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## Using Benthic Macro-invertebrates to Assess Ecological Status of the Arbuga River in the, Sengiley Mountains, National Park, Russia

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### Abstract:

*The objective of this study was to assess water quality of the Arbuga River in one of the National Parks in Russia, which is under severe stress from anthropogenic activities, using benthic macro-invertebrates as biological indicators. The study was carried out in 2012 and the findings were compared to an earlier study done in 2000. The indices used in the study to describe the invertebrate community species abundance were the Shannon-Weaver index and a density index (dominance). To assess the ecological status of the Arbuga River the Biotic Trent River Index was used. The results confirmed that the Arbuga River was in a moderately-polluted to critically polluted condition in some areas due to a range of anthropogenic impacts, at the time of the study. The health of the river had degraded from good to moderately-polluted since 2000 because of a range of anthropogenic factors.*

**Keywords:** benthicmacro-invertebrates, river health, biological indicators, Russia, anthropogenic impacts.

### 1. Introduction

Sengiley Mountains is a National Park, situated in the Ulyanovsk Region in Russia. The National Park is home to a number of endangered fauna and flora which are documented in the Red Data Book of the Russian Federation (RDBRF) (Danilov, 2001). Sengiley Mountains consists of many rivers and streams. The Arbuga River is one of the rivers that are under tremendous stress because of anthropogenic activities (Yakovleva, 2001). It is used by the locals for recreation, irrigation, as a source of drinking water for livestock. In 2004 three fish farming ponds were established near the Arbuga River. Although these water bodies play a crucial role in the health of this fragile ecosystem, and are situated in a protected area, very little research has been conducted on them to assess and monitor their quality.

Freshwater environments can be monitored by physical, chemical, and biological parameters. Biological parameters integrate information over longer periods of time and better represent the responses of aquatic habitats (Hellowell, 1986) making biotic monitoring indices excellent tools for the sustainable management of water resources (Couceiro et. al. 2012).

Benthic macroinvertebrates are commonly used as indicators in the evaluation of impacts to stream ecology and entire watersheds from a variety of point and non-point pollution sources (Barbour et al. 1999; Karr and Chu, 1997; Lenat and Crawford 1994). Benthic invertebrates have been favored in environmental effects monitoring because they are sessile or limited in their range of movement and therefore cannot avoid pollution (Gaufin, 1973).

Data derived from aquatic macro invertebrate samples provide valuable information on the biological and physical condition of streams, which along with stream habitat and fish community data permits a comprehensive assessment of stream health. Most aquatic macro invertebrates such as immature insects live for one or more years in streams, integrating the effects of environmental stressors over time. Since the majority of aquatic invertebrates have limited mobility (relative to fish), they can be good indicators of local conditions as well as upstream land and water resource factors (Plafkin et. al. 1989). Therefore, macroinvertebrates were used to assess the status of the Arbuga River.

### 2. Study Area

The Arbuga River (also called a stream), according to the State Water Russian River Registry refers to the Lower Volga basin district, water management section of the Kuibyshev reservoir of urban-type settlements. (Resources, 1966). The total length of Arbuga River is 14 km, with a watershed area of 35 square kilometers. The coordinates for the river are 54.02249, 48.59905 (mouth) and 54.10812, 48.56094 (source).



Figure 1: Map of Arbuga River and the eight study sites

According to the study sites, the width of the river ranges from 0,5 m to 1,5 m (the river is so narrow because the mouth of the river is a natural spring and the diameter of the outlet is not very large. The river widens the further it flows from the headwater), and depth from 0,05 m to 0,6 m from the source to the mouth of the river. The average flow velocity is 0,29 m/s. The main types of soil are: large, medium and small rocks, coarse gravel and silt.

Site	Velocity	Width	Depth	Soil type
1	0,4-0,5 m/c.	1,2-1,5 m	0,05-0,15 m	Coarse gravel and silt
2	0,4-0,5 m/c.	1-1,2 m	0,3 m	Large and average sized rocks
3	0,4-0,5 m/c.	1-1,2 m	0,3 m	Small rocks and silt
4	0,35 m/c.	0,6 m	0,1-0,15 m	Average sized rocks and plants
5	0,05 m/c.	1 – 1,5m	0,25 – 0,3 m	Detritus and silt
6	0,25 m/c.	0,4-0,5 m	0,05 – 0,1 m	Average sized rocks
7	0,1 m/c.	0,25 m	0,05 m	Small rocks and silt
8	0,05-0,1 m/c.	0,15-0,20 m.	0,5-0,6 m.	Silt and a lot of detritus

Figure 2: Physical characteristics of the study sites

### 3. Materials and Methods

The material for this work was collected in the Arbuga River on the territory of National Park, Sengiley Mountains. Research materials were collected in summer and autumn of 2012. A total of eight rivers sites were sampled: 1–10m from the source of the river, 2- 1,5 km from the source, 3- 30m from the confluence of the lake and river, 4- 10m below the confluence of the lake and river, 5- 1,5 km below the confluence, 6- the lower reaches of the river, about 8 km from the mouth, 7- 5 km from the mouth, 8- 3 km from the mouth of the river.

