OPEN ACCESS Journal of Fisheries and Aquatic Science
ISSN 1816-4927
DOI: 10.3923/jfas.2019.15.24

Research Article
Benthic Fauna Shifts Downstream from Alluvial Gold Mine: A Case Study in a Subpolar Urals River

[1]Leonid Nikolaevich Stepanov and [2]Timur Evgenievich Pavluk

[1]Institute of Plant and Animal Ecology, Ural Branch of Russian Academy of Science (IPAE UB RAS), 202 8-March St., Ekaterinburg, 620144, Russia
[2]Russian Research Institute for Integrated Water Management and Protection (RosNIIVH), 23 Mira Str., Ekaterinburg, 620049, Russia

Abstract
Background and Objective: Intensive industrial development of the northern territories of Russia has led to increasing impacts on aquatic ecosystems. This study presented the aquatic ecological impacts of suspended solids emitted from an alluvial gold mining site in the Hobe-U river, a small subpolar mountain river in the northern Urals. The objectives of the research were the following: To examine whether the riverine macroinvertebrate community is negatively impacted by suspended solids contamination, to test whether the Index of Trophic Completeness (ITC) and its feeding guilds were appropriate for use in this part of the world. **Materials and Methods:** The article contained two years of summer macroinvertebrate abundance and biodiversity data from pristine and two impacted locations along the river. The samples were collected with benthic D-frame kick-net with a blade length of 30 cm in 3 replicates at a riffle site. Dominant species were defined by biomass values. For each taxon the functional feeding group was determined. Common descriptive statistics (such as mean and Min-Max diapason, percentages, frequency counts) were calculated in MS Excel 2007 and statistical package STATISTICA 6.1. **Results:** During the research 31, 14 and 23 taxa of benthic macroinvertebrates were found at pristine, impacted and downstream locations of the Hobe-U river. Water turbidity upstream of the mining polygons did not exceed 5 mg L^{-1}. Impacted and the third downstream sites had mean turbidity values 30.15 and 14.4 mg L^{-1}, respectively. Of total 12 trophic guilds of Index of Trophic Completeness (ITC) their amount varied within three sampling locations as following: 2007-8, 5, 7; 2008-7, 4, 7. **Conclusion:** At the site impacted, a decline in biodiversity, species domination, trophic structure of the benthic community were observed. The most unaffected trophic guilds included active predators, scrapers and detritivores, while other guilds had disappeared completely from the benthic community. The ITC bio-assessment approach was able to distinguish between an impacted and reference site and provides ecological insights into sensitive species and the impact on ecosystem.

Key words: Gold alluvial deposits, suspended solids, ecological impact, benthic fauna, macrozoobenthos, trophic composition, benthic structure shifts

Citation: Leonid Nikolaevich Stepanov and Timur Evgenievich Pavluk, 2019. Benthic fauna shifts downstream from alluvial gold mine: A case study in a subpolar Urals river. J. Fish. Aquat. Sci., 14: 15-24.

Corresponding Author: Timur Evgenievich Pavluk, Russian Research Institute for Integrated Water Management and Protection (RosNIIVH), 23 Mira Str., Ekaterinburg, 620049, Russia Tel: +07 343 287 65 71 (Ext. 104)

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Mining in river valleys has a negative multi-factorial impact on water ecosystems and leads to violation of the existing ecological balance. Biological characteristics of aquatic ecosystems (species diversity, abundance, biomass, trophic structure, etc.) are "integrating indicators" of environmental changes observed over a long period of time[1]. However, the impact of anthropogenic factors is not necessarily an instantaneous one. There is a gradual accumulation of negative influences and transition to the stage of instability of the ecosystem with its subsequent disruption[1].

Any economic activity in river valleys, associated with disruption of the soil and vegetation cover, leads to a great increase of erosion processes with flushing of solid materials into watercourses[2]. The mean natural water turbidity in the mountain rivers of the Urals during the summer low water season was 2-5 g m^{-3}, which is due to the geological characteristics of the region, undisturbed soil and vegetation cover and low riverbed erosion of rivers embedded in bedrock[3-5].

Development of alluvial gold deposits in river basins by an open hydromechanized method caused a significant change in the regime of solid runoff: An increase of organic and mineral suspensions content in the water occurs[1,3]. The turbidity of water can arise by decades or even hundreds of times[3,5,6]. The flow of erosion material into the rivers continued even after the development had stopped, even despite of remediation of the polygons (technically developed areas left after the gold mining).

The water turbidity increasement and following deposition of sandy and clay fractions downstream the polygons led to profound changes in the structure of benthic biocenosis, the vanish of sensitive macroinvertebrates, their redistribution and drift migration[5-9].

The study of the structural organization of macrozoobenthic communities suppressed by extreme natural and anthropogenic factors is an important monitoring component of waters. The species composition and quantitative characteristics of benthic invertebrates being good indicators of sediments and waters contamination were widely used in various hydrobiological monitoring programs of aquatic ecosystems[10].

The purpose of the research was to study the impact of the open alluvial gold deposits development at the macrozoobenthos of the Hobe-U river.

The research tasks included the study of the taxonomic composition of benthic fauna, the qualitative and quantitative characteristics of macroinvertebrate communities in different parts of the river, revealing the anthropogenically caused changes in its structure.

Another goal of the research was to apply a bioassessment method-the Index of Trophic Completeness (ITC)[11,12] for the first time at a gold mining site in the subpolar Urals.

