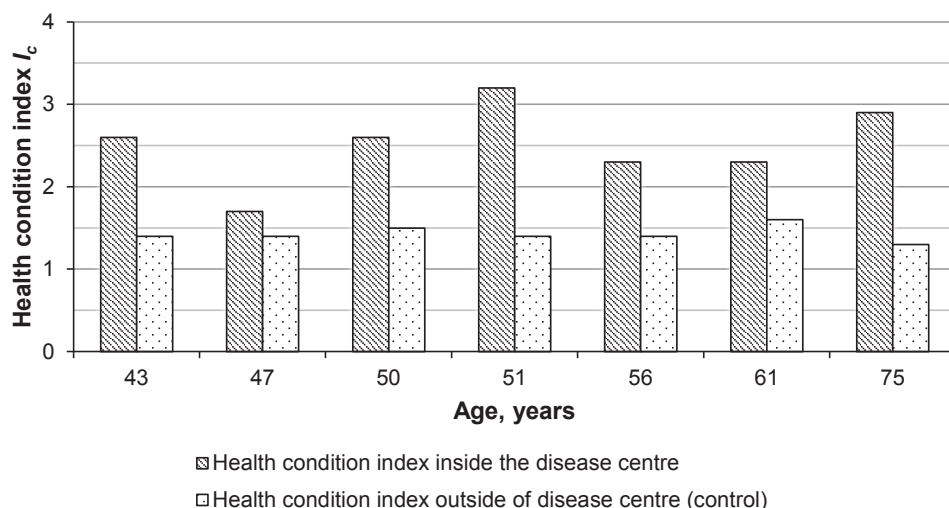


Fig. 7. The health condition index for pine stands of different age inside and outside root rot disease centres.

The given data (sample plots 3, 7-DC, 10) show that birch stands grown in fresh fairly infertile pine forest conditions were healthy ($I_c = 1.5$). The birch stand was weakened only in the sample plots 5-DC and 5-C (fresh infertile pine site type) because these forest-growing conditions are unfavourable for birch growth. Many workers (Ladeyshchikova et al. 1974, Lygis et al. 2004b, Negrutskiy 1986, Peri et al. 1990, Raspopina et al. 2013, Vasiliauskas 1989) also consider birch stands to be more resistant against annosum root rot. Establishing pure birch stands in the cut areas after stands affected by annosum root rot is especially advisable to prevent the disease. According to Alekseev (1974) and Bilous (2009), the share of birch in the composition of stands planted on former agricultural lands in fresh fairly infertile pine sites should be not less than 35 %, which will accelerate the decaying forest litter and enrich the soil with nitrogen and ash mineral substances. The growing mixed pine-birch stands will enhance soil-protective, water-conservation,

sanitary, recreational and other beneficial properties of forests and improve the biodiversity of the lands disturbed by long-term agricultural use (Ladeyshchikova et al. 2001). In addition, it will contribute to the formation of the natural composition of the soil microbiota and will provide the opportunity to create more valuable pine forest stands in the future.

In conditions of Chernihiv Polissya, Ukraine, in planted mixed pine-birch stands with a 10–20 % of birch, the productivity of the stands was 10–35 % higher than that of pure pine plantations. The birch added intensified forest litter decomposition and promoted the accumulation of nutrients in the soil (Bilous 2009).

Similar results were obtained by Raspopina et al. (2013) in the research in the Ukrainian region of Eastern Polissya. According to their data, there was a decrease of 20–49 % for the density and of 16–37 % for the growing stock volume of the pine stand in root rot disease centres in comparison with the areas outside the centres due to the disease- and pest-in-

duced mortality. The average height of planted Scots pine stands inside the disease centres was slightly lower, and the average diameter was larger than those outside them. In the disease centre, the health condition of the stand was assessed as severely weakened ($I_c = 2.6 \dots 3.4$). Outside the root rot disease centre, the stand was weakened ($I_c = 1.7 \dots 2.4$).

According to the study in Eastern Polissya, Ukraine (Vedmid et al. 2013), the growing stock volume and the value of timber of pine stands decreased by 1.5–2 times inside the disease foci as compared to outside part. The investigation of growing stock of planted pine stands affected by root rot in Ukrainian Novgorod-Severske Polissya (Lapitan et al. 2013) showed the decrease in growing stock volume by an average of 24 % and 33 % in the disease centres in pre-mature and mature pine stands respectively. In Volyn Polissya zone of Ukraine, the total standing volume and the value of timber of root rot affected planted pine stands outside the disease foci were 42 % larger than those inside the foci (Musienko et al. 2018).

At the age of 51, the growing stock volume of the pine stand affected by annosum root rot ($233.1 \text{ m}^3 \cdot \text{ha}^{-1}$) (sample plot 7-DC) was 10 % lower than the stock of the birch stand ($260.2 \text{ m}^3 \cdot \text{ha}^{-1}$) (sample plot 10). This was due to the slower growth of the pine stand resulting from its health deterioration to severely weakened ($I_c = 3.2$), in contrast to a healthy birch stand ($I_c = 1.5$). However, the growing stock volume of 61-year-old pine stand in the disease centre (sample plot 6-DC) was 16 % higher than that of the birch one of the same age (sample plot 3). This suggests that the health deterioration of the pine stand to weakened one ($I_c = 2.3$) did not significantly affect the growing stock. Therefore this pine stand is more produc-

tive than pure healthy birch stand at the sample plot 3 ($I_c = 1.5$).

According to the study of Raspopina et al. (2013), the growing stock volume of pine stands affected by annosum root rot exceeded the growing stock of birch stands by 20 %. Instead, the planted birch stands had better health condition ($I_c = 1.6 \dots 2.1$) as compared with the planted pine stands affected by root rot ($I_c = 2.6 \dots 2.9$). However, their health status was deteriorated considering that they were established in cut areas after planted pine stands affected by this fungus. In our case, the birch stands were created on former agricultural lands. In the above study (Raspopina et al. 2013), a set of factors was found to determine the root rot infection of pine stands, the main of which were growing overstocked pure plantations on abandoned agricultural lands and untimely thinning of the stands.

Conclusions

In the studied pine stands established on former agricultural lands, root rot disease centres emerged mainly in pure stands with high density of stocking (0.8–1.0). In the disease centres, the density of planted pine stands was significantly less, by 32–66 %, due to the disease-induced tree mortality, and the growing stock volume was 16–64 % lower than that outside the disease centres. The health condition index varied from 1.7 (weakened stand) to 3.2 (severely weakened stand) inside the centres of root rot disease and from 1.3 (healthy stand) to 1.8 (weakened stand) in the areas outside them. In root rot disease centres, the average height of pine stands was 0–13 % lower and the average diameter was 0–7 % over those values outside the centres. Mortality inside the disease

centres was attributable to thicker, by 14–42 %, trees as compared to the part of the stand outside them.

Birch stands established on formerly arable lands were more resistant to annosum root rot and had better health status ($I_c = 1.5$) as compared to pine stands infected by root rot ($I_c = 1.7 \dots 3.2$). Increased resistance of stands against root rot can be achieved through addition and keeping of broadleaved species (35 %), particularly silver birch, into the stand composition and timely thinning of young stands. Mixed stands will contribute to soil-protective, water-conservation, sanitary, recreation and other beneficial properties of forests and improve the biodiversity of the land disturbed by long-term agricultural use.

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NUMBER AND DISTRIBUTION OF AMUR REGION HUNTING BIRDS (TETRAONIDAE) USING GIS CARTOGRAPHIC VISUALIZATION METHODS

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Abstract

This article is based on long-standing data (2013–2017), which takes into account the number of birds during the winter route census (WRC) in the Amur region, where 5 hunting types of Galliformes occur (the black-billed capercaillie, black grouse, hazel grouse, willow ptarmigan, and the common pheasant). The collected data about their numbers and density were visualized using the ArcGIS 9.3.1 (2009) software with Spatial Analyst special analysis tools. The spatial distribution of birds in biotopes in places of our research is taken into account. The main limiting factors that cause fluctuations in the abundance of these bird species are identified. Such results of censuses of hunting birds and their analysis should be used by specialized hunting and nature protection organizations, which are obliged to regulate annually hunting of trade birds and animals in the region. In addition, data on the population and hunting ceiling for the hunting birds are the basis for the rational planning and opening of the hunting season, as well as establishing the maximum percentage of game production with no harm to the population. The study of ecological and biological features of bird species is of great importance for more successful and rational organization of hunting farms: biodiversity conservation, population monitoring, organization of reproduction, biotechnical and conservation measures, forecast of the number of hunting resources for long-term planning of the economy. Thus, such a generalized analysis of the state of populations of hunting's Tetraonidae birds in the Amur region will help ornithologists and any specialists in the field of protection and use of wild animal resources to assess the current state and adaptive features of local populations of Tetraonidae. Such research is a prerequisite for predicting the number of these birds and provides a solid foundation for the development of conservation measures.

Key words: population data of birds, spatial distribution, winter route census (WRC).

Introduction

Observation of the number and condition of forest and field bird populations used for game hunting is an important basis for their rational use, since it is based on data on the number of birds that can be discovered during the hunting season within

the hunting ceilings with no harm to their regional population.

The importance of these studies can hardly be overestimated, since such an expert assessment of the resources of hunting birds makes it possible to obtain the maximum number of products while maintaining populations at the level of

maximum sustainable productivity.

In general, almost everywhere in the country there are two opposing processes, reflecting the status of hunting resources of the Galliformes. Thus, interest in the hunting of forest and field birds has gradually decreased due to the phased reduction in the number of professional hunters who experience difficulties in storing, transporting and selling products in modern economic conditions.

At the same time, according to Gavrin (1965) and Romanov (1988), since the 1960s, there has been a tendency to reduce the forest and field bird reserves throughout Russia. First of all, this is due to a noticeable reduction in the total amount of land suitable for their habitat (deforestation, intensive economic use of land, and many fires), an increase in the number of hunting enthusiasts and an increase in poaching.

In Russia, the monitoring of hunting bird populations and the study of their ecological and biological features are conducted in various regions on a regular basis. Masaytis (2018) investigated the status of the black grouse in the northwest of the European part of the taiga area of Russia. He proposed to use the classification of the state of leks according to their dislocation to assess the status of the black-billed capercaillie population in spring. This approach allows us to develop a set of security measures based on the category of dislocated leks of the black-billed capercaillie and the recommended percentage of seizures of birds in hunting farms. A huge amount of material (for over 75 years) about the distribution and ecology of the black-billed capercaillie was consolidated by Bugaev (2011) in the territory of the Mordovia Nature Reserve located in the forest-steppe zone of the European part of Russia.

Borchtchevski (2017) studied the problem of the influence of spring weather and climatic conditions on Tetraonidae (for example, the capercaillie) as main limiting factor in Central Russia. According to our observations, this is also characteristic of the Tetraonidae living in Siberia and the Far East.

Barbazyuk (2017) studied the long-term dynamics of the number of the capercaillie in the Orenburg Nature Reserve in the steppe zone of the Ural under the influence of fires. All these studies confirm the results of observations of Tetraonidae birds within their habitat. For example, the decrease in the number of the capercaillie in the post-fire period is due to a decrease in the feeding capacity of habitats, and the destruction of nesting biotopes.

In Siberia, many studies have been devoted to the distribution, biology and ecology of the Tetraonidae. Since 1996, the monitoring of the population status and the biology of the capercaillie of the Yeniseyevskaya Plain (Central Siberia) has been conducted by Savchenko and Savchenko (2001, 2002) and Savchenko (2000, 2004, 2005). Kotlov (2011) studied the species composition, population density of hunting birds, hunting methods and the volumes of prey in the Altai territory.

In Baikal Siberia, according to Dorzhiev (2016), up to 13 species of Tetraonidae are registered. In Southern Baikal Melnikov (2015) noted that the main change in the population density of 3 species of the Tetraonidae (the black-billed capercaillie, the black grouse, the hazel grouse) occurs in summer. At the same time, the main limiting factor is the influence of ground predators (sable to the greatest extent). Estimation of the general population status of the hunting species of birds has fragmentary information. Recently, interesting calibrations have emerged

about the distribution of the black-billed capercaillie in the Baikal region (Gagina 2015; Melnikov 2007, 2016), which indicate an expansion of its habitat range to the west along the south of Baikal and in the Upper Lena. According to Labutin and Pshennikov (1993), in the north of Siberia under the harsh Yakut winter, the distribution of the black-billed capercaillie is associated with the habitat of the Dahurian larch due to their trophic relations.

The population status of the Tetraonidae is also monitored in the Far East (Sandakova et al. 2015, Kharchenko 2013, Biserov and Medvedeva 2016). Some Tetraonidae species require special attention due to the ecological and biological features of the species. Biserov (2011) believes that the number of Siberian Tetraonidae is underestimated in the Khabarovsk region. He proposes to revise the census method of the Siberian grouse and it offers a census time (mid-August – mid-September) and a different choice of location for determining the route where the number is calculated (old roads). The research of Nechaeva and Nechaev (2012) reflects the role of birds in the distribution of wild berry plants in the south of the Far Eastern taiga area, especially during the period of nomadic movement and migration.

Foreign researchers also actively study the status of hunting birds, the ecological features of the Tetraonidae. Currently, the systematic position of many species of the Tetraonidae is being revised, and the recent changes are reflected in work of McGowan and Bonan (2018). Researchers of genetic variability of the hazel grouse *Bonasa bonasia* populations in Poland (Rutkowski et al. 2012) and Lithuania (Riauba and Butkauskas 2012) highlight significant differences between populations. The mosaic structure of habitats, the influence of the glacial period and the

subsequent distribution of the species from refugia are the main causes of variability. Some experts recognize the genetic similarity of the Tetraonidae, which are represented by the same genus. For example, Ning et al. (2016) revealed family relationships between rare and poorly studied species – blood pheasant (*Ithaginis*), snow partridge (*Lerwa*) and long-billed partridge (*Rhizothera*).

In addition to monitoring bird populations in Europe, many studies are devoted to factors that cause fluctuations in the Tetraonidae population. In Central Europe and Fennoscandia, a decrease in the number of the capercaillie and the black grouse has been observed for 80 years. Jahren et al. (2016) identified a number of causes that affect the number of these species. These are natural limiting factors (weather and climatic conditions, fires, floods, etc.), habitat degradation (deforestation, extensive agricultural land) and the hunting press. A similar pattern develops over the entire area of the Tetraonidae distribution.

Huhta et al. (2017) also believe that the Tetraonidae population in Finland is gradually decreasing. In the northern forest-steppe and southern cultivated areas, the authors studied the success of nesting of the hazel grouse. This is due to the presence of old coniferous woods and mixed forests, which is associated with the abundance of the main feed (blueberries, insects, etc.). In open and semi-open landscapes, the proportion of death of broods due to predator attacks increased. Also Torfinn (2017) notes a decrease in the number of the capercaillie and the black grouse due to the influence of birds of prey and carnivorous mammals.

Researches of Scridel et al. (2017), Hofstetter et al. (2015) and Kervinen et al. (2016) indicate the importance of for-

est area for the population of the black grouse. Within 5 years, an increase in the black grouse population was observed, in cases where new forest lands accounted for about 30 %.

The Amur region, located in the Upper and Middle Amur River, is characterized by a sharply continental climate with some monsoons, as well as an ecotonic position between the taiga of Eastern Siberia and the coniferous and broadleaved woodlands of East Asia. Here, along with a long history of development, landscape and ecological heterogeneity, mosaic pattern of habitats, there is also a mixture of various elements in the plant and animal world with a predominance of Siberian species of fauna and flora. All this stipulates the specifics of this region.

However, even though in the Amur region there are quite few publications and studies on the state of populations of hunting bird species. Some of them have fragmentary population data from a short period of research or have only fragmentary character and do not reflect completely ecological and biological aspects of this question.

The aim is to comprehensively study and analyse the population size, dynamics, and population density of the game bird Galliformes; to determine their spatial distribution in the Amur region. We also identified ecological and biological features of birds and their factors affecting the current state of populations in the ecotonic zone (Siberian taiga, coniferous, and deciduous forests).

Materials and Methods

Studies of birds conducted in the winter period from 2013 to 2017 served as the basis for this work. We analysed the num-

ber of database about 5 game species of the fowl-like birds (*Galliformes*), living on the territory of the Amur region – the willow ptarmigan *Lagopus lagopus* (Linnaeus, 1758), the hazel grouse *Bonasa bonasia* (Linnaeus, 1758), the black grouse *Lyrurus tetrix* (Linnaeus, 1758), the black-billed capercaillie *Tetrao urogalloides* (Middendorf, 1853), the common pheasant *Phasianus colchicus pallasii* (Rothschild, 1903).

In general, in Russia, the winter route census (WRC) is a method of complex census, which helps to determine the number of hunting species and animals in their natural habitat (elk, roe deer, lynx, wolf, fox, corsac fox, sable, martin, chorea, wolverine, ermine, column, squirrel, hare, wild boar, red and spotted deer), and at the same time can determine the number of hunting birds (hazel grouse, black-billed capercaillie, black grouse, common and stone grouse, Siberian grouse, willow ptarmigan, gray, rock ptarmigan, bearded (Daurian) partridges, as well as the common pheasant). The WRC is the main and mandatory type of animal resource census, which is carried out on the territory of hunting grounds and protected areas (PAs) (with the exception of federal PAs) throughout the territory of the Russian Federation. Annual census of game animals and birds is carried out by the WRC method (Mirutenko et al. 2009), which allows to simultaneously receive the most complete and reliable picture of the number of animals and birds on fairly large areas.

The WRC is carried out on special routes from 15 January to 25 March in the presence of snow cover. The location of the ground route is one of the driving factors that affects the objectivity and completeness of the data collected during the WRC. Due to this, the organizers follow

strict rules governing the selection and collection of data.

According to the method of conducting the WRC, routes are laid in all categories of land: forest, field, and swamp. It must be at least 5 km long but not more than 15 km long. There should be at least 7 route censuses in the study area. Routes can be unidirectional or non-unidirectional, as well as closed (length of at least 10 km). If the route census is not unidirectional, then the change of the vector (direction) of the route census must be planned at an angle of not more than 90° to the previous vector (direction) of the route census segment.

Routes should not intersect between each other and should be located at least 200 m from feeding stations, mineral licks (salt licks), and residential buildings.

In the forest, the route censuses or part of it should not run through linear objects with a width of more than 5 m (for example, glades, roads and railways, power lines, watercourses, and ravines), as well as along them at a distance closer than 100 m. In mountainous areas, the route censuses are lay along watercourses, slopes of valleys and water gaps.

The length of all route censuses within each category of lands (forest, field, and swamp) have to be proportional to their areas, but not less than the extent determined by the following formulas:

$$DL_{forest} = \frac{DL \times S_{forest}}{S},$$

$$DL_{field} = \frac{DL \times S_{field}}{S},$$

$$DL_{swamp} = \frac{DL \times S_{swamp}}{S},$$

where:

DL_{forest} – the length of all route censuses for the group of category of lands ‘for-

est’, km;

DL_{field} – the length of all route censuses for the group of category of lands ‘field’, km;

DL_{swamp} – the length of all route censuses for the group of category of lands ‘swamp’, km;

S_{forest} – an area of the group of category of lands ‘forest’, ×1000 ha;

S_{field} – an area of the group of category of lands ‘field’, ×1000 ha;

S_{swamp} – an area of the group of category of lands ‘swamp’, ×1000 ha.

In general, the location of the route on the ground is one of the important factors that affects the objectivity and completeness of the data about the number of birds as a result of the winter route census. However, there are some drawbacks during the winter route census. The extreme winter conditions, like deep snow, low temperatures, and strong wind, which are especially harsh at the end of winter, force the birds and animals to stay in one specific location, such as glades, overnight locations, places of feeding, and otherwise, and to have short daily activity. Therefore, some birds are not encountered by the registering devices on the route due to the inaccessibility and remoteness of such areas of their concentration from the WRC routes.

The conditions and methods of the winter route census. Registration of animals is carried out on each route censuses over the course of two days. During the WRC, the route and population data are recorded using electronic tracking on a GPS device.

On the first day of the census, the animal trace recorder goes on the planned route and marks the land category boundaries on the GPS. Also the animal trace recorder removes old traces of animals on the snow, so that on the second day of the

census he would be able to register the traces that appear on this route and the number of animals that cross it.

During the passage of the route, the recorder registers each sighting of birds (bird species, number of birds, the distance from the recorder to the centre of a group of birds or a single bird, and the land category of where the birds were found). At the same time, the birds that have flown up from behind the recorder and have been seen flying are not recorded.

Rules on how to conduct the WRC's forbid doing the census in the dark, snowstorms, snowfall, in hard or dense snow (as animals do not leave tracks or tracks left by the animal cannot be identified).

If the weather changes and worsens during the census, then the census is finished. Only after the weather conditions improve, the census can restart from the beginning.

Counting and determining the number of animals and birds. The registered number of each bird species in the corresponding land categories in the study area is calculated by the following formula:

$$Z_{ru} = P_{ru} \times Q_{ru},$$

where:

Z_{ru} – is the number of individual birds of each species in the corresponding land group in the study area;

P_{ru} – is the population density of each bird species in the respective land group in the study area, birds/1000 ha;

Q_{ru} – is the area of each of the land categories in the study area, divided by 1000 ha.

Thus, to calculate the number of birds, two primary criteria are used – the number of bird encounters on the route and the conversion factor for each bird species by land category (Ravkin and Chelintsev 1990, Chelintsev 2000).

The population density of each bird species in the corresponding land category in the study area is calculated by the following formula:

$$P_{ru} = F_{ru} \times k_u,$$

where:

F_{ru} – is the index of census of each bird species in the corresponding land category in the study area;

k_u – is the conversion factor for each bird species in the corresponding land category (calculated for an individual subject of the Russian Federation).

$$F_{ru} = \frac{\sum_j^{M_r} Y_{ruj}}{E_{ru}} \times 10,$$

$$E_{ru} = \sum_j^{M_r} E_{ruj},$$

where:

Y_{ruj} – is number of individual birds registered on the part of the census route, passing in the corresponding land in the study area;

E_{ru} – is the overall index of the lengths of all routes in the census in the study area passing in its land category in kilometres;

E_{ruj} – is the doubled length of the portion of the route passing in the corresponding group of land categories in the study area in kilometres.

Conversion factor for each bird species in the corresponding group of land categories (calculated for an individual subject of the Russian Federation) by the following formulas:

$$k_u = \frac{500}{B_u}, \quad B_u = \frac{G_u}{\sum_i^{T_u} \frac{G_{ui}}{R_{ui}}}, \quad G_u = \sum_i^{T_u} G_{ui},$$

where:

B_u – the average distance from the recorder to the centre of a group of birds or a single bird in the corresponding land category of an individual subject of the

Russian Federation in meters;

i – is the number of sightings of the bird species;

R_{ui} – a distance from the counter to the centre of a group of birds or a single bird for each sighting in the corresponding land category in meters;

G_{ui} – the number of birds found in the for each sighting in the corresponding land category;

G_u – the total number of birds found in the corresponding land category of an individual subject of the Russian Federation;

T_u – the total number of sightings of the bird species in the corresponding land categories of an individual subject of the Russian Federation.

To calculate the accounting index (F_{ru}) of each animal and bird species, the actual length of the route census should be used. The index is the length of each part of the route in the group of land categories which is based on the GPS device's data.

In addition, we used 2 criteria of population density – the average and ecological density. Thus, the average density is the number of a species relative to a unit of the entire space of the area under research. Ecological density is the number of a species relative to a unit of habitable space of accessible area on a suitable land, which may be occupied by the population in reality.

The visualization of the spatial distribution of hunting birds was carried out by the cartographic method using GIS technologies. Thus, the data on the number of birds were obtained on the basis of the processed GPS tracks and primary registration data (the number of encounters of hunting bird species on census routes) recorded by people performing the work. Computer processing of the census data

and mapping of routes on which the surveys were carried out was made with ArcGIS 9.3.1 software with the Spatial Analyst spatial analysis tools (ArcGIS 9.3.1 2009).

Based on the route population data, the density is estimated and the geo-analysis is required to build a map for the visualization of the population density of hunting birds (figs 1–3). Density criteria (high, medium, low) are displayed on the map with intensity of colouring of conventional colour variances.

A large amount of registration data is accumulated in the form of tables and is constantly accompanied by mathematical processing for their analysis. At the same time, cartographic visualization significantly improves the perception of the processed material and visually displays the registration data. This is necessary for the rational regulation of territories since it permits or prohibits the hunt for birds, and also determines the size of the hunting ceilings for specific places. Such cartograms help to reveal the hidden features of the dynamics of the spatial distribution of animal resources and their annual reproduction.

Study area. The Amur region total area is 363,700 km². It is part of the natural geographic area of the Upper and Middle Priamurye, which has an ecotonic position between two large geographic zones – Siberian taiga with sharp continental climate and coniferous and deciduous forests of East Asia with humid monsoonal climate.

The study area is located south of the Stanovoy Range to the Amur River. The eastern border runs from the ranges of the Small Khingan and Turan and reaches the headwaters of the Nyukzha River in the west. The main part of the Amur region is occupied by the basins of the left confluents of the Amur River – Oldoy, Zeya,

Selemdzha, Arkhara and the lower part of the Burei River.

From the point of view of orography, the field of study has a mountain character. The mountains are mostly of medium height and are located along the northern and eastern perimeters of the region. The Stanovoy Range (the average absolute height is about 1500 m, the maximum height is up to 2414 m) is an extensive mountain system in the north of the Amur region, which has steep southern slopes within the region. The main ridge of mountains consists of crystalline schists, gneisses and granites and has a smooth surface destroyed and dissected by geological processes that took place on the ridge during long geological eras and a series of ancient glaciations. Many mountain peaks are treeless, with sharp peaks, with alpine meadows at the upper boundary of the forest and littered with small rivers feeding on water from melting snow. The Dzhukdyr Ridge (up to 2107 m) is located to the east of the Stanovoy Range, it is similar in geology, its peaks and slopes are even more treeless.

From west to east in the middle part of the Amur region, for 1,200 km stretches the system of medium-altitude ridges called Yankan-Tukuringra-Soktakhan-Dzhagdy. On the eastern border of the region, the Turan Ridge and the Yam-Alin Ridge, connected by the wide Aesop Ridge, are meridional. In the western part of the region there are many small ridges of medium height.

Plains (about 55 %) stretch to the southeast (Zeya-Bureya plain) and central regions. (Amur-Zeya and Upper Zeya plains). The Zeya-Bureya plain (total area is about 4 million hectares) is located east of the Zeya and Selemdzha rivers at an altitude of 200–300 m above sea level in combination with lowlands (less than

200 m). The plain consists of horizontally deposited layers of sand and loam, and there is a significant increase in its surface from southwest to northeast. The wide valleys of the rivers carve the plain, carrying water into the basin of the Zeya and Amur rivers.

At present, the surface of the Zeya-Bureya plain is highly susceptible to anthropogenic impact, which has contributed to the emergence of vast forests (only about 2 % of the forest area) and agricultural land. This contributes to an increase in the number of ravines and soil erosion. In some areas of opencast brown coal mining, barren sand hills and heaps appeared.

The Amur-Zeya plain (total area is about 4.5 million hectares) stretched 400 km north of the Zeya-Bureya plain to the Tukuringa – Suktakhan ridge, its length from the east (from the Zeya and Selemdzha river valleys) to the west to the low-hill terrain in the basin Urkana River is about 300 km.

The surface of the Amur-Zeya plain has a high (absolute altitude – 300–400 m) and hilly nature. In the lowlands of the plains there are numerous boggy areas. In the west and south of the plain a dense network of ravines is developed. Agricultural fields and some forests are located mainly in the south.

The upper part of the Zeya plain (total area is about 1 million hectares) is located in the intermountain subsidence in the upper part of the Zeya river valley. Currently, up to 240 thousand hectares of plain are occupied by the reservoir of the Zeya hydroelectric station, and the rest of the territory is covered with numerous boggy areas and residual hills.

In the Amur region there are many swamps (total area is 13 million hectares) and marshes, which are concentrated in

lowland and mountainous areas. They are formed due to the abundance of summer precipitation and low average annual temperatures. Thus, moss bogs dominate in the upper part of the Zeya plain and sedge swamps – on the Zeya-Bureya plain (between the Bureya and Arkhara rivers), in the foothills of the Lesser Khingan, in the middle part of the Zeya River and Upper Amur.

The territory of the Amur region combines contrasting climatic, orographic, and hydrographic features that determine the specific characteristics of the flora and fauna of the region.

Results and Discussion

On the territory of the Amur region, there are only 7 representatives of the fowl-like birds (Galliformes, Temminck, 1820). Of these, 2 species (*Falcipennis falcipennis*, Linnaeus, 1758 and *Perdix dauurica suschkini*, Poliakov, 1915) are listed in the Red Book. The remaining 5 types of fowl-like birds are game species – 4 species of forest birds (*Lagopus lagopus*, Linnaeus, 1758; *Bonasa bonasia*, Linnaeus, 1758; *Lyrurus tetrix*, Linnaeus, 1758; *Tetrao urogalloides*) and 1 species of field wild fowl – the common pheasant *Phasianus colchicus pallasii*, Rothschild 1903.

1. The black-billed capercaillie (*Tetrao parvirostris*, Bonaparte, 1856) – a common nesting nonmigratory species.

Distribution. The black-billed capercaillie is common in the forest zone of Eastern Siberia and the Far East. Within the Amur region, the species occupies one of the extreme southern regions of its habitat (Stepanyan 1990), which coincides with the distribution area of the Dahurian larch (*Larix gmelinii* (Rupr.) Rupr.), mixed forests with a predominance of

coniferous species (the Dahurian larch, the Scots pine (*Pinus sylvestris* L.), the Siberian pine (*Pinus sibirica* Du Tour), the creeping pine (*Pinus pumila* (Pall.) Regel), the Siberian spruce (*Picea obovata* Ledeb.).

Forests of the northern (Tynda, Zeya and Skovorodino districts) and central (Magdagachy, Shimanovsky, Selemdzhinsky, Mazanovsky, Romny districts) areas of the region have the greatest importance in the Amur region for the black-billed capercaillie – larch, pine, small-leaved mixed forests, where most of the species lives. Here, the main limiting factors for the spread of capercaillie are the presence of dark coniferous taiga (spruce and fir forests) and forests that make formations along the slopes of the highlands.

As we move to the south of the Amur region, the population of the capercaillie becomes much smaller, the species is specifically absent in the south-west of the region (Fig. 1). As one moves from the south of the Amur-Zeya Plain to the forest-steppe zone of the Zeya-Bureya Plain, the black-billed capercaillie becomes a rare sporadic species. This is due to the fact that it avoids huge open spaces, and the flat territory is greatly transformed by agricultural activities. The remaining small, untouched areas do not have favourable conditions – these are islets of the forest in the fields or broad-leaved forests, which it does not inhabit.

The best forage and nest places for the black-billed capercaillie are various types of forests with larch, as well as with pine, which provide an abundance of vegetable and animal feed, especially in winter. The most important are mixed larch forests interspersed with marshes with crowberry and places where young larch grows in combination with blueberries and lingonberries.

In the Amur region, the main part of the population of the black-billed capercaillie is concentrated in 4 districts located in the coniferous forest zone – from the north of the region to the east-central districts – these are Tynda, Zeya, Selezmdzhinsky and Mazanovsky districts. A rather high number of the black-billed capercaillie is concentrated on good land with coniferous deciduous forest (larch forests), mixed forest with a predominance of coniferous species, as well as alluvial areas with a predominance of forest.

Population. During the winter route census, data on the number and distribution of the capercaillie are rather relative

(due to an accidental underestimation or overestimation of their number). This is due to the fact that in winter, the black-billed capercaillie distributes in groups, which creates the effect of uneven settlement throughout the habitat, and the census routes often lie aloof from the main foci of the black-billed capercaillie, which either do not get into the census tables or, otherwise, are found in large groups.

In general, in the Amur region, the average number of the black-billed capercaillie for 5 years (according to the 2013–2017 survey data) was 85,499, and the area of land occupied by the species was 13,349.61 thousand hectares (Table 1).

Table 1. The average number and relative density of the population of the black-billed capercaillie (*Tetrao parvirostris*), and its spatial distribution by administrative areas of the Amur region (2013–2017).

Administrative district	Arkhar	Belogorsky	Blagoveshchensky	Bureya	Zavitinsky	Zeya	Ivanovsky	Konstantinovsky	Magdagachy	Mazanovsky	Mikhailovsky	Oktyabrsky	Romny	Svobodny	Selezmdzhinsky	Seryshevo	Skovorodino	Tambov	Tynda	Shimanovsky	Total in the region
The area of district, 10 ³ ha	1,440	260	310	710	330	8,750	270	180	1,480	2,830	300	340	1,010	730	4,670	380	2,050	250	8,330	1,460	36,190
The area of land suitable for habitat, 10 ³ ha	106.76	-	-	197.18	21.06	4,695.32	-	-	262.70	1,189.72	-	-	359.38	-	2,158.35	-	281.22	-	4,031.74	46.18	13,349.61
The average number by administrative areas, individuals	2,810	-	90	335	13	16,229	-	-	2,599	10,045	-	-	2,141	-	12,917	7	4,302	-	33,493	516	85,499
The relative density of the population of the species from <u>S land suitable for habitat</u> , individuals, 10 ³ ha	26.32	-	-	1.70	0.61	3.46	-	-	9.90	8.44	-	-	5.96	-	5.98	-	15.30	-	8.31	11.17	6.40
The relative density of the species population from <u>S district</u> , individuals, 10 ³ ha	1.95	-	-	0.47	0.04	1.85	-	-	1.76	3.55	-	-	2.12	-	2.77	-	2.10	-	4.02	0.35	2.36

On the whole territory of the Amur region the number of the black-billed capercaillie amounts to 2.36 per 1000 hectares, and the ecological density of the species from the area of suitable land is 6.40 per 1000 hectares.

The largest part of the black-billed population in the region is concentrated in 4 districts (72,684, which is 85 % of the population) – these are Tynda (33,493 individuals), Zeya (16,229 individuals), Selezhdzhinsky (12,917 individuals) and Mazanovsky (10,045) (Table 1). At the same time, the population density of the black-billed capercaillie here is not quite large. Although this is a huge area of the administrative district itself, there is almost no suitable land at all. For this reason, the ecological density of the black-billed capercaillie varies from 1.85 per 1000 hectares (Zeya district; 4,695.32 thousand ha of usable land) to 4.04 per 1000 hectares (Tynda district; 4,031.74 thousand ha of usable land) (Table 1).

Lower population density of the capercaillie is observed in areas with medium-quality lands with the presence of mixed forests with a predominance of small-leaved species and alluvial natural complexes with mixed and deciduous forests – in Bureya district (1.70 birds per 1000 ha), Zavitinsk (0.61), Romny (5.96), etc.

Limiting factors. The fluctuations in the number of the black-billed capercaillie are quite significant and the instability is associated with a number of unfavourable factors of weather, climate and nature in different seasons of the year.

In winter, the birds migrate in search of food, since the capercaillie-holding grounds are of a mosaic nature. Young birds become very vulnerable when it is cold in autumn and winter, especially birds infected with worms, which make up a

significant proportion of dead birds. Epizootics can lead to a catastrophic state of the capercaillie. In addition, heavy snowfalls in winter have a negative effect on birds; they hide available food, reducing the feeding capacity of habitats. Periodically during the winter, food and stomach stones hide under a snow crust (ice crust) and become completely inaccessible to birds.

To a large extent, the reduction in the number of the black-billed capercaillie occurs during the breeding season in spring. The appearance and development of young individuals during prolonged rains, when it is damp and the air temperature drops sharply, night frosts and repeated cold snaps during the day. During this period, insects that are few during the cold spring are particularly important food for nestlings. Different abiotic factors often negatively affect birds that have not yet reached puberty (the ability to reproduce occurs in males from the 3rd year of life, and in females from the 2nd year).

In addition, natural and anthropogenic fires have strong influence in the spring, worsening the food supply of birds. Especially, this is expressed in forests with pronounced pyrogenic dynamics. Fires lead to low yields of basic forage berries (blueberries, lingonberries, blackberries) and green and woody fodder. In addition, in spring (May-June) large-scale and long-lasting forest fires lead to a massive death of egg-layings and nestlings in a large area.

The main natural enemies of the black-billed capercaillie (for adult birds, young stock and egg-layings) are the northern goshawk, the Eurasian eagle-owl, the fox, the raccoon dog, small representatives of the Mustelidae – ermine, marten, and the Siberian weasel. A strong impact on the population of the capercaillie has

predation of the sable, because this bird becomes an important food for it in years when the numbers of rodents is low.

The main anthropogenic negative impact, which reduces the leks of the capercaillie and thereby worsens the biotope are logging, fires, and the destruction of the berries during the mass gathering leads to a decrease in forage reserves in the habitats of the capercaillie, etc.

Using. In the Amur region, the black-billed capercaillie procurement was ceased long ago. Hunting for the black-billed capercaillie is not very popular. In the northern areas, hunters traditionally prefer to hunt larger objects. In the central parts of the region, the hunt for the black-billed capercaillie becomes a difficult task for hunters due to the remoteness from the bird's habitats. The features of the biology of the bird itself also create difficulties for hunters (leks are difficult to access, large areas are privately owned, most leks are located on the ground, and the shortness of the song during spring mating games makes the hunt ineffective. Therefore, the black-billed capercaillie often becomes an additional prey, and amateur hunters use the black-billed capercaillie only for personal consumption. Commercial hunters often use the bird to catch sable.

2. The black grouse (*Lyrurus tetrix*, Linnaeus, 1758) – the common nesting nonmigratory species.

Distribution. The black grouse inhabits almost all of the northern Palearctic forest belt, in the south it flies deep into the forest-steppe zone, and into the steppe and even, as in the north of Kazakhstan, into semi-desert zones in some parts of its habitat (Stepanyan 1990).

The black grouse is a typical inhabitant of the taiga zone in the Amur region, where coniferous evergreen forests, mixed forests with a predominance of co-

niferous species and a forest with shrubs in the alluvial areas of the rivers have the greatest significance for the species. Such habitats of the black grouse are found on the territory of the northern districts of the region – Tynda, Skovorodino, Zeya – and central districts – Magdagachy, Mazanovsky (Fig. 1).

