RR 2004
3rd European Conference on River Restoration
RIVER RESTORATION 2004
Zagreb, Croatia, 17-21 May 2004

Macroinvertebrates trophic structure alterations as a response on effect of different contamination substances

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ABSTRACT: Effects of stress caused by anthropogenic activities in rivers negatively act on the intricate system of trophic links within invertebrate communities and other components of the aquatic ecosystem. These effects can be visible with the Index of Trophic Completeness (ITC), which was developed as an indicator for the functioning of the river ecosystem, based on the trophic classification of benthic macroinvertebrates. Response of macroinvertebrate communities to different types of pollution was studied in the period 1997-2001 in Russian rivers. The rivers were subjected to monopollutants such as chromium, copper, zinc, manganese, oil substances, organic wastes and suspended solids. Qualitative and quantitative characteristics of the communities changed in a similar way with the increase of water pollution, irrespective the type of disturbance. However, functional characteristic like trophic structure varied rather specifically in each single case. This partly allows us to distinguish the main polluting substance, taking into account the distribution of trophic groups within the macroinvertebrates community. Many these and other recent outcomes of the ITC practical trials are discussed in the paper.

KEYWORDS: Macroinvertebrates, trophic structure, bioassessment, water pollution

Introduction

Effective river or lake management takes into account ecological information, specifically geared to the water manager and decision maker [1]. Compression of this information is facilitated by use of relatively simple and integrative indices. In rivers, the community structure of benthic macroinvertebrates has become an important quality element in many of the water quality assessment procedures [2, 3]. Macroinvertebrate assemblages are considered to be useful bioindicators because of their abundance, sedentary nature, suitable life span, biodiversity and trophic levels, sensitivity and swift respond to various stress types [4]. Listed above advantages made possible to widely use macroinvertebrate indices, scores and balls have been developed since the beginning of XX century. The reason to develop new bioassessment methods is hidden in a long row of questions that left after an assessment method is applied and weakly understandable results obtained.

Functional approach in assessment of aquatic ecosystem integrity (or health) is supposed to be promising and involves the assessment of trophic groups, which are made up of animals of the same feeding type, using similar sources of energy and matter (same trophic niche). Developed Index of Trophic Completeness [5] based on functional approach allowed to have unordinary view on the assessment procedure, its results and interpretation of negative processes discovered during the study. New developed method proved the strong connections between ongoing processes in aquatic ecosystem and functional structure of macroinvertebrates.

Current paper summarises the "cause-consequence" regularities found during many years studies of trophic structure of macroinvertebrate assemblages and contamination or other disturbing factors of anthropogenic origin.

Index of Trophic Completeness (ITC) was the main tool used to discover specific alteration in trophic structure of macroinvertebrates subjected to monopollutants such as chromium, copper, zinc, manganese, oil substances, organic wastes and suspended solids.

Trophic structure though the ITC index

In the past, various authors have devised systems of trophic classification for benthic macroinvertebrates [6, 7, 8]. The Index of Trophic Completeness (ITC) assessment method is rooted in the functional approach to ecosystem study [9]. On the basis of knowledge of previous investigations five aspects of the feeding character of macroinvertebrates were selected for the definition of the trophic groups (Table 1). Each aspect was subdivided into a number of categories for differentiation of the trophic groups and to optimise the power of the ITC.

For each trophic group a five-digit code was generated, what helped to computerise the assessment procedure. These groups were termed ITC trophic groups.

Focusing on the benthic macroinvertebrate community in this way indicates the state of completeness of the functioning of the aquatic ecosystem as a whole because the 12 ITC groups are connected by trophic links to all other components of the aquatic ecosystem [5].

Table 1. Aspects of trophic character defining codes and 12 trophic groups of the ITC (all benthic macroinvertebrates definable by one of these ITC codes)