MATERIALS AND METHODS

Research area: The Circumpolar Ural mountain range in the Republic of Komi, Russia, stretches from the source of the Hulgi river in the north (65°40'N) to the Telposis mountain in the south (64°N), forming the northern flank of the Urals mountain system[13]. The climate here is continental. The three sampling sites were located on the 64 km long Hobe-U river, a typical mountain stream that runs from the eastern slope of the subpolar Urals and flows into the fish-rich Manya river (at a point 84 km from the mouth) (Fig. 1). The Hobe-U river valley is narrow and the flood plain is partly swamp. The bed mostly consists of rapids and rifts. Lake percentage of the catchment area is less than 1%. It is fed mainly by thawed snow and permafrost water.

River water physical-chemical characterization: Hobe-U river water is known to be well oxygenated, moderately mineralized, soft of the hydrocarbonate class in the calcium-sodium group[14]. The natural water turbidity of the Manya river and its tributaries is low-the mean annual value does not exceed 12 g m^{-3}, equal to 2-5 g m^{-3} in the low water seasons[3,4]. Width of the Hobe-U river in the lower reaches was 40-70 m. The current velocity varied from 0.5-1.5 m sec^{-1}. Almost 100% of the bottom material was present by stable rocky ground of boulders and large pebbles. Zooplankton was not practically developed and the benthic animals composed the basic river fauna of invertebrates. The rivers give the place to spawn for valuable species of whitefish-peled, tugun, chir, whitefish-humpback, white salmon[15,16]. Development of alluvial gold deposits in the valley of the Hobe-U river started in 2007.

The investigation was carried out in 2007-2008 in the lower reach of the Hobe-U river. Samples were collected in July, 2007 and August, 2008 at 3 sections of the river: Site 1-2 km upstream the polygons, site 2-0.2 km downstream the development polygons, site 3-at the mouth of the river, 10 km downstream the mining polygons area.

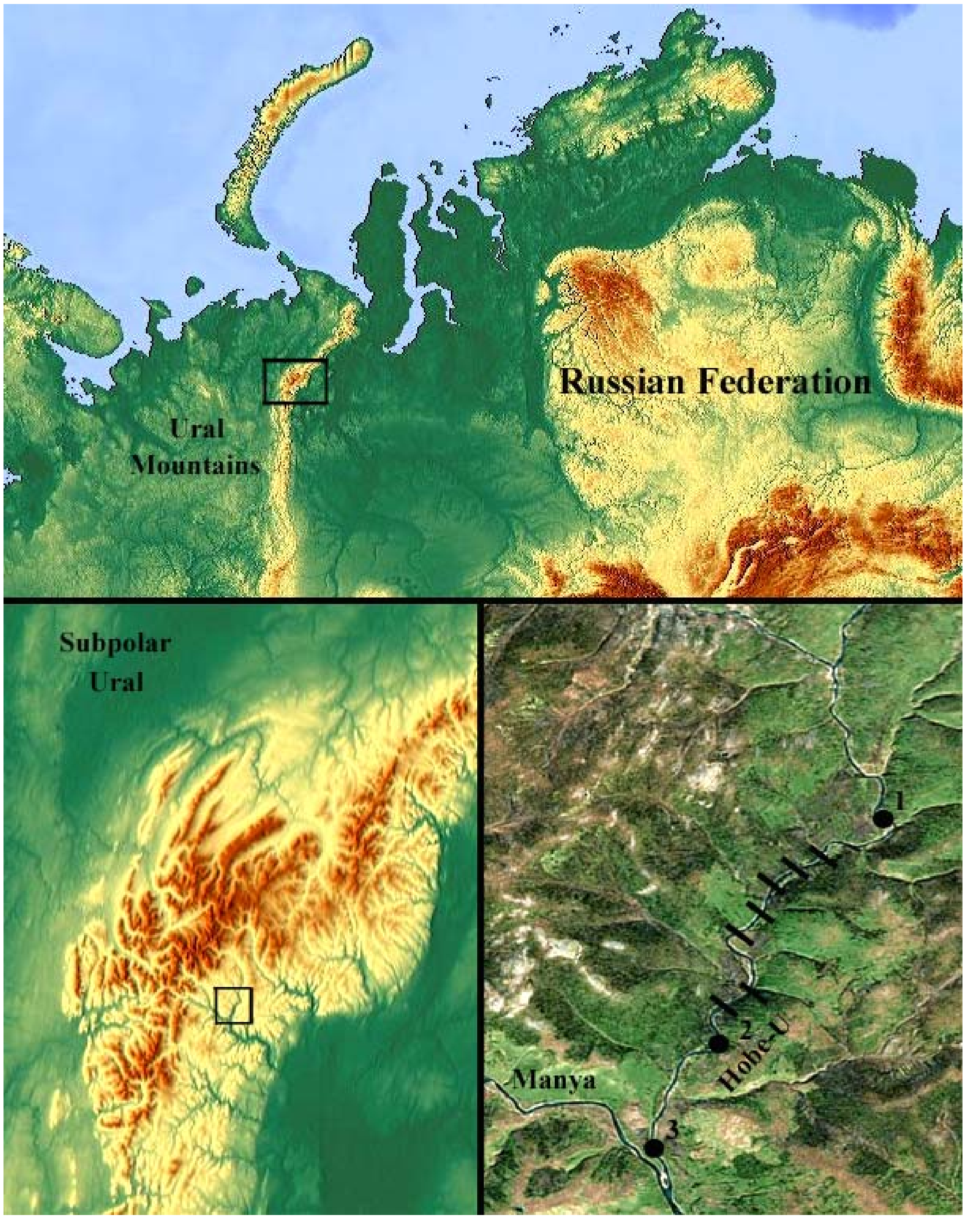

Fig. 1: Hobe-U river basin and three sampling locations. Site 1: 2 km upstream of gold mining activity, 2: 0.2 km downstream of gold mining activity, 3: 10 km downstream of gold mining activity (Dots-sampling locations, dashes-gold development polygons)

