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Family level diversity and distribution of macroinvertebrates of Madatapa, Khanchali and Bughdasheni lakes in Javakheti plateau (South Georgia)

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Abstract

We studied family level diversity and distribution of benthic invertebrate communities in three lakes (Madatapa, Khanchali, Bughdasheni) of Javakheti plateau (Georgia). In total 35 families of all major phyla were recorded (not included families of Ostracoda, Nematoda, Turbellaria) among which Chironomidae (Diptera) and Gammaridae (Amphipoda) were the most abundant and widespread. Several family based biotic indices indicated that in studied lakes, level of organic pollution (eutrophication) is high and the stability and health of ecosystems are low. In spite of the protected status of these lakes, anthropogenic pressure is still high and further research and biodiversity monitoring is needed in order to evaluate the ecosystem dynamics and most significantly affecting factors.

Key words: Javakheti, lake ecosystems, benthic invertebrates, family based biotic indices

Introduction

The degradation of freshwater ecosystem could be provoked by natural or anthropogenic factors. The later includes water pollution, physical habitat destruction and invasion that are considered as main hazards directly affecting the structure and functioning of freshwater ecosystem [1]. Due to the ever growing anthropogenic influence, freshwaters are the most threatened ecosystems among others [2,3] and its conservation is a greatest challenge to humankind. One of the obstacles that hamper the conservation of freshwaters is our limited knowledge of its biodiversity, which is especially noticeable in developing world [4,5]. E.g. all, hitherto undertaken activities for freshwater biodiversity conservation in Georgia was based on mostly on political reasoning and to lesser degree based on limited data available for fishes and freshwater associated birds. In other hand data on diversity of invertebrates and algae of Georgian freshwaters is very poorly known [6] which makes impossible to unambiguously identify the most diverse and significant freshwater ecosystems for conservation prioritization. Clearly, the absence of updated data and monitoring programs does not allow evaluating even the general trends in freshwater ecosystem dynamics in Georgia. Meanwhile, industrial development and freshwater consumption is increasing daily which points out the urgent need of freshwater diversity inventory and research in Georgia.

The aim of the present article is to contribute in our knowledge of freshwater invertebrate biodiversity of some lakes of Javakheti plateau (South Georgia). Javakheti plateau is a volcanic highland located at elevations between 1700-3300m a.s.l. and higher [7]. The most of its area is represented by treeless subalpine meadows. The region is characterized by typical continental climate with mean annual temperature of 5.3C^0 and annual precipitation of 750mm. Due to its topography the region is very rich with all kind of lotic and lentic freshwater ecosystems. Since the second half of 20th century, the freshwater ecosystems of Javakheti region underwent to strong anthropogenic influence (including habitat modification, pollution, over-exploitation of freshwater resources and introductions of non-native species) [8].

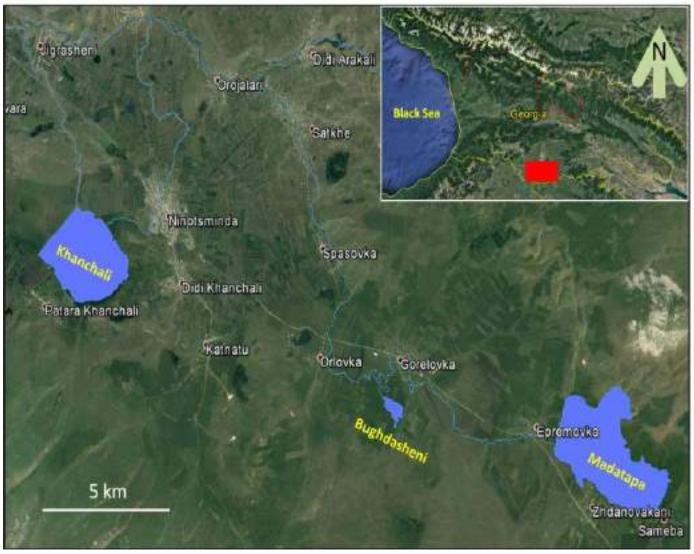

Figure 1. Map showing study lakes on Javakheti plateau.

