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Xylophagous beetles (Coleoptera) in the zones of Gomilshanski lisy National Nature Park with different management regime

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Abstract

The purpose of the research was to assess the species composition and biodiversity indices for xylophagous beetles collected by window traps in the parts of Gomilshanski lisy National Nature Park with different management regimes and anthropogenic load. Four window traps were placed in each of the five groups of sample plots: clear felling, selective felling, stationary recreation, regulated recreation and protected zone. The data were analysed using the statistical software package PAST, particularly, the Menhinick index (D_{Mn}) and dominance index (D) were evaluated and classical clustering (unweighted pair-group average [UPGMA]) was performed. A total of 42 species of xylophages (9903 individuals) were collected from Curculionidae (Scolytinae and Cossoninae), Cerambycidae, Histeridae, Bostrichidae, Buprestidae and Lymexilidae. The highest species richness was in the plots of clear and selective felling (25 and 22 species, respectively) and the lowest was in the protected zone (16 species), regulated recreation (19 species) and stationary recreation (22 species). The Menhinick index (D_{Mn}) was the lowest in the protected zone (0.27), increased in the zone of regulated recreation (0.43) and stationary recreation (0.45) and was maximal in the plots of selective and clear felling (0.69 and 0.77, respectively). The number of individuals was maximal in the protected zone and minimal at the plots of selective and clear felling. All sites were dominated by *Xyleborinus saxesenii* (Ratzeburg, 1837) (66–85% individuals) and *Anisandrus dispar* (Fabricius, 1792) (8.5–20.7% individuals). Minimal dominance (0.49) was found in the plot of clear felling. Cluster analysis showed similarity of the xylophage complex in the plots of clear and selective felling, as well as in the zone of stationary and regulated recreation, which differed from the protected zone.

Key words

window traps, species composition, management regime, biodiversity indices

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Introduction

Insects of the order Coleoptera are the most numerous in the world. More than 400,000 species from 200 families are known in the world, and in Europe, about 30,000 are known from 'Fauna Europaea' (Alonso-Zarazaga 2013).

Many beetle species are associated with wood (Lieutier et al. 2004). Xylophages develop in the wood of living trees of different health conditions and saproxylophages in the so-called 'dead' wood. Usually, xylophages attack weakened trees or their parts. Under the influence of drought (Meshkova 2021), fire (Catry et al. 2017), windstorm (Bouget and Duelli 2004; Sanginés et al. 2021; Gochnour et al. 2022) or forest management activity (Peltonen and Heliövaara 1999; Gossner et al. 2019; Leidinger et al. 2019), the number of trees available for xylophages increases. In such conditions, the outbreaks of certain species are developed where beetles attack not only weakened trees, but also healthy ones (Lieutier et al. 2004). Outbreaks of xylophagous insects cause significant economic losses to forestry (Skrylnik et al. 2019; Meshkova 2021). At the same time, an increase in the volume of dead wood at different stages of decomposition creates the niches for numerous insects of other ecological groups: saproxylophages, mycetophages, zoophages, and so on (Wermelinger et al. 2007; Lassauce et al. 2013; Carpaneto et al. 2015).

Sustainable forest management is the practice of preserving a forest health while regulating forest resources to meet the needs of society and industry (Pietzsch et al. 2021). At the same time, destroying the logging residues leads to a decrease in the number of available habitats of saproxylic species (Foit 2015).

National natural park is an area protected from most types of anthropogenic influence (Leidinger et al. 2019). Unlike reserves, in national parks, recreants are allowed to visit specially designated zones, particularly, stationary recreation and regulated recreation. In the protected zone, any activity is prohibited, and in the management zone, forest operations are allowed (Anonymous 1992). Due to the presence of such zones, in national parks, it is possible to assess insect species composition and occurrence in similar forest stands by forest site, tree species and age composition, but with different anthropogenic loads. In this regard, in 2019–2021, our studies were carried out at the Gomilshanski lisy National Nature Park (NNP).

The purpose of this research was to assess the species composition and biodiversity indices for xylophagous beetles, caught by window traps in the zones of Gomilshanski lisy NNP with different management regimes and anthropogenic load.

Material and methods

The research was carried out in 2019–2021 in Gomilshanski lisy NNP, which was established in 2004 in Kharkiv region (49º35' 36º19'). The northern border of the park is located at a distance of 45 km from Kharkiv and 5 km from the district centre of Zmiiv (Fig. 1). This NNP was established in 2004 in order to preserve, reproduce and rationally use typical and unique forest-steppe natural complexes of the Seversky Donets valley, which have important environmental, scientific, aesthetic, recreational and health value. Its territory was included in the List of officially adopted Emerald Network sites – UA0000034 Gomilshanski lisy NNP (List of officially adopted Emerald Network sites 2020).

The territory of Gomilshanski lisy NNP is located within the left bank forest-steppe zone. The climate of the region is temperate-continental (Zepner et al. 2020) (Fig. 2). January is the coldest month and July the warmest month. Period with positive air temperature lasts for 268 days (Mar 7–Nov 29), with a temperature over 5°C lasting for 219 days (Mar 29–Nov 2), over 10°C for 177 days (Apr 16–Oct 9) and over 15°C for 130 days (May 10–Sep 16). The average temperature for the vegetation period is 17.4°C. Annual precipitation is 522.5 mm and for the vegetation period, it is 287.2 mm; it is the lowest in February–April and the highest in May–July.

The relief is dominated by a flat and hilly watershed. Deciduous forests grow on the right bank of the Seversky Donets River, and Scots pine forests grow on the left bank. The researches were carried out in the deciduous stands with *Quercus robur* L. as the main forest-forming species. The oak stands are mainly coppices. *Fraxinus excelsior* L., *Tilia cordata* Mill., *Acer platanoides* L., *Betula pendula* Roth. and *Ulmus laevis* Pall. are the most spread tree species. The age of stands in the sample plots was 80–100 years old.