Sampling techniques: During the field sampling program, standard hydrobiological methods were applied[17,18]. The depth of the river at sampling locations varied from 0.4-1.0 m, the current velocity-from 0.5-0.8 m sec^{-1}. At stony-pebble substrates the macrozoobenthos samples were collected with the benthic D-Frame kick-net with a blade of 30 cm length[6]. A sack of mill gas No. 23 with a length of 1.0-1.5 m was assembled to the hoop of the scraper. Three samples of macrozoobenthos were taken at each location. All samples were fixed at the site with 4% formaldehyde solution. Further taxonomic processing of the material took place in laboratory in accordance with standard procedures[17,18]. Macrozoobenthos density (individuals m^{-2}) and biomass (g m^{-2}) were defined for each sampling location. Dominant species were defined by biomass values[19,20]. A group of constant organisms was defined by frequency[19] of more than 50%. The Sorensen[21] coefficient was used to estimate the faunistic similarity between locations.

For each taxon the functional feeding group was determined based on: Moog and Hartmann[22], Graf *et al.*[23], Pavluk *et al.*[11] and the trophic data base from the respective web site (MaTroS 2018)[24]. The ITC index and water quality classes were determined by Pavluk *et al.*[12]. The assessment system has five quality classes from "high" to "bad" (fifth one). Quality class score was calculated by the formula:

$$C_{tot} = \sum_{i=1}^{n} C_i$$

where, C_{tot} is the total score, n is the number of trophic guilds present in the data-base and C_i is the ln transformed indication value of trophic guild i. The relation between C_{tot} and the quality classes is given in Pavluk *et al.*[12] and the ITC website[24].

Statistical analysis: Descriptive statistics (such as mean and Min-Max diapason, percentages, frequency counts, mean values of the density and biomass) were calculated in MS Excel 2007 and statistical package STATISTICA 6.1. to describe and summarize data obtained.

RESULTS

During the research 36 taxa of benthic macroinvertebrates were found at the Hobe-U river (Table 1). The core of the invertebrate animals' fauna was formed by amphibiotic insects-30 taxa. The larva of mayflies and chironomids were the most diverse: 10 and 8 taxa, respectively. Most of the chironomids belonged to the Orthocladiinae sub-family.

A group of constant organisms included 12 taxa and consisted of oligochaetes *Stylodrilus heringianus* Clap., mayflies *Baetis fuscatus* L., *Baetis* gr. *vernus* Curt., *Baetis lapponicus* Bgtss., *Cinygma lyriformis* McD., *Heptagenia sulfurea* O.F. Müll., *Ephemerella ignita* Poda, stone-flies *Isoperla obscura* Zett., caddisflies *Rhyacophila nubila* Zett., *Arctopsyche ladogensis* Kol. and chironomids *Thienemannimyia* gr. *lentiginosa* (Fries) and *Orthocladius* sp.

Upstream sampling location: The river section upstream of the developments had the largest macrozoobenthos diversity-31 taxa (Table 1). Of these, 28 species were amphibiotic insect larvae, responsible for over 90% of the total biomass (Fig. 2). Most of these species, both in the number of species and in the density were mayflies (Table 1, Fig. 2), especially the Baetidae family such as *Baetis gr. vernus*, *B. lapponicus*, *C. liryformis* and *R. nubila*.

Mayflies dominated both sampling periods (summer 2007 and summer 2008) in number of taxa having main input into the abundance-41.5 and 63.0% of the total density and 40.5 and 62.8% of the total biomass (Fig. 2). A considerable part of the biomass was also made up of larvae of the caddis fauna-29.7 and 23.5% by years. Moreover, notable contributions to the biomass was made by midges (4.1% of total, site 1) and oligochaetes (8.6% of total, site 2) in summer 2008.

0.2 km downstream sampling location: The macrozoobenthos species diversity at the impacted river section was at least 2 times lower in comparison with the upstream location (Table 1). There was a decrease in the numbers of both chironomid species and mayflies. The

Table 1: Taxonomic composition and number of benthic species present at three sampling locations of the Hobe-U River

	Upstream of polygons			Downstream of polygons			Mouth of the Hobe-U			
Taxa	2007	2008	Total	2007	2008	Total	2007	2008	Total	Total in the river
Nematoda	-	-	-	-	1	1	-	1	1	1
Oligochaeta	1	1	1	-	1	1	2	1	2	3
Hydracarina	1	-	1	-	-	-	1	-	1	1
Ephemeroptera	6	7	10	6	2	6	6	4	7	10
Plecoptera	2	2	2	-	-	-	2	1	2	3
Trichoptera	4	2	4	1	1	2	3	2	3	4
Coleoptera	1	-	1	-	-	-	-	-	-	1
Limoniidae	-	2	2	-	-	-	-	-	-	2
Tipulidae	1	-	1	1	-	1	-	-	-	1
Heleidae	-	1	1	-	-	-	-	1	1	1
Simuliidae	1	1	1	-	-	-	-	1	1	1
Chironomidae	3	5	7	2	3	3	2	4	5	8
Total	20	21	31	10	8	14	16	15	23	36
Number (org m^{-2})	1502	1527		183	172		994	576		
Biomass (g m^{-2})	4.444	6.009		0.900	0.559		2.597	2.441		