At the same time, the black grouse avoids dense areas of dark coniferous taiga (spruce and fir forest), high-altitude areas in the north and northeast of the region, and also larch forests along the slopes of mountain ranges. The distribution of the black grouse is sporadic due to large areas of larch marshes, which the bird avoids. Therefore, in areas where such places are frequent, the black grouse population density drops sharply, even if there are lands that are characteristic for the species and even places of better quality. Thus, in the Seleznezhinsky district (4,670 thousand hectares) a rather extensive territory is occupied by larch, which grows in marshy lands. The area of suitable habitats for the grouse is only 83.71 thousand hectares, and its population density is 72.35 thousand birds per 1000 hectares. The bird population density is presented in the form of clusters (Table 2). Most of the birds we found are in small deciduous forests with lingonberries, alternating with blueberries and bushy marshes.

Population. Over the past 5 years, in the Amur region, the average number of black grouses was 81,242 individuals, and the area of inhabited land – 9,571.4 thousand hectares (Table 2).

The main part of the black grouse population is concentrated in the forest zone of the central and northeastern part of the Amur region – these are 4 districts – Tynda (16,644 birds), Mazanovsky (13,148 birds), Zeya (9,191 birds) and Magdagachy (8,548 birds) (Table 2). They ac-

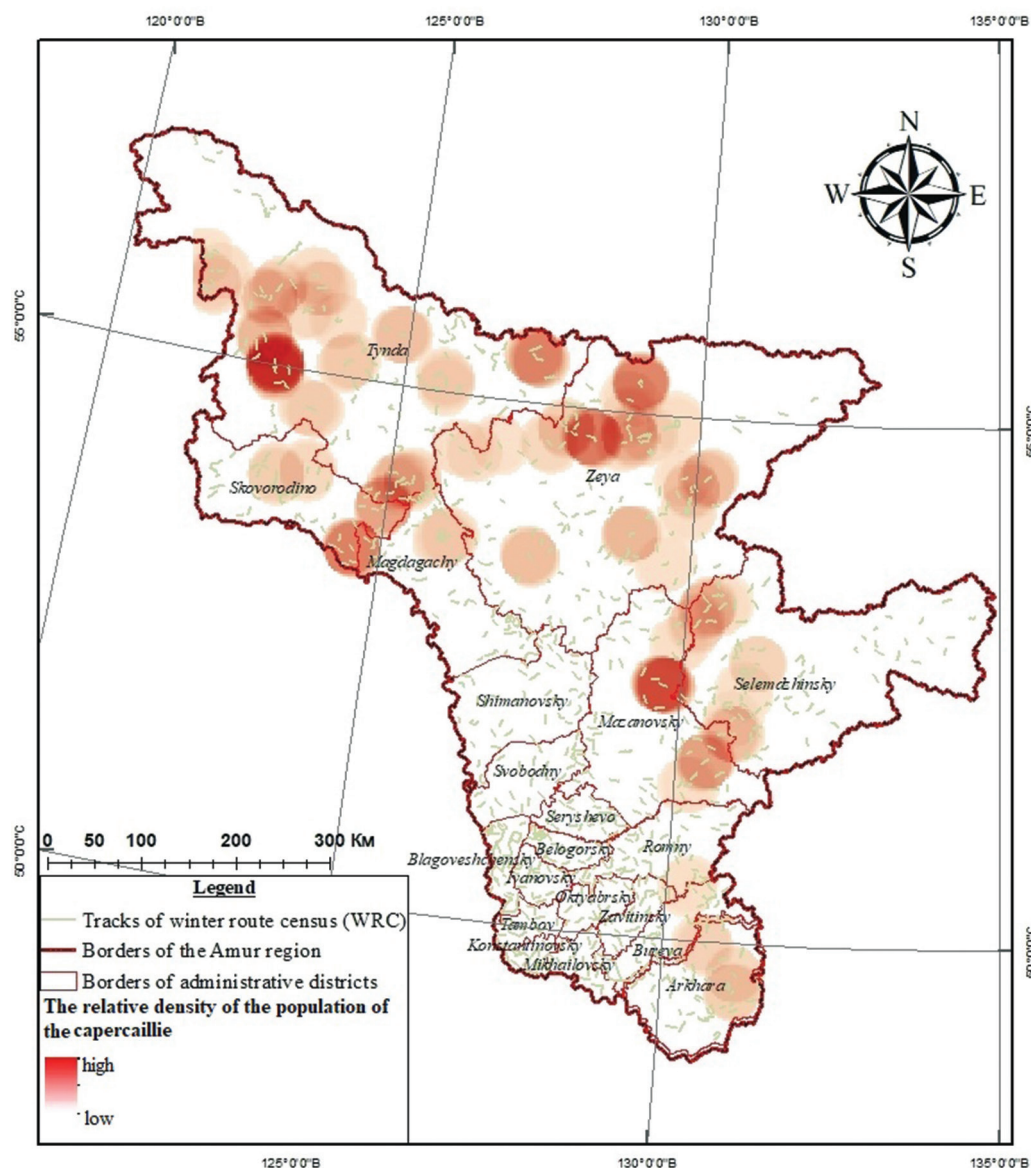


Fig. 1. The relative density of the population of the capercaillie by the number of encounters on the winter route recorded on the Amur region.

count for 47,531 black grouse (58.5 % of the total black grouse in the region). We want to note that in the Tynda district the grouse population is distributed sporadically, and the increase in the number

of birds in some years is associated there with a general increase in the bird population, the activity of their migrations and mass arrivals from neighbouring regions, and this is a common pattern.

Table 2. The average number and relative density of the population of the black grouse (*Lyrurus tetrix*), and its spatial distribution by administrative regions of the Amur region (2013–2017).

Administrative district	Arkharu	Belogorsky	Blagoveshchensky	Bureya	Zavitinsky	Zeya	Ivanovsky	Konstantinovsky	Magdagachy	Mazanovsky	Mikhailovsky	Okyabrsky	Romny	Svobodny	Selezmdzhinsky	Seryshevo	Skovorodino	Tambov	Tynda	Shimanovsky	Total in the region
The area of district, 10 ³ ha	1,440	260	310	710	330	8,750	270	180	1,480	2,830	300	340	1,010	730	4,670	380	2,050	250	8,330	1,460	36,190
The area of land suitable for habitat, 10 ³ ha	402.93	80.19	235.38	381.98	292.51	494.10	-	-	1,583.32	1,329.62	241.86	196.17	419.93	705.16	83.71	249.11	1,538.08	-	-	1,337.39	9,896.45
The average number by administrative areas, individuals	2,375	1,502	1,386	569	422	9,191	-	-	8,548	13,148	-	-	9,466	2,359	6,056	321	1,959	-	16,644	7,295	81,242
The relative density of the population of the species from <u>land suitable for habitat</u> , individuals /10 ³ ha	5.89	18.73	5.89	1.49	1.44	18.60	-	-	5.40	9.89	-	-	22.54	3.35	72.35	1.29	1.27	-	-	5.45	8.21
The relative density of the species population from <u>S district</u> , individuals /10 ³ ha	1.65	5.78	4.47	0.8	1.28	1.05	-	-	5.8	4.65	-	-	9.37	3.13	1.30	0.84	0.96	-	2.00	5.00	2.24

For mixed and small-leaved forests in the Shimanovsk district, the black grouse numbers are 5.45 birds per 1000 hectares, but their population density decreases in areas to the west, and in the Shimanovsk district their number is already 1.27 birds per 1000 hectares.

In the north and northeast of the Amur region, the mountain ranges of the Zeya district limit the spread of the black grouse. The map with relative density of the population of the black grouse can be seen on Figure 2. The black grouse was found in the village of Fevral'sk in the Selezmdzhinsky district (72.35 birds per 1000 hectares), as well as from the village of Norsk to the river Byssa and along the valley of

the river Selezmdzha. In the basins of the Tashina and Gorbys rivers in the Romny district it is 22.54 birds per 1000 hectares.

In the south of the Amur region the black grouse is found only in 8 districts (out of 13 administrative districts). This is due to the fact that the black grouse avoids the vast open spaces that in the south are present in the large Zeya-Bureya plain, which has been greatly transformed by agricultural activities.

In the southeast of the region, the black grouse avoids cedar broad-leaved forests and open spaces of the Amur-Zeya plain. Thus, the Selezmdzhinsky district has the total suitable area of 83.71 thousand hectares, where there are up to 6,056 black

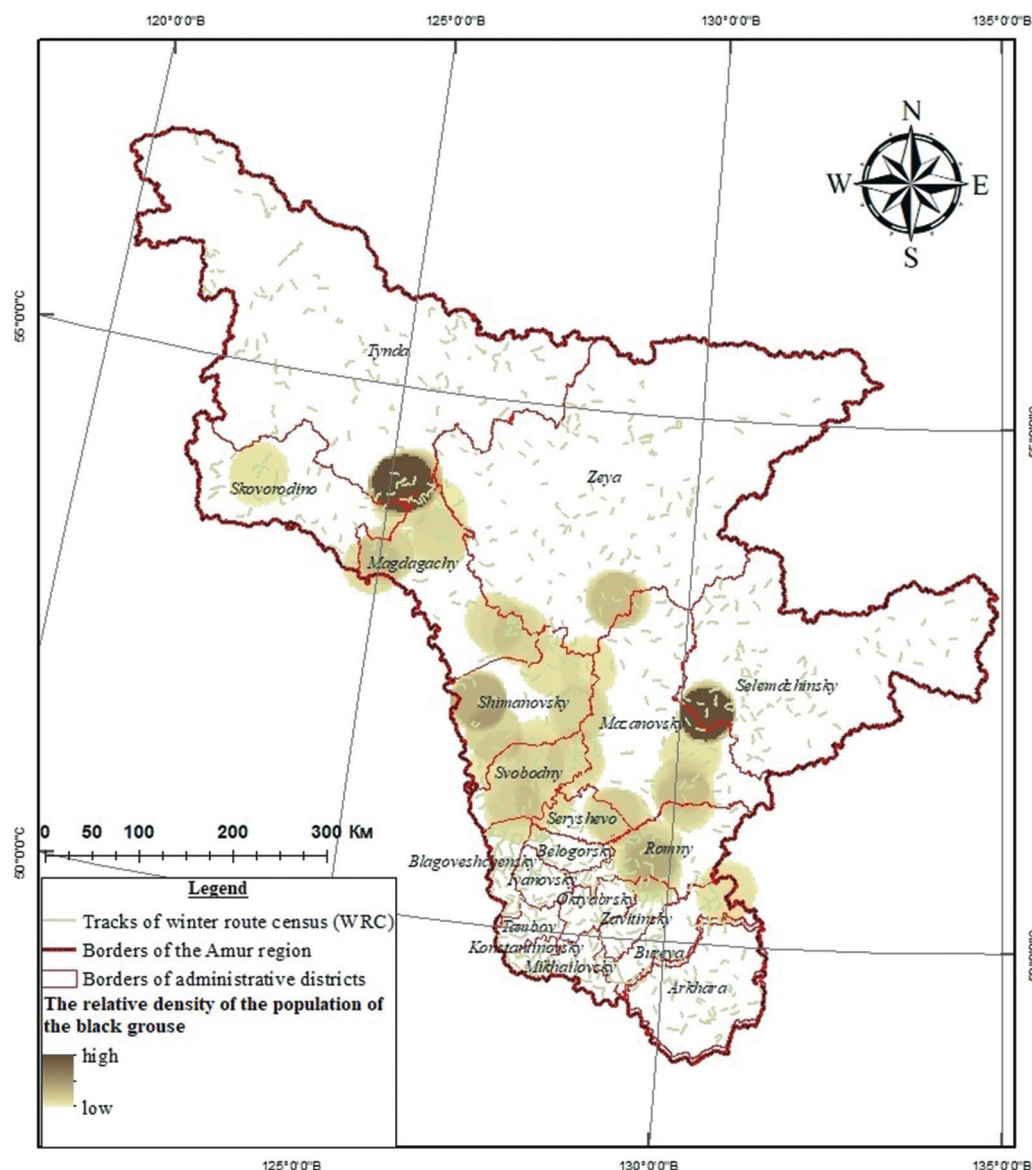


Fig. 2. The relative density of the population of the black grouse by the number of encounters on the winter route recorded on the Amur region.

grouses (72.35 birds per 1000 hectares). On the territory of Oktyabrskiy, Zavitinskiy, Bureyskiy and Seryshevo districts, the black grouse is distributed very unevenly.

To date, the number of the black grouse tends to decrease. At the same time, ac-

cording to the data of the 50–60 years of the last century, it is known that the number of the black grouse was hundreds of times higher and since the beginning of the 60s numbers have declined sharply. The reasons for the reduction of the black

grouse population in the Amur region are unclear (possibly due to rare epizootics, Newcastle disease (chick fever) or the massive treatment of forests with DDT).

Limiting factors. All factors limiting the number of the black-billed capercaillie are also valid for the black grouse. Additionally, the increased number of the Northern goshawk, high floods in the bottom of the Amur River and extensive forest fires should be noted. In addition, the proximity of the black grouse habitats to settlements contributes to a high probability of the spread of Newcastle disease, which is registered with domestic pigeons. The number of birds hunted by the hunters does not affect the black grouse population because the impact is insignificant.

Using. The situation for the black grouse in the Amur region has a tendency common to the whole country. In the last century, hunting for the black grouse was popular (including lek hunting). During their autumn feeding in flocks, birds were shot from small-caliber rifles. They are hunted up close on snowmobiles and other vehicles with off-road capabilities. Now there was a very strong decline in the interest to the black grouse. As the statistics of previous years shows, when the black grouse hunting was popular in the northern and central regions of the Amur region, the reserves in the forests of birds were not exhausted. It was regulated only by abiotic and natural biotic factors. In the southern areas, the black grouse population was exterminated by hunters and the anthropogenic impact was significant. In general, more black grouses are hunted compared to those that are registered. But there are no data about the number of birds being hunted down due to restriction for hunting as the population of the black grouse declined everywhere.

3. The hazel grouse (*Tetrastes bona-*

sia, Linnaeus, 1758) – a common nesting nonmigratory species.

Distribution. In the Amur region this is the most numerous representative of upland fowl. The hazel grouse dwells in the region almost everywhere, with the exception of the Zeya-Bureya Plain, where the largest agricultural fields are located (in the Belogorsky, Ivanovsky, Konstantinovsky, Mikhailovsky, Oktyabrsky and Tambovsky districts).

The hazel grouse is distributed over all territories of the Amur region with forests, but its distribution is extremely uneven. In the southern part of the region, it is most numerous in cedar broad-leaved and broad-leaved forests. The hazel grouse in the central regions (mainly agricultural fields) is found (rarely or very rarely) in forests of various types that border on arable land and fields, as well as in fir forests between agricultural fields. And, especially, the species becomes rare in areas where oak forests are concentrated.

The highest population density is in the taiga zone of the northern parts of the Amur region. Here, the hazel grouse prefers to inhabit small-leaved forests, grassy and shrub larch forests and pine forests, of which it densely inhabits the cowberry and blueberry ones. The hazel grouse becomes common in forests with alder undergrowth. In the upper reaches of the river, it gives preference to the alluvial complex, where it concentrates on willow islands.

The hazel grouse avoids vast wetlands (marshes, swamps, flood plains) and, in general, any open areas, including treeless peaks of ridges.

Population. The total area of land in the region, suitable for the hazel grouse, is 21,416.3 thousand hectares. The map with relative density of the population of the hazel grouse can be seen on Figure 3.

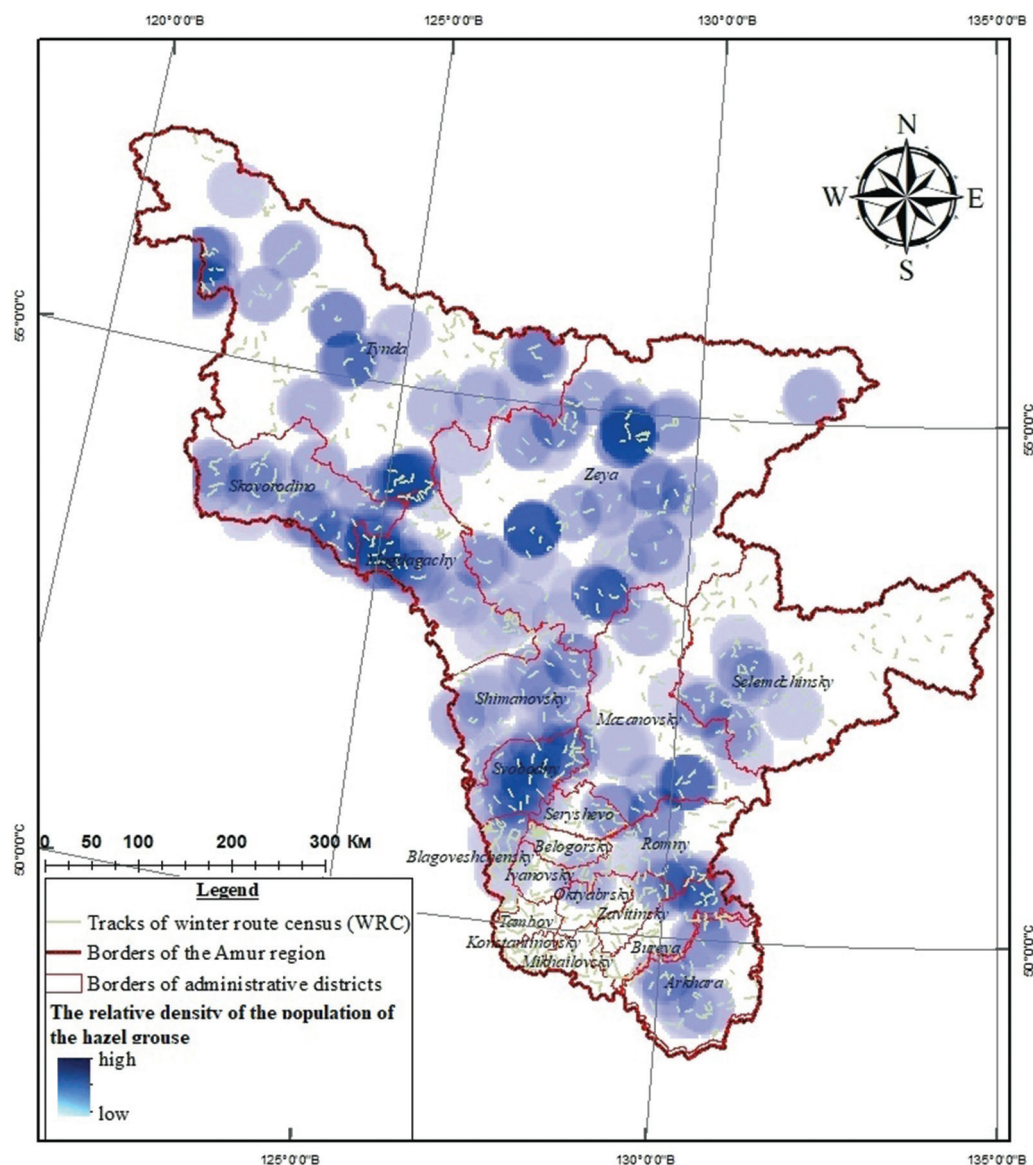


Fig. 3. The relative density of the population of the hazel grouse by the number of encounters on the WRC routes in the Amur region.

During the WRC of animals in the Amur region, the main census of the hazel grouse is carried out. Due to the ecological preferences of this species, significant errors may occur during the counting of the

bird number. The hazel grouse in winter prefers to form concentrations along the floodplains of the rivers, and thus the contours of its distribution sites take on the ribbon-like character. This fact later leads

to frequent errors during the extrapolation of registration data obtained on routes or sites.

The number of the hazel grouse is a very dynamic phenomenon; it is determined by the natural conditions during the breeding season. In the Amur region, according to figures obtained from all regions annually, the number of grouse in the last decade amounts to 938 thousand birds, and in some years with favourable

weather and climatic conditions, the number can be twice as high.

After analysing these data and comparing them with neighbouring regions, we came to the conclusion that in the Amur region the hazel grouse has a low population density of 13.85 birds per 1000 hectares, and the environmental density of the hazel grouse is 23.41 birds per 1000 hectares from the area inhabited in nature (Table 3).

Table 3. The average number and relative density of the hazel grouse (*Tetrastes bonasia*), and its spatial distribution by administrative regions of the Amur region (2013–2017).

Administrative district	Arkhar	Belogorsky	Blagoveshchensky	Bureya	Zavitinsky	Zeya	Ivanovsky	Konstantinovsky	Magdagachy	Mazanovsky	Mikhailovsky	Oktyabrsky	Romny	Svobodny	Selemdzhinsky	Seryshevo	Skovorodino	Tambov	Tynda	Shimanovsky	Total in the region
The area of district, 10 ³ ha	1,440	260	310	710	330	8,750	270	180	1,480	2,830	300	340	1,010	730	4,670	380	2,050	250	8,330	1,460	36,190
The area of land suitable for habitat, 10 ³ ha	783.11	0.58	155.52	383.97	110.88	5,841.56	-	-	1,273.61	1,288.76	2.07	31.34	482.40	459.24	3,204.71	39.84	868.11	-	5,530.12	960.52	21,416.3
The average number by administrative areas, individuals	18,980	-	4,151	8,888	1,584	122,038	-	-	34,303	44,762	-	-	8,865	29,637	37,807	469	22,998	-	142,893	23,964	501,333
The relative density of the population of the species from <u>land suitable for habitat</u> , individuals, 10 ³ ha	24.24	-	26.69	23.15	14.29	20.90	-	-	26.93	34.73	-	-	18.38	64.53	11.80	11.77	26.49	-	25.84	24.95	23.41
The relative density of the species population from <u>district</u> , individuals, 10 ³ ha	13.18	-	13.39	12.52	4.80	13.95	-	-	23.18	15.81	-	-	8.78	40.60	8.10	1.23	11.22	-	17.15	16.41	13.85

Most part of the hazel grouse population is 342,500 birds, representing 69.3 % of the total population in the region. It is concentrated in the northern and north-eastern parts – Zeya (122,038 birds), Tynda (142,893 birds), Mazanovsky (44,762

birds) and Selemdzhinsky (37,807 birds) administrative districts. Here we must take into account the fact that these northern districts have very large areas, therefore, by extrapolating the numbers obtained on the route, the hazel grouse density is

reduced. Thus, the ecological density of the grouse population ranges from 11.80 birds per 1000 hectares (Selemdzhinsky district, 3,204.71 thousand hectares of useful land) to 34.73 birds per 1000 hectares (Mazanovsky district, 1288.76 thousand hectares of suitable land) and 20.90 birds per 1000 ha (Zeya district, 5841.56 thousand hectares of suitable land). Here we need specific correction factors.

In agricultural areas without forests, located on the territory of the Zeya-Bureya plain, the hazel grouse is distributed sporadically (in the Bureya district – 23.15 birds per 1000 hectares, in Arkhara district – 24.24 birds per 1000 hectares). Probably, in some places there are narrow-local habitats (14.29 birds per 1000 hectares). There are a lot of such places in Zavitinsk district. The hazel grouse does not inhabit such areas as Belogorsky, Ivanovsky, Konstantinovsky, Mikhailovsky, Oktyabrsky, Romny and Tambov districts (Table 3, Fig. 3).

Limiting factors. All the factors that do not allow a high number of the Galliformes affect the grouse too. These are weather and climatic conditions during the breeding season. The most significant factor is the long and cold spring with high humidity. It leads to mass death of nestlings due to a lack of feed and an abundance of diseases.

Invasive and viral diseases, which often take on the character of epizootic diseases, are of particular negative significance for the hazel grouse. Also predators, especially sable, Siberian weasel, Northern goshawk, tawny owl, etc., cause significant damage to the grouse population.

Using. Currently, there is no mass hunting of the hazel grouse by professional hunters, and amateur hunters get birds for personal use (for culinary dishes, for

use as bait for catching sable). Although in the 1950s and 1960s hunting for the hazel grouse was quite popular among commercial farms – the birds were received at special points and the planned target numbers for hunted birds were strictly controlled.

Nowadays, hunting for the hazel grouse is practically popular and is mainly conducted in the autumn with a whistle and on the roads. A more popular alternative in the autumn is waterfowl hunting.

4. The common pheasant (*Phasianus colchicus pallasii*, Rothschild, 1903) – the common nesting nonmigratory species.

Distribution. The common pheasant is a subspecies that lives on the northernmost border of the distribution range of the entire species. In the Amur region the pheasant occupies the valley of the Amur River and prefers open spaces like sparse forest, fields and meadows.

In the agricultural areas of the southern, southeastern and central parts of the Amur region there are lots of the common pheasant. This species is sporadically distributed from the central parts of the region to the north within the Amur-Zeya plain. It is absolutely absent in the very north of the region – these are the southern spurs of the Stanovoi Ridge. The northern harsh wintering conditions stop the common pheasant from settlement and expansion of its range. The common pheasant does not live in the 5 northern districts – Zeya, Magdagachi, Selemdzhinsky, Skovorodino, Tynda. Although, in some favourable years, rare birds were recorded in the south of the Zeya district (flocks of up to 190 birds) and Magdagachi district (up to 410 birds).

Thus, the northern and western borders have a pronounced pulsating character. It depends on the degree of anthropogenic transformation of landscapes,

the development of agriculture and the cyclical nature of favourable climatic conditions. In the central and northern regions of the pheasant, only isolated birds can be found in the river valleys in their southernmost part. There are cases of unsustainable expansion of the boundaries of the distribution of pheasant to the north after extensive flooding in the valley of the Amur and Zeya rivers (summer 2013) and a noticeable reduction in its habitat after wintering.

Typical habitats of pheasants are pastures with a well-marked mosaic pattern and the ecotone of the taiga and meadows. The pheasants are mostly common in mixed forests, in which there are open spaces (large glades, clear-cuts, forest edges, bare places), places near agricultural fields with crops of grain and soy. The common pheasant is found quite often in abandoned fields, in places with shrubs and small oak forests, along the edges of the forest near swamps and so on. Places of concentration are usually located near soybean fields. In the southeastern part of the study area the bird is almost evenly distributed.

Conditions suitable for nesting are in floodplain or piedmont tree and shrub thickets, in habitats with small ponds overgrown with tree and shrub vegetation. In such places there is a lot of food and there are protective conditions.

Population. The number of the common pheasant is subject to significant fluctuations; this is typical for the Galliformes, which depend on the survival of the young birds during the breeding period and the main mass of adult birds that survived in conditions of extreme cold in winter.

The main problem during the work on the pheasant census is to identify the habitat area inhabited by the bird and to

characterize the biotopes by quality, as these are diverse and large areas. Fluctuations in the number of pheasants in a small area with a maximum concentration near the fields with crops of soybean or maize are especially well traced. In addition, pheasants, except for the breeding season, prefer the gregarious way of life and feed in small groups. They can unite into huge clusters in places with an abundance of food. In areas with significant agricultural fields there is a stable number and high concentration of birds.

For 5 years in the Tambov district (165.6 thousand hectares of farmland) there were registered up to 14,775 pheasants on 245.74 thousand hectares of suitable land. In the Mikhailovsky district (136.4 thousand hectares of farmland), the average number of pheasants is up to 17,452 birds (290.42 thousand hectares of usable land).

During the study period (2013–2017), the average number of pheasants was 271,866 birds, with a populated area of suitable land of 4,763.6 thousand hectares (Table 4). In recent years, there has been a tendency to a decrease in the number of pheasants in the regions throughout the world, with significant fluctuations from 188,979 (2013) to 336,227 birds (2015). At the same time, earlier in some years (2010–2013), up to 450 thousand individuals of the common pheasant were recorded in the Amur region.

Thus, every year the largest average number of pheasant (2013–2017) is observed in the agricultural areas of the south and southeast of the Amur region, located on the Zeya-Bureya Plain: Belogorsky (31,209 birds), Oktyabrsky (30,497 birds), Ivanovsky (28,420 birds), Zavitinsky (26,717 birds), Blagoveshchensky (25,101 birds) (Fig. 4).

Table 4. Average number and relative density of the population of the common pheasant (*Phasianus colchicus pallasii*) and its spatial distribution by administrative districts of the Amur region (2013-2017).

Administrative district	Arkhar	Belogorsky	Blagoveshchensky	Bureya	Zavitinsky	Zeya	Ivanovsky	Konstantinovsky	Magdagachy	Mazanovsky	Mikhailovsky	Oktyabrsky	Romny	Svobodny	Selendzhinsky	Seryshevo	Skovorodino	Tambov	Tynda	Shimanovsky	Total in the region
The area of district, 10 ³ ha	1,440	260	310	710	330	8,750	270	180	1,480	2,830	300	340	1,010	730	4,670	380	2,050	250	8,330	1,460	36,190
The area of land suitable for habitat, 10 ³ ha	429.81	255.10	218.42	327.88	240.69	104.58	252.34	157.27	51.94	488.20	290.42	327.92	260.24	440.76	46.56	322.38	17.61	245.74	-	285.75	4,763.60
The area of agricultural land, 10 ³ ha	38.6	105.1	51.6	34.6	43.9	3.1	114.2	108.7	3.0	27.6	136.4	109.9	63.6	33.4	0.2	104.3	1.3	165.6	0.2	7.1	1,152.4
The average number by administrative areas, individuals	13,484	31,209	25,101	12,043	26,717	-	28,420	15,042	-	13,938	17,452	30,497	12,488	7,442	-	20,383	-	14,775	-	2,755	271,866
The relative density of the population of the species from <u>land suitable for habitat</u> , individuals, 10 ³ ha	31.37	122.34	114.92	36.73	111.00	-	112.63	95.64	-	28.55	60.09	93.00	47.98	16.88	-	63.23	-	60.12	-	9.64	57.07
The relative density of the species population from <u>district</u> , individuals, 10 ³ ha	9.36	120.03	80.97	16.96	80.96	-	105.26	10.16	-	4.93	58.17	89.70	12.36	10.19	-	53.64	-	69.9	-	1.89	7.51

In the territory of the Amur region, the average population density of a pheasant is 7.51 birds per 1000 ha. The population density of pheasant from the area suitable for habitat is 57.07 birds per 1000 ha (ecological density).

Areas with high ecological population density of pheasant are Belogorsky (122.34 birds per 1000 hectares with 255.1 thousand hectares of suitable land), Ivanovsky (112.63 birds per 1000 hec-

tares with 252.3 thousand hectares of suitable land), Zavitinsky (111.0 birds per 1000 hectares with 240.7 thousand hectares of suitable land), Konstantinovsky (95.64 birds per 1000 hectares with 157.3 thousand hectares of suitable land).

A fairly stable low density of pheasant ranges from 31.37 birds per 1000 hectares (Arkhar district; 429.81 thousand hectares of suitable land), 28.55 birds per 1000 hectares (Mazanovsky district;

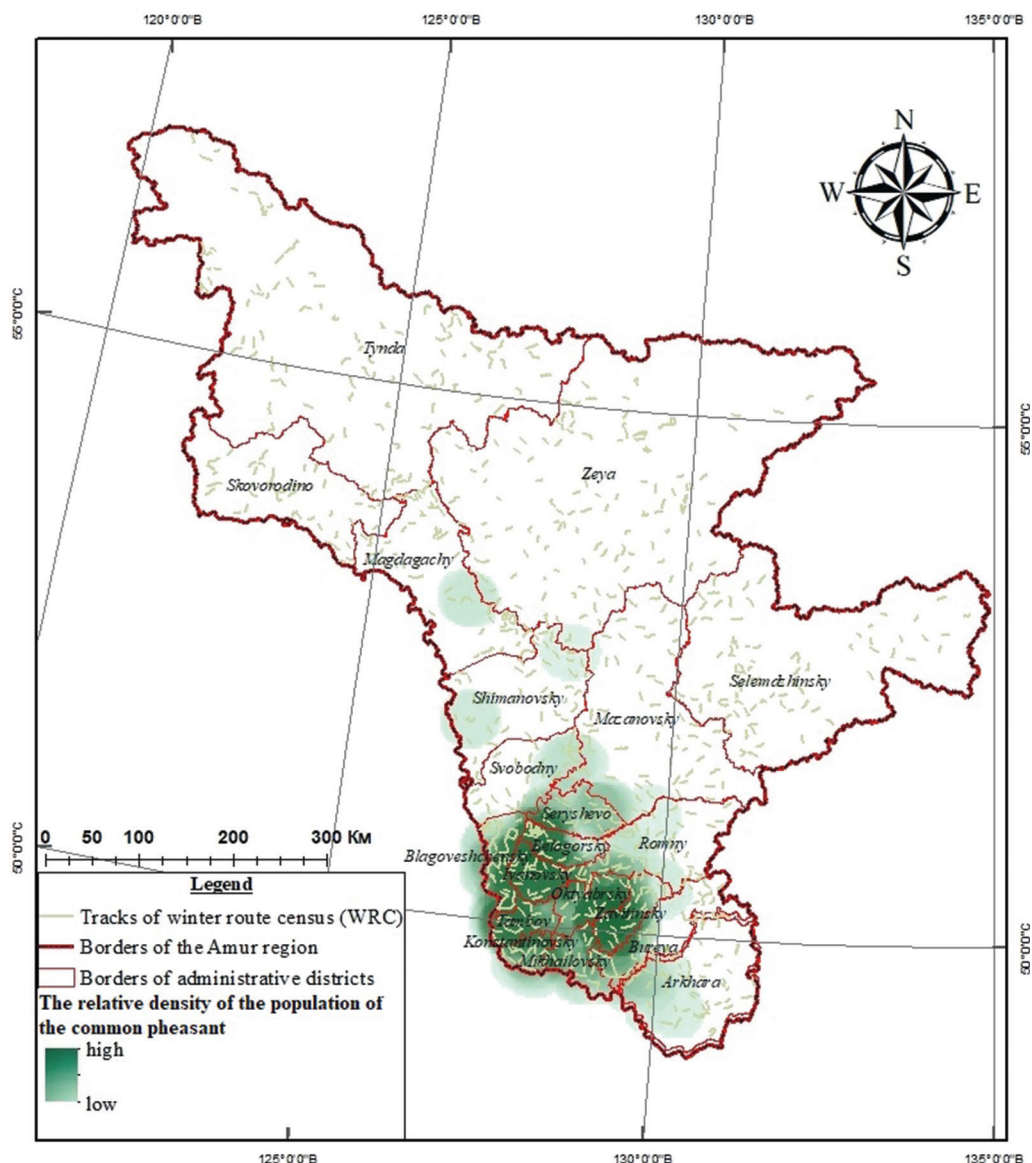


Fig. 4. Map of the relative population density of the common pheasant by the number of encounters at the routes of the WRC in the Amur region.

488.20 thousand hectares of suitable land), 16.88 birds per 1000 hectares (Svobodny district; 440.76 birds per 1000 hectares of suitable land).

Limiting factors. The number of the

common pheasant mainly depends on the weather and climatic conditions of a particular year. Especially, the cold, lingering frost and wet spring have a detrimental effect on young birds. During the period of

incubation of eggs and hatching of nestlings, temperature drops, the presence and abundance of precipitation, wind, and predators (raccoon dog, goshawk, fox, etc.) have adverse impact. Pheasants are easily affected by Newcastle disease. Extreme natural factors (fires, spring grassland fires, floods, heavy snowfall in spring and moisture) also have a limiting effect on the common pheasant. A great deal of harm is caused by anthropogenic pressure, especially poaching (many pheasants are hunted illegally).

Using. Every year pheasant hunting is becoming increasingly popular. Thus, the legal production of the common pheasant in the Amur region varies from 3 to 12 thousand birds, which, despite the considerable illegal hunting, does not exhaust resources yet.

5. The willow partridge (*Lagopus lagopus*, Linnaeus, 1758) is a common nesting nonmigratory species.

Distribution. On the territory of the Amur region, the willow partridge dwells in sparsely endangered larch forests and along the slopes of the main ridges of the northern part of the Tynda and Zeya districts in the upper reaches of the Zeya, Giluy, in the Olekma basin with small forests. The willow partridge is rarely found in Skovorodino district. Two types of partridges are often found in the area of the origins of Selemdzha, in the Selitkan basin. Inside the area of distribution of the species, the ability to form places of concentration in well nourished, protected and nesting sites is well defined. Mostly, the willow partridge prefers moss marshes and moss and shrub tundra.

Population. In the Amur region, the willow partridge population is practically

not used and information about the number of partridges is rather contradictory. The reason for this is that the conclusions on the number are made on the basis of expert sampling estimates without detailed specification of the characteristics of the populated areas for the selection of places and carrying out the census. Information on the number of willow partridges in the reports of hunters contains many gaps, therefore, the dynamics of the number of species in the area of our research usually do not reflect. Therefore, it is difficult to tell the dynamics over a period of more than 5 years.

The average number of a partridge over the last 5 years, according to the results of our census, is 18,725 birds, with significant variations in numbers by year. Thus, in 2014, the number of a partridge had a minimum value – 2,842 birds, and a maximum – 27,318 birds (2017) (Table 5, Fig. 5).

The willow partridge is concentrated in two districts – Tynda and Zeya. However, nomadic movements of long distances are typical for partridges. In winter, birds move to bushes and blueberries in the marshes, to areas of willow islets in the floodplains of rivers, and to alder thickets. Thus, in different years, the willow partridge can live in the Selemdzhinsky district (up to 5,656–10,272 birds), and goes far to the north-west to the Skovorodino district (up to 914 birds).

According to the winter route census, it is noted that the number of willow partridges is decreasing, which is confirmed by local experts who have done the census and local hunters. Birds of these species become rare in many areas of the region, and the range shifts to the north.

Table 5. The average population and relative density of the willow partridge (*Lagopus lagopus*) and its spatial distribution by administrative regions of the Amur region (2013–2017).

Administrative district	Arkhar	Belogorsky	Blagoveshchensky	Bureya	Zavitinsky	Zeya	Ivanovsky	Konstantinovsky	Magdagachy	Mazanovsky	Mikhailovsky	Oktyabrsky	Romny	Svobodny	Selendzhinsky	Seryshevo	Skovorodino	Tambov	Tynda	Shimanovsky	Total in the region
The area of district, 10 ³ ha	1,440	260	310	710	330	8,750	270	180	1,480	2,830	300	340	1,010	730	4,670	380	2,050	250	8,330	1,460	36,190
The average number by administrative areas, individuals	-	-	-	-	-	4,835	-	-	-	-	-	-	-	-	-	-	-	-	11,470	-	18,725
The relative density of the species population from S district, individuals, 10 ³ ha	-	-	-	-	-	0.55	-	-	-	-	-	-	-	-	-	-	-	-	1.38	-	0.52

Limiting factors. The number of willow partridges is determined by the weather and climatic conditions (especially during the breeding season), mass diseases, the impact of predators, and forest fires.

Using. In the Amur region, hunting for willow partridges is virtually absent and they may be hunted down during random encounters. Probably the main reason for such poor use of the resources of the willow partridge population is that the partridge habitats are difficult to reach and are located far from amateur hunters.