Group no.	Diet	Feeding mechanism	Food size (mm)	Feeding behaviour	Food ingestion	Code
1	Carnivory	Shredding/ chewing	>1	Active	Total	3-1-1-1-1
2	Carnivory	Shredding/ chewing	>1	Moderate	Total	3-1-1-2-1
3	Omnivory	Shredding/ chewing Collecting collecting	>1	Active Moderate Active moderate	Total	2-1-1-1-1 2-1-1-2-1 2-3-1-1-1 2-3-1-2-1
4	Herbivory	Shredding/ chewing	>1	Moderate	Total	1-1-1-2-1
5	Herbivory	Shredding/ chewing	<1	Moderate	Total	1-1-2-2-1
6	Herbivory	Scrapping	<1	Moderate	Total	1-2-2-2-1
7	Herbivory	Collecting	<1	Moderate	Total	1-3-2-2-1
8	Herbivory	Filtering	<1	Moderate Passive	Total	1-5-2-2-1 1-5-2-3-1
9	Carnivory	Sucking	>1	Moderate		3-4-1-1-2 3-4-1-2-2
10	Carnivory	Sucking	>1	Moderate	Total	3-4-1-2-1
11	Herbivory	Sucking	>1	Moderate	Incomplete	1-4-1-2-2
12	Omnivory	Shredding/ chewing	<1	Moderate	Total	2-1-2-2-1

Functional response of macroinvertebrates to disturbance

When in sound conditions the community of macroinvertebrates has maximum diversity of trophic groups (12), the community of strong climate conditions of streams and lakes, like in cold mountain or short wadeable rivers (less 30 km), may vary and rarely has more than 8 trophic groups of macroinvertebrates in pristine conditions. Trophic groups like active carnivores, filtrators, animal ingesters, plant fluid suckers and microomnivores (ITC groups 1, 8, 10, 11 and 12) were often absent in these extreme biotops. All 12 trophic groups were always present in middle and large rivers and reservoirs studied in Russia, Holland and Greece.

As disturbance caused by contamination, suspended solid or even intensive recreation takes place, the macroinvertebrate communities always react by decrease of diversity and alteration in total structure of the community, where the most sensitive to stress factor species eliminate. Qualitative and quantitative characteristics of the communities changed in a similar way with the increase of water pollution, irrespective the type of disturbance. However, functional characteristic like trophic structure varied rather specifically in each single case.

Number of studies, carried out in 1997-2001 on rivers polluted presumably by one main substance, allowed distinguishing specific pattern of the ITC trophic structure in each case. In turn, that becomes possible to predict the main disturbance factor of aquatic ecosystem, taking into account the distribution of trophic groups within the macroinvertebrates community.

The Index of Trophic Completeness assessment issues were as following, describing the trophic structure of the disturbed macroinvertebrate communities (Table 2).

- Pollution of water by manganese (Zhernovka river) in the concentration range of 1.8-2.7 mg/l caused disappearances from the community of trophic groups like shredding omnivores, shredders of microparticles and animal ingesters (ITC groups 3, 5 and 10) showing specific sensitivity to manganese pollution.
- Pollution of water by zinc (Rudnaya river) in the concentration range of 1.3-1.8 mg/l caused complete disappearance such trophic groups like shredding omnivores, shredders of microparticles, filtrators and animal ingesters (ITC groups 3, 5, 8 and 10), which can be marked as specifically sensitive to pollution by zinc and that disappear from the community first.
- Water disturbance by suspended substances (Nyarta-U river) within the limits of 45-70 mg/l caused disappearance of trophic groups like shredding omnivores, shredders of microparticles, filtrators and fluid sucking predators (ITC groups 3, 5, 8 and 9).
- Pollution of water by chromium salts (0.6 mg/l on average - the Chusovaya river) depresses the benthic community (mainly abundance), but does not cause complete disappearance of any trophic group. Trophic groups 10, 11 and 12 sporadically disappear from the community (animal ingesters, plant fluid suckers and microomnivores).
- Pollution of water by copper salts (0.2 mg/l - the Salda river) resulted in complete disappearance of plantivore macroshredders and animal ingesters trophic groups from macroinvertebrates community (ITC groups 4 and 10).
- Pollution of water by oil substances (0.35 mg/l - the Iset river) resulted in disappearance of many trophic groups, passive carnivores, shredding omnivores, macroshredding plantivores, shredders of microparticles, plant fluid suckers and microomnivores (ITC groups 1, 2, 3, 4, 5, 11 and 12 respectively). The given type of pollution has most destructive effect on aquatic ecosystem.