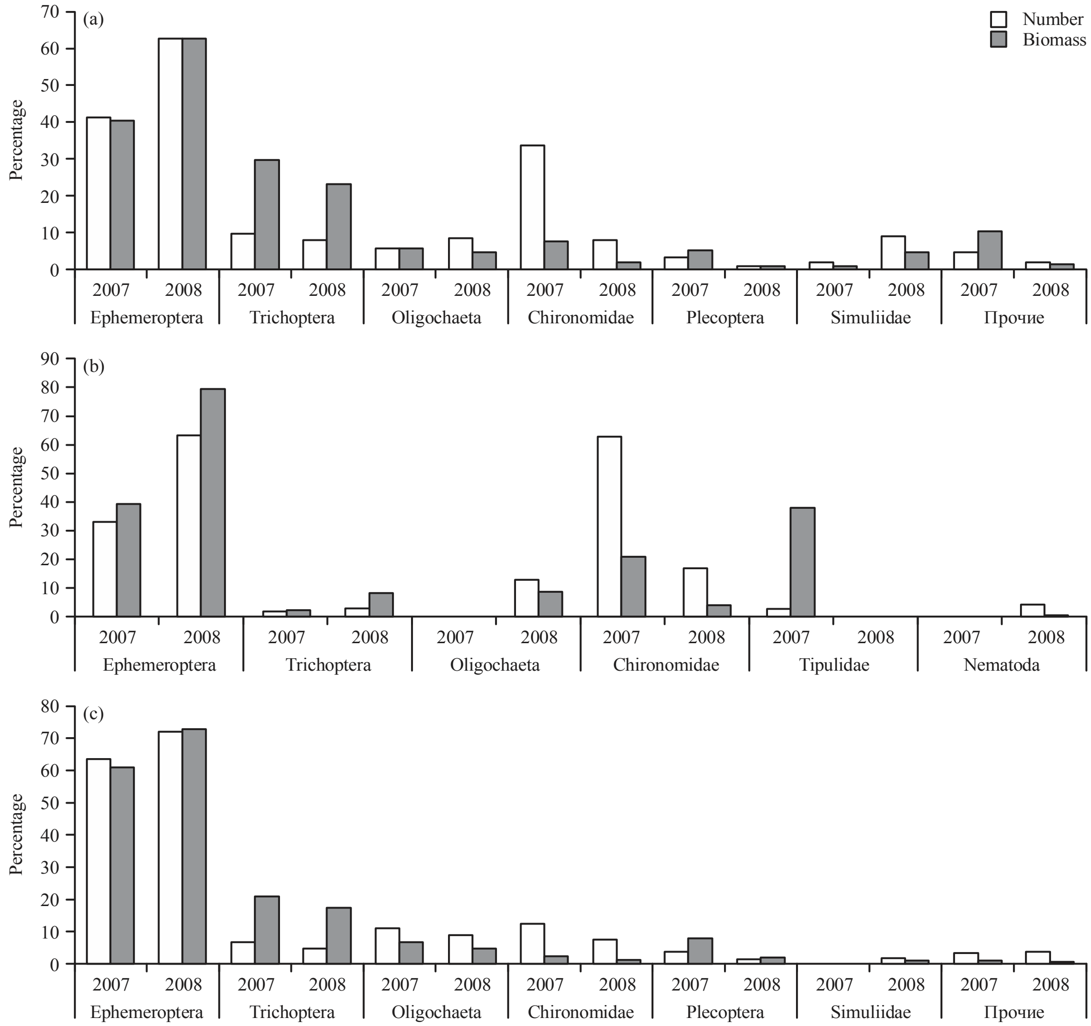

Fig. 2(a-c): Macrozoobenthos features of the Hobe-U River at (a) Locations upstream, (b) Downstream of the development and (c) The mouth area of the river

common upstream larvae of midges, stoneflies and caddis flies of *A. ladogensis* were absent in the samples. New pelophilic species appeared, like nematodes and oligochaetes *Limnodrilus hoffmeisteri Clap.* Larvae of amphibiotic insects-12 species-accounted for over 83% of the total density and biomass (Fig. 2).

In 2007, mayfly species were the most abundant among the 10 taxa observed (Table 1). Along with low density (183 ind m^{-2}), the number of invertebrates was determined by chironomids, which accounted 62.8% of the total individuals (Fig. 2). Predaceous larvae of sub-family Tanypodinae *Thienemannimyia gr. Lentiginosa* dominated among them. Mayflies and larvae of Tipulidae family accounted for 77.4% of the total biomass (Fig. 2). The organisms of the dominant complex provided 68.3% of density and 80.2% of biomass of the entire macrozoobenthos (Table 2).

Observations from 2008 showed a decrease in the total species diversity of macroinvertebrates (Table 1). Low values of both density and biomass in the community were in part due to a reduction in mayflies (Fig. 2). Oligochaetes and chironomids accounted for 29.7% of the total density. Among the chironomids, the predatory larvae of the genus Thienemannimyia were predominantly present, as in 2007. The dominant species formed 71.0% of the total density and 82.6% of the total biomass (Table 2).