The local population of the Zeiya, Tynda, Skovorodino districts do not consider the partridge as worthy prey, occasionally use it as bait for sable.

Conclusions

For the rational use of natural resources, it is important to track trends in the population status of 5 species of Galliformes

birds, which inhabit the territory of the Amur region.

Ecological and biological features of Galliformes hunting species are due to specific conditions of distribution and habitat in the study area. The Amur region is a unique geographic area and has regional specificity of landscape and ecological conditions, habitat mosaic pattern, relief contrast, etc.

The south and central part of the region are occupied by two large plains. There are large agricultural fields, sown soybean, grain cereals – these are the favourite habitats of numerous field birds, for example, the common pheasant. In the north of the region dominated by taiga with inclusions of mixed and small-leaved forests, there are numerous black-billed capercaillie grouse, black grouse and hazel grouse populations. The pheasant does not live there at all. In the north of the Amur region there are areas of moss and shrub tundra and a sparse larch covering

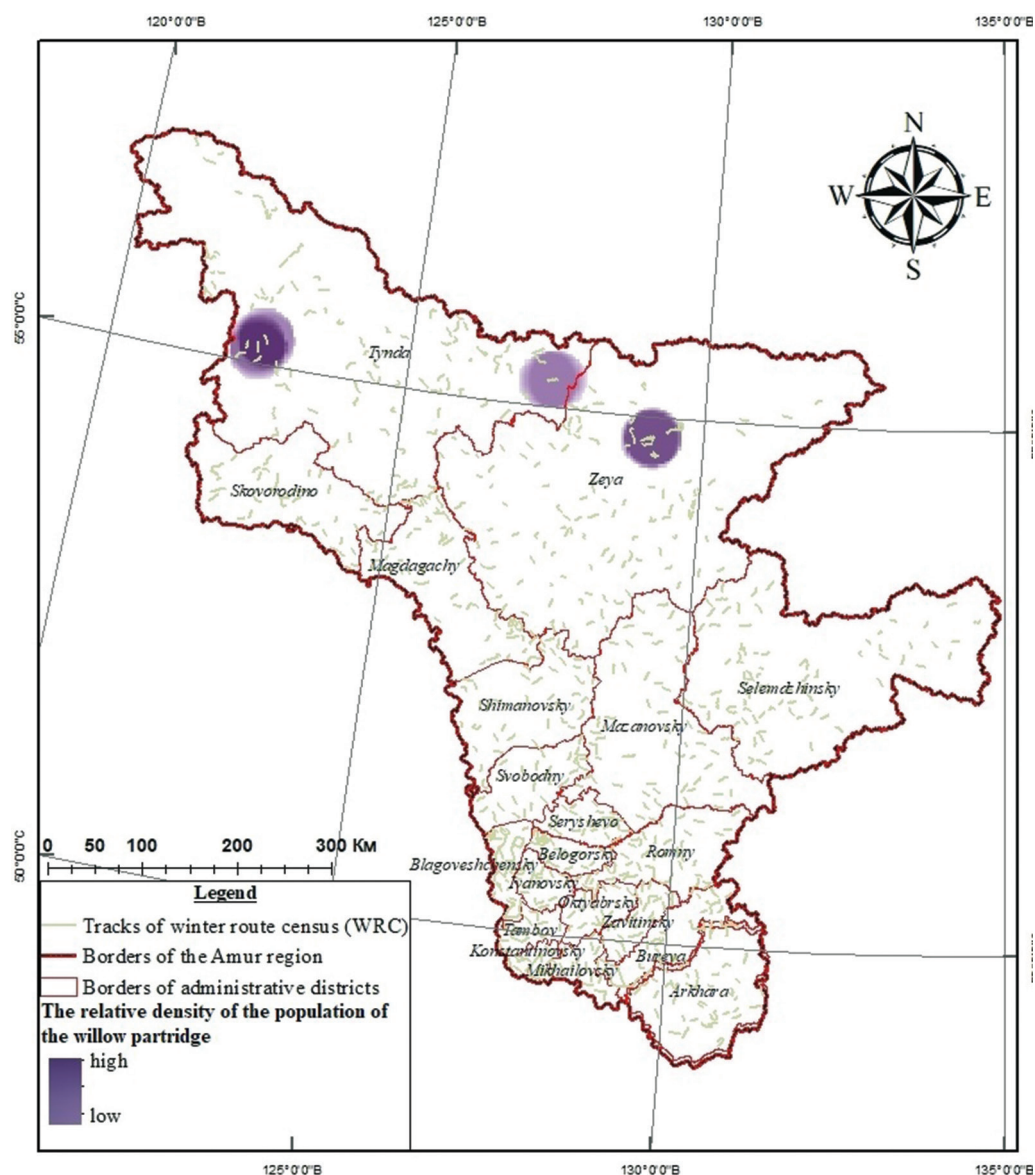


Fig. 5. The relative density of the population of the willow partridge by the number of encounters on the WRC routes in the Amur region.

the mountain ranges inhabited by the willow partridge.

The number of hunted fowl-like birds to the greatest extent is determined by the weather and climatic conditions during the

breeding season, hatching of eggs and hatching of young birds, mass diseases and epizootics, the impact of predators, forest fires, anthropogenic pressure (poaching, fires, spring grassland fires, etc.).

Despite the fact that Tetraonidae birds experience significant fluctuations in numbers in some periods, they remain important as an object of sport hunting. The data we obtained were used in the practical work of the Department for Protection, Control and Regulation of the Use of Wildlife and their Habitats of Amur region. Together with data from other specially protected natural areas, an analysis was carried out and proposals were prepared to improve the protection and use of Tetraonidae birds.

The winter route census (WRC) used in Russia for hunting resources may be different in other countries. Therefore, the authors of this study believe that the data collected on the number of birds and the results of the analysis within this study should not be used for other regions to directly compare the data. In Russia the WRC is the main type of the state system of animal resource census, which is quite different from other methods of census used in foreign studies.

The cartograms obtained during geo-analysis show the patterns of the spatial distribution of birds in the winter season. All this unevenness is connected with 2 factors – the availability of food and its abundance in winter, as well as the depth of the snow. In the northern regions, it is deep snow that will determine the success of the winter overnights of birds, which die from low temperatures and winds, if they cannot find snow shelter or due to the ice crust formed on the ground. Thus, the high density of population in winter is expressed in greater intensity of colour of bird symbols in areas with the most favourable factors.

Building zoogeographic maps is a fairly convenient visual way to reflect reality and to track trends in the number and density of birds (and animals in general). It is also

convenient to identify the boundaries of their distribution. In addition, it allows an objective assessment of the distribution of populations in the study area, to trace and clarify the ranges of animals. Thus, cartographic modelling helps to analyse various objects or processes in the animal world and to obtain qualitatively new information. The structure of the vector map helps to conveniently use geodata and operate information. Thus, the map database allows to easily store a large array of data, make requests for information on any area, and also carry out statistical processing of any sample population.

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CREATING AWARENESS OF THE VALUE OF NON-TIMBER FOREST PRODUCTS TO RURAL COMMUNITIES AROUND MABIRA CENTRAL FOREST RESERVE, UGANDA

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Abstract

Contribution of non-timber forest products (NTFPs) to rural livelihoods is vital but often ignored when drafting resource management policies. Information on the value of NTFPs for subsistence use and trade is often inadequate due to market failure. This portrays a wrong message that non-marketed products lack economic value and are not worth protecting. The study estimated the value of NTFPs from Mabira Central Forest Reserve used for subsistence and trade by adjacent communities. Data were collected through key informant interviews, questionnaire survey of 342 resource users and spot market analysis to establish the market value of used NTFPs. Mainly poor women and men aged below 61 years and with low education levels extracted NTFPs. The annual value of identified NTFPs was \$ 860,470 of which \$ 58,688 was attributed to subsistence use and \$ 801,782 to cash income. NTFPs value varied significantly between products ($F=1.67$, $df\ 16\ p=0.05$) and between villages ($F=0.000$, $df\ 13$, $p<0.05$) with charcoal offering the highest annual value (\$ 327,686) and palm leaves – the lowest (\$ 187). NTFPs from Mabira CFR have a high potential to enhance livelihoods of the poor, women and youth in the study area if sustainably harvested since availability of some plant species used for firewood and charcoal production were reported to be declining. These results indicate the need for urgent intervention measures for alternative sources of income and sustainable extraction of NTFPs to minimize pressure on the forest reserve.

Key words: Charcoal value, commercial value, subsistence consumption, valuation, wealth index, livelihoods.

Introduction

Forests play important roles in the livelihoods of rural people by providing employment, energy, nutritious foods and a wide range of goods and ecosystem services (FAO 2014). Forests have economic value and capacity of generating human welfare. Non-timber forest products (NT-

FPs) are significant goods from the forest and vital in improving livelihoods of a larger part of the world's population (Belcher and Schreckenberg 2007, Heubes et al. 2012). Over 1.2 billion rural people in the world depend on NTFPs to supplement their basic needs (Kristensen and Lykke 2003). In addition, some NTFPs are used in promotion of traditional and cultural val-

ues (Cavendish 2002). For a long time, Ugandans have harnessed firewood, timber, and poles, or used their derivatives for their energy needs, domestic comfort, security, or development. Of particular importance are the non-wood benefits from the forests, and the environmental values that contribute significantly to people's livelihoods, especially women, and yet are not reflected in the national accounting systems. In addition to subsistence consumption, trade in NTFPs has increasingly become a source of income for communities adjacent to forests. The income obtained from the sale of NTFPs makes a valuable contribution to domestic expenditure (Kristensen and Balslev 2003, Ros-Tonen and Wrrerum 2000). Schaafsma et al. (2012) revealed that local people suffer economic loss if they are denied NTFPs collection. Since NTFPs play an important role in the livelihood of forest dwellers, their harvesting can act as an incentive for participatory forest management (Ros-Tonen and Wrrerum 2000). According to Cocksedge (2001) the use of NTFPs could reduce the dependency of local people on timber whose extraction is more destructive. The total contribution of the forestry sector to Uganda's economy was estimated at \$ 154.8 million (NEMA 2016). This is presumed too low because most of the NTFPs are collected, traded and consumed outside the cash economy and therefore not adequately captured in national statistics (Chidumayo 2013). Some studies in Uganda have identified and documented the NTFPs species (Asiimwe et al. 2014, Tabuti 2012), established commercialisation of wild foods and medicinal plants (Barirega et al. 2012), or management of tree diversity (Boffa et al. 2008) without estimating their economic contribution at local, regional or national levels. Failure to recognise the economic contribution of

NTFPs to Gross Domestic Product (GDP) has led to their insufficient recognition in national planning for local livelihoods. Inadequate evidence on the economic significance of forests influences people's wrong perception about the usefulness of the resource resulting in poor management and consequently forest degradation. Awareness of NTFPs values will guide formulation of policies towards their access and utilisation in order to guard against overharvesting and eventual depletion of the resource (Tietenberg and Lewis 2012). Commercial extraction of NTFPs however, could reduce both the diversity and population of species in the forest. There is a need to maintain a balance between commercial collection and biodiversity conservation through identification of NTFPs collectors from Mabira Central Forest Reserve (CFR). It is against background that estimation of NTFPs values from Mabira CFR was guided by the following objectives: i) To identify the NTFPs from Mabira CFR consumed and traded by surrounding communities, ii) To establish the sociodemographic characteristics of NTFPs users, and iii) To estimate the value of NTFPs for subsistence and commercial use.

Materials and Methods

Study area

The choice of the study area was based on villages that heavily depend on Mabira CFR for NTFPs extraction as established from rapid rural appraisal (Tugume et al. 2016). The study was conducted in 14 out of 27 villages of Mabira (Fig. 1) that included: Dangala, Najjembe, Buwoola, Lugala, Naluvule, Nakalanga, Khonko, Bugabe, Ntunda, Kalagala, Bukuku, Nagojje, Lunya and Ssese.

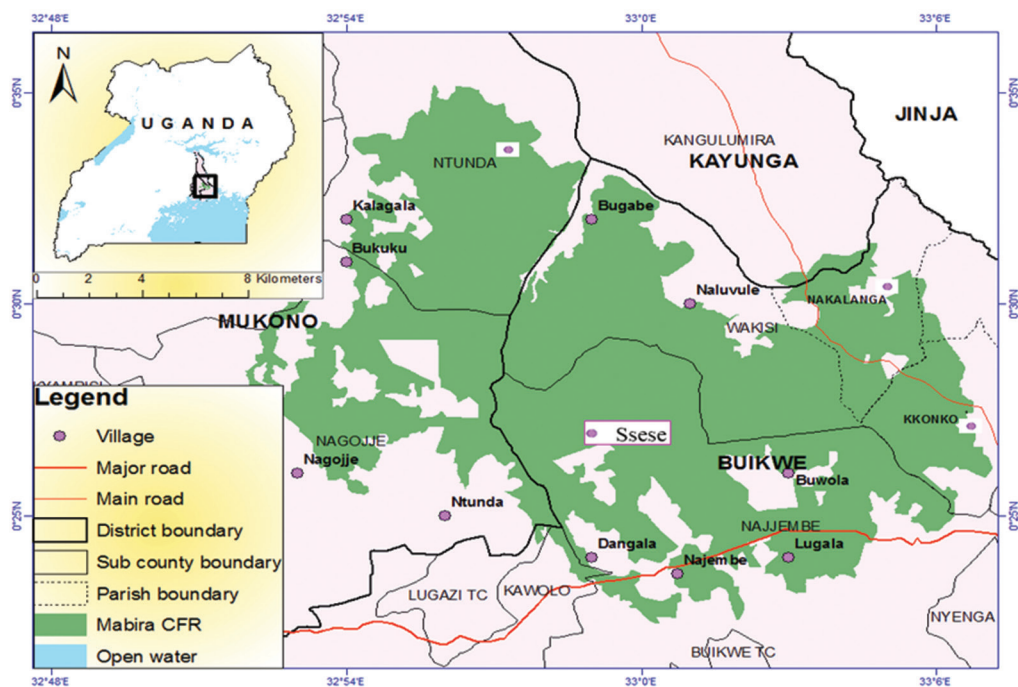


Fig. 1. Map of Mabira CFR showing study villages.

Note: Highlights sites where NTFPs user surveys were conducted and the administrative boundaries within the study area. Inserted smaller map of Uganda shows the location of Mabira CFR. The largest open water body indicated in the map of Uganda is Lake Victoria, for which the forest reserve acts as a water catchment.

The Central Forest Reserve (CFR) occupies an area of approximately 306 km² with an altitudinal range of 1070 – 1340 m above sea level (Moyini and Masiga 2006). It is situated between latitude 0°22' and 0°35' N and between longitude 32°56' and 33°02' E (Moyini and Masiga 2006). The reserve is characterised by numerous flat-topped hills and wide shallow valleys (Howard 2001). The soils are generally ferralitic sandy clay loams, with black waterlogged clays in the valley bottoms. The climate is tropical with two rainfall peaks from April to May and October to November and annual amounts ranging between 1250–1400 mm. Annual mean temperature range: minimum: 16–17 °C, maxi-

mum: 28–29 °C (Tugume et al. 2016).

There is pressure on the forest for subsistence use and commercial farming of sugar cane and tea resulting into conflicts among different stakeholders. The recent threat was the interest by the Ugandan government to convert a third of the forest for sugar cane growing in 2007 and later in 2011 amidst protests from conservationists and the general public. Over 90 % of households around the reserve satisfy their subsistence needs from the forest (MWLE 2002). The extensive use of forest resources is attributed to rapid population expansion in the 27 villages (235 people per km²) leading to pressure on the land for agriculture and on the forest for extrac-

tion of both timber and non-timber forest products (Isabirye et al. 2010). Education and income levels of forest communities are low (Agea and Fungo 2009), conditions that increase dependence on the forest for NTFPs (Vedeld et al. 2007).

Data collection

Rapid Rural Appraisal (RRA) (Tugume et al. 2016) was conducted in each of the 27 villages to assess key economic activities present. Consequently, 14 villages that heavily depend on Mabira CFR for NTFPs extraction according to village leaders were selected for resource user survey. The target population was 1,110 resource users out of which 342 were selected for the study.

An introductory meeting was held in each of the selected villages where NTFPs users were introduced to the research team by the village Chairpersons. During the inception meeting, the objectives and significance of the study were discussed, lists of NTFPs collectors generated to form a sampling frame, and a check list of all NTFPs utilized by local people prepared. Prior to the actual survey, the questionnaire was tested among 20 random NTFP users to identify any ambiguous questions which were amended in the final copy used (Barribeau et al. 2012).

NTFPs users in each village were stratified according to NTFPs used/extracted/traded and the number of users in each NTFPs category were established. Stratified random sampling was used to select at least 10 % of resource users in different use categories per village (Roscoe 1975) and 'snowball' sampling technique (De Caluwe 2011) was used to select the respondents. Semi structured questionnaires were then administered to the selected resource users in each category

per village.

Questionnaires gathered data about quantities of NTFPs consumed or sold locally, time spent gathering NTFPs, season of collection, reason for collection, market price/price of close substitutes for untraded products and availability of the product. Other data collected were on education level of traders and household income from other sources. In addition respondents were asked to list all the capital assets they own. Traders were asked to report the costs associated with NTFPs trade/collection. Spot market analysis was done. Using a checklist randomly administered to NTFPs vendors, unit selling prices and quantities of different NTFPs were established. Key informant interviews with village local council leaders, NTFPs vendors and herbalists (traditional healers and medicinal plant sellers) were conducted to supplement data collected through resource user questionnaire survey.

Construction of a wealth index

A wealth index was calculated for each resource users' household (UBOS and Marco International Inc. 2007). The household assets and type of housing used to construct the index were scored as indicated in Table 1. A wealth index scale ranging from 0.5 to 65 was created by summing up scores for each of the housing characteristics and household possessions of the NTFPs users. Out of this, four wealth classes were formed depending on total scores for each users household as lowest (0.5–13), second (14–25), third (26–36) and highest (40–65). Such an asset index has proved reliable in Uganda (UBOS and Marco International Inc. 2007) and is highly comparable to both poverty rates and Gross Domestic Product (GDP)

Table 1. Scores of nature of household and assets used to calculate the wealth index.

Wealth indicator	Score			
	0.5	1	2	3
a) Nature of main house				
Walls		Plastic sheeting	Timber and mud	Bricks
Floor		Not cemented	Cemented	Tiles
Roofing		Thatch	Iron sheets	Tiles
Window frames		Wood	Metallic	
b) Household goods		Radio	Television	Motor vehicle
		Bicycle	Motor cycle	
c) Livestock	Chicken	Goat, pig	Cow	

per capita in other low income countries (Filmer and Pritchett 1998). The lowest quintile comprised of households regarded as the poorest and the highest quintile comprised households that were wealthier.

Data analysis

Simple descriptive statistics such as means and percentages were used to present incomes and quantities of NTFPs and sociodemographic characteristics of respondents.

Market price valuation was used to determine the value of NTFPs (Godoy et al. 1993). This facilitates comparison with values beyond forest communities and provides an indirect estimate of a cost or benefit using surrogate market goods and commodities. The method has weaknesses of under/overestimating volumes harvested/sold for reasons of prestige or tax avoidance. In case of illegally traded products, there could be undisclosure by traders. These weaknesses were overcome using shadow prices to convert non market NTFPs' benefits to monetary terms for easy comparison with the value of marketed commodities. This valuation focused on product uses (output) rather than value of individual species, thus all

the various uses were summed under the different use categories.

The net value of each product was obtained by subtracting the average costs incurred to obtain the product from its market value. This was multiplied by the average number of units sold or consumed per user per annum to get the net annual value of the resource. The value of each forest product per resource user was calculated using formulas (1–3) (Vedeld et al. 2007) and formula (4) (Scott 1998):

$$NV_p = MV - C, \quad (1)$$

$$NAV_{\text{user/yr.}} = NV_p \times \text{No of units/user/yr.}, \quad (2)$$

$$NAV_{\text{village}} = NAV_{\text{user/yr.}} \times \text{No of users/village}, \quad (3)$$

Net value for all users in all villages =

$$= \sum_{n=1}^{n=14} NAV_{\text{village}}, \quad (4)$$

where: n – number of villages, MV – market value (calculated by multiplying the quantity consumed/sold with the market price), C – total cost of extraction/processing/sale associated with a NTFP, NV_p – net monetary value for each product, $NAV_{\text{user/yr}}$ is the net annual value of NTFPs for each user per annum, and NAV_{village} is the total value of a given product in the whole village. The total cost of NTFP (C)

was obtained by multiplying the cost per unit by the quantity of the product extracted/processed/sold.

The costs of extraction/processing included labour cost which was determined by multiplying the number of hours used in NTFPs collection/processing revealed during the interviews with the value of agricultural labour in the area. Through discussions with respondents, a figure of approximately two dollars per hour was estimated as the wage for agricultural labour. This was used based on the assumption that a cash wage value intrinsically reflects the opportunity cost of using labour on a person's land. However, it should be noted that the opportunity cost of agricultural output varies with season. This study was conducted during the dry season when agricultural production is low leading to low labour cost. Another cost of extraction and trade was transport. Variation in the value of NTFPs was tested using ANOVA statistic.

Estimating the value of individual NTFPs

- Value of firewood = (Average quantity collected $\times$ No of times firewood is collected in a week $\times$ No of weeks in a year $\times$ price per unit) – Costs of extraction. Users average quantity of a bundle that comprised of five logs for subsistence use or retail and an elf truck for wholesalers.

- The value of thatching materials = No of bundles consumed per household per year $\times$ market price per bundle (Martin 1995). Value of construction poles = No of poles used/ sold $\times$ market price per pole. Each user provided an estimate of the number of poles/bundles of thatch used for repair or to construct a house in the year of study.

- The value of handicrafts = (No of

products made per month $\times$ price $\times$ 12 months) – annual costs.

- The value of forest foods was obtained by multiplying the quantity by the shadow price based on market prices in the surrounding markets.

- For medicinal plants, the market price of the most commonly traded medicinal plant was used as a proxy for all. The recall method was used to estimate the quantity and value of medicinal plants collected or marketed. Value = quantity collected per month $\times$ 12 months $\times$ price.

- The value of charcoal was calculated based on the market price of charcoal in the surrounding markets. The unit of measurement for charcoal was a sack. Value = quantity used/sold per month $\times$ market price $\times$ 12 months.

Results and Discussion

Characteristics of respondents

The characteristics of respondents are recorded in Table 2. Both men and women were involved in NTFPs extraction and related activities with a clear distinction in the products preferred by each gender. Similar trends in NTFPs collection were reported in South and West Africa (Campbell and Luckert 2002, Shackleton et al. 2011). However, Sunderland et al. (2004) illustrated a dominant role by women in NTFPs marketing and sale in Africa. Within forest communities gender differences in forest use are common where collection of wild foods and firewood are often done by women and children. In the current study, women and the youth were mostly engaged in collection of firewood for domestic use, processing and selling of mats and baskets. The collection of firewood for household cooking was reported

as a common practice in Western Kenya (Kiplagat et al. 2008). The dominance of women in firewood collection is explained by the exclusive duty of cooking by women in households. Production of mats and baskets is mutually exclusive with other household chores performed by women explaining their dominance in the sale of these products. Conversely, men were involved in strenuous illegal activities like commercial extraction of firewood, charcoal burning, manufacture of racks, cupboards and stools. These require a lot of energy and the need to travel deep into the forest to harvest raw materials. In the current study men reported travelling deep into forest to obtain rattan and palm leaves. Travelling long distances was reported in the extraction of bamboo in India by Saha and Sundriyal (2012). Men are more willing to take on risk by engaging in illegal harvesting of firewood and charcoal compared to women. This corroborates the findings of Aiyeloja et al. (2012) in Nigeria and Luoga et al. (2000) in Tanzania.

A majority of respondents were below 61 years and thus physically active and energetic to engage in NTFPs collection and trade which involve walking long distances and carrying heavy loads as corroborated by findings of Balama et al. (2016). The collection of some products from Mabira CFR is restricted by National Forestry Authority (NFA). This selects against the elderly who lack the energy to run fast to dodge the NFA forest guards and so the elderly are less likely to go into the forest. Rural poverty increases the need for resources and local people's dependency on Mabira forest. However, the command-and-control approach used by NFA of restricting access to the forest has

only escalated 'forest-people' conflicts. This approach has increased illegal harvesting of forest products in order to meet the needs of the community.

NTFPs users had low levels of education (Table 2). Low education level limits the employment opportunities of respondents increasing their heavy involvement in NTFPs related activities. Similar findings were reported by Adhikari et al. (2004) who argued that higher educational levels make firewood collection unprofitable due to high opportunity costs of labour. Illukpitiya and Yanagida (2010) further reported that education increases opportunities for off farm income generation rendering NTFP extraction unattractive. In addition to NTFPs extraction respondents engaged in agriculture, petty trade, informal and formal employment (Table 2). NTFPs extraction was simultaneously carried out with other activities by 97 % of the respondents while only 3 % entirely depended on NTFPs extraction for their livelihoods. Dominance of farming in the area is due to conditions favourable for agriculture which is likely to impact both positively and negatively on the forest reserve. For instance, residents of Buwoola cultivate *Catha edulis* (Vahl) Forssk. ex Endl, which is illegal but of high value and thus inflates the value of agriculture. Dependence on illegal plant species means that should enforcement be strengthened, then there is a likelihood of a shift to exploitation of other forest products. There was evidence of encroachment by agricultural activities on the forest reserve, which, if not controlled, may lead to degradation. Land ownership for agriculture was limited to few acres or none increasing chances of forest encroachment for crop growing and NTFPs extraction.

Table 2. Socio-economic/demographic characteristics of respondents.

Socioeconomic attribute	Response rate, %	Socioeconomic attribute	Response rate, %
Age, years	<i>N</i> =342	Tertiary	2
<18	14	Occupation	
18–30	18	None	20
31–60	51	Peasant farming	65
Above 60	17	Wage labour	8
Sex		Salaried employment	2
Male	60	Petty trade	5
Female	40	Land Holding	
Household head		No land	12
Child	40	1–3 acres	61
Mother/widowed	16	>3 acres	27
Father	43	Wealth Quintile of NTFP users household	
Grandparent	5	Lowest	39
Education level		Second	41
Non formal	18	Third	14
Primary	52	Highest	6
Ordinary level	26		
Advanced level	2		

Note: *N* = number of respondents. Education levels are according to Ministry of Education and Sports in Uganda. Tertiary level comprises both Diploma and Bachelor's Degree. Wealth quintiles of households are listed in ascending order of wealth.

Wealth quintiles of resource users' households

A majority of resource users belonged to households in the lowest and second lowest wealth quintiles (Table 2) an indication that most NTFPs users are poor. This pattern of NTFP dependence was reported elsewhere (Arnold and Perez 2001, Belcher and Schreckenberg 2007). Low levels of wealth increase the chances of dependence on the forest resource. The poor often lack enough capital to engage in other economic undertakings which drives them into extraction of NTFPs that requires less capital investment. Restrictions on NTFPs extraction may impact

negatively on the poor but favour wealthy individuals who possess more political influence and thus likely to benefit more from the forest. This would aggravate poverty levels and at the same time promote forest degradation by the rich.

The value of NTFPs collected by the local community from Mabira CFR

Several NTFPs and their secondary products were collected, processed and traded (Table 3). The use of similar NTFPs is a common feature in other communities adjacent to forests (Ngugi et al. 2012, Sher et al. 2011). It is evident from the

current study that Mabira CFR is a critical resource in supplying several NTFPs used for livelihood improvement to surrounding communities. The total annual value of NTFPs extracted from Mabira CFR amounted to \$ 860,471, of which 93 % was attributed to commercial extraction and 3 % to subsistence use (Table 3). These results are consistent with findings by Saha and Sundriyal (2012) in which a high number of NTFPs were traded in local markets. However, our findings contradict those of Shepherd et al. 2012 in Uganda in which 28 % of the NTFP value was attributed to the cash sector and 72 % to the non-cash sector. This variance could be ascribed to the fact that the latter study looked at national figures yet the current study estimated values to the local economy. The importance of NTFPs as a source of non-cash income was also reported in Kiag'ombe households (Ngunji et al. 2012). Commercial extraction involves large volumes of NTFPs than subsistence use. The high proportion of commercial users in the current study corroborates findings of Belcher et al. (2005) who reported the use of high value NTFPs to obtain cash income.

Charcoal contributed the highest total annual value followed by firewood (Table 3). This could be attributed to high volumes sold and the escalating prices in the area. Other studies in Africa support this finding and report charcoal as the main source of energy and a major contributor of rural household income (Arnold et al. 2003, Angelsen and Wunder 2003). The high value of both charcoal and firewood is also attributed to their availability all year round. The value of charcoal was lower than that determined from Eastern Arc Mountains in Tanzania (Schaafsma et

al. 2012). The variance is due to difference in methods used and the size of the study areas. The current study estimated the value of charcoal to communities adjacent to Mabira CFR, while Schaafsma et al. (2012) assessed charcoal value from 13 mountain blocks spreading from Kenya to Eastern, Central and Southern Tanzania. Despite the high charcoal and firewood values, users reported a decline in abundance of *Vepris nobilis* Del., *Holoptelea grandis* (Hutch. Mibr), *Celtis mildbraedii* Engl. and *Margaritaria discoidea* (Baill.) Webster commonly used in charcoal production. Such a decline in tree species is not unique to Mabira CFR but was reported in other regions (Tabuti 2012, Saha and Sundriyal 2012) due to unsustainable harvesting. Decline in abundance of commonly used species puts significant pressure on the forest to supply fuelwood for cooking and may eventually lead to forest degradation. This is likely to have a negative impact by reducing household incomes of users.

The NTFPs collected are used for nutrition, construction, energy demands, and primary health care among others. Other studies have shown the importance of NTFPs to surrounding communities (Adepoju and Salau 2007, Kristensen and Lykke 2003). The utilization of NTFPs is a clear manifestation of their contribution to improving rural livelihoods. This is attained as a direct saving through subsistence use and local trade to get cash income. The use NTFPs frees cash resources to acquire other household needs and accumulate the necessary asset base for more secure livelihood like education, start-up capital for other economic activities and purchase of essential goods.

Table 3. Annual value of NTFPs extracted by communities around Mabira CFR for subsistence and commercial purposes.

NTFPs	Subsistenceuse, USD	Commercial use, USD	Total value, USD	Value, %
Charcoal	9,419	318,263	327,682	38.1
Firewood	34,398	119,480	153,879	17.9
Medicinal plants	3,295	77,190	80,485	9.4
Mats		75,331	75,331	8.8
Construction materials	6,502	66,234	72,736	8.5
Mingling sticks		44,009	44,009	5.1
Baskets		40,055	40,055	4.7
Brooms		15,322	15,322	1.8
Skewers		10 240	10,240	1.2
Tool handles		9,007	9 007	1.0
Bark cloth		8,519	8,519	1.0
Fodder	3,972	2,323	6,295	0.7
Stools		6,232	6,232	0.7
Wild foods	1,102	1,391	2,493	0.3
Cupboards		2,012	2,012	0.2
Raffia		1,663	1,663	0.2
Baby cots		1,601	1,601	0.2
Racks		1,569	1,569	0.2
Winnowing trays		720	720	0.1
Rattan		433	433	0.1
Palm leaves		187	87	0.02
Sum	58,688	801,782	860,471	100

Note: Figures were converted at 1 USD – Shs 2,533 (BOU – Monetary policy statements) USD=United States Dollars. NTFPs include both raw materials and value added products.

The annual values of NTFPs utilized by Mabira CFR communities varied between villages (Table 4). The high value of Charcoal and firewood suggests that people around Mabira CFR depend heavily on the reserve for domestic energy needs. This is also true for households in other parts of Uganda where woody biomass meets approximately 92 % of the energy needs for household cooking (MWE 2013). A high annual value of charcoal was also reported in Zambia (Mulenga et al. 2011) and West Africa (Falconer 1990). The high values for firewood and charcoal are not surprising given that fuel wood and charcoal forms the most common source of cooking energy in rural and

urban areas in Uganda respectively. The supply of electricity an alternative source of energy is still limited and not affordable by most households in the low and middle class income groups. The National forest plan 2011/12 – 2021/22 (MWE 2013) indicated that the nominal value of firewood and charcoal in both monetary and non-monetary terms has been on the increase attracting more individuals in their trade. Increased commercialization of charcoal and firewood is likely to further degrade the resource base on which the forest dwellers depend. The extraction of firewood and charcoal are destructive activities that may lead to loss of more forest cover. A study by Shepherd et al. (2012)

in Uganda revealed that firewood, building materials and wild edible plants were the most important contributors to household income. The high annual values of firewood and charcoal in Dangala and Bugabe respectively (Table 4) was due to increasing demand in the main towns of Kampala, Jinja and Mukono.

Wild foods contributed a low annual value (Table 4) since most users reported difficulty in finding any wild foods due to deforestation. Wild foods were harvested by the youth incidentally during firewood collection. The costs of wild food extraction exceeded the expected benefits due to long distances that had to be travelled to gather enough volumes that would make economic sense as similarly reported in Nigeria (Adedayo et al. 2010). The com-

mon foods collected were fruits, leafy vegetables and yams. A study in South Africa (Shackleton and Shackleton 2004) reported that more than 85 % of the rural people consumed wild spinaches, edible fruits and honey from the forest. Wild foods were mainly for home consumption due to minimal quantities that were available. A similar pattern of total dependence on *Oenanthe stolonifera* (Roxb.) and *Musa* sp was reported in Senapati District in North-eastern India (Pfoze et al. 2012). Though forest foods were scarce, income from other NTFPs provided economic accessibility to food. NTFPs income was reportedly used to meet household needs including buying food which appears to be a more important benefit of the forest for food security than direct collection of forest foods.

Table 4. Annual Values of NTFP extracted by local people in Villages of Mabira CFR.

Village	Firewood, USD	Charcoal USD	Medicinal plants, USD	Edible plants, USD	Construction materials, USD	Other NTFPs, USD
Dangala	84,068	4,373	28	220	3,060	3,661
Najjembe	6,261	6,641	500		5,136	67,887
Buwoola	2,168	460	19,249		3,649	13,180
Lugala	4,992	11,104	9,797		6,588	2,705
Naluvule	1,421	65,013	14,510		7,729	11,122
Nakalanga	1,356	12,140	219	942	3,747	22,058
Khonko	1,704	43,901	135	232	2,470	13,123
Bugabe	26,431	91,717	1,374	253	7,782	7,673
Ntunda	2,521	10,719		111	8,467	10,216
Kalagala	9,182	10,221	5,495	423	4,809	10,134
Bukuku	477	33,981	18,536	152	4,877	7,868
Nagojje	5,233	8,911	2,340		8,097	37,935
Lunya	4,912	26,218		161	4,923	13,361
Ssese	3,150	2,286	7,106		1,380	3,489
Total	153,879	327,686	79,288	2,494	72,713	224,412
Subsistence value and %	34,398 (22 %)	9,419 (3 %)	3,295 (4 %)	1,103 (44 %)	6,502 (9 %)	2,971 (2 %)
Commercial value and %	119,480 (78 %)	318,269 (97 %)	75,993 (96 %)	1,391 (56 %)	66,210 (91 %)	220,439 (98 %)

Note: USD = United States Dollars. Other NTFPs include; palm leaves, rattan, fodder, skewers, barkcloth and secondary products from NTFPs processing like; mats, baskets, brooms, tool handles, simple furniture, baby cots and winnowing trays.

The minimal value of medicinal plants could be attributed to low quantities collected for home use. Quantities of NTFPs extracted for subsistence consumption are likely to be less compared to quantities extracted for sale. In most cases herbal medicines are cheaper than western medicines particularly when access to traditional healers is easier. Some studies have showed that demand for traditional medicine is increasing in urban environments despite availability of western biomedicine (Mander et al. 2007, Nadembega et al. 2011) underscoring their importance. Most medicinal plants were sold in raw form except where occasional drying was done. Cakilcioglu and Turkoglu (2010) reported processing of medicinal plants by drying. However, it is important to recognise that selling unprocessed herbal medicines attracts low prices, which translates into low value to traders. This underscores the importance of value addition in maximizing returns from medicinal plants trade. Trade in me-

dicinal plants was dominant in Bukuku, Buwoola, Kalagala, Naluvule, and Lugala where the activity was the main source of income for herbalists that extracted larger volumes for sale. Mabira forest acts as a source of construction materials for rural homes. Materials used include poles, tying materials, thatch grass and reeds. The high value of construction materials is attributed to the fact that most houses in the study area are constructed using these materials which are cheaper compared to modern alternatives like bricks and iron sheets. Poles in some cases were required for supporting television antennas especially in semi urban centres that have access to electricity.

A total analysis of NTFPs from all villages revealed that firewood, charcoal, mats, skewers, baskets and mingling sticks offered high value to users (Table 5) and could be targeted for enterprise development. The variation in the mean annual value of NTFPs extracted was significant ($F=1.67$, $df\ 16$, $p<0.05$).

Table 5. Mean annual values obtained from utilisation of NTFPs.

NTFPs	Mean annual value, USD/village	Minimum value, USD	Maximum value, USD
Firewood	10,991 $\pm$ 5,884	477	84,067
Charcoal	23,406 $\pm$ 7,177	460	91,717
Fodder	787 $\pm$ 191	144	1,585
Medicinal plants	6,707 $\pm$ 2,078	28	1,930
Wild foods	312 $\pm$ 96	111	942
Mingling sticks & tool handles	4,401 $\pm$ 1,340	183	12,045
Brooms	3,064 $\pm$ 1,134	142	6,850
Rattan	217 $\pm$ 83	133	300
Skewers	10,240 $\pm$ 0		
Stools	2,077 $\pm$ 552	1,026	2,611
Mats	5,797 $\pm$ 2,362	144	31,800
Baskets	4,006 $\pm$ 1,469	411	15,558
Construction materials	5,195 $\pm$ 600	1,379	8,467

Note: Figures were converted at 1 USD = Shs 2,533 (BOU – Monetary Policy Statements), USD = United States Dollars.

The value of NTFPs varied between villages with users from Bugabe village obtaining the highest mean annual value (Table 6). This was mainly attributed to the high charcoal volumes traded. The mean annual value of NTFPs extracted by residents from different villages was statistically significant ($F=0.000$, $df\ 13$, $p<0.05$). This implies that there was disparity in the mean annual values of NTFP extracted or sold in the different villages. For instance the mean annual values of NTFP was high in Bugabe followed by Naluvule villages and lowest for Ssesse. This variation is attributed to many factors including production volumes, demand, price, level of pro-

cessing, nature of product extracted and sold, magnitude of extraction, accessibility to the forest and availability of livelihood means other than NTFP extraction. High volumes of firewood and charcoal are extracted to meet increasing demand due to the fact that both are the main sources of cooking energy in rural and urban areas in Uganda. This results into high revenues.

