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THE DIVERSITY AND SPECIES COMPOSITION OF WATER BEETLES (GYRINIDAE, DYTISCIDAE, HYDROPHILIDAE) IN A PEAT BOG IN BELARUS

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The Diversity and Composition of Assemblages of Water Beetles (Gyrinidae, Dytiscidae, Hydrophilidae) in a Peat Bog in Belarus. Shatarnova, O. — The diversity and species composition of the water beetles in peat bog lakes, streams and hollows in Belarus were studied. In total, 45 species of water beetles belonging to 3 families (Gyrinidae, Dytiscidae, Hydrophilidae) were sampled by entomological net. *Hydroporus tristis*, *Ilybius aenescens*, *Enochrus affinis*, and *E. ochropterus* are the most abundant species A rather high diversity was recorded (Shannon-Wienner diversity index H′ = 2.037–2.912). Shannon-Wienner indexes indicated higher values in the lakes, whereas the lowest values in the hollows were recorded. In addition, in hollows water beetle species composition was the most different from the other peat bog water bodies.
Key words: assemblages, water beetles, species composition, diversity, peat bog, Belarus.

Introduction

Peat bogs of Europe are habitats with very specific abiotic conditions and plant and animal communities (Spitzer, Danks, 2006), which are stable and slowly changing ecosystems if natural conditions are preserved (Bragg et al., 2003; Joosten et al., 2012).

The most of pristine European peatlands can be found in northern part of the continent, whereas in Central Europe, many of them are destroyed by drainage and peat extraction. The exceptions are Belarusian peatlands. More than half of them are least anthropogenically modified and have large areas. Therefore, Belarus is one of Europe's key peatland countries (Bambalov, Rakovich, 2005; Joosten et al., 2012; Sushko, 2016 a).

Terrestrial peat bog habitats are characterized by pronounced amplitude of daily temperatures, high humidity and very low pH values as a result of the cation exchange capacities of the *Sphagnum* moss. Besides, in many Belarusian peat bogs may be different water habitats, such as lakes, stems and hollows. The water of these habitats is acidic, low in nutrients and has a characteristic brown color, which comes from dissolved peat tannins (Wieder et al., 2006; Rydin, Jeglum, 2006).

The biodiversity of the peat bog aquatic invertebrates is very poorly studied. Most of the research in Belarus focuses on plant communities and terrestrial invertebrate assemblages (Sushko, 2007; Yelovicheva et al., 2008; Grumo et al., 2010; Sushko, 2012; Sushko, 2014 b; Sushko, 2016 a, b, c, d; Zeliankevich et al., 2016). Only several studies in Belarus reported about aquatic beetle species richness and abundance in different peatlands, including peat bogs (Shaverdo, 1995, Ryndevich, 1999, 2004, Sushko, 2014 a). However, not many detailed studies about water beetle diversity and species composition in main water body types of peat bogs of postglacial northern part of Belarus have been done. Moreover, these findings were based on studies, conducted more than 15–20 years ago. Besides, in other European countries, little is known about peat bog water insects (Peus, 1928; Roubal, 1934; Maavara, 1957; Danks, Rosenberg, 1987; Mielewczyk, 2003; Sazhnev, Philippov, 2017). It should be noted that these studies mainly contained information on the number of species, including aquatic beetles.

Among aquatic invertebrates, one of the most numerous taxa is beetles, which are playing an important role in the food chains. Therefore, the aquatic beetle assemblages may reflect differences of the environmental conditions of the peat bog water bodies. The aim of this study is to examine the diversity and assemblage composition of the peat bog water beetles in Belarus.

I hypothesized that (1) there are differences in aquatic beetle diversity and assemblage composition among various peat bog water bodies; (2) the lakes, the largest peat bog water bodies, may have the highest beetle diversity.