10-km downstream location 3: At the river Hobe-U mouth, the number of zoobenthos species has almost doubled in comparison with the second location (Table 1). The core of the species composition was composed by amphibiotic insects' larvae, among which the most rich were mayflies. Total of 23 invertebrate taxa were identified there.

Table 2: Dominant macrozoobenthos species at three sites on the Hobe-U river upstream and downstream (0.2 and 10 km) of the gold mining site

2007			2008		
Species	N (ind. m^{-2})	B (g m^{-2})	Species	N (ind. m^{-2})	B (g m^{-2})
Upstream of polygons					
R. nubila-d.	69	0.744	*B. gr. vernus*-d.	628	2.333
B. gr. vernus-sd.	228	0.445	*R. nubil a* -sd.	116	1.183
C. liryformis-sd.	33	0.444	*B. lapponicus*-sd.	261	0.878
Others	1172	2.811	Others	522	1.615
0.2 km downstream of polygons					
Tipula sp.-d.	5	0.343	*B. gr. vernus*-d.	70	0.298
C. liryformis-sd.	23	0.202	*B. lapponicus*-d.	39	0.144
T. gr. lentiginosa-sd.	100	0.177	*T. gr. lentiginosa*-sd.	14	0.020
Others	55	0.178	Others	49	0.097
Mouth of the river 10 km downstream					
H. sulfurea-sd.	67	0.533	*B. gr. vernus*-d.	211	0.885
B. fuscatus-sd.	256	0.440	*B. lapponicus*-sd.	152	0.511
R. nubil a -sd.	33	0.378	*B. fuscatus*-sd.	44	0.358
B. gr. vernus-sd.	172	0.303			
Others	466	0.943	Others	169	0.687

N: Number, B: Biomass, d: Dominant, sd: sub-dominant

Table 3: ITC score, the quality classes and the trophic guilds of macroinvertebrates present at the Hobe-U river locations studied

Sampling locations	2007	2008
Upstream of the polygons	20.93 (II)	16.002 (III)
	Guilds: 1, 4, 5, 6, 7, 8, 9, 12	Guilds: 1, 2, 3, 4, 6, 7, 8
Downstream of the polygons	11.77 (IV)	8.53 (IV)
	Guilds: 1, 4, 6, 7, 12	Guilds: 1, 6, 7, 11
Hobe-U mouth	17.10 (III)	16.94 (III)
	Guilds: 1, 3, 4, 5, 6, 7, 9	Guilds: 1, 2, 3, 6, 7, 8, 11

Samples of 2007 demonstrated domination of mayflies' species number. Their representatives composed 63.2% of individuals and 61.0% of biomass of all macroinvertebrates (Fig. 2). Along with the mayflies, the predatory larvae of the caddisfly *R. nubila* had a large share in the benthic communities. Dominant species formed 53.1% of the total density and 63.7% of the total benthic biomass (Table 2).

Samplings of 2008 showed the diversity and quantitative characteristics of invertebrates higher than at the second location. The total number of species increased almost twice (Table 1). Larvae of Simuliidae returned. Mayflies share in the total density and biomass of benthos was 71.9 and 73.1%, respectively (Fig. 2). A significant contribution to the abundance of benthic organisms was brought by oligochaetes and chironomids. Dominant species provided more than 70% of the total density and biomass of macroinvertebrates (Table 2).

Likewise, the other sampling locations, amphibiotic insects dominated in the benthic community-89.2% (86.0-89.8) and 93.8% (92.2-95.4) of the total density and biomass, respectively.

The Sorensen's coefficient of the faunistic similarity between the first and the 3rd locations of the Hobe-U river was 0.68. Its value between the first and the second locations was less than 0.5, which indicates significant differences in the species composition of the benthic fauna.

Similar trend was observed for quantitative metrics of the benthic organisms. The average density of benthos at the first location for 2 years of research was 1518 ind m^{-2}, the average biomass-5.229 g m^{-2}. At the second location these values dropped sufficiently: 198 ind m^{-2} and 0.873 g m^{-2}, respectively. At the river mouth site, the density and biomass of benthic animals increased, but were still lower than at the first location-733 ind m^{-2} and 2.535 g m^{-2}.

Trophic structure of the benthic community: It was observed that the benthic community's trophic structure had been simplified downstream of the gold extraction activities. Of total 12 ITC trophic guilds their amount varied within three sampling locations as following: 2007-8, 5, 7; 2008-7, 4, 7 (Table 3). Therefore, suspended solids of gold mining polygons caused restructuring of the benthic trophic relations in the way of vanishing the most sensitive guilds.

The ecological quality class of the ITC decreased at the 0.2 km downstream location No. 2 where the suspended solids occurred emitted from the polygons. In 2007 this quality class decrease was stronger than in 2008-2 and 1 score diminish, respectively (Table 3).

The following trophic guilds of macroinvertebrates demonstrated a high level of tolerance to the suspended solids of the gold extraction activities at downstream locations.

Guild 1: Predatory animals which feed on live zooplanktonic and benthic organisms. They actively catch prey with dimensions of linear size >1 mm and ingest them mostly completely. They hunt by ambushing or pursuing their prey.

Guild 6: Herbivorous animals with mouth organs adapted to scraping bacterial and periphyton films from solid substrata. They do not feed selectively, but ingest mineral particles and small-sized periphytic animals they meet on their path.