Variation in NTFPs values was reported in other studies (Illukpitiya and Yanagida 2010, ADB 2000). Extraction should however be done with caution in case of some products like charcoal as it leads to forest degradation and loss of the preferred tree species.

Table 6. Annual values of NTFPs assessed from different villages.

Village	Resource users, No	Total annual value, USD	Mean annual value, USD/resource user
Dangala	23	95,409.58	4,148
Najjembe	42	86,425.03	2,058
Buwoola	26	38,706.09	1,489
Lugala	22	35,185.93	1,599
Naluvule	21	99,794.80	4,752
Nakalanga	23	40,462.42	1,759
Khonko	27	61,564.60	2,280
Bugabe	19	135,230.26	7,117
Ntunda	22	32,034.14	1,456
Kalagala	24	40,264.21	1,678
Bukuku	25	65,891.24	2,636
Nagojje	49	62,516.35	1,276
Lunya	25	49,574.87	1,983
Sesse	15	17,411.38	1,161
Sum		860,471	

Note: Figures were converted at 1 \$ = Shs 2533 (BOU – Monetary Policy statements).

Variation in mean annual values is also attributed to level of NTFP processing or value addition. Villages that sold a lot of processed products presented with high annual mean values. Processing increases the cost of production which translates into higher prices directly increasing the value of such products. NTFP price differ-

ences and production volumes in the villages also contributed to variability in values. In villages where extraction of NTFP required travelling for long distances, the cost of extraction was high and this affected the value. In villages where extraction and trade in NTFP was the only means of livelihood, more time was dedicated to the

activity leading to extraction of large volumes and hence high revenues. However, this may threaten the existence of the NTFP species necessitating conservation measures. On the other hand villages where NTFP extraction and trade was a part time activity to supplement other income, the NTFP values were low. A similar scenario was reported in South Africa (Shackleton et al. 2002).

Conclusions

Mabira CFR is paramount in supplying local communities with firewood, charcoal, construction materials, wild foods and medicinal plants. NTFPs play an important role in rural livelihoods contributing \$ 860,471 p.a. in both cash and non-cash income. This underscores the importance of Mabira CFR in poverty reduction to surrounding communities and at the same time indicates the economic loss NTFPs users would bear if NTFPs extraction was absent. The NTFPs value varied significantly between villages and products. Although charcoal had the highest annual value, its extraction threatens the continued existence of the forest reserve. Despite the presence of laws and regulations of accessing the forest reserve, there is continued extraction of NTFPs an indicator that households need such products. Variability in mean annual values of NTFP across villages points to the need for intervention measures for sustainable utilisation of the resource in villages that obtained high NTFP revenues. For instance on farm conservation of preferred charcoal and firewood species should be promoted in Bugabe and Naluvule in order to reduce their overexploitation. Furthermore for species that are reducing in availability, development of nursery and multiplication

trials should be implemented in order to identify best production practices.

Meeting the actual needs of local people in the study area necessitates designing forest based initiatives/alternative NTFP sustainable livelihoods to improve household income and at the same time facilitate NTFPs conservation in order to obtain a win-win situation for all stakeholders. Such initiatives will be an incentive to divert the local people from NTFP extraction thus reducing the exploitation rates. The current study only valued NTFP of plant origin and so further studies on values of faunal species and other ecosystem services provided by Mabira CFR should be done. A similar study should be conducted in the rainy season to establish the availability of NTFP or challenges encountered in such a period.

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ABOVE-GROUND PHYTOMASS DYNAMICS IN AUTOGENIC SUCCESSION OF AN ECOSYSTEM

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Abstract

It was found that a regular growth in the above-ground phytomass occurs during autogenic succession, which is approximated by logarithmic dependence with high reliability indices. External, including anthropogenic, effects on the process of succession lead to a decrease in the rate of phytomass growth. Besides, the rate of phytomass changes is influenced by endo-ecogenesis caused by various plant species, entering the ecosystem at certain stages of succession. The above-ground phytomass portioning behaviour makes it possible to use it to create a unified indicator of dynamics. Each plant species can be only within certain indicators of the phytomass of their plant communities. At the same time, there is a normal distribution of the projective cover value. This allows us to work out synphytoindication methods for determining the dynamics indicator.

Key words: anthropogenic transformation, ecosystem dynamics, synphytoindication analysis, Ukrainian Polissia.

Introduction

One of the key issues of the integration of environmental theories is to find out the basis for their unification. The great majority of scientists believe that the thermodynamics of ecosystems should be basic (Odum 1971; Didukh 2008; Jørgensen 2002, 2006–2007; Svirezhev and Jørgensen 2004). Odum (1971) called the energy an ‘ecological currency’. The energy can serve as a means for assessing individual elements of ecosystems, structures, and various processes occurring within, including dynamic ones. The basis for energy transformations within the ecosystem are the laws of thermodynamics (Didukh 2008). The ecosystem, according to classical thermodynamics, is

an open system where a constant energy cycle occurs along with changes in the level of the entropy (Svirezhev 2000). Until today the ecosystemologists approach to assess energy content, energy flows and the problem of entropy is a measure of disorder. At this stage of the research the transition to use of thermodynamics to assess dynamic processes in ecosystems is pressing. It became possible to combine ecology with technical and economic sciences through energy factors. It gives an opportunity to simulate processes in ecosystems, to predict and to evaluate them by using engineering and economic methods. The simulation based on thermodynamic factors is the basis for modern systems and synergetic approaches to wild life study (Didukh

2008). However, an objective and accurate determination of the energy flow rate in real ecosystems is a difficult technological problem. The red hot task today is to find the objective indicators available for the study that allow the researcher to retrace the dynamics of energy flow in ecosystems (Didukh 2008).

The energy that moves within trophic chains enters the ecosystem through the producers. They transform its chemical and physical types into energy of organic compounds – that is phytomass. The exceptions are the types of energy used indirectly such as sun light besides photosynthetically active radiation, heat, ionizing radiation. These types of energy act as external environmental factors. They can limit the development of an ecosystem or influence its attractors, but it is the internal energy which is a key in determining all ecosystem processes. The problem of assessing the internal energy is difficult, but it will be definitely associated with those species that are able to move between elements of the ecosystem. Most energy varieties that act as external factors are specific with rare exceptions. Only the energy of phytomass moving by trophic chains and turning into other species unites the ecosystem into a single synergetic unit. Therefore, it is the dynamics of phytomass that can be an indicator for models of thermodynamic processes (Lindeman 1942, Didukh and Lysenko 2010). Numerous studies of phytomass changes at different stages of succession indicate the validity of this forecast (Khaurdinova 2014, Khomiak 2018, Khomiak et al. 2018).

We have chosen autogenic succession as a reference sample of ecosystem dynamics. The mechanisms of syngensis and endocogenesis work during its course with a minimum external influence.

During real observations, we do not find ecosystems where only self-organization processes exist and external effects are completely absent. A statistically reliable result can be obtained due to a large number of observations. The pattern of phytomass change in various types of autogenic succession allows us to make a hypothesis that can be an indicator of internal processes that occur in an ecosystem during successions.

Ukrainian Polissia was chosen as a model. It is characterized by a high diversity of flora, which had come from different zones of the Circumboreal Region. The ecosystems of the Ukrainian Polissia are in different edaphic, orographic and microclimatic conditions at different stages of succession under various external influences including anthropogenic ones.

Material and Methods

The research was carried out by expeditionary and stationary methods. Materials for research are 835 standard geobotanical descriptions during expeditions and 80 descriptions from stations in the territory of Ukrainian Polissia. The descriptions for the field research were carried out on square lots of 4 m² for grassy vegetation, 100 m² for shrubs and 200 m² for forestry. The vegetation located ribbon-like was investigated in rectangular areas with a length of 2 m for grassy vegetation, 5–10 m for shrubs and 10–20 m for forestry. The thickness of the rectangular area was determined by the visual homogeneity of the living cover. The above-ground phytomass value and its age were determined as a part of the descriptions. The sites were formed in strata within edaphic and microclimatic conditions and anthropogenic impact. Sites are rectangular open area of

8 by 20 m in size and located on upland lots (plakor) with an exposure close to 0°. They are oriented in length to latitudinal direction. By origin all sites were fallow sod pod soils of the first year once the cultivation was stopped. According to preliminary synphytoindication analysis the deviation in the initial factors of environment did not exceed on average 4 %: from 2 % for the total salt regime and illumination up to 8 % of the content of available nitrogen according to the Didukh-Pliuta phytoindication scale (Didukh et al. 1994). Each station was divided into 10 strata. Every year the above-ground phytomass of one of the stratum was withdrawn for weighing during the period of maximum vegetation (Rodin et al. 1967). Beforehand its standard geobotanical description was created. The removal of phytomass occurred first in the southern areas and then in the north from west to east.

A similar definition of phytomass was carried out for strata with meadow, agrocoenosis, ruderal, and shrub vegetation outside the station. The above-ground phytomass for forest ecosystems was determined by standard forest engineering methods (Anuchin 1977) or the available forest inventory materials were used. The age of perennial plants was established experimentally for shrubs, and for trees – by using classical forest engineering methods or materials of forest inventory. In woody vegetation areas where there are no forestry taxation materials, the forest density was determined by volumetric tables and tables of growth for normal-growing stock. The method error was ± 5 %. The height was determined by using an angle finder, and the diameter was defined by using a caliper. The phytomass of the undergrowth, the understory and shrubs was determined by using measurements on square lots

of 4 m² with uniform allocation or by line-intercept method (band width 1 m) for staggering location. Ten sample lots of 1 m² were laid to measure the aboveground phytomass of grass and shrub vegetation. Phytomass removal was carried out using the cut-sample method (Rodin et al. 1967).

The age of plants was determined by species for one- and two-year-olds, by an experimental approach for shrubs (cut with ring counting for 10 model species), by the number of rows of knots for some trees, and according to tables of growth in the absence of materials for other trees.

The vegetation as a part of the descriptions made was classified using the principles of Braun-Blanquet (Braun-Blanquet 1965, Weber et al. 2000) in regards to the vegetation prodrome of Ukraine (Solomakha 2008). The syntaxonomic scheme included 165 associations, distributed into 66 unions, 6 orders, and 27 classes. The power of anthropogenic impact was determined using the original synphytoindication technique (Didukh and Khomiak 2007) using the program Simagrl 1.12 (Khomiak 2018).

Results and Discussion

Lindeman (1942) foresaw a regular growth of the accumulated energy in ecosystems during self-development. Since this energy accumulates in the form of organic compounds, such changes should also relate to the phytomass or its individual parts. Our studies confirmed the growth of above-ground phytomass during the restoration of natural vegetation on sod-fields (Table 1). This type of dynamics is close to secondary autogenic succession. Under natural conditions, it is almost impossible to organize a large-scale exper-

iment where the ideal autogenic succession will be modeled, and where changes will occur only due to syngensis and endo-ecogenesis caused by the influence of biota on the environment without extraneous influences. More often we can find a combination of autogenic and allogenic successions of nature, the balance of which is shifted in a certain direction or in equilibrium (a catastrophic climax according to Odum 1971). However, we can define the direction and the type of deviation from the model under the condition of external influence. First of all, it is about anthropogenic impact. Stations with minimal anthropogenic impact will be closer to it, and will be respectful distant with the maximum one.

The rates of accumulation of above-ground phytomass differ at different sites (Table 1). And this distinction depends on the time. The results of the analysis indicated heterogeneity of indicator dispersion of the above-ground phytomass ($P=0.009$). The LSD test (ANOVA) was taken to check the reliability of differences between the studied sites within the conditions of the elevated phytomass, and the results of which were estimated taking into account the Bonferoni correction. The results of the analysis indicated significant differences between stations No 1 and No 4, No 1 and 7, and also No 4 and No 6 (Table 2). Thus, these are areas that cause the heterogeneity of the dispersion of the above-ground phytomass.

Table 1. Above-ground phytomass indicators in the stations, t·ha⁻¹.

Years	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Section										
1	8.30	9.97	13.80	15.60	18.90	20.25	20.63	21.17	21.36	21.51
2	5.65	9.09	15.16	18.13	25.93	33.65	37.50	44.29	46.69	48.00
3	9.19	11.17	18.08	18.83	20.27	20.36	24.84	28.00	28.41	31.70
4	8.73	11.17	20.23	21.53	40.52	42.72	45.39	46.59	53.43	55.25
5	6.18	15.47	19.95	20.60	26.83	27.95	29.22	36.04	36.17	36.53
6	8.22	14.77	18.00	19.83	19.93	21.52	21.52	21.55	21.80	21.48
7	12.87	16.48	23.05	23.76	33.33	41.02	45.12	48.01	48.02	48.28
8	5.47	15.59	16.80	19.26	21.39	38.81	42.58	45.38	47.30	50.89

Table 2. Estimates of differences in the above-ground phytomass taking into account the Bonferoni correction (ANOVA, LSD-test).

Station number	2	3	4	5	6	7	8
1	0.044336	0.476705	<u>0.002283</u>	0.133614	0.756575	<u>0.003095</u>	0.019049
2		0.187265	0.267753	0.598017	0.086919	0.313596	0.725953
3			0.016792	0.425322	0.687273	0.021723	0.096656
4				0.104020	<u>0.005659</u>	0.918971	0.446766
5					0.231780	0.126874	0.380988
6						0.007523	0.040387
7							0.509497

The differences in phytomass indicators at different stations are shown in the diagram (Fig. 1). As it can be seen, stations differ both in average values of phytomass and in the nature of variability (rates of growth in above-ground phytomass).

There are two most likely causes for the change in the rate of growth in the above-ground phytomass: endoecogenesis and anthropogenic impact (Fig. 2). The value of the anthropogenic impact on individual areas differed. It was overestimated in sites No 1 and No6. There were marks of live-stock grazing and poaching (recreation) here. Marks of live-stock grazing were noted in the site No 1, starting from 2-year observation, and in the site No 6 – since 5 years. At the same time, there is

a significant positive correlation between the change in the above-ground phytomass and the power of anthropogenic pressure ($r=0.77$).

High correlation is for changes in above-ground phytomass and some indicators of edaphic factors. First of all, it concerns the general salt regime (0.83), the content of available nitrogen (0.83) and the aeration of the soil (0.85). In all these cases, the inverse linear relationship was observed – in due time, these indicators decreased, and the phytomass continued growing. This process is due to several reasons. First, the strata are former agroecosystems where overestimated salinity levels, including nitrates and ammonium salts, were artificially held up. High aeration was held up by regular cultivation.

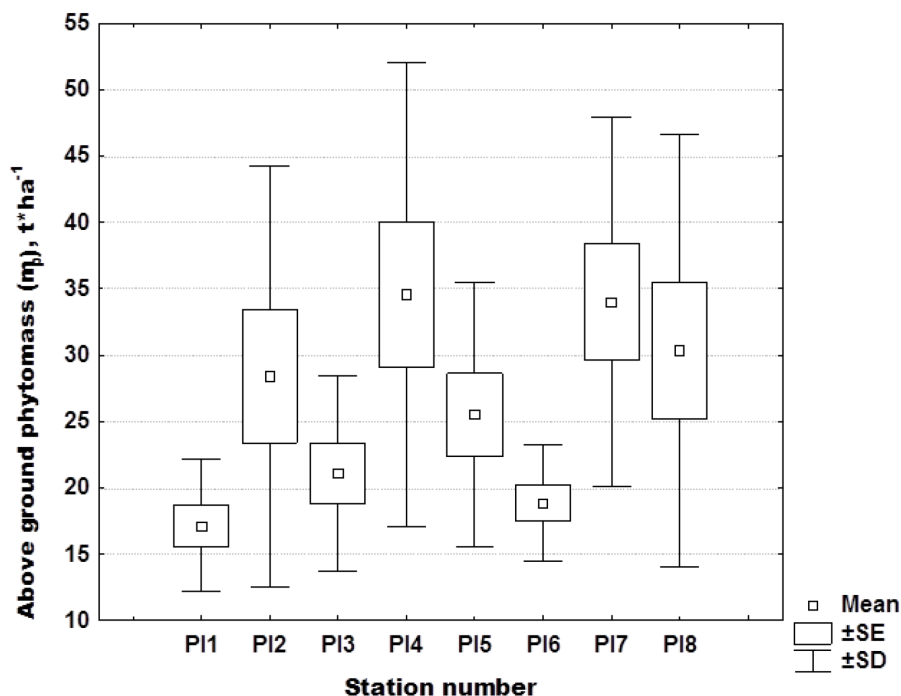


Fig. 1. Variability of phytomass indicators.

Legend: Mean – arithmetical mean; SE – standard error; SD – standard deviation, m_p – above-ground phytomass.

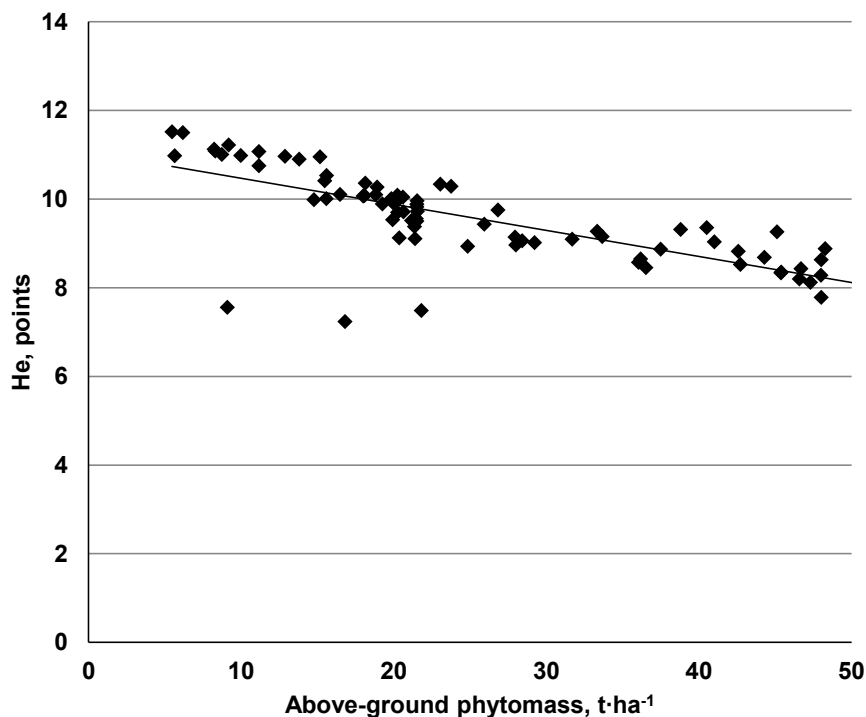


Fig. 2. Dependence of changes in the above-ground phytomass on the indicator of anthropogenic transformation (He).

Termination of crop growing started the natural processes of reducing of such indicators. They occurred faster than others at certain stations. This was facilitated by the healthy growth of phanophytes which absorbed the above-mentioned salts brought along. For example, this can be observed at the site No 4, where the decrease in the salt regime occurs most actively together with the high rates of phytomass growth. Since the fifth year the strata overgrowing, *Pinus sylvestris* L., that is an active transformer of the edaphotop, has been actively spreading here. Besides, in some sites, starting from the sixth year of the strata overgrowing, *Betula pendula* Roth appears, that is also capable to transform the edaphotop in the direction of the salt content decrease in due time.

This is particularly shown on sod-podzolic soils with low humus content (Naumova et al. 2005, Sorokina and Sorokin 2006).

Syngeneses is associated with the formation of vegetative cover from seeds or vegetative parts of plants that were already in the soil or penetrated outside. In some cases, the growth rate of phytomass may vary depending on their species composition. This can be carried out both through active endo-ecogenesis caused by these species, and their allelopathic properties. For example, the appearance of *Hieracium pilosella* L. together with *P. sylvestris* in the fourth site led to the active suppression of meadow vegetation and the formation of a floristic block close to the class *Koelerio-Corynephoretea* Klika in Klika and Novák (1941).

Thus, both the anthropogenic pressure and the transformation of the edaphotop affect the dynamics of the above-ground phytomass value in various stations due to the appearance of certain types of edificators here.

The dynamics of the above-ground phytomass in regards to the logarithmic trend line has got the measure of the approximation reliability of 0.59. The correlation index for this pattern is quite high – 0.77. Despite the differences in time and environmental conditions, these results are very close to those obtained by Khaurdinova (2014) for the Kyiv Polissia strata (Fig. 3).

The equation (1) for our model is the logarithmic function:

$$y = 4.1159 + 14.645 \cdot \ln x \quad (1),$$

where: y – stock of the above-ground phy-

tomass, $t \cdot ha^{-1}$; x – time from the beginning of the strata overgrowing, years.

It should be noted that there is a high similarity of the coefficient 'a', obtained in our case ($a=4.1159$) and in the researches of Khaurdinova ($a=3.8$) (Khaurdinova 2014). Despite the ninety-year difference in the strata overgrowth, this index is very close, which may indicate the likely possibility of creating a universal mathematical model for the dynamics forecast.

Eighty descriptions made at stations during the first ten years of strata overgrowing are not enough to create a full-fledged model of the dynamics of ecosystems. To expand the selected amount of data from the entire data set of 835 descriptions, we chose 251, close to the conditions within stations according to the conditions of edaphic indices (Fig. 4).

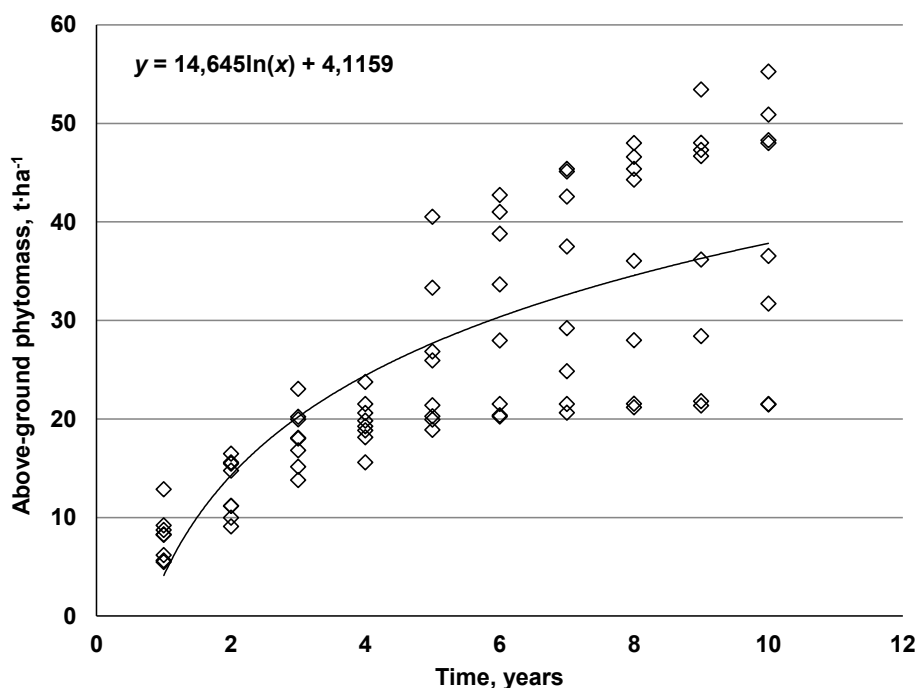


Fig. 3. The change in the above-ground phytomass at the stations in due time.

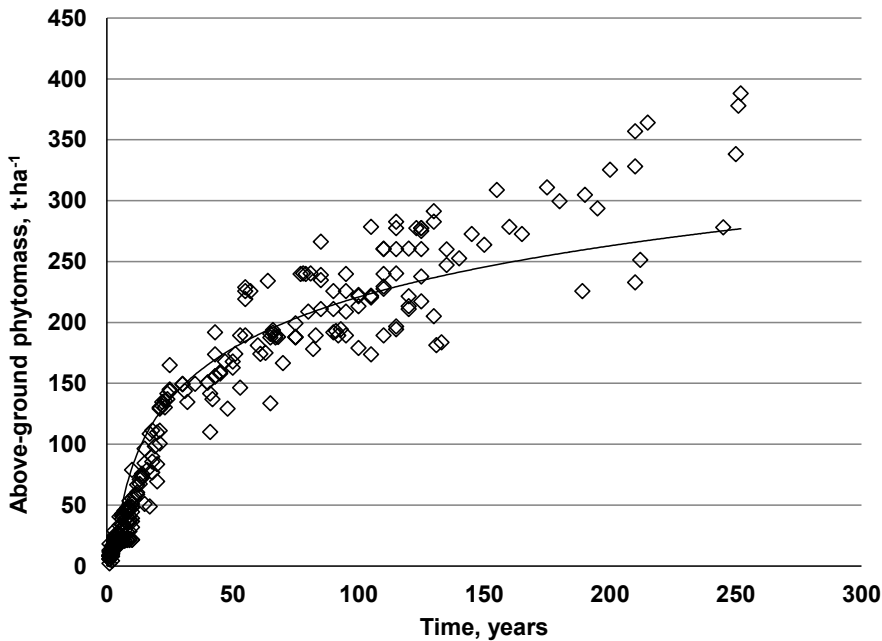


Fig. 4. The change in the above-ground phytomass in due time in the conditions of similar stations.

As a result of approximation of the logarithmic curve, we get the equation (2):

$$y = 58.785 + 60.718 \cdot \ln x \quad (2),$$

A significant difference in the indicators is due to the difference in the age of plantings, their type. Our research at stations covers the strata overgrowth in the first ten years, while the studies of Khaurdinova (2014) cover the reproduction of pine forests on the strata for 100 years. Besides, our generalized research has already included all types of plantings in similar edaphic conditions. In addition, plantings over the age of 120–130 years are very little described. Therefore, the exact location of the set of points in this zone is unknown to us. Most of the age plantings came under influence of the anthropogenic effects of various types (recreation, salvage cutting, etc.). To exclude cases of allogenic successions from our

model, we applied a filter that excluded all ecosystems elder than 10 years with a level of anthropogenic transformation above 9 points according to Didukh-Khomiak scale (according to Blume and Sukopp 1976).

This allows us to define the problem of the existence of a single mathematical model for all variants of the dynamics of ecosystems. In other words, does it lead to the expansion of the range of studies in a universal formula or whether there is its own mathematical pattern for each variant of successions? To solve this problem, it is necessary to integrate all possible measurements of phytomass reserves in plantings with the known age. If we advance the hypothesis that any deviation from autogenic succession towards allogenic leads to a decrease in phytomass, then we can take the maximum values for each

age group and build a model based on the patterns of their location. An exception to the above case may be the penetration of species with high efficiency of photosynthesis (type C4 instead of C3); anthropogenic activity is associated with artificial plantings of fast-growing phanerophytes or with growth in soil fertility with mineral fertilizers or organic waste. These cases are not common enough. Their influence can be reduced if the model is applied only for a separate environmental zone or a geobotanical sub-province, and also a significant number of measurements is used under controlled conditions (objects of the nature reserve fund).

High correlation rates were observed between the planting age and their above-

ground phytomass – 0.77 and 0.94, respectively in both cases studied. This shows the possibility of using the value of the stock of above-ground phytomass as a basis for deriving the dynamics indicator. This value will allow not only to assess the state of ecosystems as a link of succession series, but also to become the basis for predicting their future development.

We suggested a hypothesis that species can exist only with certain values of the above-ground phytomass that reserve in the ecosystem. To this end, it was established how the projective cover of certain plant species changes with a change in the above-ground phytomass of the groups to which they belonged (Fig. 5). These changes can be described by the

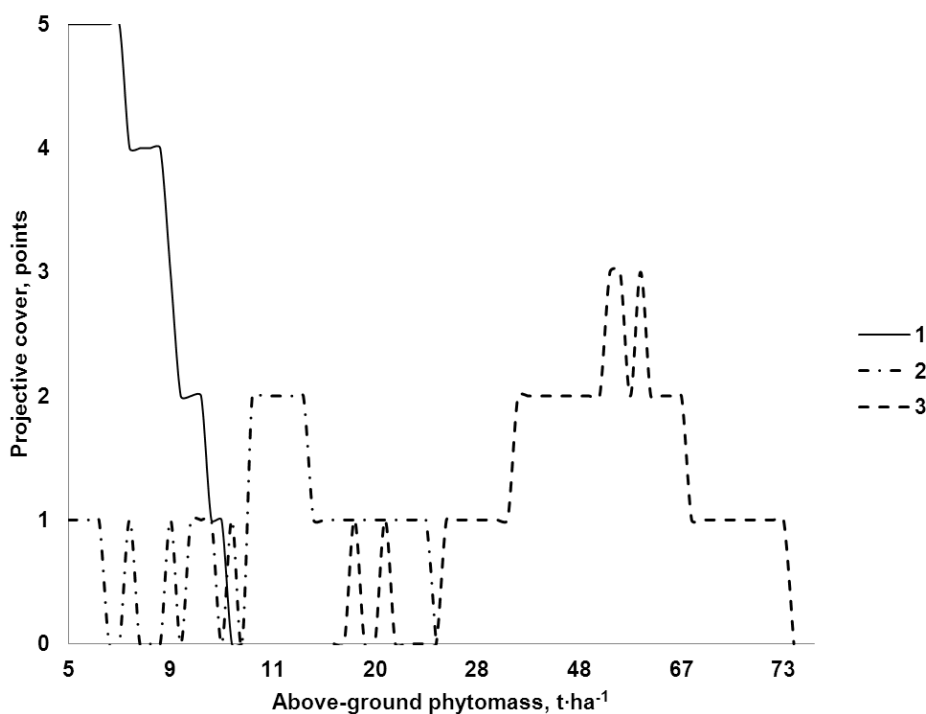


Fig. 5. Change of the complex factors of projective cover *Echinochloa crusgalli* (L.) P. Beauv. (1), *Convolvulus arvensis* L. (2) and *Salix caprea* L. (3) in groups with various indices of the above-ground phytomass.

normal distribution (Gauss curve) according to the Shelford tolerance law. Each of the species can only be in certain limits of endurance. The deviation from the optimum is accompanied by a decrease in the projective cover of the species. This opens up the possibility of using of synphyteindicative methods for determining the dynamics indicator.

Conclusions

During the process of autogenic succession, a regular growth in the above-ground phytomass occurs, which is approximated with a high reliability index by logarithmic dependence.

Anthropogenic factors and endoecogenesis, caused by various plant species that penetrate the ecosystem at certain stages of succession, affect the dispersion growth of the above-ground phytomass indices.

The regularities of the distribution of the above-ground phytomass value allow using it to create a unified indicator of dynamics.

Each plant species can be only within the certain indicators of the phytomass of their plant communities. At the same time, there is a regular distribution of the projective cover value. This allows us to develop synphyteindication methods for determining the dynamics indicator.

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PETROHAN TRAINING AND EXPERIMENTAL FOREST RANGE CAMBISOLS CLASSIFICATION

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Abstract

To classify Cambisols on a second taxonomy level, the territory of Training and Experimental Forest Range Petrohan was differentiated into 48 relatively homogeneous territorial units based on soil formation factors. The dominant influence of acidic products over the basic ones in soil formation process has been proven. Cause-effect relationships were established between ' $\text{pH}_{\text{H}_2\text{O}}$ – exchangeable Ca', 'cation exchange capacity – exchangeable acidity' and ' $\text{pH}_{\text{H}_2\text{O}}$ – exchangeable Ca: exchangeable Mg'. The leaching has been advanced, and in some cases, it covers the entire soil profile depth. The high soil acidity defines the main qualifier as *dystric* for the Cambisols classification on a second taxonomy level.

Key words: acidity, basic cations, Cambisols, forest soil, leaching.

Introduction

The first Bulgarian soil classification in Bulgarian literature is the one of N. Pushkarov in 1931. When creating the Common soil map of Bulgaria at a scale of 1:500,000, in its legend soil differences have been written – steppe, forest and azonal. Substantial changes and additions have been made after the implementation of the Russian-Bulgarian expedition in 1947, when I. P. Gerasimov and I. N. Antipov-Karataev developed a new systematic list of Bulgarian soils. In 1948 'Soils in Bulgaria' monograph was developed as well as a new soil map scheme in scale 1:1,000,000. For first time in the monograph brown forest soils were differentiated on level subtype – typical and leached. In 1956 E. Tanov developed medium-scale map of the soils in Bulgaria on

a scale 1:200,000. The same year small-scale soil map at scale 1:1,000,000 was made. On these maps brown forest soils were divided into four subtypes – brown forest soils, dark, light and secondary grassland. Based on new studies in different regions of the country the systematic list of soils has been expanded in the following years. The Instruction on identification and mapping of forest habitats and determining dendrocoenotic composition has been developed in 1976, with professor D. Garelkov as a head. For first time brown forest soils were divided into dark, light and transitional, depending on the depth of the humus accumulation horizon in them. A new classification system in which several changes have been made has been developed in 1983 (Instruction ... 1983). Brown forest soils were divided into dark, light and typical, and this divi-

sion has been used in Forest plans until 2011 when the Instruction has been updated (Raikov et al. 2011).

The Basic Soil Classification (Penkov et al. 1992) is the first to give equivalents of the names of soil units in the national classification (Instruction ... 1983) with these in the Legend of soil map of the world (FAO 1988).

The significance for brown forest soils is that they start being referred to as Cambisols in Bulgaria, in accordance to international standard, and are divided into two types – *dystric* and *eutric*. The application of this classification requires analytical determination of the quantities of the basic exchange cations and the exchangeable acidity. Until now, no studies have been carried out on the territory of Training and Experimental Forest Range (TEFR) Petrohan to establish the base saturation of the soils and their classification according to the requirements of the Basic Soil Classification in the country and hence to the World Reference Base for soil classification (WRB 2006, 2015). In practice there is no possibility of correlation between the classification used in Forest plans (FP) and in above mentioned classifications. This is confirmed by Malinova (2016).

The aim of this study is to determine the soil base saturation of Cambisols in representative areas which allows their classification according to the modern requirements of WRB (2006, 2015).

Material and Methods

The subject of this study are Cambisols of TEFR Petrohan territory which occupy 87.9 % of it. The forest range is located between 23°04' and 23°13' longitude and 43°14' latitude. It is in the Western Balkan

area, Moesian forest district, Northern Bulgaria subdistrict. The total area is 7290.4 ha. The terrain is typically mountainous, with steep slopes, deeply incised river valleys and steep minor ridges. Regarding the climate conditions, the territory is characterized by specific mountain climate – lower temperatures, significant cloudiness and intensive rainfall, high relative humidity and prolonged snow cover. The forest range altitude is between 350 and 1900 m. The average altitude is 1010.6 m (Dobrichov 2016). The largest part of the wood production area of TEFR Petrohan is in the middle mountain belt of beech and coniferous forests (600–1800 m).

An important component for the soil formation process on the territory of TEFR Petrohan is the grade of slopes. Predominantly steep slopes – 47.2 % and inclined terrains – 27.9 %. This is a precondition for rapid surface water drainage and reduces the possibilities of soil re-humidification and water retention. Very steep terrains are 18.9 %, and sloping terrains and flat ones – 5.7 % and 0.3 % of wood productivity area of TEFR Petrohan. According to the Soil Identification among the soil-forming rocks granitoides predominates (Mihailov and Donev 1971). The main tree specimen is the European beech (*Fagus sylvatica* L.). The percentage of the deciduous species is 89.3 % of the total tree species distribution, and the share of the coniferous species is 10.7 % (Dobrichov 2016).

For the study, the forest range territory is differentiated into relatively homogeneous territorial units which allow the selection of representative subjects according to the soil formation factors. The slope, the altitude, the slope exposition and the soil-forming rocks are adopted as criteria for the forest range territory differentiation. The slope is chosen as a

leading factor because of its function to determine the direction, mass and velocity of the surface runoff and in addition to influence the other factors of soil formation (Loze and Matie 1998). The similarity in the soil formation factors regarding to climatic conditions is determined by height forest belts, expositions and the similarity of soil-forming rocks – by origin and composition. The field work has been carried out in representative homogeneous territorial units, in which according to Dobrichov (2016) the soils are Cambisols. The units with the largest area are selected and in them full soil profiles are pledged. Morphological descriptions of soil profiles have been made as required by FAO (2006) and Manual for Sampling and Analysis of Soil Guidelines (Cools and De Vos 2010). The litter is characterized by its structure, thickness of its layers and type. In the mineral part of the soil are found: soil horizons, thickness, transition, colour, moisture, soil texture, structure, and effervesce with 10 % HCl solution.

Soil samples are taken for analysis from the litter by layers and from the soil by genetic horizons. Parameters that allow the definition of qualifiers, for the classification of Cambisols on a second taxonomy level for *dystic* or *eutric* are investigated. The following analysis were performed: pH(H₂O) – ISO 10390; exchangeable cations – ISO 11260 and ISO 14254, determination with AAS in 0.1 mol/L solution of BaCl₂; exchangeable acidity – ISO 11260 and ISO 14254 (extracted with 0.1 mol/L BaCl₂ solution until equilibrated desorption and titration with 0.05 mol/L NaOH); Cation exchange capacity – defined as a sum of basic cations and exchangeable acidity; base saturation.

Results and Discussion

The territory of TEFR Petrohan is divided into 48 relatively homogeneous units with respect to the soil formation factors (Table 1).

Table 1. Signatura, characteristic and area of the territorial units.