The territory of Gomilshansky lisy NNP is divided into four zones: forest management, protected, regulated recreation and stationary recreation (see Fig. 1).

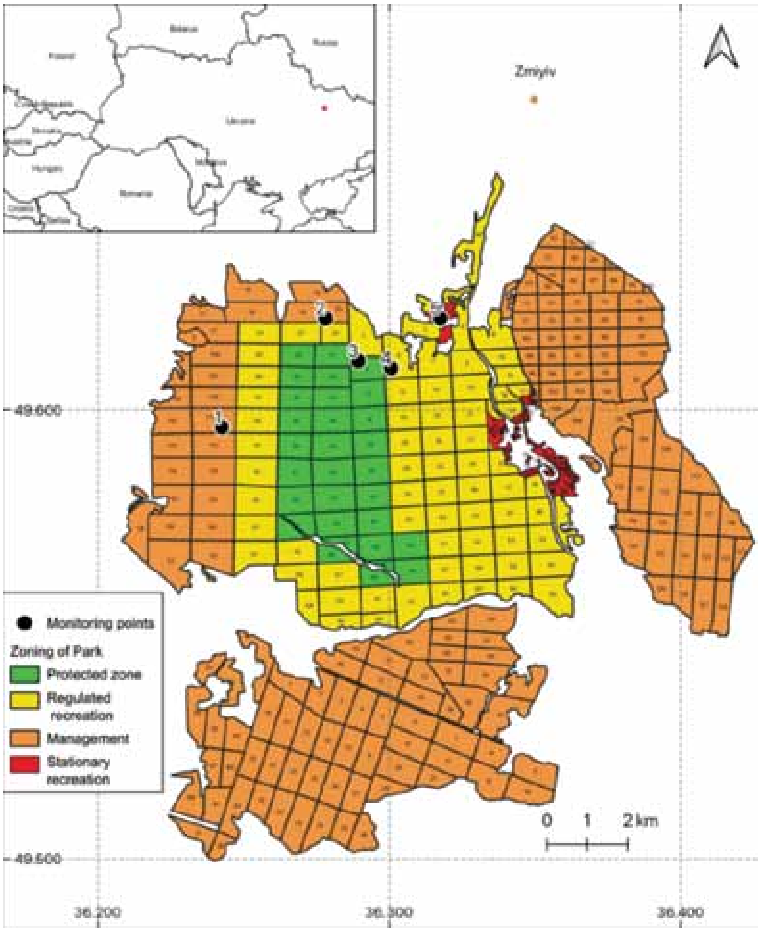

Figure 1. Location of Gomilshanski lisy National Nature Park and sample plots (1 – plot of clear felling in the managed zone; 2 – plot of selective sanitary felling in the managed zone; 3 – protected zone; 4 – zone of regulated recreation; 5 – zone of stationary recreation)

Four window traps of our own design (Skrylnik and Bieliavtsev 2020) were placed in each of the five groups of plots:

- clear felling in 2019 (forest management zone),
- selective sanitary felling in 2019 (forest management zone),
- stationary recreation zone (location of recreation centres),
- regulated recreation zone (moderate recreational load) and
- protected zone (where forest management activity and recreational load are absent) (Tab. 1).

Window traps were made of two polyethylene plates (42 × 30 cm) (Fig. 3). Wooden rails, 42 cm long (1.0 × 2.0 cm wide and high), were attached to each of them with a stapler. The plates were fastened crosswise with the help of rails. A ring with a diameter of 42 cm was fastened from below with a wire having a cross section of 2 mm. A cone made of polyethylene film was attached to the ring with scotch tape. A glass container with a volume of 100 ml was attached to the bottom of the cone with the help of rubber rings. A mixture of 96% alcohol and glycerin in a ratio of

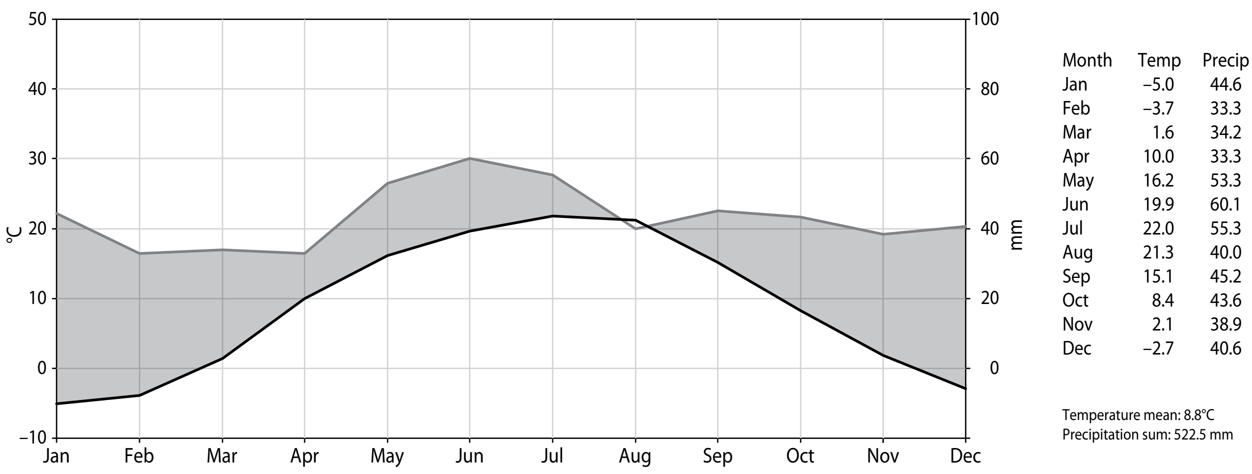

Figure 2. Characteristics of climate in the territory of Gomilshansky lisy National Nature Park (Zmiyiv meteorological station, 49.664N, 36.273E, 112 m a.s.l., climate class DFB. Years: 1990–2019 **(**Zepner et al. 2020**)**