Guild 7: These animals gather and feed on crumbly surface detritus or soil enriched with detritus and lower alga. Along with detritus many bacteria, fungi and protista are ingested. The feeding process of some representatives is similar to grazing on detritus.

On the other hand, the most sensitive guilds to the suspended solids seemed to be the following ones:

Guild 2: The predatory animals that eat any prey which cannot escape or defend itself, usually small meiobenthos (average >1 mm) of the Oligochaeta and Chironomidae. They do not track down and pursue their prey and their feeding resembles grazing.

Guild 3: Omnivores with well-developed mouthparts that eat large vegetative residuals and live plants as well as animal objects when they meet them. Some representatives of this group demonstrate elements of selectivity and high food searching activity. Others are completely non-selective, collecting detritus along with small-sized Oligochaeta and Chironomidae. The ratio of plant to animal material eaten is probably subject to seasonal fluctuations. This is a group of mixed macrofeeders.

Guild 5: Small to average sized herbivorous animals, which crush small-sized vegetative residuals (<1 mm), small-sized periphyton and phytoplankton and detritus particles. The feeding mechanism is shredding and chewing. This is the guild of small-sized shredders.

Guild 8: Herbivorous animals which get organic suspended substances: Fungi, bacteria and phytoplankton. The feeding come up by active filtration. These species do not seek for food sources and can move due to another reasons than food search.

Guild 9: Predatory animals, which hunt and suck the body fluids of their prey. The prey may leave alive or die after the contact with the predator. The non-fluid parts of the prey and other residuals not eaten come to a circle of consumption/decomposition by other animals. Hunting behaviour varies from the active to the moderate.

DISCUSSION

Alluvial gold minings at northern rivers by the hydraulic method are the main source of water pollution by fine suspended solids increased content. To determine the region-specific impacts of this human activity on macroinvertebrate community heath, chemical and physical stream characteristics and community metrics were measured in surface gold mine-affected and reference stretches at the Hobe-U river of Urals mountains.

The species composition and quantitative metrics of benthic invertebrates being good indicators of sediments and waters contamination are widely used in various hydrobiological monitoring programs of aquatic ecosystems[10,25].

This study showed that the species composition and quantitative values of the benthic invertebrates of the Hobe-U river had been formed by amphibiotic larva: Diptera, mayflies and caddis flies. The leading role in the macrozoobenthos community belonged to mayflies, in which the species of *Baetis* genus dominated. The development of the alluvial gold deposits led to changes in the structure of macroinvertebrates caused by suspended solids increase in the water and accumulation of mineral deposits on the river bedrock.

As it might be expected the upstream reference location had considerably higher number of collected macroinvertebrates than the downstream affected ones. Based on the species diversity, it observed that it was higher at the first location-31, dropped at the second-14 and lately moderately recovered at the third one-23, of the Hobe-U river.

In addition to the diversity depletion of the macrozoobenthos downstream of the polygons compared to the upstream location, the density and biomass of zoobenthos in 2007 decreased 8.2 and 4.9 times, respectively. In 2008, the total density of invertebrates decreased 8.2 times, biomass-10.7 times (Table 1).

The quantitative figures of the community development at the third location were always lower than at the upstream of the polygons location. In comparison with the second location (downstream of the polygons), the density increased 5.4 times, biomass-almost 3 times (Table 1). Nevertheless, the quantitative metrics of invertebrates at the 3rd location was 2.7 times in density and 2.5 times in biomass lower than at the first one (Table 1).

In general, it was found that suspended sediments caused a consequent decrease in macroinvertebrate density, mean total biomass, diversity and dominant taxa confirmed in many similar investigations[26-28]. So far, steady shifts in the invertebrate community was observed within 2 years at the area of polygons impact and even at the river mouth area located 10 km downstream of the gold mining developments.

One of the main factors that had a negative impact on the benthic fauna was high concentration of organic and mineral suspensions in the water. The reference turbidity of the water upstream of the polygons in the summer low water period did not exceed[3] 5 mg L^{-1}. Downstream of the polygons, its value was 24.7-35.6 mg L^{-1} and during the flood period it increased up to 500-800 mg L^{-1}. At the distance of 10 km (site 3) of the polygons area mean turbidity value[3] was 14.4 mg L^{-1}.

What was clearly found in the research, that Ephemeroptera assemblages may not be sensitive equally at different climate zones. They reacted weak at suspended solids water deterioration at subpolar Urals, although they did well at detecting gold-mining impacts in areas of eastern Amazonia[29]. At the same time the present finding corresponded to Alaska streams research of Wagener and LaPerriere[26], which had figured out the water mites (Acari) as potential macroinvertebrate indicators of habitats degraded by mining because they were rare or absent in mined streams.

Evidence was increasingly clear that anthropogenic effects (e.g., land-use) can reduce functional diversity in ecological communities[30-33].

Functional diversity commonly expressed as diversity of trophic groups, links and levels. This study demonstrated variety reactions of different ITC trophic guilds to suspended solids.

As for grazing invertebrates, Graham[34] demonstrated that suspensions of clay-sized particulates can be trapped by epilithic periphyton and reduce its attractiveness for grazing. Nevertheless, this event did not affect the 6-th ITC trophic guild (grazers-scrappers) enough to cause its disappearance, that shown in the current finding.