No	Slope	Altitude, m	Slope exposition	Soil-forming rocks	Area, ha
1	flat and slanting	0–600	south, south-east, south-west and west	metamorphic silicate rocks	13
2			north, north-west, north-east and east	sedimentary silicate rocks	6.2
3				metamorphic silicate rocks	65.4
4		650–1450	south, south-east, south-west and west	igneous–acid and medium acid rocks	14.3
5				sedimentary carbonate rocks	1.7
6				metamorphic silicate rocks	4.3
7			north, north-west, north-east and east	igneous–acid and medium acid rocks	52.9
8				metamorphic silicate rocks	48.8

No	Slope	Altitude, m	Slope exposition	Soil-forming rocks	Area, ha
9		above 1500	south, south-east, south-west and west	igneous–acid and medium acid rocks	7.3
10				sedimentary silicate rocks	110.8
11				sedimentary carbonate rocks	58.3
46			north, north-west, north-east and east	igneous–acid and medium acid rocks	6.8
12	inclined	0–600	south, south-east, south-west and west	igneous–acid and medium acid rocks	6.3
13				metamorphic silicate rocks	43
14			north, north-west, north-east and east	igneous–acid and medium acid rocks	13.4
15				sedimentary silicate rocks	155.5
16				metamorphic silicate rocks	88
17		650–1450	south, south-east, south-west and west	igneous–acid and medium acid rocks	18.7
18				sedimentary carbonate rocks	13.8
19				metamorphic silicate rocks	21.6
20			north, north-west, north-east and east	igneous–acid and medium acid rocks	75.4
21				metamorphic silicate rocks	57.5
22		above 1500	south, south-east, south-west and west	igneous–acid and medium acid rocks	28.5
23				igneous basic rocks	0.9
24				sedimentary silicate rocks	22.9
25				sedimentary carbonate rocks	37.3
26			north, north-west, north-east and east	igneous–acid and medium acid rocks	18.2
27				sedimentary silicate rocks	0.1
28				sedimentary carbonate rocks	0.4

No	Slope	Altitude, m	Slope exposition	Soil-forming rocks	Area, ha
29	steep and very steep	0–600	south, south-east, south-west and west	igneous–acid and medium acid rocks	4.1
30				sedimentary silicate rocks	29.8
31				metamorphic silicate rocks	146.2
32				igneous–acid and medium acid rocks	116
33		650–1450	north, north-west, north-east and east	sedimentary silicate rocks	137.8
34				metamorphic silicate rocks	386.2
35				igneous–acid and medium acid rocks	937.4
36				sedimentary carbonate rocks	49
37				metamorphic silicate rocks	387.3
38				igneous–acid and medium acid rocks	1865.3
48				sedimentary silicate rocks	27.3
39				metamorphic silicate rocks	1163.2
40				igneous–acid and medium acid rocks	346.8
41				sedimentary carbonate rocks	34.5
47				metamorphic silicate rocks	24
42				igneous–acid and medium acid rocks	384.6
43		above 1500	south, south-east, south-west and west	sedimentary silicate rocks	0.8
44				sedimentary carbonate rocks	26.6
45				metamorphic silicate rocks	35.4

Fourteen soil profiles are investigated, placed in nine of the largest areas. The selected territory units are 4383.3 ha and they comprise 61.8 % of forest range wood production area. The main soil-forming rock in the soil profiles is granite, but

there is also sandstone. In the soil profiles all genetic horizons are developed (*A*, *Bw*, *C*). The litter depth varies between 1 and 5 cm. It is separated into two organic layers – *L* (fresh organic material) and *FH* (fragmented and partially decom-

posed organic matter). The forest litter is determined as *moder* type. The depth of the soil profiles (*A+B_w* horizons) varies between 20 cm and 109 cm. Depending on the degree of erosion *A* horizon depth varies between 8 cm and 41 cm. *B_w* horizon is between 20 cm and 97 cm+, which meets the requirements for cambic diagnostic horizon.

The pH (H_2O) in *A* horizon of the investigated soil profiles is between 5.5 and 4.1. Most of the soils are assessed as very acidic (profiles 1, 2, 9, 10, 11, 18, 21, 22, 23, 24, 25 and 30). In profile 3 the soil is highly acidic and in profile 28 is medium acidic. The highly soil acidity is result of the complex influence of acidic soil-forming rocks and mountainous climate of the northern slope of the Balkan. According to Nustorova (1988) the composition of soil microflora in this region produces roughly humus compounds with acidic reaction. Producing mainly acidic products of decomposition of organic matter is prerequisite for high leaching of basic elements and soil acidification. According to Ganev (1990) within the soils with pH lower than 4.8 acidification has advanced to the extent that in the soil present free fulvic acids and this explains the lower values of pH. As you can see from the results in Table 2 pH of the litter layers varies between 5.7 and 4.6, average with one pH unit higher than *A* horizon. The analysis shows that the influence of pH of litter layers is lower compared to the acidic products in the mineral part of the soil. Within the soil depth of the profiles pH usually increases and this is related to the increasing influence of soil-forming rocks, which are one of the main sources of basic cations for the soils. This regularity is observed not only on carbonate and basic rocks (Koinov et al. 1998, Teoharov et al. 2009), but also in soils formed on acidic silicate rocks. Ma-

linova (2014) for example has concluded a statistically significant difference in the values of pH in soil profiles with low and medium acidic reaction on the soil surface horizon of *dystric* Cambisols from the forest ecosystems large-scale monitoring network in the country. In the soil depth of the investigated soils is established an increase of pH values in profiles 1, 10, 18, 21, 22, 23, 24 and 25 in *B* horizon and for profile 21 this is observed in *C* horizon. In the other profiles (2, 3, 9, 11, 28 and 30), the profile distribution of pH does not differ in values. The high acidity covers the entire depth of the soil profiles. Similar results are established in Cambisols by Malinova (1996, 2015), Petrova (2018) and others. Contribution to the high acidity of the soils also have acidic atmospheric deposition, which according to Ignatova (2012) in separate years exceed critical loads. The balance between acidic and basic products of soil formation is in favour of acidic ones. Litter cation exchange capacity (CEC) is high and is due to cations with basic functions (Table 2).

The litter is saturated with bases and this is confirmed by other authors in other parts of the Balkan Mountains (Malinova 2016). It depends on a number of factors such as the characteristics of soil-forming rocks, applied forestry practices for example – the raking of litter (Hüttl and Schaaf 1993, Robert et al. 2012) and others. Important for this process is the influence of acidic soil-forming rocks (Blaser et al. 2008, Ferreira et al. 2016). It is considered that beech forests have specific impact on soil. According to Völker (1992) and Wittig (1986) the soil acidification at the base of the beech tree trunk is due to the large amount of stem flow. The effect leads to a decrease in saturation with soil bases close to the stems.

The exchangeable Ca predominates

Pro- file No	Hori- zon	Soil depth, cm	pH(H ₂ O)	Exch. Ca	Exch. Mg	Exch. K	Exch. Na	Exchange- able acidity	Exch. Mn	Exch. Fe	Sum of basic ex- changeable cations	Cation ex- change capacity CEC	Base satura- tion, %
18	L	4-0	5.3	36.22	3.78	1.22	0.03	0.81	1.41	0.02	41.25	42	98
	FH	1-0	5.2	49.01	3.04	0.63	0.03	1.32	1.12	0.01	52.71	54	98
	A	0-10	4.4	1.42	0.30	0.17	0.03	8.90	0.14	0.04	1.92	10.82	18
	Bw	10-62	4.8	0.76	0.09	0.05	0.04	5.22	0.02	0.01	0.94	6.16	15
	L	4-0	5.4	37.98	4.06	1.24	0.04	1.08	1.55	0.03	43.33	44	98
21	FH	1-0	4.4	32.30	2.05	0.51	0.02	2.20	1.44	0.02	34.88	37	94
	A	0-17	4.2	1.51	0.28	0.15	0.03	11.14	0.13	0.07	1.97	13.11	15
	Bw	17-90	4.7	0.58	0.07	0.04	0.03	4.38	0.03	0.01	0.73	5.11	14
	BwC	90-↓	5.2	0.32	0.02	0.02	0.02	1.13	0.01	0.01	0.38	1.52	25
	L	4-0	5.4	42.50	5.43	1.85	0.04	1.08	1.25	0.01	49.82	51	98
22	FH	1-0	4.5	33.68	2.39	0.77	0.04	2.11	1.41	0.03	36.88	39	95
	A	0-12	4.3	1.86	0.31	0.22	0.03	9.51	0.11	0.05	2.43	11.93	20
	Bw1	12-84	4.9	0.59	0.04	0.02	0.02	2.66	0.01	0.01	0.67	3.33	20
	Bw2	84-109-↓	5.2	0.29	0.02	0.02	0.02	0.94	0.00	0.01	0.35	1.29	27
	L	4-0	5.3	34.67	3.86	1.45	0.01	1.00	1.72	0.02	39.99	41	98
23	FH	1-0	4.6	33.25	2.04	0.56	0.04	1.77	2.27	0.03	35.89	38	95
	A	0-13	4.1	1.31	0.24	0.23	0.02	10.52	0.18	0.03	1.80	12.32	15
	Bw	13-47	4.9	0.55	0.04	0.02	0.02	2.85	0.02	0.01	0.64	3.49	18
24	LF	2-0	5.1	33.09	3.62	1.20	0.03	0.92	1.22	0.02	37.94	39	98
	A	0-12	4.5	1.40	0.24	0.20	0.03	7.81	0.08	0.04	1.87	9.68	19
	Bw	12-75	4.8	0.50	0.04	0.03	0.03	4.55	0.02	0.01	0.60	5.15	12

Pro- file No	Hori- zon	Soil depth, cm	pH(H ₂ O)	Exch. Ca	Exch. Mg	Exch. K	Exch. Na	Exchange- able acidity	Exch. Mn	Exch. Fe	Sum of basic ex- changeable cations	Cation ex- change capacity CEC	Base satura- tion, %
											cmol(+)·kg ⁻¹		
25	L	4–0	5.3	37.86	4.29	1.49	0.05	0.92	1.83	0.02	43.69	45	98
	FH	1–0	4.6	35.33	2.67	0.90	0.05	1.68	2.17	0.03	38.96	41	96
	A	0–8	4.1	1.62	0.35	0.21	0.03	10.76	0.13	0.09	2.22	12.98	17
	Bw1	8–20	4.6	0.53	0.12	0.07	0.02	5.97	0.04	0.01	0.74	6.72	11
	Bw2	20–58	4.9	0.41	0.04	0.03	0.03	3.34	0.02	0.01	0.51	3.86	13
28	BwC	58–105–↓	5.4	0.15	0.01	0.01	0.02	0.93	0.01	0.00	0.20	1.12	17
	A	0–8	5.5	9.06	0.65	0.13	0.04	0.82	0.06	0.01	9.88	10.70	92
	Bw	8–20	5.8	6.36	0.58	0.04	0.03	0.71	0.02	0.01	7.01	7.72	91
	BwC	20–58	6.0	7.51	0.93	0.07	0.05	0.41	0.01	0.01	8.56	8.97	95
	LF	1–0	4.9	28.93	2.79	0.89	0.03	1.43	1.20	0.03	32.64	34	96
30	A	0–10	4.4	3.07	0.49	0.35	0.02	7.02	0.17	0.07	3.94	10.96	36
	Bw	10–63	4.7	0.14	0.06	0.04	0.03	4.76	0.04	0.01	0.27	5.03	5
	C	63–93–↓	4.7	0.11	0.04	0.03	0.02	3.26	0.01	0.01	0.19	3.45	6

and varies in layer *LF* between 28.17 cmol(+)-kg⁻¹ and 42.51 cmol(+)-kg⁻¹ and in *FH* from 32.30 cmol(+)-kg⁻¹ to 49.01 cmol(+)-kg⁻¹. Litter base saturation is between 95 – 98 %. This high litter base saturation in beech stands of western Balkan Mountains area is confirmed by other authors. According to Malinova (2014) the difference between the content of exchangeable Ca in the litter and in the topsoil is 14 times in favour of the litter. The difference between the content of the total calcium in litter and in the topsoil is 18 times. This is due to the high acidity of the soil, which favours the presence of increased amounts of easily uptake of calcium for the plants and through the litterfall is back into the litter. It should be noted that litter basic richness is not inherent of the soil surface horizon. Soil leaching occurs and impoverishment of calcium and other mobile elements in acid soils.

Results show that conversion of heterogeneous organic material in the litter into homogeneous humic substances in the soil is connected to significant loss of basic cations. This is proven by the values of CEC in the surface soil horizon. In it CEC highly varies between 1.38 cmol(+)-kg⁻¹ and 13.11 cmol(+)-kg⁻¹, and decreases compared to its quantities in the litter – between 3 and 13 times over. According to Vanmechelen

(1997) CEC scale value in majority of the obtained values is classified as high – profiles 18, 21, 22, 23, 25, 28 and 30, medium – in profiles 9, 10 and 24 and low – in profiles 2, 3 and 11. Only in profile 1 the value is very low. The variation of the results for CEC in A horizon is mainly due to changes of the quantities of exchangeable Ca and exchangeable acidity, which are connected and with changes of active soil acidity.

Cause-effect relationship 'increasing acidity – decreasing values of the exchangeable Ca' is illustrated in Figure 1. It is proven with moderately high value of correlation coefficient ($r=0.69$). Along with the decrease of exchangeable Ca, the soil exchangeable acidity increases, and this affects the magnitude of CEC. CEC increases due to increasing of soil exchangeable acidity ($r=0.80$) (Fig. 2).

In the soil profiles depth, the values of CEC decrease, except in profile 1, which

is highly leached and has lower values of exchangeable Ca (Table 1). It should be noted that although very high soil acidity the leaching is on a stage where the exchangeable cations are ordered by quantity in their usual order exchangeable Ca > exchangeable Mg > exchangeable K > exchangeable Na. The ratio between exchangeable Ca: exchangeable Mg in A horizon is decreased to a maximum of 3 (profile 1) with pH 4.5 and is highest – 14 (in profile 28) with pH 5.5. These changes are due to a reduction in the quantities of exchangeable Ca in the process of soil acidification. The correlation between 'pH–exchangeable Ca: exchangeable Mg' is proven by the correlation coefficient $r=0.66$. Thirteen of the fourteen investigated soil profiles correspond to the definition for qualifier *dystic*. The base saturation in A horizon of these profiles varies between 13 % and 36 %, in Bw horizon is between 4 % and 39 %. The value of 4 % base

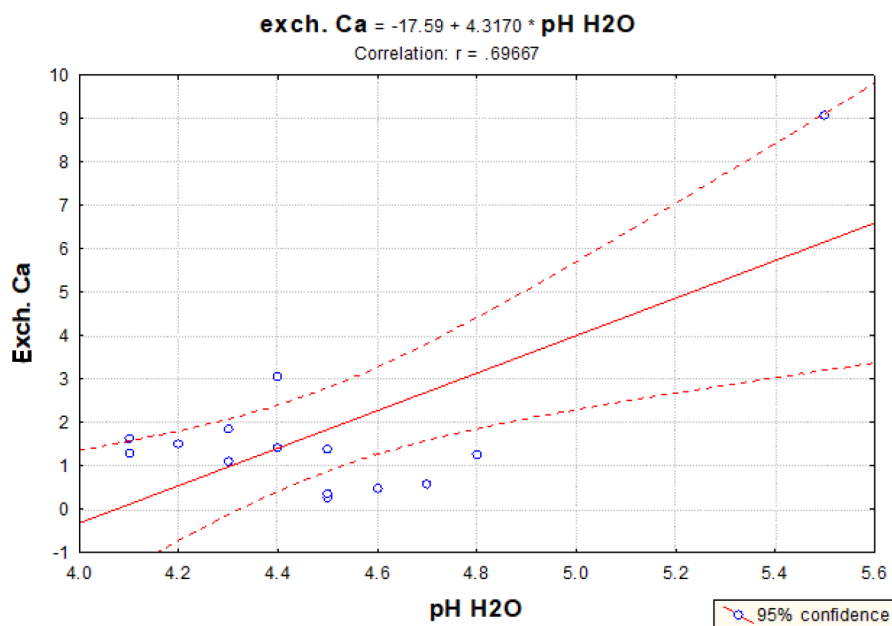


Fig. 1. Relationship between soil active acidity and exchangeable Ca.

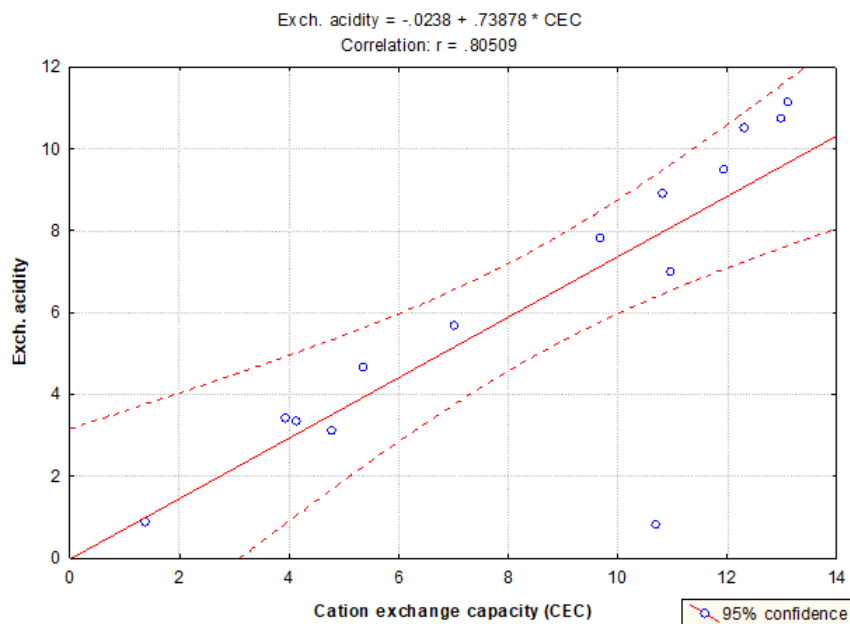


Fig. 2. Relationship between magnitude of Cation exchange capacity (CEC) and soil exchangeable acidity.

saturation is very low, but it remains above the critical 3 % below which damage to the roots of beech seedlings was observed (Richter et al. 2007, Richter et al. 2011).

In one of the soil profiles – 28 the soil is with high base saturation – 91–92 % within the surface horizon and in cambic horizon.

The cation exchange properties of Cambisols in the representative samples show that on a second taxonomy level they classify as *dystic*. In only one soil profile the qualifier is *eutric*.

Conclusions

The soil formation process in the investigated Cambisols of TEFR Petrohan is aimed at the dominant influence of acidic products obtained of the decomposition of organic matter over basic ones – associated with soil weathering processes in

soil-forming rocks. The leaching is increased, and in some cases, it covers the whole soil profile depth. The high soil acidity defines as a main qualifier *dystic* for the Cambisols classification on a second taxonomy level.

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ASSESSING OF THE TOLERANCE OF *PINUS HALEPENSIS* MILL. SEEDS TO WATER AND SALINE STRESS AT THE GERMINATION STAGE

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Abstract

Arid and semi-arid ecosystems cover a large part of the southern fringe countries of the Mediterranean basin. Drought and salinization are the major processes of steppe land degradation. The objective of this work was to investigate the tolerance to water and saline stress of Aleppo pine (*Pinus halepensis* Mill.) seeds at the germinating stage. The adopted methodology used increasing concentrations under a controlled temperature of 20 °C for 30 germination days of seeds. Germination responses of seeds to different degrees of salt stress caused by NaCl (1, 2, 3, 4, and 5 g·L⁻¹) and the water stress caused by polyethylene glycol (–0.05, –0.25, –0.5, –1, and –2 bars) under a temperature of 20 °C showed that salt and water stress have decreased the percentage of seed germination of Aleppo pine seeds for a period of 30 days. In the control treatment (distilled water) with no stress the seeds showed a germination rate of 89 % for salt stress and 90 % for water stress. The results of the study showed that salt and drought have a depressive effect on the germination rate of Aleppo pine with a tolerance of 4 g·L⁻¹ and –1 bars for the stresses used.

Key words: Aleppo pine, drought, germination tests, NaCl, Polyethylene glycol (PEG), semi-arid.

Introduction

Algeria is one of the most water-deficient regions in the world, and the water resources are subjected to strong natural, climatic and anthropogenic pressures (Bellal 2011). The water deficit is more than 20 % for the western region, 13 % for the central and 12 % for the eastern part of the country (Ould Amara 2000, Bouguerra 2001). Arid and semi-arid area cover very large surface and are characterized by a high rainfall irregularity. These areas re-

ceive an annual average rainfall between 100 and 300 mm for the arid and between 300 and 600 mm for the semi-arid one (Le Houerou 1995, Nedjraoui 2003, Ramade 2003). Besides, they are characterized by very restrictive edapho-climatic conditions, thus posing challenges to survival of some indigenous plant species, which are subjected to constant stress by the severe environment.

In these regions, the availability of water, salinity and some other soil characteristics are among the main factors limiting

plant productivity (Zid and Grignon 1991). In Algeria, the long-observed drought has clearly led to the process of salinization of soils on 3.2 million hectares (Benmahioul et al. 2009). This natural constraint has had a huge impact on the stability of ecosystems and caused a large part of desertification and soil salinization (Sadio 1989, Szabolcs 1992).

Aleppo pine is a major forest tree species in the Mediterranean basin, covering more than 250,000 km² (Quezel 2000). In Algeria it occupies 850,000 ha (Mezali 2003). The pine forests have been experiencing intense human pressure for centuries (clearing, illegal logging, fire, grazing), causing deforestation and decline of native plants. Aleppo pine is the most widely used tree in the reforestation in arid and semi-arid degraded areas. It is characterized by relatively shorter life span, usually not exceeding 150 years. Its growth can reach 10 m in 20 years. It is a tree that has a pivoting rooting depending on the nature of the soil and its fertility. Like other pines, it is a monoecious tree characterized by winged seeds between 5 and 7 mm in length (Bentouati 2006). Old Aleppo pine stands do not always regenerate easily, except in the case of fire. Foresters encounter difficulties in regenerating these mature stands, where the regeneration is often absent. In this context, managers seek to understand and know the techniques and treatments that facilitate the natural regeneration of these pine forests (Prévosto et al. 2009).

Seed dormancy is one of the tolerance mechanisms developed by plants found under conditions of high aridity, temperature, and salinity (Fenner 1985). The maintenance of plants under limiting environmental conditions is primarily dependent on the success of germination (Ungar 1982, 1991). Several factors inter-

act in the regulation of germination (water, temperature, light and salinity). Also, germination is regulated by genotypic characteristics (Guterman 1994). Thus, seed germination is the most sensitive stage of plants exposed to salt and water stress (Boulghalagh et al. 2006). Most plants may be considered to be more sensitive to salinity during their germination and emergence phases (Maillard 2001). Among the causes of inhibition of germination in the presence of salt, the change in hormonal equilibrium was evoked (Kabar 1987). A delay in the germination caused by salinity was shown in several species (Ndour and Danthu 1998, Benata et al. 2006, Boulghalagh et al. 2006). Work carried out on Halophytes showed that the inhibitory effect of NaCl on germination would be essentially osmotic in nature, with salt preventing the implantation of the seed (Katembe et al. 1998).

In relation to the above statements, the aim of this work was to study the effect of the main environmental constraints affecting seed germination of Aleppo pine, including drought and salinity, modelled in laboratory conditions. Aleppo pine was selected as a subject of study because of the problems existing with its regeneration in arid and semi-arid areas, which are the last ramparts against desertification.

Materials and Methods

Collection of Aleppo pine seeds

Mature three-year-old cones were selected for our study. They were harvested in early August 2016. Further on, they were put in plastic bags and exposed to the sun for one or two months to allow the cones to burst and release the seeds (General Directorate of Forests nursery Technique).

Cones from older trees were harvested in the pinewood of Fenouane (geographic coordinates 34°30'13.08" N; 3°28'17.16" E) (Fig. 1), located in the territory of the wilaya of Saida, some 550 km southwest

of Algiers and about thirty kilometres to the west of Saida (BNEF 1990). It is managed by the Conservation service of the forests of Saida and is part of the district of Ain El-Hajar wilaya of Saida (Algeria).

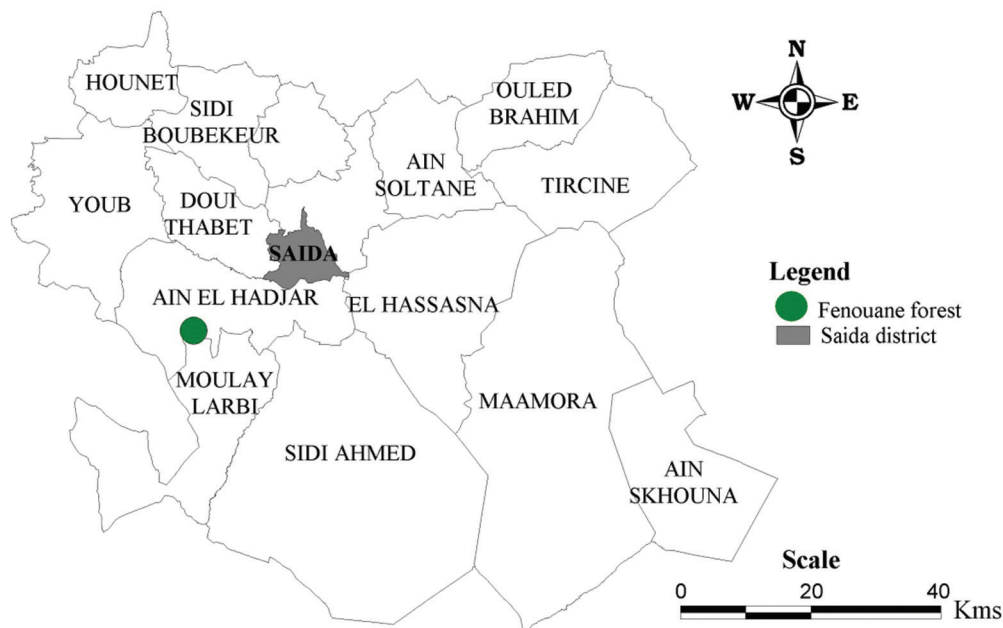


Fig. 1. Location of the harvest area of the *Pinus halepensis* grains (BNEFER 1992, modified by Zouidi).

Effect of osmotic stress on germination

Integumentary inhibition was lifted following a protocol that recommends disinfection of seeds for 10 minutes in an 8 % sodium hypochlorite solution and then rinsing the seeds by water several times followed by soaking the seeds in distilled water for 24 hours (Nedjimi et al. 2014). Germination tests were carried out under different levels of water potentials through the use of Polyethylene glycol (PEG), which forms a non-permeable, hydrosoluble non-ionic polymer for the cells. It is used to induce a water deficiency by reducing water availability without causing physical damage to

plants (Romo et al. 2001), having a molar mass of 6000. Germination tests were carried out with 20 seeds per petri dish (diameter 9 cm).

Each petri dish was coated with two layers of filter paper at optimum germination temperature (20 °C). Polyethylene glycol (PEG) 6000 solutions of increasing concentrations and inducing also increasing water potentials (by the equation established by Michel and Kaufman (1973)) were used to induce the different levels of osmotic stress tested. The water potential values tested were 0, -0.05, -0.25, -0.5, -1, and -2 bars. The duration of the test was set at the germination period, which spread over 30 days, and the counting

of the germinated seeds was done daily. According to Michel and Kaufman (1973), the equation (1) linking the various parameters was as follows:

$$\Psi_h = -(1.18 \cdot 10^{-2}) C - (1.118 \cdot 10^{-4}) C^2 + (2.67 \cdot 10^{-4}) C \cdot T + (8.39 \cdot 10^{-7}) C^2 \cdot T, \quad (1)$$

where: Ψ_h – is water potential in bar; T – incubation temperature in °C; C – concentration of PEG 6000 in g·L⁻¹.

Effect of salinity on germination

We conducted the germination tests under saline stress using the optimum germination conditions determined by previous experiment. Seeds were germinated in petri dishes on filter paper, watered daily with distilled water containing different concentrations of NaCl (0, 1, 2, 3, 4, and 5 g·L⁻¹) and arranged at optimum germination temperature (20 °C) (Thanos and Skordilis 1987). The test duration was determined by the 30-day germination period. Germination was monitored every 24 hours, and germinated seeds were counted and removed from the batch. The time taken for the germination percentages of all replicas to reach 50 % was recorded as TG50. The counting of germinated seeds was carried out on a daily basis.

Parameters measured

The germination rate for each batch (TG) is the best indicator for identifying the concentration of PEG and NaCl that present the physiological limit of germination of the seeds. It is expressed by the ratio of the number of seeds germinated to the total number of seeds. On the germination test the definitive percentage of germination was determined (Agrobio 2013). The rate of germination may be expressed by the median germination time (Scott et al. 1984) or by the mean germination times

(the time at which 50 % of the seed germination is reached) (Côme 1970, Lachiheb et al. 2004). It is expressed in equation (2):

$$V = T_1 + [(0.5 - G_1 / G_2 - G_1) \cdot (T_2 - T_1)], \quad (2)$$

where: G_1 (%) is the cumulative seed germination with a value closer to 50 % (lower) and G_2 (%) cumulative seed germination with a value closer to 50 % (higher) (Lachiheb et al. 2004); T_1 – number of days is the cumulative percentage of sprouted seeds whose value is closer to 50 % (lower); T_2 – number of days is the cumulative percentage of sprouted seeds whose value is closer to 50 % (higher).

Statistical analysis

The results were subjected to analysis of variance (ANOVA) with a single factor of variation at 5 % probability level ($P \leq 0.05$) after controlling normality distribution for comparing the averages of germination rates with stress. The post-hoc Fisher (LSD) test was applied for multiple comparisons of means. We used Statistica software package version 7.0.

Results

Effect of osmotic stress on the germination

Our results showed the effect of increasing PEG concentrations on Aleppo pine seeds subjected to different osmotic stresses. Thus for untreated seeds (controls) the germination rate was highest – 90 % with a short latent phase that lasts only six days. It was also noted that the application of osmotic stress of (-1 bar) resulted in a low germination rate not exceeding 21 %, while there was no germination at higher stress (-2 bar).

The analysis of the variance (ANOVA single factor) showed a highly significant effect ($P < 0.001$) of the different concen-

trations of Polyethylene glycol (PEG 6000) on the rate and velocity of germination of the seeds of Aleppo pine (Fig. 2).

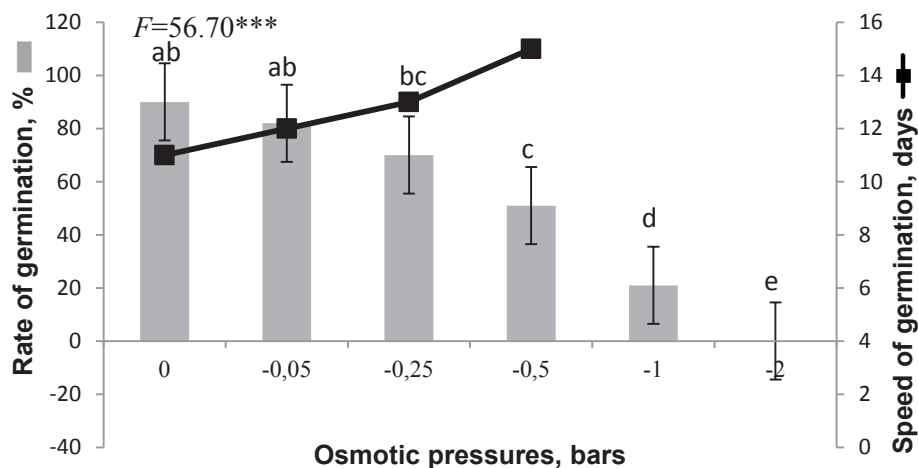


Fig. 2. Effect of different osmotic pressures on the rate and velocity of germination of Aleppo pine seeds.

Note: The bars and whiskers represent the mean $\pm$ standard deviation ($n=5$ repetitions). Significance level: * – $P < 0.05$, ** – $P < 0.01$, *** – $P < 0.001$, NS – not significant.

Effect of saline stress on the germination

The results of the effect of NaCl on the germination of Aleppo pine seeds are presented in Fig. 3. The first germination of seeds was observed in petri dishes containing seeds soaked in distilled water after 7 days of experiment initiation. The results also showed that seed germination rates decreased with increasing of NaCl dose from the control to $4 \text{ g} \cdot \text{L}^{-1}$. It was observed that the germination rate of Aleppo pine seeds differed from one concentration to another. Based on these results, a maximum value of 89 % for unstressed NaCl seeds was observed, and a gradual decrease was registered with the increase in NaCl concentration to 21 %

for the highest saline stress ($4 \text{ g} \cdot \text{L}^{-1}$). Our results clearly show that the seeds of *Pinus halepensis* germinate better in the absence of salt or in a medium enriched with NaCl at low concentration 1, 2 and $3 \text{ g} \cdot \text{L}^{-1}$. When the salt concentration increased to $5 \text{ g} \cdot \text{L}^{-1}$ NaCl, seeds did not germinate. In general, the rate of germination decreases considerably with increasing saline stress of the substrate.

The results of ANOVA showed that there is a significant difference in the germination rate of Aleppo pine ($P < 0.001$) seed soaked by different salt-concentrated solutions (Fig. 3).

Salt affects the rate of germination, and a slowdown was observed with the increase in salt in the water. In the absence of salt, the seeds required 11 days

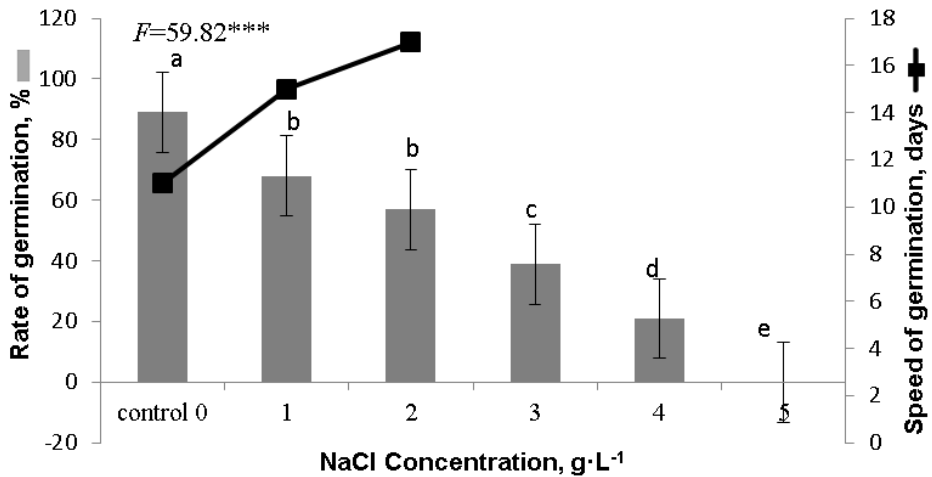


Fig. 3. Effect of different saline stress on the rate and speed of germination of Aleppo pine seeds.

Note: The bars and whiskers represent the mean $\pm$ standard deviation ($n=5$ repetitions). Significance levels: * – $P<0.05$, ** – $P<0.01$, *** – $P<0.001$, NS – not significant.

to reach a rate of 50 %, while in the presence of salt (1 and 2 g·L⁻¹) they needed 15 and 17 days, respectively, to reach 50 % germination in comparison with the controls.

Discussion

Effect of water stress on germination

Aleppo pine is an important forest tree species in the Mediterranean area. In Algeria, it is used as a major species in reforestation and repopulation to ensure the equilibrium and maintenance of many semi-arid and arid ecosystems (Bentouati et al. 2005, Kadik 1986). Indeed, some authors have shown that due to its plasticity and its low requirements, Aleppo pine remains the most used species in these degraded areas. It adapts to all soil types, when the climatic conditions are favourable (Bentouati et al. 2005, Kadik 1986).

The use of this species in afforestation programmes offers a sustainable reforestation solution in arid and semi-arid areas characterized by warm and dry climate and would, therefore, provide opportunities for diversified farms. Nevertheless, the success of the germination and growth phases of this species inevitably results in a good knowledge of its germination and developmental characteristics, as well as its behaviour towards environmental conditions. Our results show that the average germination rate of control treatment (0 bars) is 90 %. According to Hamrouni et al. (2011), the germination rates in Tunisia exceed 80 % irrespective of the provenance and the place of cultivation.

The same authors showed that the germination rate can reach 70 % for good quality lots (-0.05 bars) and (-0.25 bars). These results indicate that the germination rate decreases considerably with increasing substrate water stress. Usually

most of the studies on the impact of osmotic stress on germination show that the germination rate decreases considerably with increasing the stress. Similar results were obtained in various studies on *Pinus ponderosa* Douglas ex C. Lawson and *P. eldarica* Medw. (Djavanshir and Reid 1975), *P. brutia* Ten and *P. eldarica* (Calamassi et al. 1980), *P. taeda* L. (Dunlap and Barnett 1984), and *P. halepensis* and *P. brutia* (Thanos and Skordilis 1987).

In the absence of sufficient moisture, even if the seed is properly placed in the soil, it does not evolve, and in case of drought persistence the situation can result in an absence of emergence (Feliachi et al. 2001).

Drought is one of the major environmental factors that greatly affects the germination of cultivated species and reduces their survival in early stages of development. Our results also show that the rate of germination becomes slow with increasing of stress. According to Bliss et al. (1986b) the delayed germination of the seeds, as well as the decrease in the average daily germination of all genotypes with the increase in water stress is explained by the time necessary for the seed to put in place mechanisms allowing it to adjust its internal osmotic pressure. When the seeds are subjected to osmotic pressure, this velocity becomes even lower, while the final percentage of germination is affected only when the osmotic potential is low. This is observed in most *Pinus* species (ISTA 1976 in FAO 1992) and the delay can be attributed to the seed layer acting as a barrier to water penetration into the embryo (Thalouarn 1975).

Falusi et al. (1983) studied the effects of substrate water potential on germination and on the first stage of root growth of 4 provenances of Aleppo pine (Israel, Morocco, Greece, and Italy) and showed

a significant reduction in germination in % at -2 bars, while root growth was assigned to -4 bars. Different sources demonstrated significantly different responses to water stress. Our results showed that seeds harvested in the semi-arid zone exhibited significantly different responses to water stress with great germination power under ideal conditions (control). On the other hand, those who have undergone stress presented a low rate of germination and therefore are less resistant to the extreme climatic conditions of the zone.

Effect of saline stress on germination

The results of the variance analysis revealed significant differences in the germination rate of Aleppo pine ($P < 0.001$) seeds soaked by different salt-concentrated solutions. Indeed, the higher salt concentrations of the environment caused decreasing of germ power. Most plants are more susceptible to salinity during their germination and emergence phases (Maillard 2001). Of the causes of inhibition of germination in the presence of salt, the change in hormonal equilibrium has been outlined (Ungar 1978, Kabar 1987). Although halophytes have very high salt content in their adult tissues, their seeds are not as salt tolerant at the germination stage (Belkhodja and Bidai 2004). This stage is often limited by soil salinity and is more sensitive than other stages (Bouda and Haddioui 2011). Salinity may result in a decrease in the final germination rate and may in turn lead to the establishment of irregular stands and reduce harvest yields (Yildirim and Güvenç 2006).

The excessive presence of soluble salts can cause high osmotic pressure in plants and inhibition of seed germination as well as the development of the whole plant by reducing its ability to retain water

with consequences on the level of growth and metabolic activity (Belkhodja and Bidai 2004). The inhibitory effects of salinity on the germination process can also be explained by altered enzymatic activity, which is indispensable for cell reactivation during this phase. Thus, salinity inhibits the activity of several enzymes (Larcher 1995). Our results clearly show that the seeds of Aleppo pine germinate better in the absence of salt with a good concentration rate and at a speed accelerate and even in a medium enriched with NaCl at low concentration 1, 2, and 3 g·L⁻¹.