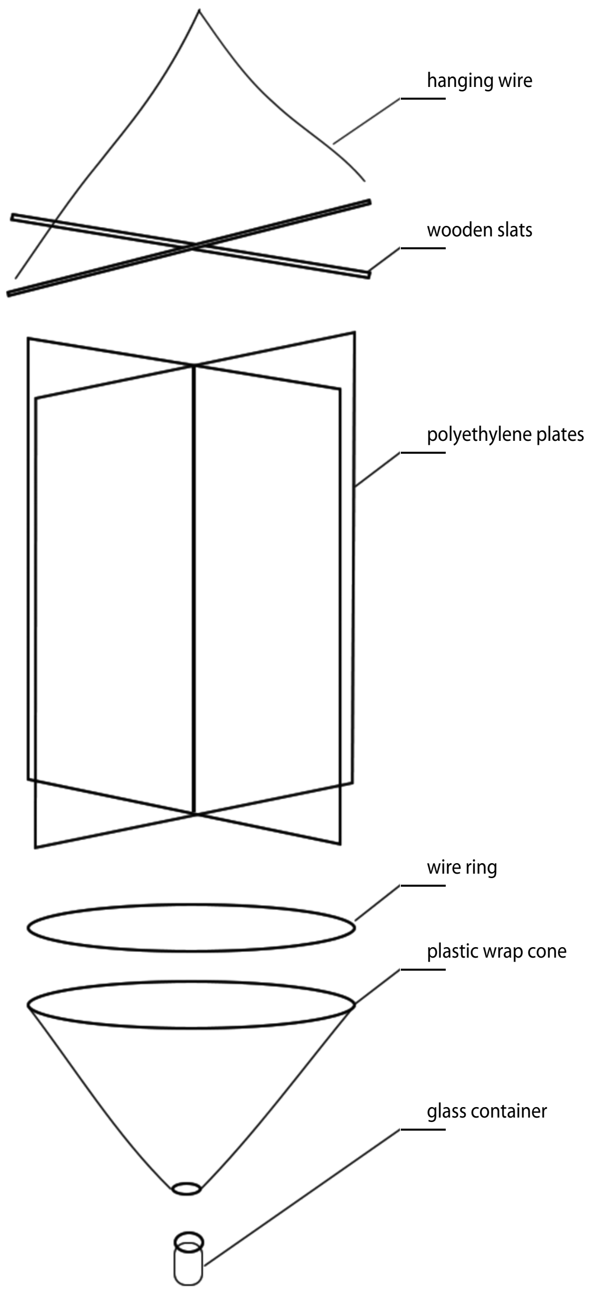

Figure 3. Design of window trap (Skrylnik and Bieliavtsev 2020)

4:1 was poured into a container. The total catch area was 2 × 42 × 30 = 2520 cm^2 or 0.25 m^2. Knitting wire was attached to the wooden rails, behind which the trap was hung at a height of 1.5–1.8 m.

Table 1. Location of sample plots

Sample plots	Latitude [°N]	Longitude [°E]
1. Plot of clear felling in the managed zone	49.5962	36.2427
2. Plot of selective sanitary felling in the managed zone	49.6204	36.2782
3. Protected zone	49.6109	36.2895
4. Zone of regulated recreation	49.6092	36.3007
5. Zone of stationary recreation	49.6204	36.3176

Every 10 days, the insects from traps were collected in separate Eppendorf tubes, which indicated the trap number and date of catch. In the laboratory, the contents of each tube were identified and counted.

Insect species were identified using a microscope MBS-9 and special publications (Tarbinsky and Plavilshchikov 1948; Richter 1949; Danilevsky 2014), and compared with the specimens from the collection of the Forest Protection Laboratory of Ukrainian Research Institute of Forestry and Forest Melioration and Kharkiv Entomological Society.

The relative richness of each xylophagous species was calculated as the proportion of individuals of this species from the total number of individuals of all analysed species. The prevalence of species was assessed on the following scale: single – up to 0.1% of the total, rare – 0.1–1%, common – 1–5%, abundant – more than 5% (Bieliavtsev and Skrylnik 2020).

The data were analysed using the statistical software package PAST: Paleontological Statistics Software Package for Education and Data Analysis (Hammer et al. 2001).

The Menhinick index (D_{Mn}) shown in equation (1) was chosen because it is not very sensitive to the absolute values of *S* and *N* and is recommended for comparing samples of different sizes.

$$D_{Mn} = \frac{S}{\sqrt{N}} \quad (1)$$

where:
D_{Mn} – the Menhinick index,
S – the number of species,
N – the number of individuals.

Dominance index (*D*) shown in equation (2) was evaluated considering that the higher the level of dominance, the more unfavourable are the conditions for the studied species.

$$D = \sum_i \left(\frac{n_i}{n}\right)^2 \qquad (2)$$

where:

ni – the number of individuals of taxon *i*.

Classical cluster analysis was used to compare lists of species found in different groups of sample plots. Clusters were joined based on the average distance between all members in the two groups, that is, by unweighted pair-group average (UPGMA).

The species composition in different sample plots was compared using the Sorensen–Chekanovsky index shown in equation (3) (Leontyev 2007).

$$C_{sc} = \frac{2c}{a + b} \qquad (3)$$

where:

a – the number of species in the first sample,
b – the number of species in the second sample,
c – the number of species common to both samples.