The effects of such anthropogenic influence remain unknown, as there is no early historical data available on the freshwater biodiversity of the region. Unfortunately, even the postindustrial period was not productive by means of freshwater biodiversity research of Javakheti region and only few studies are available giving some information on selected taxa [6,9,10]. Only recently, a research project aiming the primary biodiversity data collection in major lakes of Javakheti plateau was lunched which is a first attempt to provide detailed reference data on invertebrate and fish species. This kind of data will supposedly help to identify current conditions of studying lakes as well as provide bases for future monitoring programs. As part of this project, here we provide a preliminary data summary on the family level taxonomic diversity and distribution of benthic macroinvertebrates of lakes Madatapa, Bughdasheni and Khanchali (Fig. 1). In addition, we made a preliminary evaluation of lake conditions based on family based metrics.

Materials and Methods

Studied lakes (See table 1 for physical parameters) are located in southernmost part of Javakheti region and are interconnected by Bughdasheni River system. All the lakes are of natural origin and feeding mainly by underground currents and temporal mountain streams, although the shape and water levels of lakes Madatapa and Khanchali were several times modified in the past.

Lake	Latitude	Longitude	Altitude	Surface area (km^2)	Depth (max)	Depth (average)	Mean water temp. (°C)
Madatapa	41.18907	43.78218	2112	8.78	1.7	1.5	12
Khanchali	41.25622	43.54853	1931	5	1.4	0.5	12.5
Bughdasheni	41.20157	43.68584	2040	0.39	0.8	0.4	11.8

Table 1. Physical characteristics of studied water ecosystems

In this regard, Khanchali is the most disturbed one as it experienced heavy anthropogenic changes in the last 50 years. In particular, the shape and water level of Khanchali was several times altered to met some industrial needs during the Soviet time and after. In years of 1968 and 1980 the lake was completely drayed up for agricultural purposes and later only a half of the lake was remained due to buildding of drainage system and dam in its north-western part. Several years later (1997) the lake was swelled, destroyed the dam system and the whole lakes was almost completely disappeared. After this the lake was rebuild again as it looks like today. Currently it is the half of its original size after the amelioration of the north-western part of the lake for agricultural purpose [11,12]. Madatapa Lake was affected to lesser degree by human. E.g. as the lake was suffering strong natural eutrophication, in early twentieth century the water level was artificially raised up 30-40cm to maintain the lake ecosystem [12]. In contrast, Lake Bughdasheni is free from aforementioned anthropogenic influence.

In all this lakes, samples of benthic macroinvertebrates were collected during the years of 2013-2015. For each year seasonal sampling (except winter) was performed. For each lake 3 sampling point were selected to account the habitat variability and in each, three subsamples (40-50 meter from each other) were collected. These resulted in 27 samples for single season and more than 170 samples in total.

Macroinvertebrates were collected using kick-net with mesh size 0.5mm, frame width 30cm and height 30cm. Samples were fixed in ethanol (70%) and transferred to the laboratory for sorting and identification.

At this stage, most of the materials have been identified at the family level using the relevant identification keys [13–15]. In order to determine the quality of the studied ecosystems, strength of organic pollution and stability of studied lake ecosystems we applied various indices that considers a diversity and relative abundance of represented families [16,17]. This includes:

Family	Madatapa	Khanchali	Bughdasheni	Tolerance scores for FBI	Tolerance scores for BMWP
Chironomidae (Diptera)	1167	791	205	6	2
Chaoboridae(Diptera)	65	2		8	1
Ceratopogonidae (Diptera)	6	3	4	6	4
Tabanidae (Diptera)	10			6	5
Syrphidae (Diptera)	1	2		10	2
Stratiomyidae (Diptera)		8		7	3
Empididae (Diptera)	1			6	4
Hydropsychidae (Trichoptera)	2			4	5
Phryganeidae (Trichoptera)	15			4	10
Limnephilidae (Trichoptera)		125	6	4	7
Elmidae (Coleoptera)	25	65		4	5
Dytiscidae (Coleoptera)	27	51	2	5	5
Anthribidae (Coleoptera)			2	-	-
Haliplidae (Coleoptera)		1		5	5
Notonectidae (Hemiptera)	15	1	15	5	5
Corixidae (Hemiptera)	115	584	33	5	5
Coenagrionidae (Odonata)	115	11	1	9	6
Lestidae (Odonata)	41	1		9	8
Aeshnidae (Odonata)	11			3	8
Libellulidae (Odonata)	5	25		9	8
Calopterygidae (Odonata)	103			5	8
Gammaridae (Amphipoda)	13	1006	4134	4	6
Asellidae (Isopoda)	2		287	8	3
Glossiphoniidae(Rhynchobdellida)	30	72	16	6	3

Erpobdellidae	63	41	13		
(Arhynchobdellida)				6	3
Hirudinidae	3				
(Arhynchobdellida)				6	3
Tubificidae (Oligochaeta)	483	912	573	9	1
Lumbriculidae (Oligochaeta)	59	22	36	5	1
Enchytraeidae (Oligochaeta)	12	29		10	1
Propappidae (Oligochaeta)	1			8	1
Naididae (Oligochaeta)	14			8	1
Haplotaxidae (Oligochaeta)	1		1	5	1
Lymnaeidae (Gastropoda)	98	86		6	3
Planorbidae (Gastropoda)		279		7	3
Lynceidae (Diplostraca)		781		-	-
Ostracoda	21			8	2
Nematoda	11				
Turbellaria			1000	4	6

Table 2. Total abundance of individuals per family represented in a studied lakes with tolerance scores (see text for more details on tolerance). The last for taxon did not identified at family level and three taxon did not used in calculation of biotic indices due to absence of reference to their tolerance values.

a) Family Biotic Index – $FBI = \sum \frac{x_i t_i}{n}$, where x_i is the number of individuals in the i taxon, t_i is the tolerance (to organic pollution or other stress) value of the taxon i, and n is the total number of organisms in the sample. Tolerance values for each family is predetermined from the literature [16]. As the proportion of tolerant taxa is increasing, the value of FBI is also increasing indicating more stressful environment.

b) Biological Monitoring Working Party – $BMWP = t_i$ and Average Score Per Taxon – $ASPT = \frac{t_i}{n}$ (in later case n indicates total number of families. Both this indices provide information on the community sensitivity to the organic pollution of the lake. Higher indices indicate lower pollution level if the tolerance values are higher in concert with taxon sensitivity.

c) Taxa Richness - TR is a total number of taxa (families in our case). This index shows the health of the ecosystem by means of the taxonomic richness. Higher TR – higher the ecosystem health or resilience.

d) The Ephemeroptera, Plecoptera, and Trichoptera – EPT index represents the total number of families represented in the ecosystem. As these taxa are considered as sensitive to stressful environment, then the higher score of the index indicate less disturbed environment.

e) Ratio of EPT to Chironomidae – $EPT/C=EPT_{ab}/Chironimdae_{ab}$. As the EPT groups are sensitive to water disturbance while chironomids are considered as tolerant, then this ratio indicates the balance and health of the ecosystem. I.e. higher the index, more health and balanced the ecosystem is.

f) Percent contribution of dominant family – DF is the measure of the relative abundance of dominant family. Higher proportion of dominant family indicates less evenness of ecosystem diversity and could be interpreted as an effect of disturbance.