Increasing of salt concentration to 5 g·L⁻¹ NaCl alters the seed germination. Salt stress tolerance in pines is moderately low as shown by Rocco et al. (2013). In the presence of salt stress the proteins in the Aleppo pine needles affected by stress include the proteins involved in photosynthesis. Aleppo pine is affected by high concentrations, which was reported also for other species. For example, Bouda and Haddioui (2011) applied the same treatment on *Atriplex* seeds, and found that the rate of germination inhibition of seeds stressed by NaCl stops at 5 g·L⁻¹. The decrease in germination rate and the slowing of germination velocity of seeds exposed to salinity is explained by an increase in external osmotic pressure, which affects the absorption of water by seeds due to accumulation of Na⁺ and Cl⁻ ions in the embryo (Groome et al. 1991). This toxic effect can lead to the alteration of the metabolic processes of germination and in extreme cases to death of the embryo by excess of ions. Thus the emergence of radicle would be controlled by the osmolality of the medium (Bruggeman et al. 2002).

According to Bliss et al. (1986a) the delay in germination following the increase in salt stress is due to the fact that

the salt seems to prevent the hydration of the seeds to reach the threshold when germination becomes visible. This is also due to the time required for the seed to put in place mechanisms allowing it to adjust its internal osmotic pressure and thus allowing for a germination.

Sidari et al. (2008) showed that seed germination and the activities of the main enzymes involved in *Pinus* seed reserve utilization (glyoxylate cycle enzymes) decreased with increasing PEG, NaCl and seawater concentrations.

Conclusions

In the arid and semi-arid zones of Algeria, the long-observed drought has clearly led to salinization of the soils. The combination of these two natural stresses becomes increasingly stressful for the germination and growth of plants in their natural environment. The study of the germination of Aleppo pine is very important since it is considered very important species for reforestation. It is introduced to restore the degraded areas and occupied bare land in steppe areas, in arid and semi-arid zones. The main peculiarities of the germ behaviour of Aleppo pine seeds in the face of abiotic stresses can be summarized as follows: For water stress, the germination rate and the average daily germination are strongly affected and decrease with increasing the concentration of added PEG. In the absence of stress, the maximum germination rate in the presence of sufficient moisture is about 90 %. Stressed seeds did not withstand more than -1 bar PEG with low germination rates (21 %). For saline stress the species germinated better in a salt-free treatment (control) with a germination rate of 89 % and an average daily germination

of 2.96. On the other hand, the seeds with a stress in the order of $4 \text{ g}\cdot\text{L}^{-1}$ NaCl have a low germination rate of the order of 21 %. The rate of germination could be considered an early criterion for selection of plant species tolerant to salt stress and water stress. According to the results obtained, it can be concluded that Aleppo pine is a fragile species at the time of seed in dry media and media rich in NaCl and does not tolerate large concentration of NaCl. The estimated degree of tolerance to the stress salts is $4 \text{ g}\cdot\text{L}^{-1}$ and to water stress is -1 bar.

The rate of germination decreases considerably with the increase of abiotic stress, whether water or saline. The natural regeneration of pine is difficult to achieve, because it is subjected to multiple abiotic and biotic constraints and their interactions, which remain only partially known (Adili 2012). A better understanding of these factors is necessary for the development of silvicultural recommendations to increase natural regeneration.

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INCIDENCE AND SEVERITY OF SYMPTOMS ASSIGNED TO *FRAXINUS EXCELSIOR* BACTERIAL DISEASE IN THE LEFT-BANK FOREST STEPPE OF UKRAINE

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Abstract

The aim of the research was to estimate the spread of bacterial disease on European ash (*Fraxinus excelsior* L.), ocularly estimated by lens-shaped blisters, swellings and cracks of the bark in Pridonetsky and Vorskla-Pselsky forest typological sector of the Left-bank Forest-Steppe zone of Ukraine. Studies were carried out in the year 2018 at 112 sample plots in Trostyanetske Forest Enterprise of Sumy region (Vorskla-Pselsky forest typological sector), Chugujevo-Babchanske and Skrypavivske Forest Enterprises of Kharkiv region (Pridonetsky forest typological sector). In spite of the fact that both the incidence and severity of ash bacterial disease symptoms are significantly higher for particular forestries and pooled data from Sumy region, the health condition index (HCI) of ash trees is greater for forestries of Kharkiv region. Therefore, ash stands in the inspected forestries of Sumy region are weakened, and in those of Kharkiv region are severely weakened. Ash tree mortality was rather low in them. The highest ash mortality was registered in Krasnyanske forestry (12.1 %) of Trostyanetsky forest enterprise. No significant correlation was proved between parameters of ash bacterial disease and altitude. Significant correlation was proved between the incidence and severity of ash bacterial disease symptoms, health condition index and mortality, diameter at breast height (DBH) and disease severity. However, only the correlation of incidence and severity of ash bacterial disease symptoms is high for Kharkiv region ($r_p=0.74$, $r_s=0.95$) and moderate ($r_p=0.54$) or high ($r_s=0.73$) for Sumy region. Obtained distinction in ash disease incidence and severity in different forest typological sectors data may be explained by climate features. Higher precipitation and moisture indices in Vorskla-Pselsky forest typological sector is favorable for ash bacterial disease. However, higher temperature together with lower humidity in Pridonetsky forest typological sector are unfavorable to ash and increases its susceptibility to other damage causes, particularly frost and insects.

Key words: bacterial canker, European ash, health condition, mortality.

Introduction

Health condition of European ash (*Fraxinus excelsior* L.) in Europe have been worsening since recent years (Kowals-

ki 2006, Goberville et al. 2016), which is connected with climate change, unfavorable for forest trees (Shvidenko et al. 2017), and with a spread of injurious organisms. Many causes of European ash

decline have been observed, particularly insect pests (Davydenko and Meshkova 2017, Meshkova and Borysova 2017) and pathogens (Goychuk and Kulbanska 2014, Matsiakh and Kramarets 2014, Langer 2017), including invasive fungus *Hymenoscyphus fraxineus* (Kowalski 2006, Pautasso et al. 2013, McKinney et al. 2014), which is present also in Ukraine (Davydenko et al. 2013).

Bacterial disease of European ash, or bacterial canker, or so-called 'tuberculosis' of ash reveals clearly visible symptoms so called 'Eschenrindenrosen' = ash bark roses (Tubeuif 1936). These are smooth layers of suberized tissue surrounding a wound penetrating to the wood. The causal agent of these disease symptoms is the bacterium *Pseudomonas syringae* subsp. *savastanoi* pv. *fraxini* (Kulbanska 2015a). The disease is spread in the natural range of European ash, including the most part of Europe (Janse 1981a, 1982), particularly Ukraine (Goychuk and Kulbanska 2014, Kulbanska 2015a). According to many researchers, infection of trees, occurs through bark wounds and cracks, damage by frost, hail, game, and human activity (Janse 1981b, Kulbanska 2015b).

The data on the disease and its correlation with certain climatic or forest conditions are fragmentary (Kulbanska 2015a, Meshkova et al. 2018). Studies are usually focused on the pathogen itself and the peculiarities of pathological changes in tree plants under the influence of pathogen or on the resistance of different *Fraxinus* species to infection (Kulbanska 2014).

However, comparative assessment of spread and development of ash bacterial disease in different regions has not been carried out yet.

The aim of the presented study was to estimate the spread of bacterial disease of European ash in Pridonetsky and Vorsk-

la-Pselsky forest typological sector of the Left-bank Forest-Steppe zone of Ukraine.

Materials and Methods

Study was carried out in 2018 in two groups of forest stands in the fresh ash and lime oak stands of the Left-bank Forest-Steppe zone of Ukraine. The territory of Trostyanetske Forest Enterprise belongs to Vorskla-Pselsky forest typological sector, and the territory of Chugujevo-Babchanske Forest Enterprise and Skrypavivske Training and Experimental Forest Enterprise belongs to Pridonetsky forest typological sector (Ostapenko and Vorobyev 2014, Nazarenko and Pasternak 2016).

The parameters by which the territory of the certain forest enterprise belongs to a particular forest-typological sector were evaluated from long-term data (2005–2018) of air temperature and precipitation for two meteorological stations: Zmiyiv (49°41' N, 36°21' E) in Kharkiv region and Trostyanets (50°48' N, 34°96' E) in Sumy region (rp5.ru 2019).

The following climatic parameters were calculated:

T-index (*T*) is the sum of the average monthly air temperatures over the months with temperatures above 0 °C. Moisture index (*W*) according to Vorobyev (Ostapenko and Vorobyev 2014) is evaluated by formula (1):

$$W = (R/T) - 0.0286 \times T, \quad (1)$$

where: *R* is precipitation for months with positive air temperature.

Continentality index *A* is the difference between mean monthly temperature of January and July (Ostapenko and Vorobyev 2014). Additionally, Selyaninov hydrothermal index (HTI, Selyaninov 1937) was calculated for 2005–2018 by the for-

mula (2):

$$HTI = 10 \times \frac{\sum P}{\sum t}, \quad (2)$$

where: $\sum P$ is precipitation for a period with mean month air temperature over 10 °C, mm; $\sum t$ is the sum of daily air temperature for the same period, °C (Table 1).

Table 1. Climatic parameters for investigated group of points (2005–2018).

Meteorological station	T, °C	R, mm	W	A, °C	HTI mm/°C
Zmiyiv (49°41' N, 36°21' E), Kharkiv region	105.9	383	0.59	27.5	0.97
Trostryanets (50°48' N, 34°96' E), Sumy region	103.0	421	1.14	27.0	1.10

Survey of stands partially timbered with European ash was carried out in four forestries (Neskuchanske, Lytovske, Makivske and Krasnyanske forestries) of Trostryanetske Forest Enterprise of Sumy region and in two forest enterprises of Kharkiv region: Chugujevo-Babchanske Forest Enterprise (Kochetokske forestry) and Skrypayivske Training and Experi-

mental Forest Enterprise (Skrypayivske and Mokhnachanske forestries) (Table 2). Sample plots were located along the profiles, directed perpendicular to the river terraces (Nazarenko and Pasternak 2016). The altitude of sample plots location was 143–182 m a.s.l. in Sumy region and 107–184 m a.s.l. in Kharkiv region (see Table 2).

Table 2. Location of inspected forest stands.

Forest Enterprises	Forestry	Latitude, N	Longitude, E	Altitude, m a.s.l.	Number of plots	Number of ash trees
Sumy region (Vorskla-Pselsky forest typological sector)						
Trostryanetske	Krasnyanske	50°48"	34°77"	182	19	513
Trostryanetske	Lytovske	50°36"	34°86"	143	26	409
Trostryanetske	Makivske	50°53"	34°97"	165	8	34
Trostryanetske	Neskuchanske	50°46"	34°90"	171	20	573
Kharkiv region (Pridonetsky forest typological sector)						
Chugujevo-Babchanske	Kochetokske	49°52"	36°44"	151	10	433
Skrypayivske	Skrypayivske	49°70"	36°53"	107	12	490
Skrypayivske	Mokhnachanske	49°74"	36°51"	184	28	690
Total	—	—	—	—	112	3142

Broadleaved tree species (*Quercus robur* L., *F. excelsior* L., *Betula pendula* Roth, *Alnus glutinosa* (L.) Gaertn, *Acer platanoides* L., *Ulmus laevis* Pall, etc.) dominated in both groups of stands.

Survey covered 3142 trees of European ash (see Table 2) at the age of 5–110 with 0.6–0.8 relative density of stocking.

2–4 subplots of 10×10 m were inspect-

ed in each forest plot. The number of plots depended on ash proportion in the stand. The aim was to assess at least 25 ash trees per plot, if possible. Only in inspected stands of Makivske forestry were rather few ash trees.

Stand age was not homogenous in most of plots, because ashes of vegetative origin and seed specimens of differ-

ent age were presented. Therefore, we considered the diameter at breast height (DBH) as more reliable parameter.

Besides DBH several parameters of ash health condition were additionally assessed in each sample plot.

The incidence of bacterial disease related to *Pseudomonas syringae* subsp. *savastanoi* pv. *fraxini* was estimated as proportion of living ash trees with characteristic symptoms (lens-shaped blisters and swellings as well as vertical and lateral cracks, Fig. 1) within the sample plot. Then the average value was calculated for each forestry.



Fig. 1. Lens-shaped blisters and swellings on the ash bark attributive to bacterial disease of ash.

Severity of bacterial disease for each ash tree was estimated by score: 0 – absence of lens-shaped blisters and swellings; 1 – sporadic lens-shaped blisters and swellings as well as vertical and lateral cracks; 2 – multiple lens-shaped blisters and swellings with numerous vertical and lateral cracks (Janse 1981b). Severity of bacterial disease for each sample plot was evaluated as an arithmetic average of all trees scores.

Tree mortality was expressed as a percentage of dead ash trees out of the total ash trees per plot.

Category of tree health condition was evaluated on a range of visual characteristics (crown density and color, the presence and proportion of dead branches in the crown, etc.) according to 'Sanitary rules in the forests of Ukraine' (Anonymous 1995). Each tree was referred to one of six categories of health condition (1st – healthy; 2nd – weakened; 3rd – severely weakened; 4th – drying up; 5th – recently died; 6th – died over year ago). Health condition index (HCI) for each plot was calculated as mean of the health condition categories of studied trees.

According to 'Sanitary rules in the forests of Ukraine' (Anonymous 1995) the stands with HCI 1.5–2.4 are considered as weakened, with HCI 2.5–3.4 as severely weakened, with HCI 3.5–4.4 as drying up and with HCI above 4.5.

The data for all inspected plots were pooled for each forestry, and then for each region for analysis.

Normality tests, summary statistics, one-way analysis of variance (ANOVA), Tukey HSD test with a significance level of $p < 0.05$ were performed. Shapiro-Wilk test has proved the normality of analyzed parameters (ash bacterial disease incidence, severity, health condition index and mortality) when pooling them together

for all plots in every forest typological region. At the same time normality was not proved when considering data separately for diameter and health condition index of particular forestries. Therefore, we calculated correlations between analyzed parameters by parametric and non-parametric methods (Pearson's and Spearman's correlation). Microsoft Excel software and statistical software package PAST: Paleontological Statistics Software Package for Education and Data Analysis (Hammer et al. 2001) were used.

Results and Discussion

The data of Table 1 show that the temperature parameter T-index is a bit higher in Zmiyiv (Pridonetsky forest typological sector), and precipitation for vegetation period is higher in Trostyanets (Vorsk-

la-Pselsky forest typological sector). Both *W* and HTI are higher in the neighborhood of Trostyanets meteorological station, than in the neighbourhood of Zmiyiv meteorological station. Such climate features agree with the location of inspected regions. Investigated plots in Vorskla-Pselsky forest typological sector are characterized by greater latitude and lower longitude (Table 2). Therefore, it is characterized by lower temperature and more precipitation (Table 1).

Proportion of ash trees per plot was the lowest in Makivske forestry (10.6 % in average), respectively about 50 % in other inspected forestries of Sumy region and 30–40 % in inspected forestries of Kharkiv region (Table 3). At the same time, in separate plots of each forestry the proportion of ash trees varied within a rather wide range, for example from 3.1 to 81.8 % in Lytovske forestry.

Table 3. Ash trees parameters in inspected forestries*.

Forestry	Proportion of ash trees per plot, % **±SE	DBH, cm ±SE **
Sumy region (Vorskla-Pselsky forest typological sector)		
Krasnyanske	54.4±3.17a (32.1–80.0)	35.8±2.19a (13–54)
Lytovske	46.0±6.01a (3.1–81.8)	34.5±2.77a (3–67)
Makivske	10.6±3.73b (2.0–29.4)	7.6±1.01b (4–13)
Neskuchanske	51.2±3.19a (27.4–83.7)	34.5±2.02a (16–53)
Kharkiv region (Pridonetsky forest typological sector)		
Kochetokske	40±3.3d (20–50)	29.0±1.5c (23–39)
Skrypayske	39.2±4.17d (10–50)	27.8±3.62c (10.2–43.8)
Mokhnachanske	31.8±3.2d (10–70)	23.1±1.85c (5.8–52.6)

Note: *The data for all inspected plots were pooled for each forestry. **Means followed by the same letter are not significant within column at the 95 % confidence level. Figures in brackets show the minimal and maximal value.

Average DBH of ash trees (and age, respectively) was the lowest in Makivske forestry (7.6 cm) and almost the same (34.5–35.8 cm) in the rest inspected forestries of Sumy region, but significantly

lower (23.1–29 cm) in inspected forestries of Kharkiv region (Table 3).

Bacterial disease of ash was revealed in all inspected forestries, except Makivske forestry, and varied within each

forestry (Table 4). So, in some areas of Krasnyansky and Lytovske forestries, disease incidence ranged from 0 to 100 %,

however, the average values differed more than three times (9.3 and 30.1 %, respectively).

Table 4. Health condition parameters.

Forestry	Disease incidence, % $\pm$ SE	Disease severity score $\pm$ SE	Health condition index $\pm$ SE	Tree mortality $\pm$ SE
Sumy region (Vorskla-Pselsky forest typological sector)				
Krasnyanske	9.3 $\pm$ 5.14 b (0–100)	0.4 $\pm$ 0.07 b (0–0.78)	1.9 $\pm$ 0.10 a (1.3–2.9)	12.1 $\pm$ 2.29 (3.6–19.4)
Lytovske	30.1 $\pm$ 6.61 a (0–100)	0.8 $\pm$ 0.14 a (0–1.63)	2.2 $\pm$ 0.12 a (1.2–3.0)	14.3***
Makivske	0.0 c	0.0 c	1.8 $\pm$ 0.36 a (1.0–3.0)	0.0
Neskuchanske	18.6 $\pm$ 3.82 ab (0–50)	0.7 $\pm$ 0.13 a (0–1.66)	1.9 $\pm$ 0.08 a (1.2–2.5)	2.4***
Kharkiv region (Pridonetsky forest typological sector)				
Kochetokske	10.7 $\pm$ 1.53 d (1.5–17.5)	0.11 $\pm$ 0.017 d (0.01–0.2)	2.7 $\pm$ 0.07 b (2.4–3.0)	3.1 $\pm$ 0.81 d (0–7.5)
Skrypaysivske	8.4 $\pm$ 1.58 de (0–15.9)	0.11 $\pm$ 0.024 d (0–0.24)	2.6 $\pm$ 0.04 b (2.4–2.8)	2.3***
Mokhnachanske	5.0 $\pm$ 0.95 e (0–16.1)	0.06 $\pm$ 0.011 e (0–0.16)	2.6 $\pm$ 0.07 b (2.1–3.3)	2.1 $\pm$ 0.95 d (0–22.9)

Note: *Means followed by different letters in each column are significantly different at the 95 % confidence level. **Figures in brackets show minimum and maximum of parameter in each forestry. ***Tree mortality observed only in one plot.

Analysis of pooled data for Sumy and Kharkiv regions show that both average ash tree diameter (31.9 and 25.5 cm) and bacterial disease incidence (16.1 and 7.0 %) are significantly higher in Sumy region (Fig. 2).

Test for equal means proves such significance: $F=4.89$, $p=0.03$ for diameter and $F=7.75$, $p=0.04$ for bacterial disease incidence.

Bacterial disease severity score was rather low in most of Sumy (0.4–0.8 points) and Kharkiv plots (0.06–0.11 points) (Table 4).

Analysis of pooled data for Sumy and Kharkiv regions (0.64 and 0.08 point respectively) show that average severity score is significantly higher in Sumy re-

gion ($F=55.4$, $p<0.001$) (Fig. 3).

In spite of the fact that both, the incidence and severity of bacterial disease, are greater for particular forestries and pooled data from Sumy region, the HCI of ash trees is greater for forestries of Kharkiv region (Table 4).

For plots from Sumy region, the value of HCI is the least (1.8) for inspected plots in Makivske forestry with an absence of bacterial disease of ash. The value of health condition index is 1.9 for inspected plots in Krasnyanske and Neskuchanske forestries with disease incidence 9.3 and 18.6 % and is the highest for inspected plots in Lytovske forestry with maximal disease incidence (30.1 %). Significant difference of health condition index of

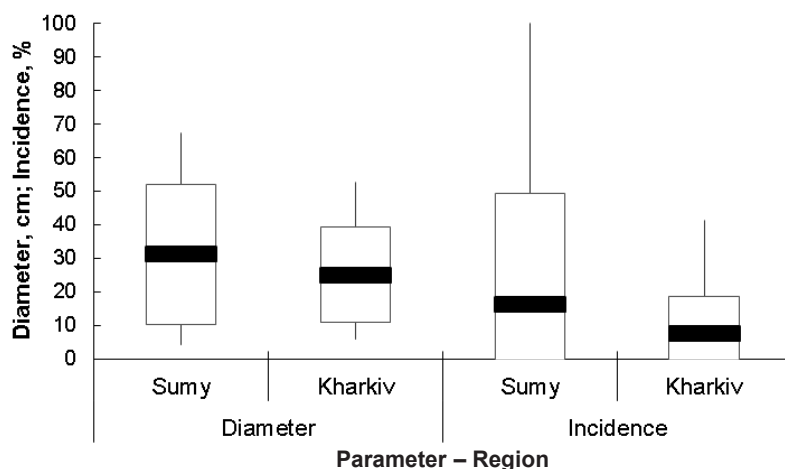


Fig. 2. Incidence of ash bacterial disease and mean tree diameter pooled by regions.

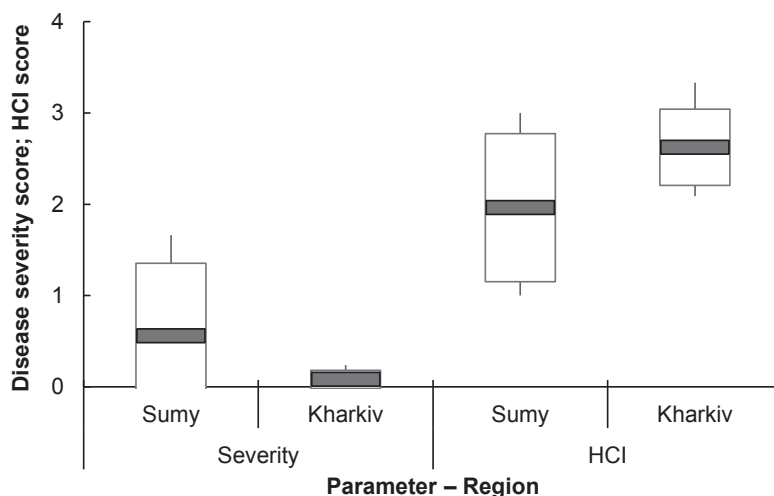


Fig. 3. Severity of ash bacterial disease in inspected forestries and HCI pooled by regions.

stands was proved between forestries of Sumy and Kharkiv region. For pooled data HCI is 2 and 2.6 points for Sumy and Kharkiv region respectively ($F=73.4$, $p<0.001$).

Therefore, according to 'Sanitary rules in the forests of Ukraine' (Anonymous 1995) ash stands in the inspected forestries of Sumy region are weakened, and

in the inspected forestries of Kharkiv region are severely weakened.

Ash tree mortality was rather rare among inspected plots (Table 4). No mortality of ash was observed at all in inspected plots of Makivske forestry and only on one of the plots in Lytovske Neskuchanske and Skrypavivske forestries. The highest ash mortality was registered

in Krasnyanske forestry (12.1 %) of Trostyanetsky forest enterprise.

No significant correlation was proved between parameters of ash bacterial disease and altitude ($p>0.1$). Significant correlation using both Pearson's and Spearman's tests was proved between bacterial disease incidence and severity, HCI and

mortality, as well as DBH and disease severity (Table 5). However, only the correlation between bacterial disease incidence and severity is high for Kharkiv region ($r_p=0.74$, $r_s=0.95$) and moderate ($r_p=0.54$) or high ($r_s=0.73$) for Sumy region. The other correlation index values are slight or moderate.

Table 5. Correlation between diameter, health condition, mortality of ash trees, and bacterial disease incidence and severity.

Re-gions	DBH – Inc	DBH – Sev	DBH – HCI	DBH – Mort	Inc – Sev	Inc – HCI	Inc – Mort	Sev – HCI	Sev – Mort	HCI – Mort
Pearson r (p in brackets)										
Kharkiv	0.29 (0.04)	0.39* (0.01)	0.09 (0.54)	-0.15 (0.30)	0.74* (<0.01)	0.29* (0.05)	0.17 (0.26)	0.17 (0.24)	0.20 (0.17)	0.53* (<0.01)
Sumy	0.06 (0.63)	0.31* (0.01)	-0.13 (0.31)	-0.04 (0.76)	0.54* (<0.01)	0.34* (0.01)	-0.14 (0.29)	0.24 (0.06)	-0.17 (0.19)	0.28* (0.03)
Spearman's r (p in brackets)										
Kharkiv	0.35* (0.01)	0.33* (0.02)	0.05 (0.72)	-0.12 (0.43)	0.95* (<0.01)	0.20 (0.18)	0.23 (0.12)	0.16 (0.28)	0.21 (0.15)	0.44* (<0.01)
Sumy	0.19 (0.14)	0.28* (0.03)	-0.21 (0.11)	-0.03 (0.79)	0.73* (<0.01)	0.40 (<0.01)	-0.05 (0.70)	0.18 (0.17)	-0.12 (0.33)	0.25* (0.05)

Note: Inc – disease incidence; Sev – disease severity; Mort – ash tree mortality; significant correlations ($p<0.05$) are marked with an asterisk.

Slight correlation between bacterial disease incidence and DBH was proved only for Kharkiv region using Spearman's test ($r_s=0.35$).

Obtained dissimilarity in ash bacterial disease parameters and health condition in different forest typological sectors data might be explained by climate features (Table 1). Higher precipitation and moisture indices are usually favorable for ash bacterial disease (Kulbanska 2015a). Therefore, this disease was spread and developed in greater degree in Vorskla-Pselsky forest typological sector (Sumy region). At the same time, the water shortage is unfavorable to ash growth and increases its susceptibility to other damage causes, particularly frost,

mechanical damage, wood decay fungi and insects (Meshkova and Borysova 2017). Therefore, ash health condition was worse in Pridonetsky forest typological sector (Kharkiv region), characterized by higher temperature together with lower humidity during the vegetation period (Table 1).

The findings suggest that bacterial disease incidence and severity depend on many factors that should be considered in further analysis. Among them, heterogeneity of forest stands by origin, age, ash participation, the relative density of stocking, location in the forest, particularly the distance from roads, clear-cuts as well as additive influence of other damaging agents are of the highest importance.

Conclusions

Research of the spread of bacterial disease of European ash (*Fraxinus excelsior*) in Pridonetsky and Vorskla-Pselsky forest typological sector of the Left-bank Forest-Steppe zone of Ukraine brings to following conclusions:

1. Ash bacterial disease incidence is 16.1 and 7.7 %, and its severity 0.6 and 0.1 points for Sumy and Kharkiv region respectively. Both parameters are significantly higher for particular forestries and pooled data from Vorskla-Pselsky forest typological sector (Sumy region), than for Pridonetsky forest typological sector (Kharkiv region).

2. The health condition index (HCI) of ash trees is higher for forestries of Kharkiv region (2 and 2.6 points for Sumy and Kharkiv region respectively). According to these values, ash stands in the inspected forestries of Sumy region are considered as weakened, and in the inspected forestries of Kharkiv region as severely weakened.

3. Ash tree mortality in inspected plots was rather low (1.6 and 1.8 % for Sumy and Kharkiv region respectively).

4. No significant correlation between parameters of ash bacterial disease and altitude has been observed. Significant correlation was proved between ash bacterial disease incidence and severity, health condition index and mortality, DBH and disease severity. However, only the correlation between ash bacterial disease incidence and severity, was high for Kharkiv region ($r_p=0.74$, $r_s=0.95$) and moderate ($r_p=0.54$) or high ($r_s=0.73$) for Sumy region.

5. More intensive incidence and severity of ash bacterial disease in Vorskla-Pselsky forest typological sector (Sumy region) can be explained by higher mois-

ture indices ($W = 0.59$ and 1.14 , $HTI = 0.97$ and 1.1 for Kharkiv and Sumy region respectively).

6. Higher health condition index and mortality of ash trees in Pridonetsky forest typological sector can be explained by higher temperature together with lower humidity of vegetation period, which is unfavorable to ash and increases its susceptibility to other damage causes, particularly insects.

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FEATURES OF CREATION AND CURRENT STATE OF THE TERESHCHENKO FAMILY PALACE AND PARK COMPLEXES IN ZHYTOMYR REGION, UKRAINE

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Abstract

The article is devoted to the analysis of the experience of Tereshchenko family palace and park complexes' creation. The current state of parkland and its structure is examined with historical, landscape, taxonomic and aesthetic perspective. In the article, the authors defined the prospects for further studies of old parks.

Key words: aesthetic evaluation, degradation, dendroflora, geobotanical region, type of park landscape.

Introduction

Tereshchenko's family left a significant mark in the history of Ukraine. The Tereshchenko's family members have achieved prominence not only in Ukraine, but also in the world as businessmen, entrepreneurs, landowners, and philanthropists, beginning in the 18th century. The family has Cossack roots and comes from the city of Hlukhiv (now Sumy region), the former residence of the Hetmans of Left-bank Ukraine (Kovalinskiy 1998).

The founder of the line was Artem Tereshchenko (b 1794, d 1873), who made a fortune during the Crimean War (1853–1856) by supplying the army with bread and boat timber and then turned to sugar refining and other manufacturing industries. After the agrarian reform of 1861

he and his sons, Mykola, Fedir, and Semen, accumulated estates in Ukraine and Russia. By the turn of the century, they owned 153,000 ha and were among the largest landowners in the Russian Empire. In 1911–1912 they also owned 10 large sugar refineries. Mykola Tereshchenko (b 1820, d 1903) and his sons, Ivan and Olexander Tereshchenko, were well-known patrons of the arts; Mykola was a financial supporter of the Kyiv and Hlukhiv art museums, and Ivan supported the Kyiv Drawing School. Mykola's collections later formed the basis of the Ukrainian and Russian art museums in Kyiv (see Kyiv National Museum of Russian Art). Mykola's grandson, Mykhailo Tereshchenko (b 1888, d 1956), was a prominent figure in Russian politics. He was a member of the Fourth State Duma, chairman of the War

Industry Committee in Kyiv (1915–1917), minister of finance (March–May 1917) and of foreign affairs (May–October 1917) in the Provisional Government, and a participant in negotiations with the Central Rada. After the October Revolution in 1917 he emigrated to Monaco (Canadian institute of Ukrainian studies 2001).

In 1870, Mykola, Fedir (b 1832, d 1894), and Semen Tereshchenko (b 1839, d 1893) founded the 'Association of beet sugar and refineries factories of Tereshchenko brothers'. About 80 % of the profits were transferred to the charity fund 'Tereshchenko', which was involved in the construction of hospitals, schools, churches, etc. (Kovalinskiy V. 2003). The motto of their family crest was 'Aspiring for the common good' (Fig. 1).



Fig. 1. Coat of arms of the Tereshchenko family.

It is impossible to describe in one article the significant contribution of this great family in the development of Ukraine and Russia in the early twentieth century. The main purpose of the publication is to study the history and current state of Tereshchenko family palace and park complexes, some of which have been preserved to the present day. These are parks, mon-

uments of landscape architecture, Andrushivskiy, Chervonskiy, Turchinovskiy, 'Yulino' and the least preserved palace in the village of Denyshi in Zhytomyr district.

According to Kuznetsov and Klimenko (2003), the problem of the restoration of old parks in Ukraine has historical, biological, landscape and social aspects. The biological aspect of the restoration of parks deserves attention. A considerable number of works are devoted to the landscape evaluation of parklands (Antipov et al. 1985, Bondar and Absinova 1982, Goranov et al. 1958, Gostev and Yuskevich 1991, Antipov et al. 2002) and, at the same time, insufficient attention was devoted to biological researches of park groups. Such investigations were started at the National Botanical Garden of the National Academy of Sciences of Ukraine by Rubtsov (1956, 1979) and then continued in the departments of dendrology and park science (Klymenko 2009, 2010, 2012; Kuznetsov and Bagatskaya 2011). Changes in park crop phytocoenoses are associated with biological age-related changes in tree plants and intensive anthropogenic interference or its complete absence (Kuznetsov and Klimenko 2003).

According to Klymenko (2012), when developing conceptual approaches to the reconstruction of parks created on the basis of indigenous vegetation, the comparative phytocoenic method should be used, that is, to compare taxonomic composition and quantitative participation in planting of park-type species in the surveyed area with such indicators in indigenous undamaged planting, which is in a similar type of forest vegetation.

Using the experience of our colleagues in this article, we explore the process of transformation of palaces and park complexes over time without the professional care of specialists in landscape archi-

ture. To achieve the goal of the work we studied the historical analysis of the creation of objects detected features of dendroflora, and investigated the dominant structure of parklands. Also, we researched the landscape structure of parks and conducted an aesthetic, architectural and planning assessment of park ensembles.

Material and Methods

During the work on the publication, we used various materials, which were not included in references: historical information and scheme of the parks from organizations, which use the objects nowadays. To achieve the purpose of the paper, we needed to determine the taxonomic composition of dendroflora. We studied species composition of trees and shrubs by route method. At the same time determining the current health status of the trees using a scale of Sanitary Rules (Sanitary rules ... 2016): 1 – healthy trees, 2 – weakened, 3 – very weak, 4 – dried, 5 – fresh deadwood, 6 – old deadwood.

Aesthetic appreciation of the parkland areas was carried out by classification of Kucheryaviy (2008, 2017), which includes phytocoenotic and emotional scales. The phytocoenotic scale is characterized by following indicators: forest site, the moisture content of the soil, the shape of the ground, storeyed structure, density of undergrowth, floristic composition of forest floor, the age of trees, scoop and soil trampling, lesions and plant diseases. Emotion scale includes valuation of the plant community, structure and age of phytocoenosis, taint and feeling of suddenness. For greater convenience, arithmetic meanings are grouped into three classes of aesthetic value.

Landscapes analysed for classification of Rubtsov (1956, 1979) are allocated into 6 types: forest, park, meadow, garden, alpine and regular. He said that landscape is a specially arranged in gardens and parks interconnected systems of vegetation, topography, soil, water and engineering structures that are designed to ensure people certain sanitary conditions, to create the best environment for a particular type of recreation and to provide people the same emotional response. This classification allows us to carry out, in different types of landscapes, certain measures to optimize them. Forest type of landscape is characterized by the high crown closure of plantations (0.7–1.0) and large areas. The forest-meadow landscapes, which consist of open meadow spaces with picturesque groups of trees, are park landscapes. Trees and shrubs in this type of landscape are represented by large groves, groups and individual plants. The meadow type of the landscape is characterized by the presence on the banks of rivers and reservoirs of individual specimens of moisture-loving trees and the increase in grassy high-growth and broad-leaved grass.

The planned composition of the parks was determined by Simonds (1965).

Results and Discussion

First of all, we decided to describe the historical features of park complexes, and after that, we will provide information about their current state.

Mykola Tereshchenko worked and lived almost all the time in Kyiv, and Semen – in Moscow. In Zhytomyr region, Fedir was the biggest landowner. He had the manor in Adrushivka.

His daughter Nadiya Mouravieff-Ap-

ostol (b 1887, d 1967) lived in the village Denyshi near Zhytomyr. Unfortunately, her palace was destroyed and robbed after the revolution in 1917. Today this territory hasn't a status of Nature Reserve

Fund like the other four parks. Besides, we don't even know the boundaries of the estate. That's why we present only the current state of the palace, not parklands, as in other parks (Fig. 2).



Fig. 2. The current state of the estate in the village Denyshi.
(co-ordinates 50°12'19.03"N, 28°24'44.29"E)

The palace was built in 1910–1911 by architect P. Holandskyi using advanced architectural and construction techniques. During construction, builders used concrete, figured elements made with plaster on brick. Holandskyi also took part in the creation and planning of the park in the village Denyshi. Unfortunately, today we haven't information about the features of this park, which species of trees and bushes were planted, which was the architectural and planning structure of park, etc.

Figure 2 shows that the palace is almost completely destroyed today. The territory near the building belongs to Teterevska

rural territorial communities. The palace is not protected; it is freely accessible.

Estates of Fedor Tereshchenko (in Andrushivka), his son Fedor F. Tereshchenko (in v. Chervone) and his daughter Natalia Uvarova (in v. Turchynivka) are parks, monuments of landscape architecture. They belong to the Nature Reserve Fund of Ukraine and are protected by law.

The Palace of Fedir Tereshchenko in Andrushivka (Fig. 3) is the embodiment of the French Neo-Renaissance style, park-palace ensemble with front entrance gate.

This palace is a true monument of



Fig. 3. Fedir Tereshchenko's palace today.
(co-ordinates 50°00'58.43"N, 29°01'24.64"E)

architecture of the 19th century. It's a two-storey building made of brick, asymmetrical in its volume. The Tereshchenko family bought the castle in 1848 from Bierzynski Princes. The palace has a park, which is preserved until today, with ancient oaks, cedar, and the only and one of a kind cork oak tree.

The palace of Fedir F. Tereshchenko in v. Chervone is made in Victorian Gothic style and stands out from the other buildings of the neighbourhood (figs 4 and 5).

This palace was built by Polish officer Adolf Grokholsky. He was married twice, but neither marriage brought him a heir, so the palace went to his second wife, who sold the castle and the village together to Mykola Tereshchenko. He presented the

palace to Fedir Tereshchenko. The palace was inherited by his son Fedir, who gave the building even more spectacular appearance that we can observe today. He reconstructed the palace, made the tower below the second tier, and added a portico with a balcony facing the main tower, giving it a gothic look. Also, Fedir made a reconstruction of the parklands. The palace preserved a cast-iron fountain, beautiful tower, many Gothic elements.