The level of competition between xylophages in different groups of sample plots was assessed by analysing the rank distribution of species (Tarasova et al. 2004). The relationship between the proportion of individuals of each species and its rank is described by an equation of the form:

$$\ln p(i) = a - b \times \ln i$$

where:

p – the proportion of individuals of each species from the total number of individuals of all species in the community,
i – the rank of this species.

Factor *a* characterises the population density of the dominant species and factor *b* the competition between species.

Results

A total of 42 species of xylophages (9903 individuals) were found from Curculionidae, Cerambycidae, Histeridae, Lymexilidae, Bostrichidae and Buprestidae (Tab. 2).

The highest species richness was found in the plots of clear and selective felling (25 and 22 species, respectively) and stationary recreation (22 species). The lowest species richness was in the protected zone (16 species) and regulated recreation (19 species).

Curculionidae: Scolytinae (bark beetles) prevailed in all sample plots (21 species or 50%). The second place was occupied by Cerambycidae (longhorn beetles – 13 species or 31%) and the third place by Buprestidae (jewel beetles – four species or 9.5%). The rest of the families were represented by one species each and together made up 9.5% (Fig. 4).

Bark beetles dominated in all groups of sample plots; however, in the protected zone, bark beetles accounted for 75% of the species and longhorn beetles

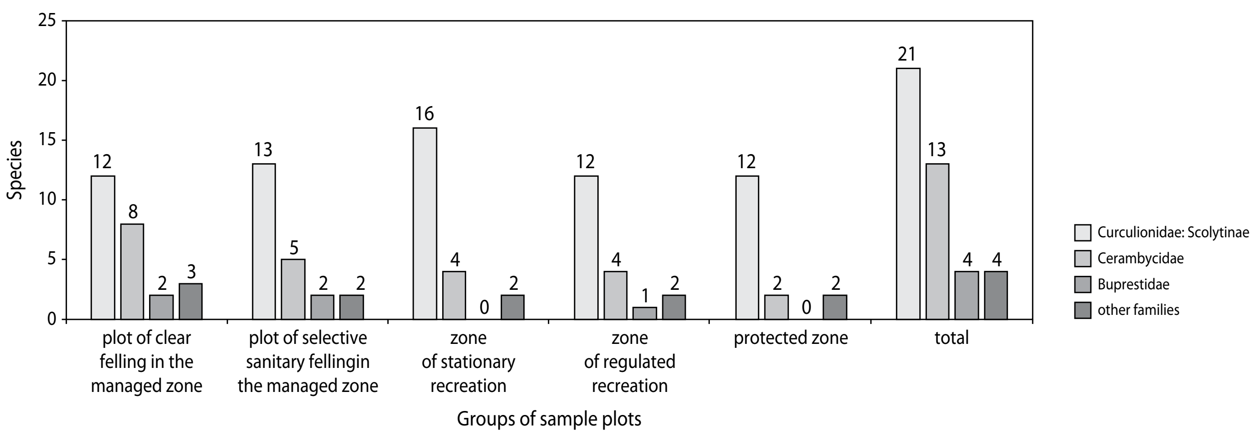

Figure 4. Number of xylophagous species in different zones of Gomilshanski lisy National Nature Park

Table 2. Xylophagous beetles (Coleoptera) in different zones of Gomilshanski lisy National Nature Park

Species	Insect counts per groups of sample plots					Total
	plot of clear felling in the managed zone	plot of selective sanitary felling in the managed zone	zone of stationary recreation	zone of regulated recreation	protected zone	
1	2	3	4	5	6	7
Curculionidae: Scolytinae						
Anisandrus dispar (Fabricius, 1792)	199	87	222	413	426	1347
Anisandrus maiche (Stark, 1936)	5	8	4	0	0	17
Dryocoetes villosus (Fabricius, 1792)	0	1	0	0	1	2
Hylesinus crenatus (Fabricius, 1787)	0	0	2	1	0	3
Hylesinus toranio (Danthoine, 1788)	33	0	2	2	14	51
Hylesinus varius (Fabricius, 1775)	6	0	14	0	2	22
Lymantor coryli (Perris, 1855)	0	1	0	0	0	1
Pteleobius vittatus (Fabricius, 1787)	0	0	21	1	0	22
Scolytus intricatus (Ratzeburg, 1837)	2	12	6	0	2	22
Scolytus koenigi (Schevyrew, 1890)	2	3	4	7	2	18
Scolytus laevis (F. Chapuis, 1869)	0	2	0	0	0	2
Scolytus mali (Bechstein, 1805)	1	0	3	0	0	4
Scolytus multistriatus (Marsham, 1802)	8	18	22	3	1	52
Scolytus pygmaeus (Fabricius, 1787)	0	0	1	0	0	1
Scolytus rugulosus (Müller, 1818)	0	0	4	0	0	4
Scolytus sp.	0	0	0	2	0	2
Trypodendron signatum (Fabricius, 1792)	0	1	0	2	4	7
Xyleborinus attenuatus (Eichhoff, 1876)	36	18	19	43	73	189
Xyleborinus saxesenii (Ratzeburg, 1837)	701	854	2053	1469	2718	7795
Xyleborus dryographus (Ratzeburg, 1837)	5	3	1	4	1	14
Xyleborus monographus (Fabricius, 1792)	26	10	26	42	87	191