Materials and methods

Study area and data collection

The study was conducted in the Viciebsk Region in Northern Belarus. The mean summer air temperature is 17 °C, the vegetation growth period lasts from 185 to 195 days, and the annual rainfall is approximately 600–700 mm. Peat bogs occupy about 185,4 thousand hectares in the region. Kazjanskij State Landscape Reserve (55°32´ N, 29°26´ E) among the largest (4900 hectares) peat bogs in North of Belarus. Moreover, it is one of the largest protected wetlands in Central Europe and least modified by humans (Kozulin, Vergeithik, 2005).

45 sampling places were selected across various types of water bodies: lakes, hollows, and streams. Beetles were sampled in five lakes, five hollows and three streams. At each lake and hollow, I chose three sampling places; additionally, I took five sampling places from the each stream since of such water bodies only three were found. Thus, each of the three studied types of water bodies included fifteen sampling places (fig. 1).

Beetles were sampled during six expeditions in spring (April, May), summer (June, July), and autumn (September, October) of 2017. At each sampling place, ten 1 m sweeps with a dip net six times were performed (i. e. 60 sweeps per sampling place, 900 sweeps per water body type). The net had a surface area of 1 m^2 and 1 mm mesh. The material was sorted in the laboratory and preserved in 70 % ethanol.

The taxonomy and names of species are given according catalogues of water betlees of Palearctic (Hájek, Fery, 2019; Nilsson, Hájek, 2020; Przewoźny, 2020).

The following physical and chemical water parameters were measured at each sampling place in situ using a Hanna Instruments COMBO HI 98121 portable meter: pH, conductivity and water temperature.

Lakes (L). The length of the shoreline of the lakes ranged from 200 to 800 m, and depths are about 2 m. The shores were covered by *Sphagnum* mosses, ericaceous shrubs and cotton-grass. The mean pH — 4.37 ± 0.03, conductivity — 47 ± 6.42 μS/cm, temperature — 17.44 ± 3.24 °C.

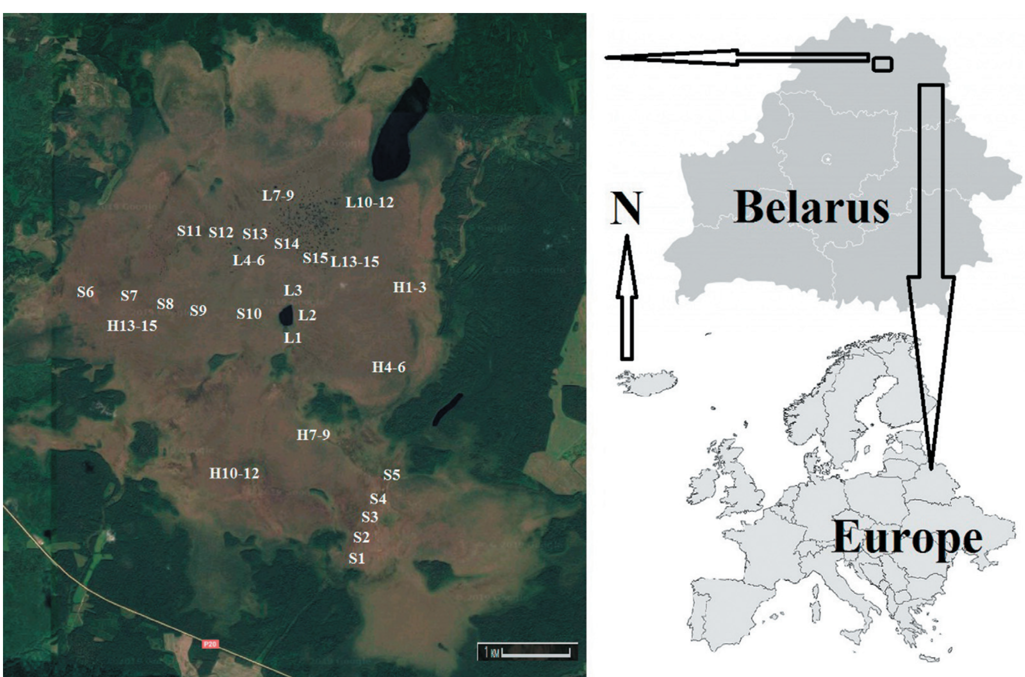

Fig. 1. Study area and the sampling places: L — Lakes, H — Hollows, S — Streams.