Samples were collected using a single pole rectangular style kick-net (sometimes called surber on a stick), equipped with a frame and a 500-micron mesh netting. All samples were taken from depths of less than 1 m. Samples were collected by placing the net firmly on the river bed. The net holder faced up-stream. The net was then tipped backwards at about a 45-degree angle from the water's surface. This provided greater surface area and more even flow into the net. Holding the net with one hand, the net holder disturbed the area directly in front of the net to loosen the benthic organisms. The loose particles were then washed into the net by stream flow. Boulders and vegetation were also rubbed to ensure that any benthic organisms on them were also loosened (Barton, Metcalfe-Smith, 1992).

Field processing included activities such as sorting, removing debris and sieving macroinvertebrate samples in the field. After the nets were removed from the river, the contents were placed into a white tray with dimensions of 450 x 300 x 80 mm and then carefully using forceps the benthic organisms were selected and placed in glass containers and preserved in 96% ethanol. Identification was to the lowest practical taxonomic level using the identification keys of Lepnova (1964, 1966), Fedorov (2000) and Raikov (1994). Sample processing was carried out in the laboratory.

Abundance of animal species was calculated using the formula:  $P = (m / n) * 100\%$ . For the qualitative and quantitative characteristics of waterways and to identify benthic biocenosis the density index (dominance) the modified version was used by Mordechai-Boltovskii (Mordechai, 1975).

The diversity index proposed by Shannon and Weaver (1963) was used to measure how many different types of species were found in the dataset. To assess the ecological status of the river we used the Trent Biotic Index (Woodiwiss, 1964).

#### 4. Results and Discussion

We collected 1,160 individuals. They belonged to 7 major taxonomic groups. *Simuliidae* was the most dominant species, while *Odontocerum albicorne* showed the highest biomass (the average weight of the site location - 32510 mg /m<sup>2</sup>). The total number of organisms most widely represented were the taxa: *Simuliidae* (55,50%), *Tanypodinae* (24,89%) *Odontocerum albicorne* (8,78 %), *Nemoura flexuosa* (3,61%), *Hydropsyche instabilis* (3,61%). Species similarity coefficient ranged from 40% - 52%, which is typical for mountain rivers (Yakovlev, 2000). The species diversity index ranged from 0.09 to 1.39, the average value being 1.02, indicating that the species diversity of the river is poor. The Biotic index indicated that the level of pollution along the river ranged from moderately polluted to critically polluted.

##### 4.1. Dominance Index Mordukhai-Boltovskii

The index proposed by Mordukhai-Boltovskii was used to calculate species dominance. Using the formula  $Di = p_i \sqrt{B_i / B_s}$ , where  $p_i = m_i / M$  - the occurrence of species  $i$ ,  $m_i$  - the number of samples, in which the species was found,  $M$  - total number of samples,  $B$  - average biomass of species. The results are presented in Figure 3.

No	Taxon	Average number of species at study sites	Average biomass of species at study sites	Species Occurrence at study sites	Dominance index Mordukhai-Boltovskii
1	<i>Odontocerum albicorne</i> (Scopoli, 1763)	160,68	32,51	88%	501,75
2	<i>Hydropsyche instabilis</i> (Curtis, 1834)	66	2,02	37%	52,59
3	<i>Nemoura flexuosa</i> (Aubert 1949)	113,62	0,79	25%	22,22
4	<i>Baetis tricolor</i> sp. (Tshernova 1928)	1,37	0,01	12%	1,20
5	<i>Baetis</i> sp. (Leach, 1815)	9,62	0,07	25%	6,61
6	<i>Paraleptophlebia</i> sp.	1,37	0,01	12%	1,20
7	Family: <i>Simuliidae</i>	1015,73	2,85	50%	84,41
8	Family: <i>Rhagionidae</i>	1,37	0,04	12%	2,40
9	Family: <i>Tanypodinae</i>	455,5	2,66	37%	60,35
10	Family: <i>Nepidae</i>	2,75	0,67	12%	9,82
11	<i>Erpobdella octoculata</i> (Linnaeus, 1758)	1,37	0,11	12%	3,98
12	Class: <i>Gastropoda</i>	0,75	0,24	12%	5,88

Figure 3: Dominance index indicators

The results show that the dominant taxa are: *Odontocerum albicorne* - index 501.75, subdominant - *Simuliidae*- index 84.41, *Tanypodinae*- index 60,35, *Hydropsyche instabilis*-index 52.59.