1	2	3	4	5	6	7
Curculionidae: Cossoninae						
Rhyncolus ater (Linnaeus, 1758)	2	0	1	0	0	3
Cerambycidae						
Cerambyx (Microcerambyx) scopolii (Fuessly, 1775)	5	1		1	0	7
Leioderes kollari (Redtenbacher, 1849)	0	3	0	0	0	3
Leiopus linnei (Wallin, Nylander, Kvamme, 2009)	2	0	0	0	0	2
Mesosa curculionoides (Linnaeus, 1761)	1	0	2	0	0	3
Plagionotus arcuatus (Linnaeus, 1758)	1	0	0	0	0	1
Plagionotus detritus (Linnaeus, 1758)	1	0	0	0	0	1
Pogonocherus hispidulus (Piller, Mitterpacher, 1783)	2	0	1	2	0	5
Pyrrhidium sanguineum (Linnaeus, 1758)	3	0	3	1	1	8
Rhagium (*Megarhagium*) *mordax* (De Geer, 1775)	1	0	0	0	0	1
Rhagium sycophanta (Schrank von Paula, 1781)	0	1	3		1	5
Ropalopus macropus (Germar, 1824)	0	0	0	1	0	1
Stenocorus (*Anisorus*) *quercus* (Gotz, 1783)	0	1	0	0	0	1
Xylotrechus arvicola (Olivier, 1795)	0	1	0	0	0	1
Histeridae						
Abraeus granulum (Erichson, 1839)	1	1	1	0	4	7
Lymexilidae						
Elateroides dermestoides (Fleming, 1921)	2	0	0	1	77	80
Bostrichidae						
Bostrichus capucinus (Linnaeus, 1758)	0	1	0	1	0	2
Buprestidae						
Agrilus angustulus (Illiger, 1803)	1	0	0	0	0	1
Agrilus hastulifer (Ratzeburg, 1839)	0	1	0	0	0	1
Agrilus sulcicollis (Boisduval, Lacordaire, 1835)	1	2	0	0	0	3
Chrysobothris affinis (Fabricius, 1794)	0	0	0	1	0	1
Total individuals	1047	1030	2415	1997	3414	9903
Total species	25	22	22	19	16	42

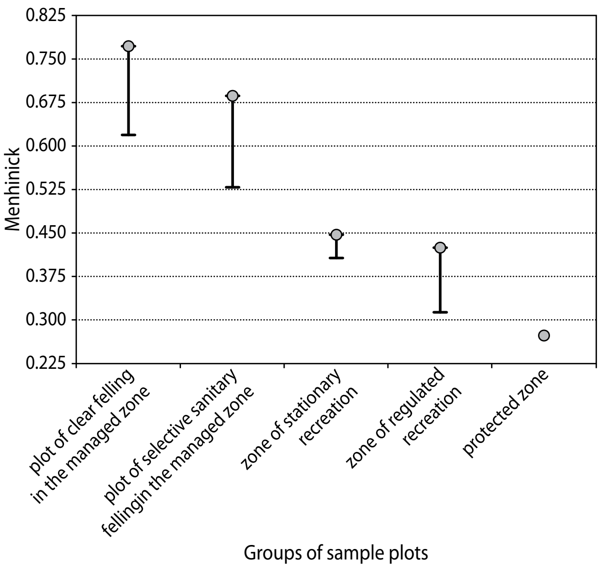

Figure 5. Menhinick index of xylophagous insects in different zones of Gomilshanski lisy National Nature Park

accounted for 15.5%, while at the sample plot of clear felling, bark beetles and longhorn beetles made up 48% and 32%, respectively. Jewel beetles were not collected at the plots of stationary recreation and protected zone (see Fig. 4).

The number of individuals was the highest in the protected zone (3414 specimens) and the lowest in the plots of clear felling and selective felling (1047 and 1030 specimens, respectively) (see Tab. 2). Bark beetles made up 97.6–99.6% of individuals in different groups of sample plots. The highest proportion of bark beetle individuals was collected in the protected zone and in the zones of regulated and stationary recreation. Longhorn beetle individuals prevailed at the plot of clear felling.

Menhinick index (D_{Mn}) was the lowest in the protected zone (0.27), increased in the zone of regulated recreation (0.43) and stationary recreation (0.45) and was maximal in the plots of selective and clear felling (0.69 and 0.77, respectively) (Fig. 5).

At all sample plots, the proportion of abundant and common species was the lowest and rare and single species the highest (Fig. 6). Rare species were almost half of all species at the plots of clear felling and stationary recreation. Single species dominated in all other sample plots.

In terms of the number of individuals, 12 species averaged 99% (from 97.4% in the clear felling area to 99.7% in the protected zone) (Tab. 3). All sample plots were dominated by *Xyleborinus saxesenii* (Ratzeburg, 1837) (67–85% individuals) and *Anisandrus dispar* (Fabricius, 1792) (8.5–20.7% individuals).

Both scolytids were abundant in all sample plots; only *A. dispar* was common at the plot of selective felling (see Tab. 2). Minimal dominance (0.49) was found in the plots of clear felling and a bit higher (0.58) in the zone of regulated recreation. At the other groups of sample plots, this indicator was 0.65–0.73. (Fig. 7).

In the protected zone, the common species were *Xyleborus monographus*, *Elateroides dermestoides* and *Xyleborinus attenuatus*, rare species were *Hylesinus toranio*, *Trypodendron signatum* and *Abraeus granulum* and single species were *Hylesinus varius*, *Scolytus intricatus*, *Scolytus koenigi*, *Dryocoetes villosus*, *Scolytus multistriatus*, *Xyleborus dryographus*, *Pyrrhidium sanguineum* and *Rhagium sycophanta* (see Tab. 2).