Streams (S). The length of the streams ranged from 50 to 500 m, and depths are about the 0.5 m. The stream shores were covered by *Sphagnum* mosses, ericaceous shrubs and *Carex* spp. The mean pH — 5.11 ± 1.21, conductivity — 69 ± 15.31 μS/cm, temperature — 16.24 ± 4.42 °C.

Hollows (H). Hollows were about 30 m in diameter. They are covered by *Sphagnum* mosses and *Rhynchospora alba.* The depth of the hollows was 5–20 cm. The mean pH — 3.42 ± 0.12, conductivity — 60 ± 8.31 μS/cm, — 18.89 ± 6.75 °C.

Data analyses

The data of collected beetles of all fifteen sampling places of one water body type were pooled and used in statistical analysis. For calculating of relative abundance of each species, all sampling places of a respective water body were pooled too. The difference among the number of species, number of individuals and diversity indexes were examined by the Kruskal-Wallis test and Dunn's post-hoc test.

Non-parametric sample-based estimator Chao 2 to assess true species richness was used. The estimator was calculated using the software SPADE (Chao et al., 2015). Individual-based rarefaction curves for calculating and extrapolating species richness were calculated and illustrated using PAST 3.25 (Hammer et al., 2001).

Alpha diversity was represented by Shannon-Wienner diversity index (H′) and Pielou evenness index (J′) (Magurran, 2004). Non-metric multidimensional scaling (NMDS) was used as measure of beta diversity of water beetle assemblages at different water bodies. NMDS was based on the Bray-Curtis distance measure (Jongman et al., 1995). Analysis of Similarities (ANOSIM) was used to assess the significance of dissimilarity among the water beetle assemblage clusters. Principal component analysis (PCA) was performed to ordinate species composition of different water bodies. The data were log10 (n + 1) transformed. Species which less five individuals was found were omitted from analysis (Jongman et al., 1995). The analyses were done using the software packages PAST 3.25 (Hammer et al., 2001).

Results

A total of 45 species of water beetles belonging to the families Gyrinidae, Dytiscidae, and Hydrophilidae were collected. The highest number of species was recorded from Dytiscidae (34). Other families were represented by smaller numbers of species: Hydrophilidae — 9 and Gyrinidae — 2.

The Dytiscidae, Hydrophilidae and Gyrinidae assemblages included from 10 to 31 species. The highest mean number of species was recorded in the lakes. The lowest species richness was recorded in the streams (table 1). The mean species richness significantly differed among the water bodies (Kruskal-Wallis test H = 12.14, p = 0.002).

The species accumulation curves based on species richness and abundance of water beetles show rather steep gradients, but only assemblages of stream nearly approaches an asymptote (fig. 2). On the other hand, the species richness estimator of Chao 2 showed good average expected species richness, which is close to the observed number of species recorded in the water body types (table 2).

Table 1. The diversity parameters of water beetle assemblages in three different water body types

Parameters	Water bodies		
	Lakes	Streams	Hollows
The mean number of observed species (S)	30^{bc}	8.8^{ac}	26.7^{ab}
S standard error	0.44	0.37	0.76
The maximum number of observed species	31	10	28
Chao 2	33	11	33
Chao 2 standard error	0.55	0.25	0.10
Shannon-Wiener index (H')	2.969^{bc}	2.736^{ac}	1.970^{ab}
H' standard error	0.028	0.015	0.009
Pielou index (J')	0.679^{c}	0.762^{c}	0.558^{ab}
J' standard error	0.016	0.011	0.009

Note. a, b, c — Letters indicate significant differences based on Kruskal-Wallis test and Dunn's post-hoc test.