Some of these indices (FBI and BMWP/ASPT) indicate how “clean” the water is by means of organic pollution while other do not bear any meaning when used separately, however could provide important insights if compared among the ecosystems or among the periods of time. The tolerance values were assigned to each taxon according to [16,17]. Worth to note, that these values are different for FBI and BMWP indices (Table 2).

Results and Discussion

The diversity of benthic invertebrates in Madatapa, Khanchali and Bughdasheni

In total more than 14000 individuals, representing 35 families were sampled (not included families of Nematoda, Ostracoda and Turbellaria). The most diverse taxon is Diptera (8 families) following by Trichoptera and Oligochaeta (6-6 families respectively). The most abundant families are Gammaridae (37%), Chironomidae (16%) and Tubificidae (14%) accounting 67% in total. However, lakes are different with this respect. In Madatapa the dominant family is Chironomidae while in remaining two lakes Gammaridae is predominating (Table 2; Fig. 2). In part of samples the abundance of Gammaridae was very high (more then 1000) and such cases only a truncated number (1000) were used. Hence, the actual proportion of Gammaridae could be higher which is especially true for Bughdasheni Lake. Compared to literature data [9], representatives of Ephemeroptera and Plecoptera were not found in our sample. In case of Plecoptera this was expected as plecopterans are usually associated with lentic waters [18] and the reporting of these insects in [9] may reflect the samples collected in a points were rivers confluence to the lakes. Unfortunately, details of sampling area are not provided in the referred article, while we have both taxa sampled from the rivers related to the studied lakes (our unpublished data). In contrast, we have collected a number of families do not known before (Table 2).

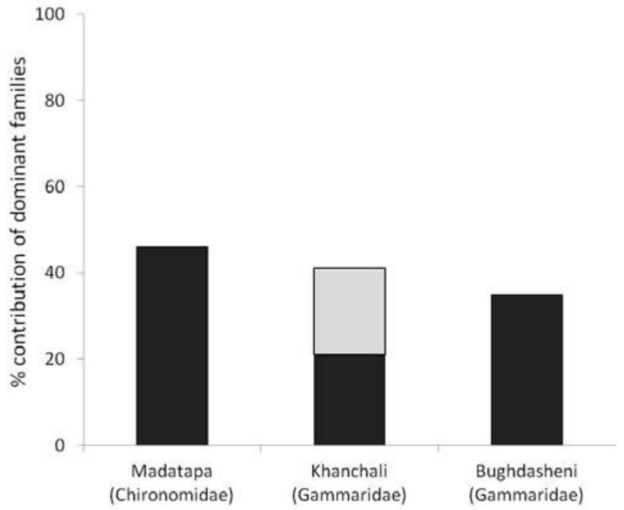

Figure 2. Bars showing the abundance proportion of dominant families in each lake. Length of vertical axis represents the total abundance (100%). Note that gray part of the bar for Khanchali Lake represents the second dominant family *Tubificidae* (Oligochaeta)

Absence of these families in the [9] seems to be an sampling artifact as these animals are usually occurring in natural lake ecosystems worldwide [19]. Our data could not be readily compared to those provided by [9] as the sampling techniques used by these authors are not known. However, there are some apparent differences. I.e. if the representatives of Mollusca was a dominant in all the studied lakes in [9], they are only in minority in our data (Fig. 3). In addition, the family Lynceidae (Diplostraca) was not recorded during the previous study while they are quite abundant (up to 15%) in our samples from the Lake Madatapa. Such kind of differences could not be ascribed only to probable sampling differences, but also indicates significant changes of the community composition during the two sampling occasion (1959 and 2013-2015).