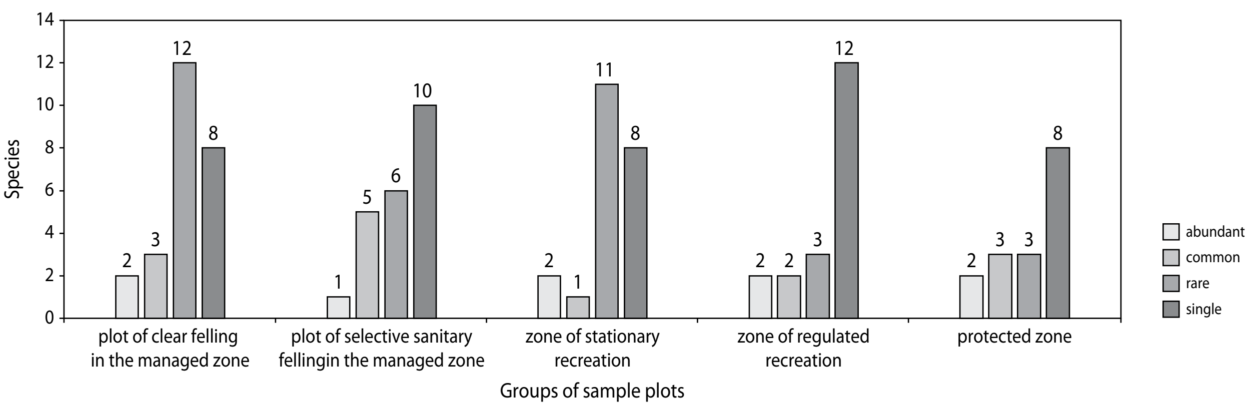

Figure 6. Xylophagous species abundance in in different zones of Gomilshanski lisy National Nature Park

Table 3. The proportion of the most abundant xylophagous beetles (Coleoptera) in different zones of Gomilshanski lisy National Nature Park*

Species	Insect counts per groups of sample plots					Total
	plot of clear felling in the managed zone	plot of selective sanitary felling in the managed zone	zone of stationary recreation	zone of regulated recreation	protected zone	
Xyleborinus saxesenii	67.0	82.9	85.0	73.6	79.6	78.7
Anisandrus dispar	19.0	8.5	9.2	20.7	12.5	13.6
Xyleborus monographus	2.5	1.0	1.1	2.1	2.6	1.9
Xyleborinus attenuatus	3.4	1.8	0.8	2.1	2.1	1.9
Elateroides dermestoides	0.1	0.0	0.0	0.1	2.3	0.8
Scolytus multistriatus	0.8	1.8	0.8	0.1	0.1	0.5
Hylesinus toranio	3.2	0.0	0.1	0.1	0.1	0.5
Hylesinus varius	0.6	0.0	0.6	0.0	0.1	0.3
Pteleobius vittatus	0.0	0.0	0.8	0.1	0.0	0.2
Scolytus intricatus	0.2	1.2	0.3	0.0	0.2	0.2
Scolytus koenigi	0.2	0.2	0.2	0.3	0.1	0.2
Anisandrus maiche	0.4	0.7	0.2	0.0	0.0	0.2
Total for these species	97.4	98.1	99.1	99.2	99.7	99.0

Notes: *Species are arranged in decreasing order of occurrence.

In the zone of regulated recreation, the common species were *X. attenuatus* and *X. monographus*, rare species were *S. koenigi*, *X. dryographus* and *S. multistriatus* and single species were *H. toranio*, *T. signatum*, *Pogonocherus hispidulus*, *H. crenatus*, *Pteleobius vittatus*, *Cerambyx scopolii*, *P. sanguineum*, *Ropalopus macropus*, *Bostrichus capucinus*, *Chrysobothris affinis* and *E. dermestoides* (see Tab. 2).

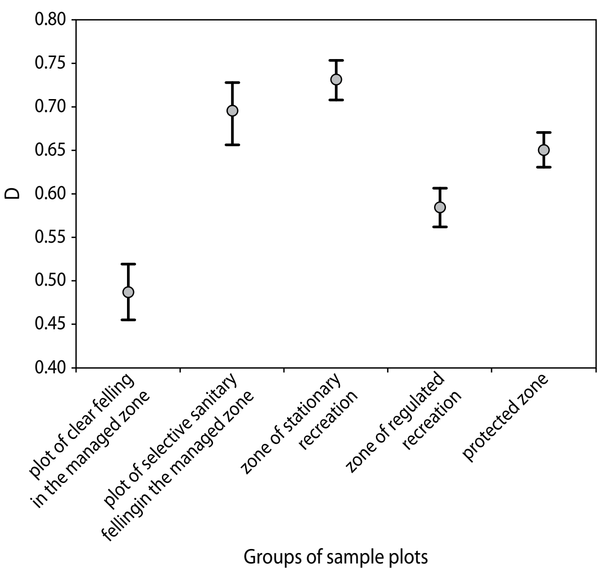

Figure 7. Dominance of xylophagous insects in different zones of Gomilshanski lisy National Nature Park

In the zone of stationary recreation, the common species was only *X. monographus,* rare species were *C. multistriatus*, *Pt. vittatus*, *X. attenuatus*, *H. varius,* *S. intricatus*, *Anisandrus maiche*, *S. koenigi*, *Scolytus rugulosus*, *Scolytus mali*, *P. sanguineum* and *Rh. sycophanta* and single species were *H. crenatus*, *H. toranio,* *Mesosa curculionoides*, *S. pygmaeus*, *X. dryographus,* *Rhyncolus ater*, *P. hispidulus* and *A. granulum* (see Tab. 2).