Table 2. Species composition and relative abundance of water beetle assemblages in three different water body types

Species/Family	Code	Percentage of total abundance		
		Lakes	Streams	Hollows
Gyrinidae				
Gyrinus natator (Linnaeus, 1758)	*Gyr nat*	0	27.27	0
Gyrinus substriatus Stephens, 1828	*Gyr sub*	0	4.04	0
Dytiscidae				
Acilius canaliculatus (Nicolai, 1822)	*Aci can*	1.75	14.14	8.51
Acilius sulcatus (Linnaeus, 1758)	*Aci sul*	5.26	17.17	4.26
Agabus biguttulus (Thomson, 1867)	*Aga big*	0	4.04	0
Agabus congener (Thunberg, 1794)	Aga con	1.75	0	0.71
Agabus sturmii (Gyllenhal, 1808)	*Aga stu*	2.63	0	0
Agabus uliginosus (Linnaeus, 1761)	*Aga uli*	1.75	0	0.71
Bidessus unistriatus (Scharnk, 1781)	*Bid uni*	0.88	0	0.71
Colymbetes fuscus (Linnaeus, 1758)	*Col fus*	3.51	0	0
Colymbetes paykulli Erichson, 1837	*Col pay*	0	2.02	0
Colymbetes striatus (Linnaeus, 1758)	*Col str*	0.88	0	0
Cybister lateralimarginalis (Degeer, 1774)	*Cyb lat*	1.75	0	0
Dytiscus circumcintus (Ahrens, 1811)	*Dyt cir*	9.65	4.04	0.71
Dytiscus marginalis Linnaeus, 1758	*Dyt mar*	4.39	0	0
Graphoderus zonatus (Hoppe, 1795)	Gra zon	1.75	0	0
Hydaticus seminiger (Degeer, 1774)	*Hyd sem*	3.51	0	1.42
Hydaticus transversalis (Pontoppidan, 1763)	*Hyd tra*	1.75	0	0
Hydroporus dorsalis (Fabricius, 1787)	*Sup dor*	0.88	0	0.71
Hydroporus erythrocephalus (Linnaeus, 1758)	*Hyd ery*	0.88	5.05	2.84
Hydroporus incognitus Sharp, 1869	*Hyd inc*	0	0	0.71
Hydroporus melanarius Sturm, 1835	*Hyd mel*	0	0	1.42
Hydroporus morio Aube, 1838	*Hyd mor*	0	0	0.71
Hydroporus obscurus Sturm, 1835	*Hyd obs*	0	0	1.42
Hydroporus planus (Fabricius, 1781)	*Hyd pla*	1.75	0	0.71
Hydroporus tristis (Paykull, 1798)	Hyd tri	0	0	8.51
Hydroporus umbrosus (Gyllenhal, 1808)	*Hyd umb*	0	0	2.13
Hygrotus decoratus (Gyllenhal, 1810)	*Hyg dec*	0.88	0	0
Hygrotus versicolor (Schaller, 1783)	*Hyg ver*	2.63	0	0
Ilybius aenescens Thomson, 1870	*Ily aen*	10.53	0	1.42
Ilybius erichsoni Gemminger et Harold, 1868	*Aga eri*	0	0	1.42
Ilybius fenestratus (Fabricius, 1781)	*Ily fen*	1.75	0	0
Ilybius guttiger (Gyllenhal, 1808)	*Ily gut*	7.89	13.13	0
Porhydrus lineatus (Fabricius, 1775)	*Por lin*	0	0	0.71
Rhantus latitans Sharp, 1882	*Rha lat*	2.63	0	2.13
Rhantus sututellus (Harris, 1828)	Rha sut	0	0	5.67
Hydrophilidae				
Anacaena lutescens (Stephens, 1829)	*Ana lut*	0	0	10.64
Enochrus affinis (Thunberg, 1794)	*Eno aff*	1.75	0	22.70
Enochrus ochropterus (Marsham, 1802)	Eno och	15.79	0	0
Enochrus quadripunctatus (Herbst, 1797)	*Eno qua*	0	0	0.71
Helophorus aquaticus (Linnaeus, 1758)	*Hel aqu*	1.75	0	5.67
Helophorus grandis Illiger, 1798	*Hel gra*	0	9.09	0