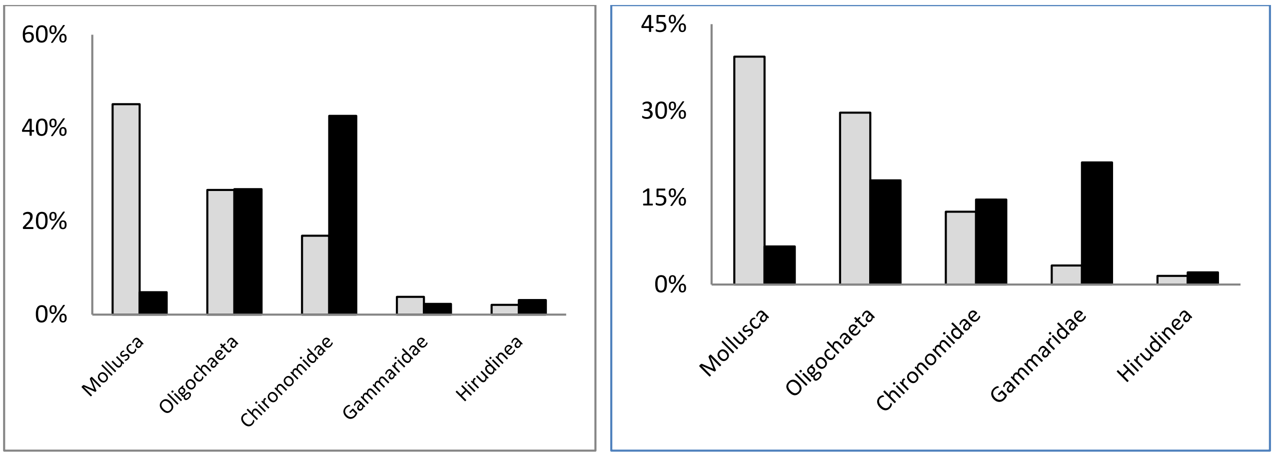

Figure 3. Proportions of some taxa in Madatapa (left panel) and Khanchali lakes in [9] (gray bars) and our data (black bars). Only taxa recorded in both studies are shown.

An assessment of the conditions of studied lakes

Family Biotic index (FBI) is highest in Madatapa Lake followed by Bughdasheni and Khanchali lakes respectively (Table 3). According to [16] the values of FBI (<5) indicate that the water

Lake	FBI	BMWP	ASPT	TR	EPT	EPT/C	DF
Madatafa	6.7	120	3.8	31	0.6	0.01	1
Khanchali	4.1	87	3.8	25	2.5	0.2	0
Bughdasheni	4.7	58	3.6	19	0.1	0.02	1

Table 3. Values of indices characterizing the ecosystem health and diversity in studied lakes.

quality is fairly good in Bughdasheni and Khanchali lakes indicating to some organic pollution. In contrast, Madatapa Lake has shown significant organic pollution based on FBI value (>5). At current, the bordering area of Madatapa Lake is extensively used for grazing (sheep and cattle) and drainage waters are caring large amount of nutrients every year. This could at least partly explain why Madatapa may experience higher nutrient loads than Bughdasheni or Khanchali. In contrast, the difference in FBI values between the later two lakes is not very intuitive to explain. In other hand, Khanchali were frequently empted, which could be reflected in the amount of nutrients as well as in community composition. Similar to FBI index, BMWP and ASPT indices showed that Madatapa and Khanchali are less loaded with organic pollution than Bughdasheni. Although the values of ASPT are less than 4 indicating a sever organic pollution [16]. Nevertheless, these indices is depending on the number of taxa and is increasing even when the number of pollution tolerant taxa increases. Hence, the comparison between lakes is less informative, and it should be used in temporal comparisons (i.e. between time lags).

The diversity of families (TR index) in contrast is highest in Madatapa Lake followed by Khanchali and Bughdasheni. Higher diversity means more resilience of the ecosystem and less influence of stress factors. However, this could not be considered in abstractions, as other factors may be responsible for the diversity of taxa. E.g., Madatapa Lake is almost two times larger than Khanchali Lake and 16 times larger than Bughdasheni. Indeed, 96% of family level diversity variation is successfully explaining by the available surface area (least square regression, $p<0.001$). This means that family level diversity in studied lakes is strongly affected by the available area which is in concordance with the theory of species-area relationship [20].