At the plot of selective felling, the common species were *A. dispar*, *S. multistriatus*, *X. attenuatus*, *S. intricatus* and *X. monographus*, rare species were *A. maiche*, *S. koenigi*, *X. dryographus*, *Leioderes kollari*, *Scolytus laevis* and *Agrilus sulcicollis* and single species were *D. villosus*, *Lymantor coryli*, *T. signatum*, *C. scopolii*, *Rh. sycophanta*, *Stenocorus (Anisorus) quercus*, *Xylotrechus arvicola*, *A. granulum*, *B. capucinus* and *Agrilus hastulifer* (see Tab. 2).

At the plot of clear felling, the common species were *X. attenuatus*, *H. toranio* and *X. monographus*, rare species were *S. multistriatus*, *H. varius, A. maiche*, *X. dryographus*, *C. scopolii*, *Py. sanguineum*, *S. intricatus*, *S. koenigi*, *Rh. ater*, *Leiopus linnei*, *P. hispidulus* and *E. dermestoides* and single species were *S. mali*, *M. curculionoides*, *Plagionotus arcuatus*, *Pl. detritus*, *Rhagium mordax*, *A. granulum*, *Agrilus angustulus* and *Ag. sulcicollis* (see Tab. 2).

L. linnei, *Pl. arcuatus*, *Pl. detritus, Rh. mordax* and *Ag. angustulus* were found only at the plot of clear felling (see Table 2). *L. coryli*, *S. laevis, L. kollari*, *St. quercus*, *X. arvicola* and *Ag. hastulifer* were found only at the plot of selective felling.

R. macropus and *Ch. affinis* were found only at the zone of regulated recreation. *S. pygmaeus* and *S. rugulosus* were found only at the zone of stationary recreation. No xylophagous species have been identified only in the protected zone (see Tab. 2).

Cluster analysis showed the greatest similarity between the xylophage complexes at the plots of clear and selective felling, as well as between such complexes in the zones of stationary and regulated recreation, and both pairs of sample plots differed from the protected zone (Fig. 8).

Table 4. Calculation of Sorenson–Chekanovsky index (C_{sc}) for xylophagous complexes in the different sample plots of Gomilshanski lisy National Nature Park

Group of sample plots (zone) A	Species number in A	Group of sample plots (zone) B	Species number in B	Number of common species for A and B	C_{sc}
Selective sanitary felling	22	Protected	16	12	0.63
Selective sanitary felling	22	Regulated recreation	19	10	0.49
Selective sanitary felling	22	Clear felling	25	12	0.51
Selective sanitary felling	22	Stationary recreation	22	11	0.50
Protected	16	Regulated recreation	19	11	0.63
Protected	16	Clear felling	25	13	0.63
Protected	16	Stationary recreation	22	13	0.68
Regulated recreation	19	Clear felling	25	12	0.55
Regulated recreation	19	Stationary recreation	22	12	0.59
Clear felling	25	Stationary recreation	22	17	0.72

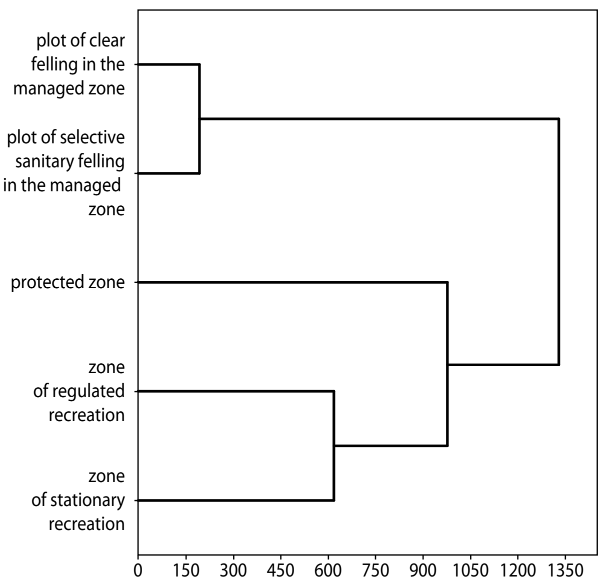

Figure 8. Clusters of sample plots of Gomilshanski lisy National Nature Park by xylophagous insect occurrence

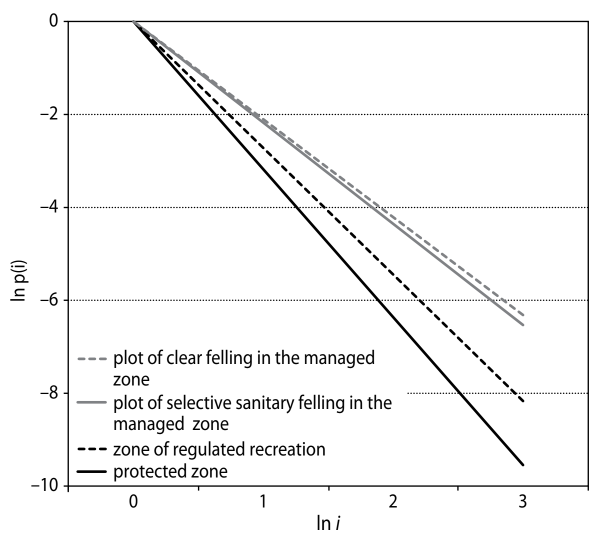

Figure 9. Competition level between xylophages at the different sample plots of Gomilshanski lisy National Nature Park

A similar conclusion was obtained by calculation of the Sorenson–Chekanovsky index (C_{sc}) (Tab. 4).

Analysing the rank distribution of species showed that the relationships between the proportion of individuals of each species and its rank were significant for all analysed communities (R^2 – 0.95–0.99), and such correlation was the highest for the plots of clear felling and selective sanitary felling (Fig. 9).