In 1889 Fedir Tereshenko began building the palace in the v. Turchynivka. After his death in 1894, his daughter Natalia has completed the construction of the palace in 1900. The palace was built in Renaissance style. Unfortunately, we do not know the name of the architect. Now



Fig. 4. The current state of the estate in the village Chervone.
(co-ordinates 49°57'27.06"N, 28°52'50.31"E)

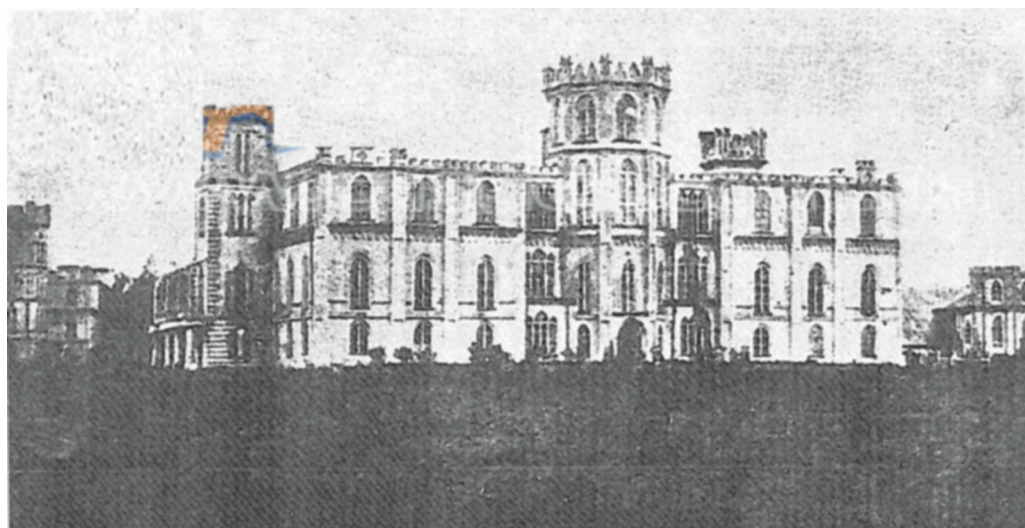


Fig. 5. The estate in the village Chervone in 1914.

the area of the park and the palace itself are professional technical school number

30 (Fig. 6). That's why the building is well preserved.



Fig. 6. Natalia Uvarova palace today.

(co-ordinates 50°01'44.57"N, 28°15'42.90"E)

The park around the palace was renovated by architects who were invited by Natalia from Europe. She even planted trees by herself. The basis of the parklands were indigenous oak and pine forests.

Since the sixteenth century, the lands east of the village Potapovychi Ovruch district were owned by the Baranowski family who were part of the Ukrainian aristocracy. In the early twentieth century, the son of Mykola Tereshchenko Alexander bought the land for his lover Julia. He decided to create the park and invited architects and gardeners from Italy. They planned the construction of buildings in

baroque style, planted a lot of rare species (Fig. 7).

After the revolution in 1917, the Soviet authorities nationalized the territory of the park and created a farm of fruit trees 'Yulino'. Unfortunately, plantings laid by gardeners were almost completely destroyed, leaving only some areas of primary parklands, an alley with *Picea abies* (L.) Karst and *Populus alba* L. (Fig. 8). Today the park is a territory of the professional technical school number 35.

After historical analysis of estates creation, we have to describe the features of the territory and planting of parks (Table 1).



Fig. 7. The current state of the estate 'Yulino'.
(co-ordinates 51°13'45.69"N, 28°47'07.04"E)



Fig. 8. Alley with *Picea abies* (L.) Karst and *Populus alba* L. (nowadays).

Table 1. Territory distribution of the parks area.

Park, location	Total area, ha/%	Area type, ha/%					
		green area	buildings	footpaths	lakes	sports grounds	others [*]
'Yulino' (village Potapovich	<u>25.0</u>	<u>13.21</u>	<u>0.3</u>	<u>1.02</u>	<u>1.39</u>	<u>0.00</u>	<u>9.07</u> ¹
Ovruch district)	100	52,8	1,2	4,1	5,6	0,00	36,3
Andrushivskiy (v. Andrushivka)	<u>9.38</u>	<u>8.61</u>	<u>0.05</u>	<u>0.61</u>	<u>0.11</u>	<u>0.00</u>	<u>0.00</u>
	100	91,8	0,5	6,5	1,2	0,00	0,00
Turchynivskiy (v. Turchynivka	<u>11.0</u>	<u>6.0</u>	<u>0.2</u>	<u>0.6</u>	<u>2.4</u>	<u>1.0</u>	<u>0.8</u> ²
Chudnivskiy district)	100	54,5	1,8	5,5	21,9	9,1	7,2
Chervonskiy (v. Chervone	<u>36.0</u>	<u>33.07</u>	<u>0.18</u>	<u>1.71</u>	<u>0.71</u>	<u>0.33</u>	<u>0.00</u>
Andrushivskiy district)	100	91,7	0,5	4,8	2,0	1,0	0,00

Note: 1 – tillage, grasslands; 2 – tillage, grasslands, houses.

Green area dominates in all parks. A large area in park 'Yulino' are tillage and grasslands because this territory is used like an educational farm for students.

There is such a situation in Turchynivskiy park (Fig. 9). Green area is the most important area type for our research because parklands are the basis of the parks.



Fig. 9. Grasslands in Turchynivskiy park.

Next step of our investigation is an analysis of dendroflora of parklands. In the inventory, we have identified 47 spe-

cies of trees and shrubs. Maximum species are growing in the Turchynivskiy park (Table 2).

Table 2. Structure of dendroflora of the parks.

Park	Systematic unit			
	families	genera	species	varieties, hybrids
'Yulino'	13	21	24	1
Andrushivskiy	10	20	23	1
Turchynivskiy	14	23	34	—
Chervonskiy	15	22	26	1

Picea abies (L.) Karst., *Acer negundo* L., *Acer platanoides* L., *Betula pendula* L., *Carpinus betulus* L., *Malus domestica* Borkh., *Parthenocissus quinquefolia* Planch., *Pyrus communis* L., *Robinia pseudoacacia* L., *Sambucus nigra* L., *Tilia cordata* Mill. grow in all parks. They are the most widespread species in the parks. *Quercus suber* L. grows only in Andrushivskiy park. *Acer tataricum* L., *Armeniaca vulgaris* Mill., *Cerasus avium* (L.) Moench., *Cerasus vulgaris* Mill., *Gleditschia triacanthos* L., *Juglans nigra* L. grow only in Chervonskiy park. *Pinus nigra* Arn., *Morus nigra* L., *Padus serotina* (Ehrh.) Agardh, *Robinia pseudoacacia* v. *Decaisneana* grow only in Turchynivskiy park. *Lonicera caerulea* L., which is included in the IUCN Red List, grows only in park 'Yulino'.

It is very important to explore the dominant structure of parklands because parks of XVIII–XIX centuries are usually created from indigenous forests. They spent felling some trees, eliminating clutter, paved paths, creating lakes and so on. So for short time owners of estates got a beau-

tiful park.

The analysis of the dominant structure of parklands today shows us phytocoenosis changes (Table 3). The plants communities with indigenous species are very important for landscape originality of parks.

The former dominant species *Pinus sylvestris* L., *Quercus robur* L. and *Carpinus betulus* L. (Barbarych 1977) are absent today. *Fraxinus excelsior* L., *Tilia cordata* Mill. and *Acer platanoides* L. occupy a lot of the parklands area. In our view, a major problem for the plantations is an area where there are no dominant species.

Thus, for the areas of research parks, which were created on the basis of natural vegetation or artificial, but using dominant species of native forests and their satellites, is characterized by phytocoenosis degradation. It is most dangerous for plantations of old parks because of the replacement threat of plantings with subsidiary crop.

It is very important to determine the landscape structure of the parks for the restoration work in old parks (Table 4).

Table 3. Comparing current state of parks planting with indigenous plantings.

Park	former dominant	Green area, ha/%							no dominant species	garden	lawn, meadows	alleys
		<i>Fraxinus excelsior</i>	<i>Tilia cordata</i>	<i>Robinia pseudoacacia</i>	<i>Populus alba</i>	<i>Acer platanoides</i>	<i>Ulmus glabra</i>	<i>Betula pendula</i>				
'Yulino'	Ps	–	–	–	<u>3.22</u> 24,4	–	<u>1.57</u> 11,8	<u>4.33</u> 32,7	<u>1.23</u> 9,3	<u>0.77</u> 5,8	<u>1.58</u> 11,9	–
												<u>0.53</u> 4,0
Andrushivskiy	Qr,	<u>2.45</u>	<u>1.16</u>	–	–	<u>2.28</u>	–	–	–	<u>2.07</u>	–	<u>1.32</u>
	Cb	26,1	12,4	–	–	24,3	–	–	–	22,0	–	14,1
Turchynivskiy	Qr,	<u>4.55</u>	–	<u>1.11</u>	–	–	–	<u>0.22</u>	–	–	–	<u>0.13</u>
	Cb	75,8	–	18,4	–	–	–	3,7	–	–	–	2,1
Chervonskiy	Qr,	<u>2.89</u>	<u>4.13</u>	<u>1.26</u>	–	<u>2.49</u>	–	–	<u>13.33</u>	<u>6.58</u>	<u>0.72</u>	<u>1.33</u>
	Cb	8,7	12,5	3,8	–	7,5	–	–	40,3	19,9	2,2	4,0
												<u>0.34</u> 1,0

Legend: Ps – *Pinus sylvestris*, Qr – *Quercus robur*, Cb – *Carpinus betulus*.

Table 4. Distribution of the types of landscapes at parks.

Park	Total area, ha	Type of landscape's area, ha/%					
		Forest	Park	Meadow	Garden	Alpine	Regular
'Yulino'	25,0	<u>4.13</u>	<u>2.6</u>	<u>15.91</u>	<u>1.58</u>	–	<u>0.78</u>
		16,5	10,4	63,7	6,3	–	3,1
Andrushivskiy	9,38	<u>2.0</u>	<u>5.91</u>	<u>1.32</u>	–	–	<u>0.15</u>
		<u>21.3</u>	63,00	14,1	–	–	1,6
Turchynivskiy	11,0	<u>3.27</u>	<u>6.05</u>	<u>1.03</u>	<u>0.32</u>	–	<u>0.33</u>
		29,7	55,0	9,4	2,9	–	3,0
Chervonskiy	36,0	<u>28.97</u>	<u>2.96</u>	<u>3.77</u>	<u>0.30</u>	–	–
		80,5	8,2	10,5	0,8	–	–

A lot of 'Yulino' park area is a meadow because the territory is used as an educational facility for students of professional technical school number 35 (Fig. 10).

The park type of landscape is dominated in Turchynivskiy and Andrushivskiy parks (more than 50 % of parks area). Forest type of landscape is dominated in

Chervonskiy park. In ancient parks it is advisable to increase the share of park type by reducing the types of forest and meadow landscape. This can be done by holding landscape cutting and planting trees and shrubs.

Aesthetic evaluation scale (Table 5) conducted by Kucheryaviy (2008).



Fig. 10. Plowed field in 'Yulino' park, resulting in lost integrity of the park composition.

Table 5. Aesthetic evaluation of parks.

Park	Assessment of signs, GPA			Class aesthetic value
	phytocoenotic scale	emotional scale	grade point average	
'Yulino'	1,88	1,99	1,94	III
Andrushivskiy	2,1	2,3	2,2	II
Turchynivskiy	1,89	1,86	1,88	III
Chervonskiy	1,92	1,89	1,91	III

From data tab 5.3 it is evident that parks have the lowest class of aesthetic assessment – III, only Andrushivskiy Park – II class. Certain sections of the Chervonskiy and Turchynivskiy parks have a second class of aesthetic value, but most of the territories are represented by the third class. This is due to the fact that the maintenance of the research objects of the

nature reserve fund is not carried out, the plantations have a high degree of clutter, there are signs of consolidation of the soil, some areas of the parks have high availability of plantations, low level of illumination of the submarine space and there is no depth of perspective. Most parcels in the parks have a simple shape, growth and underbrush are poor. When designing

reconstruction projects, it is important, first of all, to eliminate the above mentioned disadvantages, thereby enhancing the class of aesthetic value of parks.

To determine the architectural and planning features of the research objects, the following characteristics were used:

the presence of the palace, the planning of the object, the type of compositional scheme and the percentage of track-path network from the total area (Table 6). These indicators are important for the adoption of project solutions for the reconstruction of parks in the future.

Table 6. Architectural and planning features of parks.

Park	Palace	Planning	Type of compositional scheme	Footpaths, %
'Yulino'	saved	regular	axis	4,1
Andrushivskiy	saved	compounded	beam	6,1
Turchynivskiy	saved	compounded	beam	5,5
Chervonskiy	not saved	compounded	beam + stellate	4,8

According to Table 6, palaces were built in four parks. Presently the palace ensembles have been preserved in Turchinovsky and Chervonsky parks due to the fact that there was an agricultural technical school in the first time, and in the second there was a vocational school in Soviet times (now a Ukrainian Orthodox congregation's monastery). Despite of this, the present condition of the palace in the village of Chervone urgently needs reconstruction and restoration.

Most objects have mixed planning, which combines elements of regular and landscape. Regular planning is represented by alleys and row landings, various architectural buildings. As it was established by the historical certificate about the tract 'Julino', the park had regular planning, now only alleyways from *Populus alba* and *Picea abies* have been preserved. Most *Populus alba* trees are dead and are in ruins.

The compositional scheme in the research parks is represented mainly by the beam in combination with the axial and star types. The percentage of track and path network is different, its largest indi-

cators are characteristic of the park Andrushivskiy and Turchynivskiy.

Conclusions

After conducting our research, we can draw the following conclusions:

1. The Tereshchenko family made a significant contribution to the development of landscape gardening in Zhytomyr region at the beginning of the 20th century, involving the laying and reconstruction of parks of the best European architects, planting introduced and acclimatized wood and shrubs, building palace complexes, placing fountains and sculptures in ancient and Renaissance styles.

2. The former dominant species *Pinus sylvestris* L., *Quercus robur* L. and *Carpinus betulus* L. are absent today. *Fraxinus excelsior* L., *Tilia cordata* Mill. and *Acer platanoides* L. occupy a lot of the park-lands area.

3. Areas of research parks, which were created on the basis of natural vegetation or artificial, but using dominant species of native forests and their satellites, are char-

acterized by phytocoenosis degradation.

4. In ancient parks it is advisable to increase the share of park type by reducing the types of forest and meadow landscape. This can be done by holding landscape cutting and planting trees and shrubs.

5. The maintenance of the research objects is not carried out, the plantations have a high degree of clutter, there are signs of consolidation of the soil, some areas of the parks have high availability of plantations, low level of illumination of the submarine space and there is no depth of perspective. Most parcels in the parks have a simple shape, growth and underbrush are poor.

6. Subsequent studies should focus on the functional zoning of parks and the restoration of their landscape structure.

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COARSE WOODY DEBRIS IN MATURE OAK STANDS OF UKRAINE: CARBON STOCK AND DECOMPOSITION FEATURES

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Abstract

Forest ecosystems play crucial role in climate changes mitigation, providing the carbon (C) sequestration process. Here we overview increasing ecological importance of mature and over-mature oak forest stands in Ukraine, with strong focus on dead biomass compartment of those. We examined respective national forest inventory data, permanent sample plots, logs' samplings for estimation of decomposition dynamics. Founding out that coarse woody debris (CWD) is insufficiently accounted in forest inventory data, we have estimated potential of this compartment to store 4.5 % of total oak stand biomass C according to empirical data. Mean dead biomass C stock (CWD and fine litter together) is nearly 9.3 % of total biomass stock. Obtained C stock estimations based on field measurements correspond to previous studies in Ukraine. Modelling of oak downed logs decomposition indicates that deadwood may remain in ecosystem for decades, achieving 40–50 kg·m⁻³ wood density at 100 years point after tree death, thus playing substantial role not only as habitat for species, but also as C sink in mid-term perspective. Imperfections in national forest inventory system and local management regimes lead to unrecognized biases in efforts to assess oak deadwood values in Ukraine. Herewith, target consideration of CWD importance in current silvicultural practices is needed for maintaining this important ecosystem component.

Key words: dead biomass, deadwood, litter, logs, snags.

Introduction

To date, carbon (C) sequestration is in a special focus of international society among ecosystem services as an import-

ant component of climate changes mitigation efforts (Grassi et al. 2017). Naturally, C is stored in organic matter of aquatic and terrestrial ecosystems, including forest biomass and soils (Bazylevych et al.

1978). C cycle in forests is defined by plants photosynthetic productivity (Bonan 2008), starvation and decomposition processes (Yatskov et al. 2003), impact of natural disturbances (Seidl et al. 2014) and several lateral fluxes (Chen et al. 2014). Knowledge, whether given ecosystem is either a net C sink or source, is a crucial for defining local climate mitigation capacity, together with ecosystem evapotranspiration, surface albedo and land use regime (Schwaab et al. 2015). Hence, Ukraine, signing and ratifying in 2016 Paris Climate Agreement, became responsible for inventory of national C budget, *inter alia*, of forest ecosystems (Shvidenko et al. 2017).

Deadwood, being a crucial component of forest ecosystems, is tended to be strictly considered in national forest, climate and biodiversity maintaining policies worldwide (Franklin et al. 2007). Deadwood in managed forests presented by late-seral species which are defined by low decomposition rates, thus may store C for decades, with moderate emissions until final felling (Harmon et al. 1986). In conservation areas it is an important structural legacy after natural disturbances and plays rather preserving role as a habitat for microbiota, saproxylic and avian fauna (Kuuluvainen 1994, Franklin et al. 2002, Thom et al. 2018, Lakyda et al. 2019). Importantly, coarse woody debris (CWD) must be considered as a key part of larger ecosystem compartment – dead biomass, which includes, *inter alia*, fine litter of branches and leaves, dead branches on the live trees, dead roots, etc. (Bilous et al. 2017a).

Ukrainian forest ecosystems, being located in temperate zone and Mid-Latitude Xeric belt, are rather net C sinks (Sytnyk et al. 2017, Lesiv et al. 2018). Those cover 15.9 % of country area according to last

forest accounting at state scale carried out in 2011. Furthermore, forest stands of Oak spp. genus together take a significant share (22 % of forested area in Ukraine), being a second the most abundant genus. Common, or European oak (*Quercus robur* L.) is the main deciduous tree species in Ukraine; however, some areas are covered by Downy oak (*Q. pubescens* Willd.), Red oak (*Q. rubra* L.) and Sessile oak (*Q. petraea* (Matt.) Liebl.).

Common oak is a typical temperate late-seral tree species, which prefers well-drained soils with high fertility values and medium moisture regime (Lakyda et al. 2006). There are common oak stands in Forest-Steppe subzone of Ukraine; however, a number of forest patches in Polissya (subzone of mixed forests (i.e. Scots pine (*Pinus sylvestris* L.) with soft-leaved species like Silver birch (*Betula pendula* Roth.) in Northern Ukraine) and Steppe (forestless subzone in Southern Ukraine) are covered by Common oak.

This species in Ukraine is highly abundant in areas where occurrence of these stand-replaceable natural disturbances like intense wildfires or storms is rare. Hence, oak forests can accumulate the substantial stocks of CWD, or deadwood: snags (standing dead trees) and logs (stumps, downed dead stems and large branches). Threshold is mainly defined by management regime, including final felling and salvage loggings. To date, in Ukraine salvage loggings is hitherto used treatment aimed to remove CWD from ecosystem that even was not threatened by insects or diseases and irrespective whether storm of wildfire had occurred before (Pasternak 2011).

A series of studies has been carried out with aim to estimate growth and yield, net primary productivity (NPP), C stocks and some other regulating ecosystem

services (oxygen and energy productivity) of oak stands in Ukraine (Lakyda et al. 2006, 2011). However, studies considered deadwood or whole dead biomass compartment as an essential for oak ecosystems, were conducted only on landscape (Bilous et al. 2017a) or regional scale (Pasternak 2011). So, Pasternak and Yarotskii (2013) concluded that CWD in oak stands of North-Eastern Ukraine (Kharkiv region) was mainly presented in patches with clearly defined borders, i.e. under impact of gap-scale natural disturbances (relatively not severe storms, pest outbreaks, disease affections).

A number of studies represent increasing understanding of deadwood importance for ecosystem functioning in Central Europe: natural oak forests in Austrian Alps (Rahman et al. 2008); stands of sessile oak in Hungarian Carpathians (Bölöni et al. 2017), focusing on biodiversity (Ranius 2002, Horak et al. 2014). Natural consideration seems to be a key requirement for sufficient accumulation of deadwood in oak forests: Vandekerckhove et al. (2009) in their review analysis of forest inventories throughout Central and North-Western Europe concluded that only in protected areas logs (i.e. downed CWD) could reach 75 % of oak dead biomass pool. Rahman et al. (2008) reported that CWD had reached 39 % ratio to whole biomass stock in Austria natural oak forests. However, Bölöni et al. (2017) reported that managed Hungarian forests accumulate quite low CWD stocks, and these values were relatively larger only in old-growth, protected oak stands.

While national forest inventories and field sample plots can be a comprehensive tool for estimation of current dead biomass C stocks, studying of decomposition rates for CWD is needed for prediction of deadwood accumulation. Chron-

osequence method (discussed in a classic study of Harmon et al. 1986) is frequently used worldwide: for boreal forests in Russia (Yatskov et al. 2003); temperate rainforests in Coastal Alaska (Yatskov 2016); in Germany (Herrmann et al. 2015); in natural forests of New Zealand (Garrett et al. 2019). Herewith, decaying patterns are dependent on various factors: moisture, temperature regimes, nutrient availability for decomposing agents (Schowalter et al. 1998, Gora et al. 2018), altitude (Petrillo et al. 2015) and differ among logs components (Shorohova and Kapitsa 2016). To date, data on oak deadwood decomposition in Ukraine is actually lacking.

In this paper we describe our study of dead biomass role in Ukrainian oak forests, with focus on mature and over-mature stands, through: (i) presence and ecosystem distribution (i.e. links to forest type and site index) patterns of CWD in data of national forest inventory; (ii) estimation of C stock in a number of sample plots located in Central and Northern Ukraine with focus on CWD and fine litter; (iii) determination of some features of deadwood decomposition (annual decaying velocity independent on site conditions, relativeness to sampling size and type) using collected oak logs samples.

Data and Methods

Data

According to forest inventory evidence (databases of 'Ukrainian State Forest Inventory Project'), oak stands of Ukraine grow on 1.8 million ha area and accumulate 377 million m³ of growing stock volume (GSV), thus they have been used for analysis. Data is represented by 427 thousand inventory units, where stands

of all age cohorts (young (1–40 years), middle-aged (41–80), immature (81–100), mature (101–140), over-mature (141+), relative to the lowest allowed final felling (LAFF) age in Ukraine, i.e. 101 years) have been found.

Sample plots were established in 12 mature and over-mature oak stands (101+ years old). These plots present mixed, mostly high-productive (site index I–II) stands within areas owned by State Enterprise 'Lubny forestry' (Poltava region, Central Ukraine, plots No 1–10) and of park 'Feofania' (Kyiv, Northern Ukraine, plots No 11–12). All plots represent geographical and climatic conditions common for Forest-Steppe subzone. Plots No 1–10 are located in the areas of continental climate subtype with mean temperature for

the year 7.6 °C and average precipitation amount for the year 600 mm. Similar climatic conditions are observed for the areas where plots No 11–12 are located: for the year, average temperature and total precipitation are 7.2 °C and 690 mm, respectively (Weatherbase Climate Summary 2019). See Supplementary materials (Appendix 1) for list of geographical coordinates of sample plots, its location is given in Figure 1.

Representing biological productivity, site indexes in Ukrainian forest science range from the most productive stands (I_d-I_a) to the least productive (V_a-V_b) (Ostapenko and Tkach 2002). Forest types represent soil fertility (A – poor sand with the lowest fertility, B – sandy soils, C – loamy soils, D – loamy and clay soils with

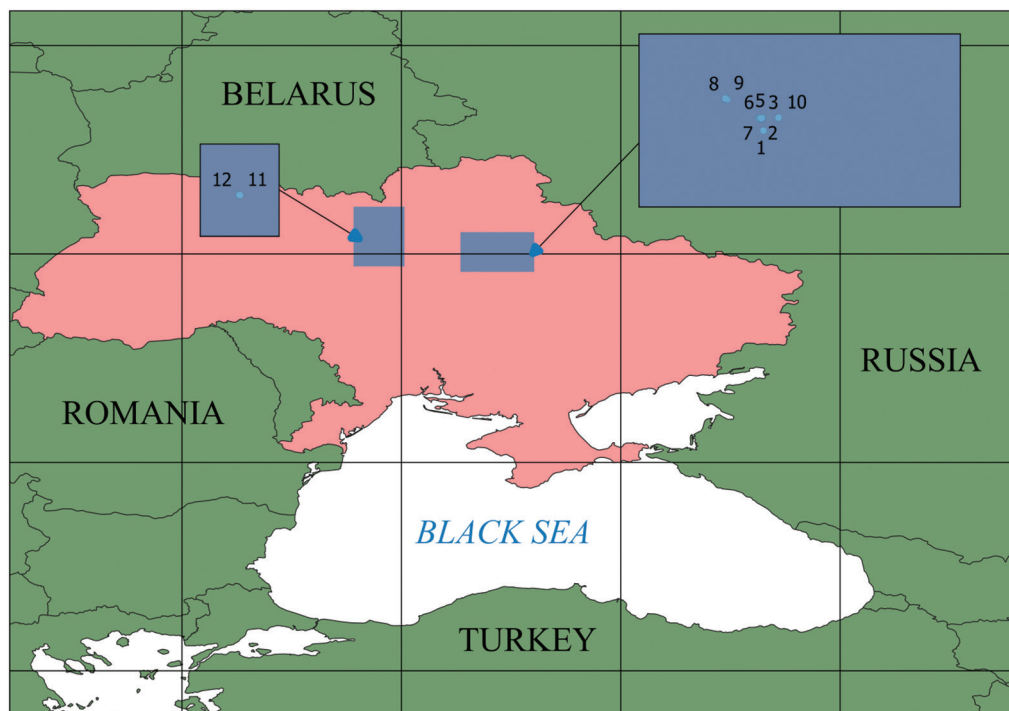


Fig. 1. Location of sample plots: stands No 1–10 belong to Poltava region and are situated in Forest-Steppe subzone that is common for oak, while stands No 11–12 are linked to Kyiv city and the northern edge of Forest-Steppe.

the highest fertility) and soil moisture (0 – extra-dry, 1 – dry, 2 – medium, 3 – wet, 4 – extra-wet, 5 – swampy). Growing with European hornbeam (*Carpinus betulus* L.), Norway maple (*Acer platanoides* L.), Littleleaf linden (*Tilia cordata* Mill.), European ash (*Fraxinus excelsior* L.), insignificant admixtures of European white elm (*Ulmus laevis* Pall.), Black locust (*Robinia pseudoacacia* L.) and Sour cherry (*Cerasus avium* L.) within, all 12 stands (Table 1) have soil and hydrological conditions

which correspond to suitable development of Common oak (forest type – D₂). This forest type corresponds to mesic loamy soils, sufficient moisture content and high content of soil nutrients (Ostapenko and Tkach 2002). Typically, there is absence of understory due to the lack of light. Here-with, oak stands without European hornbeam contain understory formed by Common hazel (*Corylus avellana* L.), European spindle (*Euonymus europaeus* L.) and White dogwood (*Cornus alba* L.).

Table 1. Studied oak stands.

No of stand	A, years	D, cm	H, m	Relative stocking	GSV, m ³ ·ha ⁻¹	Site index	Forest type
1	122	40.3	27.2	0.7	545	I	D ₂
2	122	37.5	22.7	0.6	304	I	D ₂
3	107	42.5	24.5	0.6	445	I	D ₂
4	117	43.9	25.1	0.6	464	I	D ₂
5	102	44.2	31.1	0.5	518	I	D ₂
6	102	60.2	34.1	0.6	506	I	D ₂
7	115	58.8	25.5	0.6	480	II	D ₂
8	137	40.2	24.0	0.6	273	III	D ₂
9	127	51.5	24.6	0.6	462	IV	D ₂
10	107	41.8	24.0	0.6	520	I	D ₂
11	178	68.2	34.8	0.4	496	II	D ₂
12	175	52.0	35.0	0.7	304	II	D ₂

Note: Site indexes presented here according to Ukrainian classification are relatively medium.

A number of logs samplings have been gathered for density dynamics estimation. These were collected mainly in the most common for oak growth conditions (D₂) presenting 79 % of the samplings' quantity, while forest types C₂ and D₃ were presented by 12 % and 9 % of total number, respectively. See Supplementary materials (Appendix 2) for detailed description of each sampling.

Thus, 94 logs' samplings with 1–50 years of time since tree death (Table 2) have been collected. Descriptive statistics for two main variables (remained density

Pt and time since tree death *t*) are given in Table 3.

High values of variation and significant difference between skewness and excess indicate evident absence of normal distribution, because of presence of exponential distribution. We tested normality of distribution of remained wood density for samplings with Shapiro-Wilk test: obtained *p*-value 0.023 is lower than significance level (0.05), so respective null hypothesis must be rejected. Further analysis of model quality has thus been performed using nonparametric tests.

Table 2. Logs' samplings gathered for density dynamics estimation.

Component	Sampling diameter, cm	Time since tree mortality, years					Total
		1–10	11–20	21–30	31–40	41–50	
Stumps	to 20 cm	11	6	4	2	1	24
	over 20 cm	7	4	2	1	1	15
Other logs	to 20 cm	13	9	7	3	3	35
	over 20 cm	10	4	3	2	1	20
Total	–	41	23	16	8	6	94

Table 3. Descriptive statistics for logs' samplings.

Variable	<i>M</i>	<i>Me</i>	min	max	<i>v</i> , %	<i>Es</i>	<i>As</i>
Remained density, kg·m ⁻³	380	385	87	580	31	-0.89	-0.14
Time since tree death, yr	15	11	1	49	85	-0.57	0.84

Note: *M* – mean value; *Me* – median; *v* – coefficient of variation; *Es* – excess; *As* – skewness.

Methods

Processing of national inventory data

With aim to analyze ecosystem distribution of snags and logs (ratio to GSV in different combinations of site index and forest type), national forest databases were processed and filtered using following restrictions: (i) data with errors (e.g., presence of snags or logs and simultaneous absence of GSV) was excluded; (ii) each given combination of site index and forest type was excluded if its area did not exceed 100 ha; (iii) abnormal ratios (> 100 %) of CWD to GSV were excluded from analysis.

Measurements on sample plots

Permanent rectangular sample plots with area ranged from 0.05 ha to 0.84 ha were established following Lakyda et al. (2011) recommendations. Since studied forest stands had nature protection considerations and felling down of model trees could not be allowed there, for calculating

the GSV we used common linear model with basal area, mean height and ratio coefficient as predictors (Svynchuk et al. 2014). Therefore, we conducted total survey of trees on sample plots with measuring of model trees heights via height-meters. Aiming to assess the wood density and mass of live biomass components, information-support materials (Lakyda et al. 2006, 2011) were used.

During sample plots establishment, field data was collected using software and hardware system 'Field-Map' (Buksha et al. 2006). Evidence from range-finder, height-meter and electronic caliper was passing into field computer where sample plot map had been created for further processing.

Dead biomass components on each sample plot were assessed according to common methodology of Harmon et al. (1986) and methods modified for Ukraine (Bilous et al. 2017b). Simultaneously with trees total survey, dead stems (snags) were determined by crown branches presence (I–IV groups) and decomposition state (I–II classes). Downed logs also

were examined with length and diameter measuring and classification by decomposition state (I–V classes) and branches presence and wholeness (I–VI groups). This classification was performed with aim to use respective wood density ratios for different decomposition classes (based on Lakyda et al. 2006 data).

Three square plots with area 1 m² were established on each sample plot for coarse branches ($d > 1$ cm) litter and fine litter (including fine branches ($d < 1$ cm) and leaves litter) examination. Litter of coarse branches was estimated separately according to the method proposed by Bilous et al. (2017b), since this compartment is linked to specific microbiota that also is presented in forest logs and snags and rarely can be found in fine litter. Stock of dead roots was estimated with use of respective root content coefficients (as a ratio to stem live biomass, relating to snag biomass instead), according to Lakyda et al. (2006) data. Dead roots stock was computed in a same way, as a share to snags dead biomass stock. The same assumption was made for estimation of non-stem live biomass compartments (leaves and branches).

Estimation of biomass and C stocks

It was based on empirical and analytic data and was carried out according to Ravindranath and Ostwald (2008), and Intergovernmental Panel on Climate Change (IPCC 2006) recommendations. Carbon stock in every biomass component was estimated as a share of biomass in dry weight. For the stem and branches mass this ratio is 0.5 Mg C·t⁻¹·m⁻³, for the crown leaves in live trees – 0.45 Mg C·t⁻¹·m⁻³, for leaves litter in fine litter biomass component – 0.37 Mg C·t⁻¹·m⁻³ (IPCC 2006). In order to estimate the dead biomass (lit-

ter of fine branches, leaves, and coarse branches) in dry weight, samplings were oven-dried until constant mass, then its weight was compared to the fresh one. There is a reference data (Lakyda et al. 2006) used for estimation of dry weight ratio for other biomass compartments (all live biomass compartments, CWD as mentioned above).

Processing of logs' decomposition data

Logs' samplings have been collected due to Harmon et al. (1986) and Yatskov (2016) recommendations in the areas either not linked to sample plots mentioned above (National Natural Park 'Holosiivskiy' and Boyarka Forest Research Station, in Kyiv) or within abovementioned park 'Feofania' in Kyiv. Samplings were collected only within stands where dates of tree mortality (loggings, storms, etc.) could be identified using forest planning materials. Diameters' distribution (to and over 20 cm) was chosen according to Harmon et al. (1986) conclusion that these logs' groups of late-seral tree species differ significantly in its density and decaying patterns. The chronosequence exponential equation by Olson (1963) for logs' density dynamics estimation is defined as (1):

$$P_t = P_0 \cdot e^{-k \cdot t} \quad (1),$$

where: P_t – remained density (kg·m⁻³) at time t (yr) since tree death; P_0 – basic density (0.57 kg·m⁻³ for Ukrainian oak forests where samplings were collected); k – decomposition rate per year constant (yr⁻¹), computed as $\ln(P_t \cdot P_0^{-1} \cdot t^1)$.

We tested similarity of distributions for different groups of samplings (stumps and logs with $d <$ and > 20 cm) with non-parametric Kolmogorov-Smirnov test, aiming to examine whether dataset must be separated for further modelling or used whole

(if estimated p -value for two sample distributions < significance level, i.e. 0.05). Same method was used for testing quality of exponential model, comparing observed and predicted values of wood density.

Results

CWD in mature and over-mature oak stands: analysis of national inventory

From the nearly 40 thousand of inventory units where mature and over-mature stands are formed by oak as main tree species (15.6 % of area), mean GSV has been found out as $280.6 \text{ m}^3 \cdot \text{ha}^{-1}$, which corresponds to $75.6 \text{ Mg C} \cdot \text{ha}^{-1}$ of mean

C stock. Respective total stem over bark live biomass is 31.8 million t, which corresponds to 15.9 Tg C of sequestered C stock.

Since last state forest accounting in Ukraine (2011), snags (dead standing stems) and logs (downed stems, their huge parts and stumps) were accounted on the quite insignificant areas of oak mature and over-mature stands: 11.2 % and 4.1 % to total inventory unit's quantity, respectively, while any deadwood has not been found in 72.2 % of respective stands total area. Only 3.3 % of those forests had as snags as logs according to forest inventory data. Age cohort structure analysis is given in mean (Fig. 2) and total (Table 4) values.

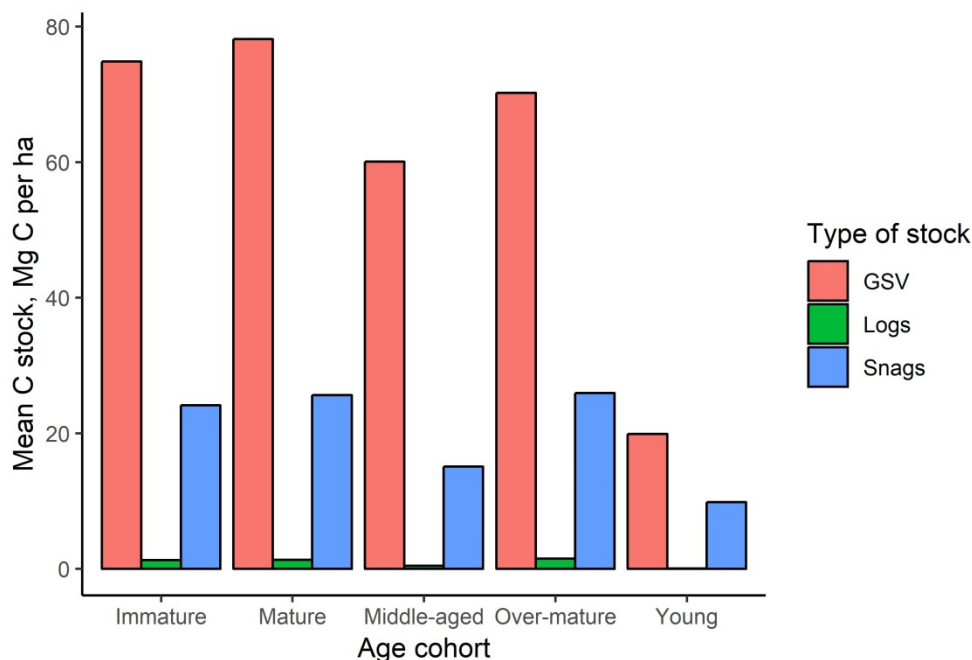


Fig. 2. Age cohort structure of mean C stock in GSV, snag and logs' compartments of oak stands in Ukraine.

Note: Mean values for GSV are given for all oak stands, irrespective whether those contain (according to inventory data) deadwood or not.

Table 4. Carbon of the stands where deadwood has been found: total values.