The absence of Ephemeroptera/Plecoptera complexes in the studied lakes could be ascribed as to high level of pollution as well as the characteristics of the lake. In particular, absence of ephemeropterans seems to be mainly due to excess of organic pollution as these animals are normally met in lakes [21] and was also known from Madatapa and Khanchali [9]. In contrast, the absence of plecopterans, could be due to the excess pollution or due to the unsuitability of this lake ecosystems in general [18]. Accordingly, EPT and EPT/C indices calculated without these taxa may not be meaningful as is based on only the diversity of trichopterans, however the later index showing the strength of the balance between most sensitive (Trichoptera) and most tolerant (Chironomidae) taxa in an ecosystem. Since the value of EPT/C could actually exceed 1, the obtained results are too low indicating strong imbalance in the studied ecosystems. This view is also supported by the DF index, which shows the percentage of dominant taxa (Fig. 3). In Madatapa and Bughdasheni, the dominant family, Chironomidae and Gammaridae accounts more than 50 percent of total abundance respectively. Relatively low percentage of dominant family (Gammaridae) in Khnachali Lake is due to high density of Tubificidae (Oligochaeta) that also accounts about 20% of total density. As a whole these two families represents ca. 40% of total diversity.

Conclusion

Since 2011 all three studied lakes represents the part of Javakheti protected areas however the anthropogenic pressure is still evident there. This is mainly due to highly polluted drainage and waste waters carring large amount of organic materials in the lakes. All the area around the lakes is used extensively for agricultural purpose or cattle and sheep grazing in spite of the protected status. This kind of disturbance is especially strong in Madatapa Lake. Since all the lakes are very shallow, the effect of nutrient load could be significant in a short term. As a result eutrophication rate is very high in all studied lakes which is affecting the composition of local communities and ecosystem functioning. This is supported by the significantly low number of sensitive taxa in all studied lakes (Fig. 4).

Another factor the effect of which is not yet well known is the invasion of Gibel carp (*Carassius gibelio*) in all freshwater systems of Georgia [22]. This fish is known to affect strongly the lake ecosystems in many ways [23, 24]. Gibel carp is only fish and very abundant in Madatapa Lake while it is very rare in Khanchali and its relative abundance is moderate in Bughdasheni [26, own unpublished data].

Madatapa is big lake, free with other fish species and with abundance of feeding resource. In relation to other factors, the invasive population of gibel carp can significantly affect the community composition of lake ecosystems and support the eutrophication processes. Indeed, Madatapa and Bughdasheni lakes in which the gibel carp population is relatively large, the level of organic pollution and ecosystem stability is lower based on the analyses of invertebrate communities.

Such conclusion and others reported here, however, is only a preliminary and further research and monitoring is needed to evaluate the ecosystem dynamics and disentangle most significant factors affecting these lake ecosystems.