Absolute correspondence obtained in this study for filter-feeding invertebrates (8-th ITC trophic guild). Newcombe and MacDonald[35] noted that high levels of suspended solids can clog feeding structures, reducing feeding efficiency and therefore reducing growth rates, stressing and even killing these organisms. Filter-feeders vanishing appeared to be a good indicator of adverse effect of suspended solids on functional composition of benthic invertebrates.

Another research of Yule *et al.*[36] mentioned shredders to be sensitive as well to suspended solids, but this wide functional group is divided into tiny shredders (5-th ITC trophic guild) and shredders omnivorous (3-d ITC trophic guild)[11,24]. Nevertheless, both of them appeared to be highly sensitive to the harmful effect of mineral suspensions. As it was foregoing said 3-d and 5-th trophic guilds had completely disappeared from the second affected location of the Hobe-U river.

In spite of great variation of taxonomy structure among different regions, we are of the opinion that food-web streams organisation might be a good and robust metric when globally compare Tropic and Nordic aquatic ecosystems.

CONCLUSION

The existing gold mining activities in the area, which caused increase turbidity in the river was the main identified factor for the observed changes. The mean reduction of 2.2 times in the benthos species diversity was found at the locations downstream of the polygons. Larvae of the stoneflies, midges and caddis-flies of Arctopsyche genus disappeared from the benthic fauna composition. The density of macroinvertebrates at the second location has decreased in average 7.6 times, biomass-6 times.

The most tolerant trophic guilds hardly suffering from suspended solids were active predators, scrapers and detritivores. The others, for instance, tiny predators, omnivores macro-feeders, tiny shredders, filter-feeders, body fluid suckers, demonstrated much stronger suffering caused their complete disappearance from the benthic community. The ITC bioassessment approach had a good reliability and proved the destructive processes within the benthic communities caused by the alluvial gold mining.

SIGNIFICANCE STATEMENT

This study discovered that the functional analysis of macroinvertebrate community deterioration caused by fine suspended solids is a viable alternative when advances in macroinvertebrate ecological research is restricted by the level of species identification. Focus on adaptations of macroinvertebrates to habitats and the utilization of food resources (i.e., Index of Trophic Completeness) has facilitated ecological evaluation of the impacted river ecosystem. Results obtained may be beneficial for assessment of real functional loss to the benthic community with the following development of the river rehabilitation program. This study will help the researchers to widen their scope about shifts within aquatic ecosystem based not only on highly volatile taxonomy, but on the steadier functional trophic groups.

ACKNOWLEDGMENTS

The article preparation, collection and processing of samples was performed within the frameworks of the State Contract with the Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences (project No. 18-9-4-24).