Helophorus granularis (Linnaeus, 1761)	*Hel grn*	0	0	4.26
Helophorus griseus Herbst, 1793	*Hel gri*	9.65	0	0
Hydrobius fuscipes (Linnaeus, 1758)	*Hyd fus*	0	0	8.51

The mean number of specimens significantly differed among the water bodies (Kruskal-Wallis test H = 5.86, p = 0.05). The lowest abundance of water beetles was in the stream, whereas the highest abundance was captured in the hollows (fig. 3).

The species *Enochrus ochropterus* (Marsham, 1802) (15.79 %), *Ilybius aenescens* Thomson, 1870 (10.53 %), *Dytiscus circumcintus* (Ahrens, 1811) (9.65 %), and *Helophorus griseus* Herbst, 1793 (9.65 %) were collected from lake in high abundance. The species *Gyrinus natator* (Linnaeus, 1758) (27.27 %), *Acilius sulcatus* (Linnaeus, 1758) (27.27 %), *A. canaliculatus* (Nicolai, 1822) (14.14 %), *Ilybius guttiger* (Gyllenhal, 1808) (13.13 %), and *Helophorus grandis* Illiger, 1798 (9.09 %) were the most abundant in stream. In the hollows, such species as *Enochrus affinis* (Thunberg, 1794) (22.70 %), *Anacaena lutescens* (Stephens, 1829) (10.64 %), *Hydroporus tristis* (Paykull, 1798), *Hydrobius fuscipes* (Linnaeus, 1758), and *A. canaliculatus* (8.51 %) were recorded in high abundances (table 2).

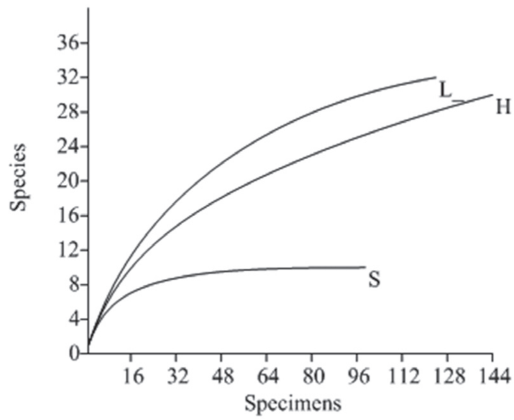

Fig. 2. The species accumulation curves of water beetle assemblages in three different water body types: lakes (L), streams (S), and hollows (H).

The mean Shannon-Wienner index values significantly differed among the water bodies (Kruskal-Wallis test H = 12.7, p = 0.001). Diversity measures indicate a higher values in the lakes (H′ = 2.969) and hollows (H′ = 2.736) compared to the stream (H′ = 1.970), which had the highest values of evenness (J′ = 0.762) (table 2).

Water beetle species composition was different among three types of biotopes, such as lakes, streams and hollows. ANOSIM showed significantly dissimilarity (R = 0.89, p = 0.001). NMDS analyses indicated clear differences among water beetle assemblages and revealed higher similarity among assemblages of lakes and streams, whereas the hollows were the most different from the streams (fig. 4). The stress for the first two ordination axes is small, at 0.06.

PCA ordination showed clear preferences of many species for certain water bodies. The first two PCA axes explained 59.08 and 37.12 % of the variation. *G. natator* and *A. sulcatus* correlated with streams. *E. ochropterus*, *H. griseus* and *D. circumcinctus* are most associated with lakes. Correlation with the hollows was shown by *E. affinis*, *A. lutescens* and *H. tristis* (fig. 5).