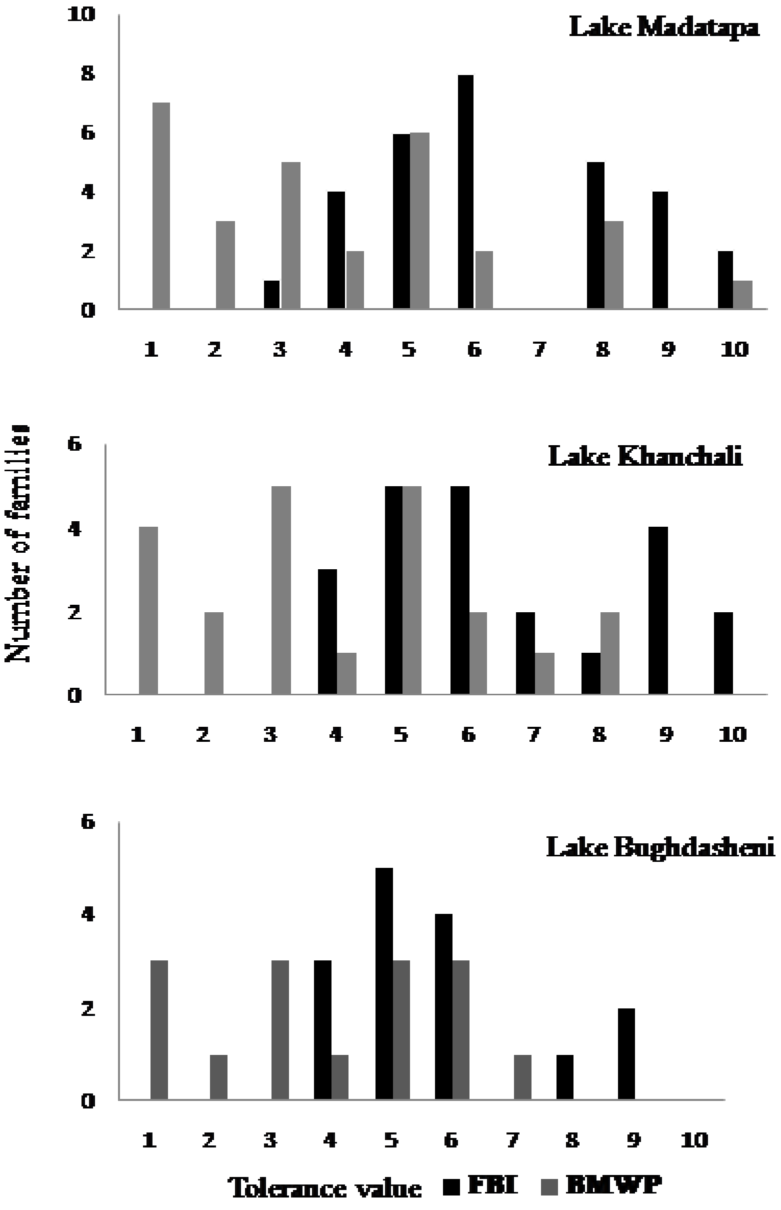

Figure 4. The frequency of families according to their tolerance values. This graph is based on data provided in table 2.

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გაბელაშვილი ს., ბიკაშვილი ა., შუბითიძე ჟ., გიოშვილი მ., ფანქველაშვილი ე., მუმლაძე ლ., ჯაფოშვილი ბ.

რეზიუმე

ნაშრომში შესწავლილია ბენთოსური უხერხემლო ცხოველების ოჯახების მრავალფეროვნება და განაწილება ჯავახეთის სამ ტბაში (მადათაფა, ხანჩალი, ბუღდაშენი). კვლევის შედეგად სულ მოპოვებულია ყველა ძირითადი ტიპის 35 ოჯახი (გარდა Ostracoda, Nematoda, Turbellaria წარმომადგენლებისა, რომელთა ოჯახების დონეზე კვლევა არ მომხდარა). მათ შორის ყველაზე მრავალრიცხოვანი და ფართოდ გავრცელებულია ოჯახები Chironomidae (Diptera) და Gammaridae (Amphipoda). ოჯახების მრავალფეროვნებაზე დამოკიდებული ბიოტური ინდექსების მიხედვით ტბების ორგანული დაბინძურება დიდია და ეკოსისტემების სტაბილურობის ხარისხი დაბალი, რისი მიზეზიც უმთავრესად ანთროპოგენური გავლენაა, მიუხედავად ტბების დაცული სტატუსისა. აღნიშნული ტბების შემდგომი კვლევა და მონიტორინგის წარმოება მნიშვნელოვანია იმისათვის, რომ შევისწავლოთ ეკოსისტემების განვითარების დინამიკა და გამოვავლინოთ ფაქტორები, რომლებიც ეკოსისტემების მდგომარეობაზე ძლიერ უარყოფით გავლენას ახდენს.