Table 2. Pattern of functional changes in trophic structure of the macroinvertebrate communities disturbed by different factors

ITC trophic groups	Type of disturbance					
	Mn	**Zn**	**Cu**	**Cr**	**Oil**	**Susp. solids**
1	■	■	■	■		■
2	■	■	■	■		■
3			■	■		
4	■	■		■		■
5			■	■		
6	■	■	■	■	■	■
7	■	■	■	■	■	■
8	■		■	■	■	
9	■	■	■	■	■	
10				▨	■	■
11	■	■	■	▨		■
12	■	■	■	▨		■

Note: blank bricks mean absence of related trophic groups; lined bricks mean rarely found trophic groups, but not disappeared completely.

Therefore, as it is seen from the table 2 the trophic pattern varies and is specific for macroinvertebrate communities disturbed by different factors. At the same time, in the opposite way it is possible to predict type of water disturbance judged on the trophic structure of macroinvertebrates. Practically, this approach might be useful for non-governmental organisations and different societies for nature protection, because it substitutes the instrumental control of water quality.

Further studies of rivers with monodominant pollutant could expand knowledge of trophic pattern reaction of benthic macroinvertebrates and support sufficiently the extensive monitoring of rivers and lakes, getting simultaneously information about the type and level of aquatic ecosystem disturbance.

Conclusions

Opportunity to use ITC approach widely is restricted by a number of precise limitations:

1. It is recommended not to use the ITC in severe climatic conditions, when mean annual air temperature is lower than -3 °C.
2. In order to implement the ITC quality scale, the stream length should be longer than 30 km, with precondition that a stream runs into freshwater ecosystem (lake or river), and longer than 60 km, in the case that a stream runs into marine ecosystem.
3. The ITC is not recommended to use for water objects, which are located higher 1000 m above sea level.

In biodiversity restoration program we recommend to use as a target point not recolonization of a single species of macroinvertebrates, but appearance an ITC trophic group, which vanished and may exist after improvement of the water quality.

Therefore, next steps in the ITC development include update of the ITC calculation program (MaTroS) for WINDOWS 2000 and XP edition (MaTroS for WINDOWS 95/ 98 is valid); investigation of "cause-consequence" connections between type of disturbance and pattern of ITC trophic structure for other substances and ecological doubts.

Acknowledgements

The help of Valery Mukhutdinov, Elena Pavluk and Alexander Minin in assistance of sampling and identification of macroinvertebrates, and Prof. Alexander Chernyaev in coordination of studies has been highly appreciated.

References

1. Van der Velde, G., Leuven, R.S.E.W., 1999. Polluted river systems: monitoring and assessment of ecotoxicological risks. Acta Hydrochim Hydrobiol. 27, 251-256.
2. Rosenberg, D. M., Resh, V.H., 1993. Freshwater biomonitoring and benthic microinvertebrates. Chapman & Hall, New York.
3. Canfield, T.J., Kemble, N.E., Brumbaugh, W.G., Dwyer, F.J., Ingersoll, C.G., Fairchild, J.F., 1994. Use of benthic invertebrate community structure and the sediment quality triad to evaluate metal contaminated sediment in the Upper Clark Fork River, Montana. Environm. Toxicol. Chem. 13, 1999-2012.
4. Metcalfe-Smith, J.L., 1994. Biological water quality assessment in rivers: use of macroinvertebrate communities. In: Calow, P., Petts, G.E. (Eds.), The Rivers Handbook, Vol. 2. Blackwell Scientific Publications, Oxford, pp. 144-170.
5. Pavluk T.I., Abraham bij de Vaate & Heather A. Leslie. Development of an Index of Trophic Completeness for benthic macroinvertebrate communities in flowing waters. Hydrobiologia 427: 135-141, 2000. Kluwer Academic Publishers 2000.
6. Konstantinov, A.S., 1967. Obshaya Gydrobiologiya (Principals of Hydrobiology). Vysshaya shkola, p. 430 [in Russian].
7. Cummins, K.W., 1973. Trophic relations of aquatic insects. Annu. Rev. Entomol. 8: 183-206.
8. Miroshnichenko, M.P. 1983. Znachenye oligochet v trophicheskoi strukture biocenozov bentosa Tzilianskogo vodohranilisha (The place of Oligochaeta in the trophic structure o benthic biocenoses of the Tzimliansky resevoir). Materialy chetvertogo vsesousnogo symposiuma, Tbilisi 5-7 October 1983, Tbilisi: Izd-vo 'Metzniereba'; 58-63 [in Russian].
9. Odum E.P., 1971. Fundamentals of Ecology. W.B. Saunders Co., Philadelphia, 574 pp.

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