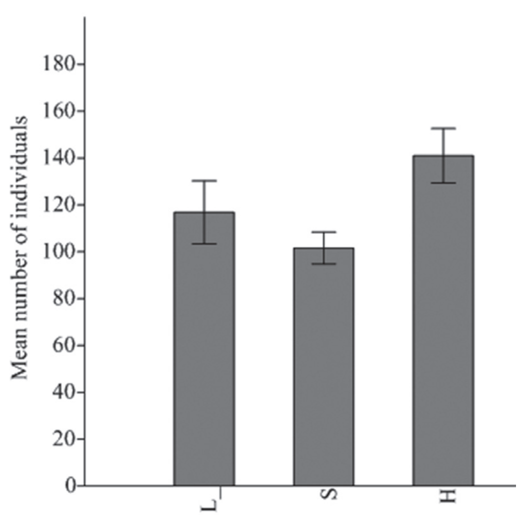

Fig. 3. Mean numbers of individuals (± SE) of water beetle assemblages in three different water body types: lakes (L), streams (S), and hollows (H).

Discussion

This study showed significant differences among species richness, diversity and species composition of aquatic beetles

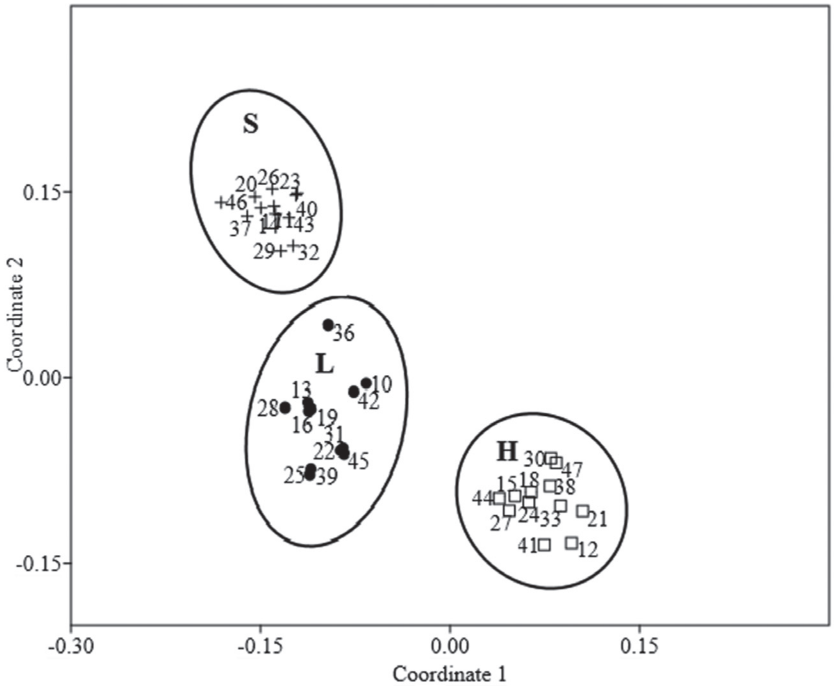

Fig. 4. Non-metric multidimensional scaling ordination according to the characteristic resemblance matrix (Bray-Curtis distance) of water beetle assemblages in three different water body types: lakes (L — samples marked as dots), streams (S — samples marked as pluses), and hollows (H — samples marked as squares).