The factor of competition was the highest in the protected zone (b = 3.17), less at the plots of regulated (b = 2.71) and stationary recreation (b = 2.30) and the lowest at the plots of selective sanitary felling (b = 2.16) and clear felling (b = 2.09), that is, where there were more species of xylophagous beetles.

Discussion

Human activity, in particular, forest management and recreation, changes the microclimate of forest stands, their structure and health condition (Aussenac 2000; Foit 2015; Holuša et al. 2021). As a result, the conditions for many species change, of which the insects are the most numerous and vulnerable (Peltonen and Heliövaara 1999; Wermelinger et al. 2007).

Much research has been devoted to the insect communities of dead wood in order to determine the ways to conserve them (Wermelinger et al. 2007; Lassauce et al. 2013; Carpaneto et al. 2015). At the same time, xylophages that inhabit living trees and commercial timber are considered mainly from the point of view of the possibility of reducing their harmfulness (Lieutier et al. 2004; Meshkova 2021; Gochnour et al. 2022).

The protected zone of NNP serves for the conservation of ecosystems, protection of threatened species and scientific research, particularly, to compare the insect communities in the zones with the different anthropogenic load (Anonymous 1992). Although the Gomilshanski lisy NNP has existed since 2004, relatively few studies have been devoted to its entomofauna (Bartenev and Terekhova 2006, 2011). Our research in Gomilshanski lisy NNP performed in 2019–2021 made it possible to identify 340 species of insects of the order Coleoptera (Meshkova et al. unpublished) in deciduous stands, of which xylophages consist of 42 species or account for 12.35%. Harmfulness (Bieliavtsev and Meshkova 2019), trophic structure (Bieliavtsev and Skrylnik 2020) and features of seasonal changes in species composition (Skrylnik and Bieliavtsev 2020) were evaluated.

The comparison showed the highest species diversity of xylophages at the plots of clear and selective felling of forest management zone (Tab. 2). Such logging residues and severely weakened trees attract xylophages (Foit 2015).

The increase of available resources for xylophages due to the appearance of severely weakened trees in the stationary recreation zone compared with the protected zone is associated with anthropogenic impact. The weakening of trees occurs as a result of soil compaction, fires, and direct damage to trees by recreants **(**Monz et al. 2013; Marion et al. 2016; Arnberger et al. 2018).

Among xylophagous Coleopters, bark beetles (Curculionidae: Scolytinae) dominated in all groups of sample plots, mainly due to the two most abundant species – *X. saxesenii* and *A. dispar*. Therefore, in the protected zone, the bark beetles make up 75% of the species and are the highest number of individuals and the proportion of longhorn beetles increases at the plots of felling (Fig. 4).

A. dispar and *X. saxesenii* are also the most abundant beetles in different regions **(**Bussler et al. 2011; Saruhan 2013; Sarikaya 2015; Tanaskovic et al. 2016). Both species are polyphagous; however, *A. dispar* prefers thin branches and *X. saxesenii* the stem part of the tree (Skrylnik et al. 2019; Holuša et al. 2021)**.**

Menhinick index (D_{Mn}) was used for biodiversity description, as the sample size of insects is different in particular sample plots. This index grows with species number and is inversely proportional to the square root of the number of individuals. Therefore, D_{Mn} is the lowest in the protected zone and the highest at the plots of felling (Fig. 5).

The absence of xylophagous species identified only in the protected zone (see Tab. 2) means that the xylophagous complex is rather stable. Some species in the protected zone are able to attack living trees, but they are rare (*H. toranio*, *T. signatum*) or single (*H. varius*, *S. intricatus*).

Common species at the plot of selective felling (*S. multistriatus*, *X. attenuatus*, *S. intricatus*, *X. monographus*) and clear felling (*X. attenuatus*, *H. toranio*, *X. monographus*) are able to weaken trees or wood at the early stages of destruction **(**Bieliavtsev and Meshkova 2019). Such species can be dangerous for forests and commercial wood.

In the zone of regulated recreation, a jewel beetle *Ch. affinis* was found, which attacks weakened trees (Bieliavtsev and Meshkova 2019). In the zone of stationary recreation, *Scolytus* sp. were found, which are able to weaken the trees during maturation feeding and then colonise them and vector the pathogens.

Low dominance indices show that the sample plots of clear felling and in the zone of regulated recreation appear to be the most favourable for xylophagous insects (Fig. 7). Minimal dominance in the plot of clear felling is associated with a decrease in the proportion of bark beetles and an increase in the proportion of longhorn beetles, which inhabit the coarse woody debris (Bartenev and Terekhova 2011).

Cluster analysis shows the three clear distinct groups of sample plots by xylophagous beetles' diversity: the plots with forest management activity (clear and selective felling), with recreation loading (zones of stationary and regulated recreation) and protected zone (Fig. 8), which is supported by Sorenson–Chekanovsky index (Tab. 4).

Obtained data confirm that both felling and recreation essentially affect xylophagous beetles' diversity.

Conclusions

A total of 42 species of xylophages (9903 individuals) were found from Curculionidae (Scolitinae), Cerambycidae, Histeridae, Bostrichidae, Buprestidae and Lymexilidae. Xylophagous species richness was the highest at the plots of clear and selective felling and the lowest in the protected zone. The number of individuals was maximal in the protected zone and minimal at the plots of selective and clear felling. All sites were dominated by *X. saxesenii* (Ratzeburg, 1837) and *A. dispar* (Fabricius, 1792). Minimal dominance was found at the plot of clear felling. The high similarity of the xylophage complex is proved at the plots of clear and selective felling, as well as in the zones of stationary and regulated recreation, which differ from the protected zone. The factor of the xylophages' competition increases with species biodiversity from the plot of clear felling to the protected zone.

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