REFERENCES

1. Ramm, A.E., 1988. The community degradation index: A new method for assessing the deterioration of aquatic habitats. Water Res., 22: 293-301.
2. Alabaster, D. and R. Llojd, 1984. [Water quality criteria for freshwater fish]. Light and Food Industry, Moscow, Russia, (In Russian).
3. Bogdanov, V.D., L.A. Dobrinskaya, A.V. Lugaskov, V.M. Shishmarev and M.I. Yarushina, 1982. [Ecological study of the Manya River ecosystem]. USC AS USSR, Sverdlovsk, Russia, (In Russian).
4. Dobrinskaya, L.A., A.I. Lukyanetz and A.V. Lugaskov *et al*., 1985. [Prospective of rational use of river ecosystems of the Sub-Ob North at mineral deposits development]. USC AS USSR, Sverdlovsk, Russia, (In Russian).
5. Voronin, R.N., S.V. Degteva, A.N. Lavrenko, O.A. Loskutova and V.A. Martynenko *et al*., 1994. Vliyanie razrabotki rossypnykh mestorozhdeniy Pripolyarnogo Urala na prirodnuyu sredu [Influence of development of placer deposits at the Subpolar Urals on the environment]. Syktyvkar, pp: 167, (In Russian).
6. Shubina, V.N., 2006. [Benthos of Salmonids Rivers of the Urals and the Timanskij Logs]. Nauka Publ., St. Petersburg, Russia, (In Russian).
7. Stepanov, L.N., 2009. [Impact of alluvial gold deposits development at macrozoobenthos of the Subpolar Urals mountain rivers]. Vestnik KrasGAU, 12: 100-104, (In Russian).
8. Shubina, V.N. and O.A. Loskutova, 1994. [Fauna of aquatic invertebrates of the Kozhim River]. In: [Impact of Alluvial Gold Deposits Development of the Subpolar Urals at Environment], Degteva, S. (Ed.). Komi SC UrB RAS, Syktyvkar, Russia, pp: 67-76, (In Russian).
9. Shubina, V.N. and O.A. Loskutova, 1994. [Influence of Mineral Developments in Mountains at Benthos]. In: [Impact of Alluvial Gold Deposits Development of the Subpolar Urals at Environment], Degteva, S. (Ed.). Komi SC UrB RAS, Syktyvkar, Russia, pp: 112-120, (In Russian).
10. Bakanov, A.I., 1987. [Domination quantitative assessment in ecological communities]. Manuscript dep. in VINITI 12/08/1987, No. 8593-B87, Borok, Russia, pp: 1-63.
11. Pavluk, T.I., A. bij de Vaate and H.A. Leslie, 2000. Development of an index of trophic completeness for benthic macroinvertebrate communities in flowing waters. Hydrobiologia, 427: 135-141.
12. De Vaate, A.B. and T.I. Pavluk, 2004. Practicability of the index of trophic completeness for running waters. Hydrobiologia, 519: 49-60.
13. Kemmerih, A.O., 1970. [Subpolar Urals Handbook]. Physical Culture and Sport, Moscow, Russia, (In Russian).
14. Vodogretckiy, V.E., 1973. Resursy Poverkhnostnykh Vod SSSR. Altay i Zapadnaya Sibir. [Surface Water Resources of the USSR. Altai and Western Siberia]. Vol. 15, Vyp. 3. Nizhniy Irtysh i Nizhnyaya Ob [Issue 3. Lower Irtysh and Lower Ob]. Gidrometeoizdat, Leningrad, (In Russian).
15. Bogdanov, V.D., 1997. Ecologia molodi i vosproizvodstvo sigovyh ryb Nizhney Obi [Smolt ecology and spawning of white fishes of the Low Ob River area]. Ph.D. Thesis, Institute of Ecological and Radiological Research, Ural Branch of the Russian Academy of Sciences, Moscow, (In Russian).
16. Bogdanov, V.D. and I.P. Melnichenko, 2010. [Role of the Manya River in reproduction of white-fish resources of the Low Ob River]. Agrarian Bulletin of the Urals, 11–1 (77): 49–52, (in Russian).
17. Morduhai-Boltovsky, F.D., 1975. [Study Technique of the Inner Waters Biogeocenoses]. Nauka Publ., Moscow, Russia, (In Russian).
18. Komulainen, S.F., A.N. Kruglova and V.V. Hrennikova *et al*., 1989. [Methodical recommendations for investigation of hydrobiological regime of small rivers]. KF AS USSR, Petrozavodsk, Russia, (In Russian).
19. Bakanov, A.I., 2000. [Use of zoobenthos for monitoring of freshwaters (review)]. Biol. Inland Waters, 1: 68-82, (In Russian).
20. Ulfstrand, S., 1968. Benthic animal communities in Lapland streams. Oikos, 10: 1-120.
21. Sorensen, T.J., 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyses of the vegetation on Danish commons. Biologiske Skrifter, Bind V, Nr. 4, I Kommission hos E. Munksgaard, København, Denmark, pp: 1-34.
22. Moog, O. and A. Hartmann, 2017. Fauna aquatica Austriaca-3. Lieferung. Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (BMLFUW), Wien, Austria.
23. Graf, W., J. Murphy, J. Dahl, C. Zamora-Munoz, M.J. Lopez-Rodriguez and A. Schmidt-Kloiber, 2006. Trichoptera indicator database. Euro-Limpacs Project, Workpackage 7-Indicators of Ecosystem Health, Task 4, Version 5.0.
24. Pavluk, T., 2018. MaTroS. http://macro.nemi-ekb.ru/index.php?r=site/login&lang=en
25. Albutra, Q.B., C.P. Ascano II and C.G. Demayo, 2017. Water quality assessment using macroinvertebrates along the mining area of Brgy. Int. J. Adv. Applied Sci., 4: 99-103.

26. Wagener, S.M. and J.D. LaPerriere, 1985. Effects of placer mining on the invertebrate communities of interior Alaska streams. Freshwater Invertebr. Biol., 4: 208-214.
27. Quinn, J.M., R.J. Davies-Colley, C.W. Hickey, M.L. Vickers and P.A. Ryan, 1992. Effects of clay discharges on streams. 2. Benthic invertebrates. Hydrobiologia, 248: 235-247.
28. Milner, A.M. and R.J. Piorkowski, 2004. Macroinvertebrate assemblages in streams of interior Alaska following alluvial gold mining. River Res. Applic., 20: 719-731.
29. Dedieu, N., M. Rhone, R. Vigouroux and R. Cereghino, 2015. Assessing the impact of gold mining in headwater streams of Eastern Amazonia using Ephemeroptera assemblages and biological traits. Ecol. Indic., 52: 332-340.
30. Houghton, D.C., 2007. The effects of landscape-level disturbance on the composition of Minnesota caddisfly (Insecta: Trichoptera) trophic functional groups: Evidence for ecosystem homogenization. Environ. Monit. Assess., 135: 253-264.
31. Schweiger, O., M. Musche, D. Bailey, R. Billeter and T. Diekotter *et al*., 2007. Functional richness of local hoverfly communities (Diptera, Syrphidae) in response to land use across temperate Europe. Oikos, 116: 461-472.
32. Flynn, B.F.D., M. Gogol-Prokurat, T. Nogeire, N. Molinari and T.B. Richers *et al*., 2009. Loss of functional diversity under land use intensification across multiple taxa. Ecol. Lett., 12: 22-33.
33. Larsen, S., G. Pace and S.J. Ormerod, 2011. Experimental effects of sediment deposition on the structure and function of macroinvertebrate assemblages in temperate streams. River Res. Applic., 27: 257-267.
34. Graham, A.A., 1990. Siltation of stone-surface periphyton in rivers by clay-sized particles from low concentrations in suspention. Hydrobiologia, 199: 107-115.
35. Newcombe, C.P. and D.D. MacDonald, 1991. Effects of suspended sediments on aquatic ecosystems. North Am. J. Fish. Manage., 11: 72-82.
36. Yule, C.M., L. Boyero and R. Marchant, 2010. Effects of sediment pollution on food webs in a tropical river (Borneo, Indonesia). Mar. Freshwater Res., 61: 204-213.