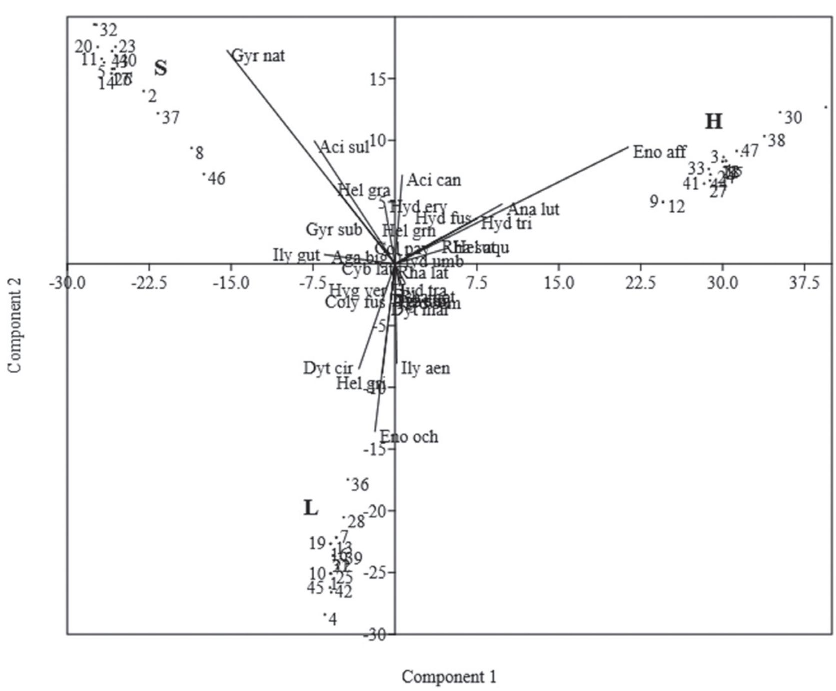

Fig. 5. Principal component analysis ordination according of water beetle assemblages in three different water body types: lakes (L), streams (S), and hollows (H). Complete species names are given in table 2.

of water bodies within large protected peat bog. Thus, results support the first hypothesis.

A similar species richness (about 40 species) peat bog water beetles belonging to the families Gyrinidae, Dytiscidae and Hydrophilidae in Germany and the Czech Republic has been recorded (Peus, 1928; Roubal, 1934). Whereas, in other countries the number of species varied. In particular, 19 species of aquatic beetle have been found in Estonia (Maavara, 1957). In Russia were recorded 12 species of the families Dytiscidae and Hydrophilidae in peat bog water bodies (Sazhnev and Philippov, 2017). Previous research showed the lower species richness of peat bog water beetles in comparison to fens, swamps and not bog lakes in Belarus (Ryndevich, 2004). The presented studies showed a low species richness of aquatic beetles in various types of water bodies in particular. This is not surprising, since the peat bog environmental conditions are considered extreme for plants and animals, including terrestrial invertebrates (Rydin, Jeglum, 2006; Spitzer, Danks, 2006; Zeliankevich et al., 2016; Sushko, 2014 b; Sushko, 2016 b, c).

Ryndevich (2004) reported two species, *Hydroporus melanarius* and *Helophorus tuberculatus*, as specialized peat bog dwellers. In the presented studies carried out in the north of Belarus, only *Hydroporus melanarius* was recorded. Such species as *H. tristis, I. aenescens, E. affinis,* and *E. ochropterus* are the most abundant species, which play an important role in peat bog food chains. These species are common in various stagnant water bodies in Belarus (Ryndevich, 2004). At the same time, they were found in peat bogs in different countries (Peus, 1928; Roubal, 1934; Maavara, 1957).

The high abundance of several species led to the low diversity and evenness of the water beetle assemblages. A similar trend can be observed on some peatlands in Poland (Buczyński et al., 2017).

On the other hand, the diversity of water beetle assemblages was higher compared to the terrestrial beetles (Sushko, 2014 b).

Shannon-Wienner diversity indexes indicated higher values in the lake assemblages. This result supports the second hypothesis and indicates the most favorable environment conditions of lakes compared to other peat bog water bodies.

In addition, it should be noted that the hollow water beetle assemblages were the most different from the other peat bog water bodies. Hollows are very specific habitats of sphagnum bogs, which are characterized by the highest acidity and specialized and species poor plant communities. They are part of the so-called hummock-hollow complexes and are very sensitive to the disturbance of moisture conditions in the peat bogs (Zeliankevich et al., 2016). A general recommendation for the conservation of rare, protected, and specialized peat bog insects is to avoiding disturbances to the regional water table (Spitzer, Danks, 2006). Large peat bogs preserved in Belarus are protected areas and can be favor for the conservation of aquatic insect diversity of European wetlands.

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Conflicts of Interest. The author declares no conflict of interest.

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