##### 4.2. Shannon-Weaver Biodiversity Index

$$H = - \sum_{i=1}^n p_i \log_2 p_i$$

Species biodiversity was calculated using the Shannon-Weaver Biodiversity Index, using the formula: where  $p_i$  is the proportion of individuals belonging to the  $i$ th species in the dataset.

№	1	2	3	4	5	6	7	8
Index	1,22	1	0,09	1,25	1,39	1,19	0,72	0,09

Figure 4: Distribution of index values along the eight study sites

The index values range from 0,09 – 1,39. The lowest values are at study sites 3 and 8. The highest is at study site 5. The index characterized the river as having a low species diversity. This in turn suggests an imbalance of the ecosystem.

#### 4.3. Biotic Index

№	1	2	3	4	5	6	7	8
Index value	7	6	6	3	6	5	5	4

Figure 5: Biotic index values of study sites

At the source of the river the value of the index ranges from 7-6, which according to the value table suggested by Woodiwiss (1964), means that the water is slightly contaminated. The index value drops to 3 on site number 4, indicating highly polluted water. This is an indication that the river at this point is receiving high quantities of organic pollution. Next, the index increases, which means an increase in the purity of the water. According to the values on sites 5-7, where the values range from 6-5, the river is moderately contaminated. Downstream at site number 8 the value goes down to 4 which means that the river is highly contaminated. This can be explained that while we were sampling upstream from sample 8 we observed cattle grazing and drinking from the river.

In Yakovleva's (2001) publication the results of the analysis of the biological condition of the Arbuga River stated that 17 samples were collected and the following 9 taxonomic groups were identified: Nematomorpha, Oligochaeta, Crustacea, Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Diptera, Mollusca. The macroinvertebrates that dominated at the time of Yakovleva's study were the following groups of organisms: *Halesusdigitata*, *Baetisfuscatus*, and *Limoniidae*.

According to John Capinera (2008), organic discharge and eutrophication have been noted to decrease macro-invertebrate's species richness and distribution because many species are sensitive to surplus of nutrients. We can observe from Yakovleva's studies and compared to our study, that 2 taxonomic groups are absent, namely, Nematomorpha and Crustacea. The significant difference between the results obtained in Yakovleva's study and ours, can be explained by the fact that in 2004 (4 years after Yakovleva's research), three ponds with a total water surface area of 5.6 hectares for the cultivation of carp and organization of recreational fishing were established near the Arbuga River.

Thus, the ecological state of the river in 2012 differs from that in 2000 as follows;

- 1) recorded a decrease in the number of main taxonomic groups from 9 to 7;
- 2) The average value of the diversity index for Shannon-Weaver fell from 1.86 to 1.02;
- 3) The Biotic index dropped from 1.0 - 1.5 points to 1.8 - 2.7 points. Therefore, according to the Biotic index, the level of organic pollution increased from unpolluted or very slightly polluted to moderately polluted and at certain sample sites to critically polluted.

#### 5. Conclusions

Taking into account the changes in the values of the above mentioned indices we can confirm that a significant deterioration of the ecological state of the Arbuga River has occurred from 2000 – 2012, despite being located in an Environmental Protection Area.

The results confirmed that significant differences in the conditions and the benthic macro invertebrate communities found at the studied river sites situated upstream and downstream of the fish ponds.

The absence of pollution sensitive benthic macroinvertebrate groups Ephemeroptera, Plecoptera, and Trichoptera at some of the sites and their poor distribution is a clear indication of organic pollution caused by the water from the fish farms. The dominance of the species Diptera at the study sites below the fish ponds was to be expected. According to Capinera (2008), increases in the percentage composition of the insect community belonging to Diptera, usually occur below releases of poorly functioning sewage treatment plants, industrial plants and other anthropogenic inputs.

Given the continued use of the site by the general public, and for livestock and crop farming activities, further environmental control may be required to safeguard the environmental quality of the Arbuga River. Taking all this into account we advise that other watercourses located in the Sengiley Mountain National Park should also be monitored to assess their environmental health.

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