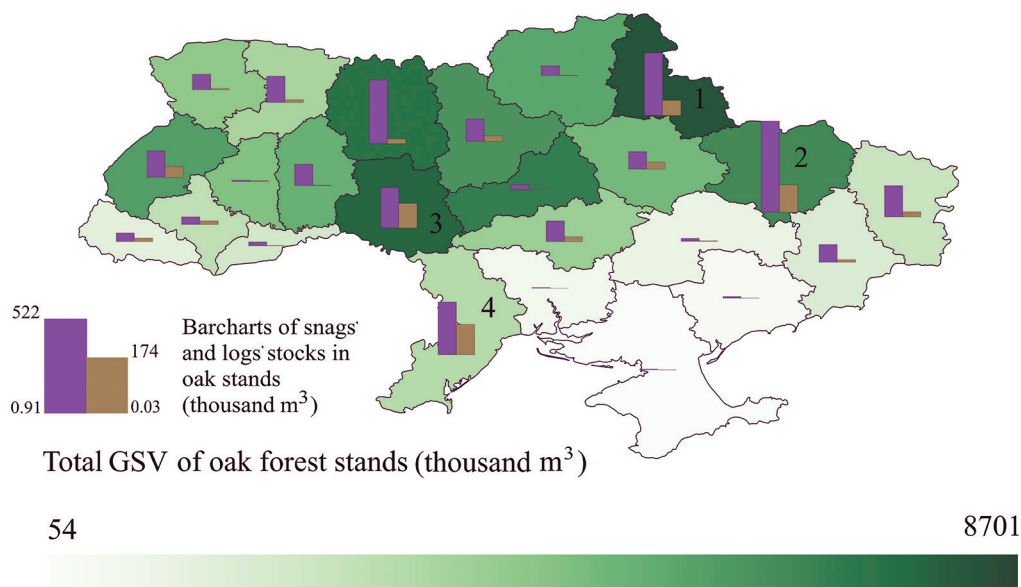
Age group	Stands area, thousands ha		Stored carbon, Gg C	
	with snags	with logs	snags	logs
Young	3.1	1.8	7.0	4.0
Middle-aged	148.4	42.3	399.2	102.8
Immature	92.2	31.6	265.1	78.7
Mature	45.7	17.2	152.6	44.5
Over-mature	6.6	2.0	26.3	6.6

Total volume snag stock of mature and over-mature stands has been found out as 0.7 million m³, logs' volume stock – 0.2 million m³. The carbon stock of these dead biomass components is 0.2 and 0.05 Tg C, respectively (Table 4). Logs, according to inventory data, start to accumulate only in age close to LAFF for common oak (Fig. 2); however, due to the competition between young trees, snags are presented in forest ecosystem starting

actually from canopy closing.

Here is an analysis of spatial distribution given for GSV, snags' and logs' stocks in oak forests (all age cohorts) linked to administrative regions of Ukraine (Fig. 3).

Map in Figure 3 rather focuses on the administrative regions with specific values. Sumy region (1) is located in Polissya subzone, i.e. partially in the zone of mixed forests, and occasionally according to inventory data contains the highest

**Fig. 3. Spatial distribution of oak GSV (gradient green scale), snags' and logs' stocks in Ukrainian administrative regions.**

Note: Ranges of values are presented on legend scales. Regions with specific values here are presented as: 1 – Sumy region, 2 – Kharkiv region, 3 – Vinnytsya region, 4 – Odesa region.

total oak GSV among Ukrainian regions. The highest snags' total stock belongs to Kharkiv region (2) – typical area within Forest-Steppe subzone. The best geographical conditions for growth of oak are linked to Vinnytsya (3) region; however, stands located there contain the highest logs' stock among regions. The north of Odesa (4) region belongs to Forest-Steppe subzone, while coastal regions are relatively forestless. Herewith, this region not only contains the largest oak stands in southern Ukraine, but also accumulates substantial stocks of deadwood.

In order to analyze ecosystem distribution of either snags' or logs' ratio to GSV in mature and over-mature oak forests, we assessed mean values for inventory units (i.e. stands) linked to site indexes and forest types. Assessed composition for all age cohorts for Ukrainian oak forests is given in Supplementary materials

(Appendix 3) for comparison. Here compositions for studied age cohorts (mature and over-mature) are given for mean snag ratio (in %) to GSV (Fig. 4) and mean logs' ratio to GSV (Fig. 5).

Figure 4 does not contain site indexes such common for oak in Ukraine: I, Ia, Ib and Ic. Same situation occurred for logs to GSV ratio (Fig. 5). Herewith, extra-dry sites (forest types A) are also not given in these heatmaps. Gaps in graphs and absent combinations indicate that these classes were presented only on the sites with total area < 100 ha.

Data on CWD presence in national inventory databases is however limited. On the other hand, Figure 4 and Figure 5 explicitly explain ecosystem distribution of oak deadwood: higher ratios are given for combinations of drier and especially wetter forest types and stands with low productivity (site indexes 2–4).

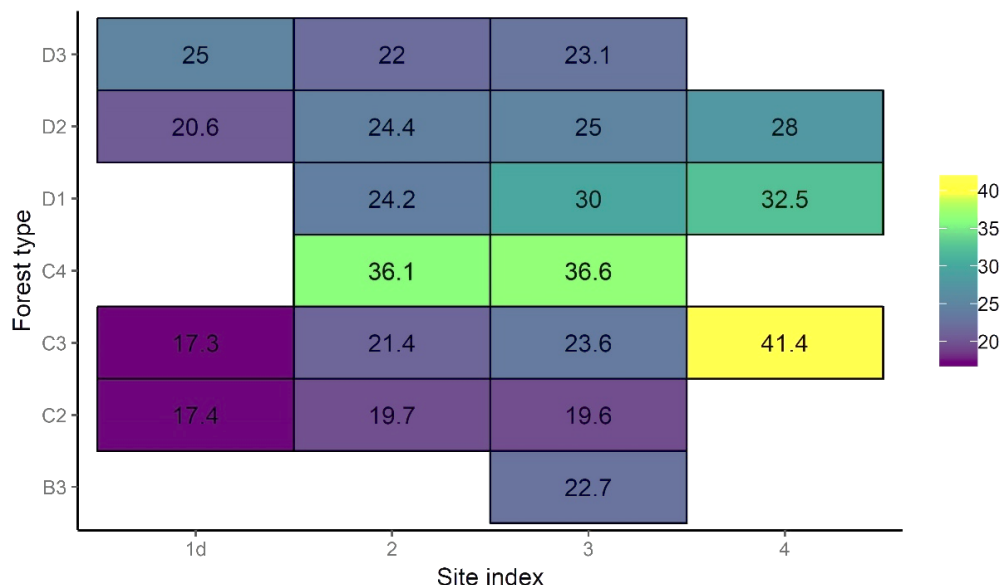


Fig. 4. Heatmap of ecosystem distribution of snag compartment.

Note: Numbers and color of boxes represent gradient scale of mean snag ratio (in %) to GSV. Data was computed explicitly for each oak stand, then mean values were estimated.

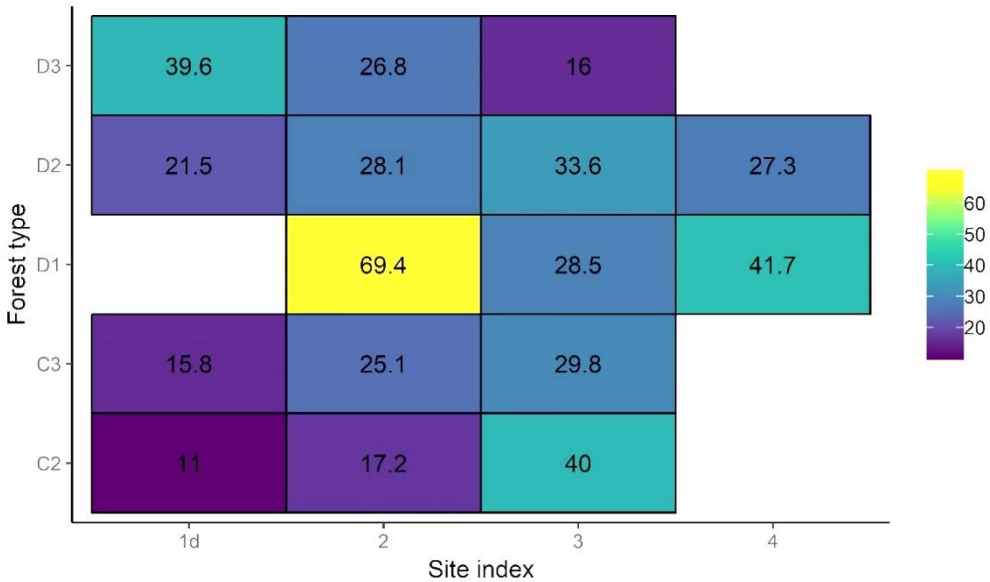


Fig. 5. Heatmap of ecosystem distribution of logs' compartment.

Note: Gaps in the graph correspond to the absence of compartment in the stands with respective combination of site index and forest type or restrictions described in Methods and Materials.

Dead biomass in studied stands

Since only C stock in live stem biomass of oak stands could have been estimated through forest inventory databases, potential carbon share of the rest live biomass compartments (crowns, roots) and dead biomass may be obtained with use of sample data from studied stands. Box-whisker plots with median and mean values for C stock of dead biomass compartments are given in Figure 6. Table with values given for all studied stands see in Supplementary materials.

Hence, mean carbon stock of dead biomass in studied oak stands is $15.6 \pm 1.4 \text{ Mg C} \cdot \text{ha}^{-1}$. Share of CWD and fine litter is almost equal: 7.5 and 7.6 $\text{Mg C} \cdot \text{ha}^{-1}$, respectively, the rest is accounted for under-ground dead biomass (Fig. 6). The carbon stock in live biomass of stems, crowns and roots of studied

stands is $153.2 \pm 8.7 \text{ Mg C} \cdot \text{ha}^{-1}$. Therefore, $168.8 \pm 9.2 \text{ Mg C} \cdot \text{ha}^{-1}$ is sequestered in total stand biomass of studied oak forests, while dead biomass takes 9.3 % share within.

Logs wood density dynamics

Statistical difference between samplings that represent logs and stumps with d more and less 20 cm was tested using Kolmogorov-Smirnov λ -test. D -statistics (supremum function of difference between two sample distributions, empirical and predicted ones, i.e. core value of λ -test) for all tested combinations (logs with d less and more 20 cm, stumps with d less and more 20 cm, all logs and all stumps, all sampling with $d < 20 \text{ cm}$ and with $d > 20 \text{ cm}$) were given as 0.2, 0.13, 0.16 and 0.11, respectively, and all estimated p -values were higher than significance

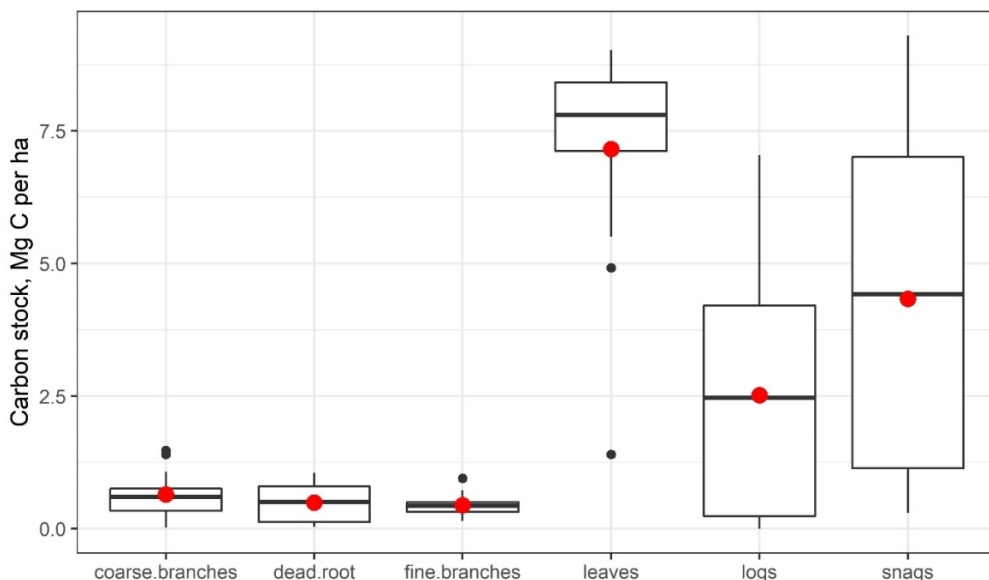


Fig. 6. Box and whisker plots of C stock among 12 sample oak stands.

Note: Horizontal line in each box is a median, while box represents 0.25–0.75 quantiles. Whiskers indicate to full range of compartment C stock. Red points are the respective mean values.

level (0.05): 0.69, 0.97, 0.58, 0.96. Result of this test has thus shown that no difference between samplings relative to its diameter or type (either log or stump) exists. As no statistical difference between diameter groups was found, model of oak logs decomposition was built basing on all 94 logs' samplings (Fig. 7).

Regression (Fig. 7a) shows next exponential-based model (2):

$$P_t = 514.5 \cdot e^{-0.023 \cdot t} \quad (2)$$

Coefficient of determination (R^2) is 0.75. Observed and predicted by model (2) values are agreed quite well, being adequately distributed along 1:1 reference line on the graph (Fig. 7b). Residuals of the model are randomly distributed, irrespective to sampling diameter (Fig. 8).

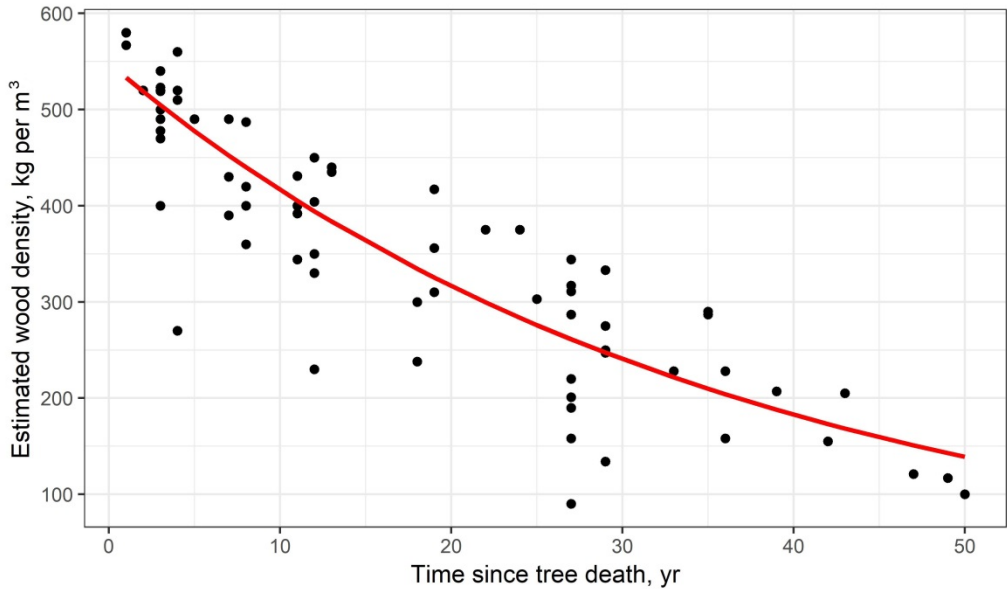
We tested model quality using non-parametric Kolmogorov-Smirnov λ -test. Estimated value of D -statistics is 0.13,

and estimated p -value is 0.43 (with significance level 0.05). Since estimated p -value is higher than significance level, null hypothesis of distributions similarity between observed and predicted wood density with given model cannot be rejected, indicating to adequacy of mentioned exponential model.

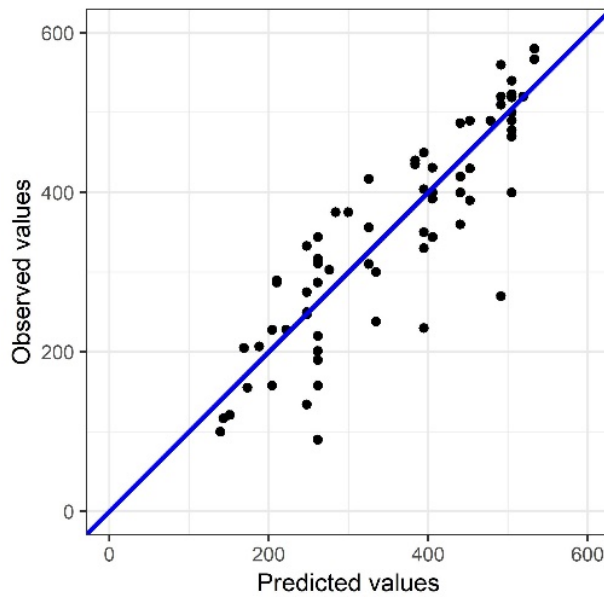
Discussion

Empirical and inventory data on CWD

CWD thus has been found more in studied stands than considered in forest inventory databases. According to that evidence, actually only 1.4 % C as a ratio to live biomass sink is sequestered in CWD (coarse branches litter is not considered). In studied oak stands, CWD share in C stock



a



b

Fig. 7. Pattern of Common oak logs' decomposition: a) exponential model is drawn for empirical data; b) agreement between observed (empirical) and predicted (modelled) values of basic wood density at time unit since tree death.

Note: Blue line represents 1:1 line.

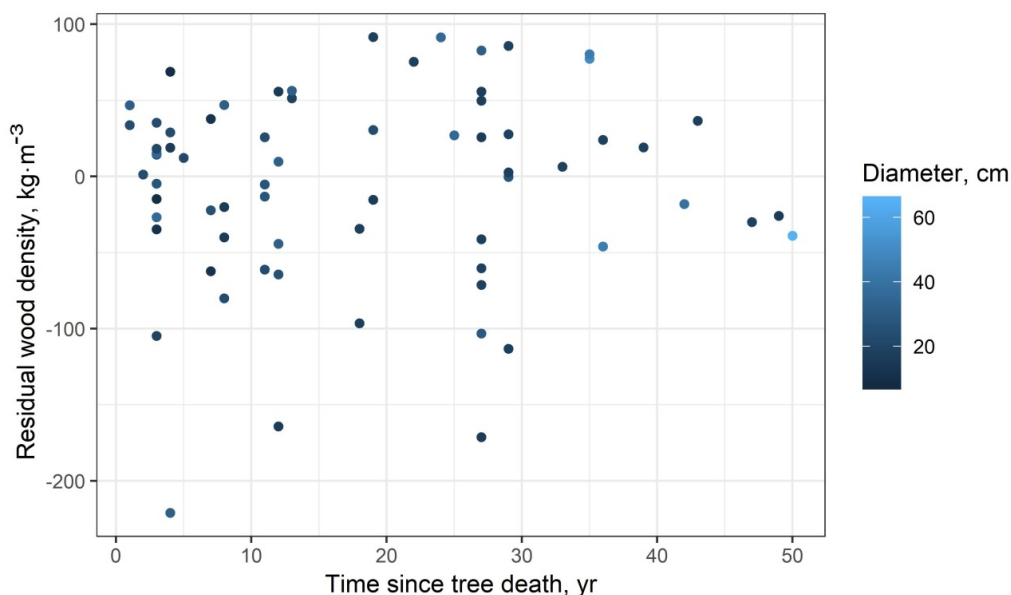


Fig. 8. Residuals of predicted wood density for oak logs' samplings are coloured by samplings' diameter.

structure is much higher – 6.0 %. Such insignificant CWD stocks in mature oak forests of Ukraine accounted in forest inventory data can be explained by the fact that dead stems (snags) and/or downed logs are only started to be accounted by inventory officers if they evaluate its presence at level $5 \text{ m}^3 \cdot \text{ha}^{-1}$ or more (Matsala and Bilous 2017).

Actually, there is still common to take out these dead biomass components from the forest during the silviculture activities in many state forest authorities with stands without nature considerations or protection regime. Moreover, as studied oak stands are concentrated in areas with high nature value, even there CWD stocks must be higher, especially after gap-scale natural disturbances (wildfires, storms, pest and diseases affection). Herewith, massive salvage loggings in the forest

with nature concern (like sample stands in 'Lubny forestry', Poltava region) or in the park located within the capital city (like sample stands in 'Feofania', Kyiv), are still common practices with aim to prevent fast pest spreading after outbreaks occurrence or to provide humans safety, respectively (Pasternak 2011).

Fine litter remains a main dead biomass compartment in oak stands until achieving maturity. Further, CWD accumulates higher C stocks, simultaneously leading to increasing C emissions from deadwood through decomposition, but being a key ecosystem component related to biodiversity preservation. This pattern can be seen comparing fine litter ratio in studied stands (49 % of dead biomass C stock) to Bilous et al. (2017a) data (43 % ratio in over-mature stand), while this ratio in middle-aged (75 years) exceeded 73 %.

Reliability of plot and inventory data

Pasternak (2011) found out that oak stands of North-Eastern Ukraine had had 1.3 % snags' ratio to GSV (forest type – D_2) in mature stands and 9.2 % ratio in over-mature forests (state on 2006). Snags' and logs' carbon stock (in the stands of all age cohort groups) also was estimated, for D_2 forest type in particular. Resulted mean C stocks are 2.5 Mg C·ha⁻¹ for snags and 2.1 Mg C·ha⁻¹ for logs, which are less with 41 % and 16 % than C of these dead biomass components from studied stands presented in this study, respectively. Such difference might be explained by the fact that Pasternak took into account stands of all age cohorts (with no data separated by these cohorts) while we focused on ma-

ture and over-mature forests.

Comparison of stem over bark live biomass carbon with Lakyda et al. (2006) data from Podillya oak woods (South-Western Ukraine) has shown 17.5±3.5 % deviation (Fig. 9), taking into account four 102–107 years old stands (site index I, forest type D_2) that are the most similar to our studied data. Such comparison was needed because of high dependence of different compartments presented in this study (crown and root live biomass, dead roots) on stem over bark stock. Deviation mentioned above could be explained by difference in precipitation and temperature regimes, soil conditions, with regard that plots in our studied stands were established actually in central and northern part of Ukraine, where continental climate

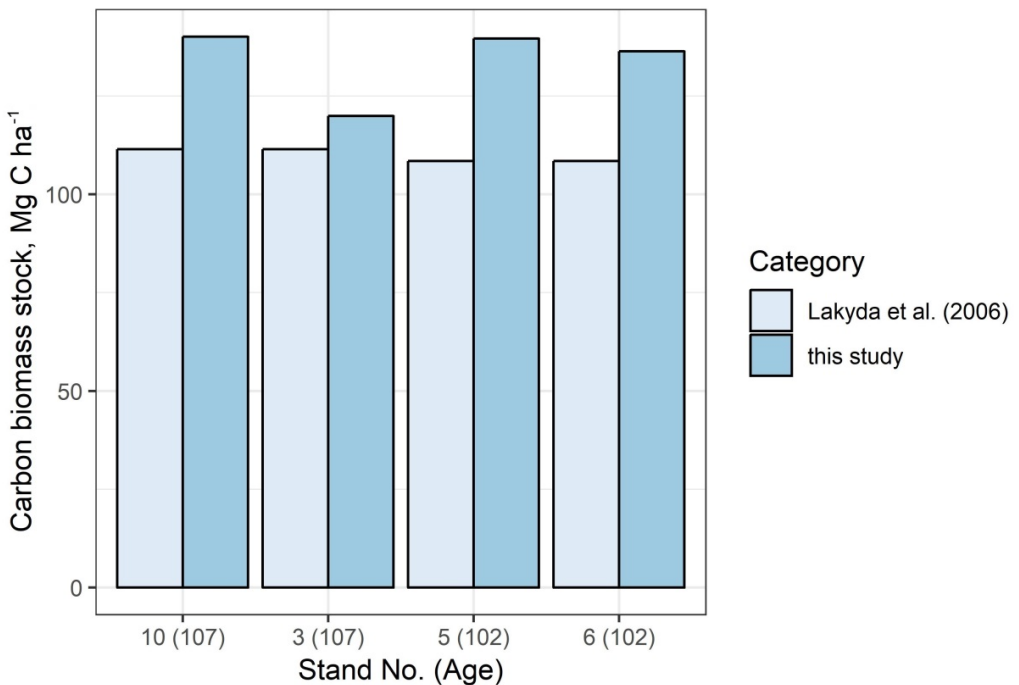


Fig. 9. Comparison of sample plot data from this study and Lakyda et al. (2006) data (stem live biomass C).

Note: Stand numbers are given according to Table 1.

defines local forest growth and yield more explicitly (Bilous et al. 2017a).

Herewith, apparent biases in accounting of CWD in Ukrainian forest inventory data aggregated in 2011 still exist. This study focuses on mature and over-mature oak stands, and for these two age cohorts the share of inventory units with odd values (absent data on GSV or snags'/logs' stocks that exceed GSV for given stand) is relatively low – 1.6 %. However, if all age cohorts are taken into account, this share will achieve 14.7 % level. Such biases create discrepancies in efforts to examine CWD accumulation patterns along oak forest life cycle in a robust way.

Carbon stock in CWD according to ecosystem distribution

The highest CWD ratio relatively to stem live biomass is observed in conditions not suitable for oak successful growth: too dry or too wet, soils with limited amount of nutrients (Figs 4 and 5), which corresponds to less productivity of those stands. Larger stocks of CWD there might be explained by higher natural mortality rate and worse resistance to the insect outbreaks, disease affections and even storm damage. Another explanation could be that less productive oak stands and forests which have been grown in very dry or wet conditions occur mostly in nature reserves, so CWD is not used to being removed from there during silvicultural activities (Bilous et al. 2017b). Furthermore, such mature stands are often not felled for a long time and become over-mature, so have possibility to store more carbon exactly in CWD (Bölöni et al. 2017).

Heatmaps (Figs 4 and 5) actually do not contain data on less fertile forest types (A and B), because of insignificant areas covered by such oak stands. On

the other hand, CWD accumulated there can achieve relatively high ratios to GSV (70–90 %). Herewith, this feature may correspond to the errors in national forest inventory data mentioned above. Another feature is that the most common site indexes for managed oak forests in Ukraine (i.e. I, Ia, Ib, Ic), which simultaneously correspond to high biological productivity there, are absent in given heatmaps. We can explain this by management regime been typical in Ukraine: high-productive oak forests due to high timber prices are commonly cut with final felling in the age of 101–110 years, while the 'worse' in economic sense stands (site indexes II–V) can be retained: rarely – for tree species diversity and other natural concerns, more often – with aim to reduce financial loss if such stands would be felled (Pasternak and Yarotskii 2013).

Figure 4 shows typical CWD composition among the oak stands with different range of nature-protection regimes. To date, one forest owners linked to state authorities retain logs and snags as the significant ecosystem component while others prefer to remove those in order to minimize wildfire, pest and diseases spreading risk, aiming to keep high-value wood in mature stands safe and even despite the fact that those stands had natural provenance and were characterized by sustainable growth (Pasternak 2011). On the other hand, coarse branches litter does not fluctuate so much like compartments of snags or logs. Downed branches with $d > 1$ cm but those are relatively thinner than 'logs' (which thus can be removed from forest during salvage logging or other silvicultural activity), is the crucial component of oak dead biomass, being a specific habitat for microbiota and subsequently positively influencing on forest soil fertility (Holaka al. 2017).

Logs density dynamics

Regression equation used by Yatskov et al. (2003) shows reliable chronosequence of logs' decomposition process. Results correspond to Harmon et al. (1986) evidence about potential of CWD in late-seral forests to store C until full decomposition for decades. No statistically significant difference in remained wood density between diameter groups has been found in contrast to coniferous species in north-western part of USA studied by Harmon et al. (1986), which have apparently other biological features and conditions than common oak in continental Europe. Herewith, stumps also have not shown any difference in decomposition pattern with the logs, although these are used to having larger contact surface with soil (and consequently with its microbiota). Yatskov et al. (2003) indicated that moisture is the main factor that drives CWD decaying, while high mean annual temperatures also cause substantial impact on decomposition, amplifying this process. Therefore, low influence of CWD size on its decaying can be explained by the fact that relatively dry continental regime in Ukraine along all seasons does not actually support decomposers activity, thus keeping decomposition process stable irrespective of logs size. Same situation was found by Bölöni et al. (2017): dry-mesic sites create conditions that decrease decomposition velocity.

However, Herrmann et al. (2015) estimated that with increasing of logs' diameter decomposition velocity is dampening: comparing groups with $d < 20$ cm and $d > 40$ cm, respective rates for European beech (*Fagus sylvatica* L.) and Scots pine (*Pinus sylvestris* L.) decreased twice. Herewith, no significant difference was found for Norway spruce (*Picea abies* L.).

Study sites from Herrmann et al. (2015) research were located in Northern Germany, i.e. on the same latitude with Ukraine, however climate there is relatively more humid. Another suggestion why this study has not found difference for diameter groups in oak CWD decomposition could be in biophysical parameters of oak stemwood.

Exponential modelling shows that logs can decompose until $40\text{--}50\text{ kg}\cdot\text{m}^{-3}$ remained wood density for 100 years, which proves CWD potential to store C so long in temperate latitudes. Therefore, oak deadwood in Ukraine is crucial not only as a habitat and preservation source for species diversity in forest ecosystem, but also as mid-term C sink with relatively low decomposition rates and consequently – C emissions back to atmosphere. This fact thus opens new evidence for preserving CWD in managed forests and keeping old-growth oak stands intact.

Conclusions

By accumulating carbon for decades, dead biomass plays significant role in mature and over-mature oak forest ecosystems of Ukraine. However this pool is smaller in Ukrainian oak forest compare to natural and protected oak forest in other European countries. Insignificant dead biomass stock in oak stands might be explained by high economic demand on wood taken off during the management activities aiming to reduce the risk of insects' and fungi's outbreaks.

On the other hand, coarse woody debris pool is underestimated by Ukrainian forest inventory. CWD takes a special place as an effective C sink in mid-term perspective according to low decomposition rate: carbon in deadwood may be

stored during 100 years until actually total biomass decaying. This fact is quite important for efforts to maintain the forest biodiversity and mitigate climate changes.

Hopefully, following the comprehension of role of forests and dead biomass in particular as a strong source of different ecosystem services and due to commitments taken in climate change and biodiversity issues on international level, conditions for CWD accounting and preservation in oak forests of Ukraine will occur soon.

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Appendix 1

Table A1. Geographical coordinates of sample plots.

No of stand	Age cohort	Latitude (N), °	Longitude (E), °
1	Over-mature	32.999	49.990
2	Over-mature	32.977	50.059
3	Mature	32.981	50.060
4	Mature	32.982	50.060
5	Mature	32.994	50.059
6	Mature	32.993	50.060
7	Mature	32.987	50.058
8	Over-mature	32.809	50.162
9	Over-mature	32.800	50.167
10	Mature	33.078	50.062
11	Over-mature	30.484	50.344
12	Over-mature	30.496	50.341

Appendix 2

Table A2. Description of oak logs' samplings collected for decomposition analysis.

No of sampling	Pt , $\text{kg}\cdot\text{m}^{-3}$	t , yr since death	D, cm	Group
1	450	12	16	logs
2	250	29	18	logs
3	560	4	10	logs
4	121	47	19	logs
5	117	49	16	logs
6	490	7	12	logs
7	430	7	16	logs
8	330	12	13	logs
9	190	27	19	logs
10	540	3	12	logs
11	520	3	14	logs
12	400	11	16	logs
13	333	29	19	logs
14	567	1	10	logs
15	580	1	8	logs
16	228	36	19	logs
17	440	13	16	logs
18	311	27	18	logs
19	510	4	8	logs
20	500	3	12	logs
21	431	11	14	logs
22	417	19	18	logs
23	420	8	16	logs
24	300	18	18	logs
25	400	8	12	logs
26	390	7	12	logs
27	375	22	18	logs
28	435	13	16	logs
29	317	27	18	logs
30	500	3	12	logs
31	490	3	16	logs
32	207	39	19	logs
33	205	43	18	logs
34	287	27	16	logs
35	275	29	19	logs
36	520	4	24	logs
37	500	3	28	logs
38	404	12	32	logs
39	392	11	28	logs
40	360	8	24	logs

No of sampling	Pt , $\text{kg}\cdot\text{m}^{-3}$	t , yr since death	D , cm	Group
41	287	35	50	logs
42	430	7	26	logs
43	290	35	44	logs
44	350	12	32	logs
45	344	27	32	logs
46	523	3	22	logs
47	519	3	26	logs
48	344	11	24	logs
49	520	2	24	logs
50	155	42	40	logs
51	487	8	32	logs
52	375	24	36	logs
53	440	13	28	logs
54	303	25	36	logs
55	490	5	22	logs
56	230	12	16	stumps
57	90	27	16	stumps
58	540	3	10	stumps
59	520	3	12	stumps
60	400	11	16	stumps
61	134	29	18	stumps
62	567	1	18	stumps
63	580	1	12	stumps
64	228	33	19	stumps
65	440	13	18	stumps
66	201	27	19	stumps
67	510	4	16	stumps
68	400	3	20	stumps
69	431	11	16	stumps
70	310	19	16	stumps
71	420	8	16	stumps
72	238	18	18	stumps
73	400	8	16	stumps
74	390	7	12	stumps
75	375	22	18	stumps
76	435	13	19	stumps
77	220	27	18	stumps
78	470	3	12	stumps
79	490	3	10	stumps
80	330	12	26	stumps
81	158	27	30	stumps
82	540	3	24	stumps

No of sampling	Pt , $\text{kg}\cdot\text{m}^{-3}$	t , yr since death	D, cm	Group
83	520	3	36	stumps
84	400	11	28	stumps
85	247	29	28	stumps
86	567	1	24	stumps
87	580	1	32	stumps
88	158	36	45	stumps
89	440	13	32	stumps
90	100	50	65	stumps
91	270	4	32	stumps
92	478	3	36	stumps
93	431	11	24	stumps
94	356	19	24	stumps

Appendix 3

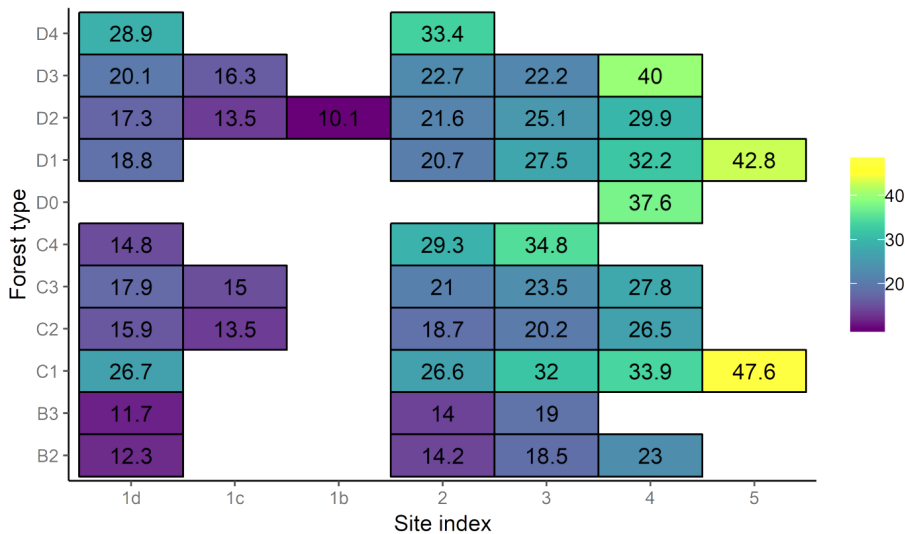


Fig. A3-1. Heatmap of ecosystem distribution of snag compartment in oak stands of all age cohorts.

Note: Numbers and colour of boxes represent gradient scale of mean snag ratio (in %) to GSV. Data was computed explicitly for each oak stand, then mean values were estimated.

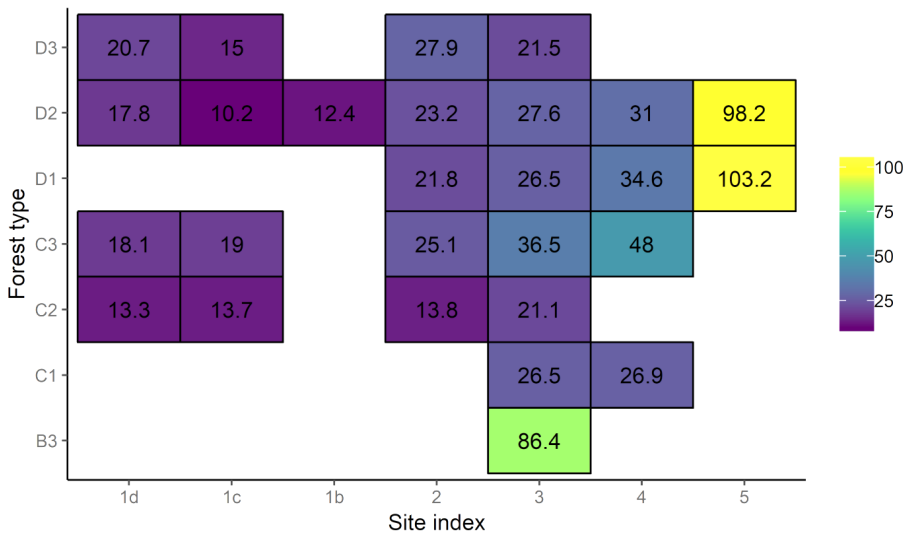


Fig. A3-2. Heatmap of ecosystem distribution of logs' compartment in oak stands of all age cohorts.

Note: Gaps in the graph correspond to the absence of compartment in the stands with respective combination of site index and forest type or restrictions described in Methods and Materials.

ANNOUNCEMENT FOR CONFERENCE

International Scientific Conference '*Forestry: Bridge to the Future*'

6–9 May 2020, Sofia, Bulgaria

University of Forestry Sofia has the pleasure to invite you to participate in the International Scientific Conference '*Forestry: Bridge to the Future*'. The Conference will take place in Sofia, Bulgaria, in the period May 06–09, 2020.

The Conference is dedicated to the 95th anniversary of higher forestry education in Bulgaria and is organized by the University of Forestry, Sofia and Faculty of Forestry.

The Conference sessions will be focused to the following topics: Climate Policy and Forest Sustainability (main topic) and following additional topics: i) Forest Biology and Ecology; ii) Forest Operations and Wood Processing; iii) Forest Economics and Management.

Key speakers:

- Prof. Valeriu-Norocel Nicolescu – Transilvania University of Brasov, Romania;
- Prof. Raffaele Spinelli – Italian National Research Council, Rome, Italy;
- Dr. ir. Mart-Jan Schelhaas – Wageningen University & Research, Netherlands;
- Dr. Georgi Kostov – University of Forestry, Sofia, Bulgaria.

Important dates:

- Registration opens: 1 October 2019
- Submission date: 3 February 2020
- Confirmation for acceptance: 17 February 2020
- Early registration deadline: 9 March 2020
- Cancellation deadline: 1 April 2020
- Hotel booking deadline: 6 April 2020

All information regarding the Conference and its facilities: registration, accommodation, payments, program, abstract submission can be found on the official conference web-site: <http://conf2020.forestry-ideas.info>

We shall look forward to meet you in Sofia in May 2020.

Prof. DSc. Ivan Iliev
Honorable Chairman of the Organizing
Committee
Rector of the University of Forestry
Sofia, Bulgaria

Assoc. prof. Dr. Marius Dimitrov
Chairman of the Organizing Committee
Dean of the Faculty of Forestry
University of Forestry
Sofia, Bulgaria