V.F.Shuisky, T.V.Maximova, D.S.Petrov

THE ISOBOLIC METHOD OF MULTIFACTOR ANTHROPOGENIC IMPACT ON FRESH-WATER ECOSYSTEMS EVALUATION AND STANDARD-SETTING BY MACROZOOBENTHOS STATE

Saint Petersburg
2004

Shuisky V.F., Maximova T.V., Petrov D.S.
The isobolic method of multifactor anthropogenic impact on fresh-water ecosystems evaluation and standard-setting by macrozoobenthos state: International Academy of Ecology, Man and Nature Protection Sciences (IAEMNPS). 2004. 304 p.

SUMMARY

The monograph contains the theoretical basis and detailed description of evaluation and standard-setting quantitative method of complex (multifactor) impacts on fresh-water ecosystems. The suggested method uses the revealed general laws of the best hydroecosystem bioindicator reaction – macrozoobenthocoenoses – to multicomponent external impact, which is estimated by the original isobolic index. The present techniques and data are based on representative long-term hydroecological research results executed by the group of authors. Basic methodological positions and practical applications of this method are illustrated in detail by the factual data. Particular examples of the method used for solving various environmental protection problems are also considered.

Chapter 1. Problem of quantitative evaluation of multifactor anthropogenic impacts on fresh-water ecosystems

The comparative analysis of various methods of fresh-water ecosystems state and its change evaluation is realized.

The following positions are proved:

- The quantitative evaluation of multifactor impacts should be carried out on the universal index development base.
- This index should correspond to the following requirements:
  - to be isobolic (its concrete value should correspond to all multifactor impact isoboles and determine reciprocal reaction of biota);
  - to reflect adequately and exactly the effect of every combination of interacting factors;
  - to express the rate of excess by the current impact level to its maximum permissible level (i.e. to carry out standard-setting of current impact).
- Anthropogenic successions of hydroecosystem should be evaluated on the basis of the changes caused to the most indicative bioindicator – macrozoobenthos state.
- The major macrozoobenthos characteristic is its species composition. Accordingly, the maximum permissible level of anthropogenic impact is its greatest impact level, which does not cause changes of macrozoobenthos species composition. Anthropogenic changes of quantitative structural and functional macrozoobenthos characteristics also are important for bioindication, but they are secondary, auxiliary.

The importance is proved of establishing and describing the basic quantitative laws of macrozoobenthos species composition and its structural functional characteristics reaction on the multifactor anthropogenic impacts, expressed by isobolic index. Development and approbation of this index and method of quantitative evaluation and standard-settings of multifactor anthropogenic impacts on fresh-water ecosystems will be presented in the following chapters.

Chapter 2. Materials, techniques, model hydroecosystems

This work generalizes some of the results of a long-term (1983-2002) study of anthropogenic succession of polytypic aquatic objects (the rivers, lakes, a basin cooler, friths, streams, temporary reservoirs) ecosystems. Hydroecological research work was done in Northwest and Central regions of Russia (the Leningrad, Pskov and Ryazan regions) and in Finland. The used database includes the results of processing more than six thousand macrozoobenthos samples and more than one thousand water and bottom samples. Description of the used initial material, methods of samples gathering and processing are given. Model

hydroecosystems, which will further be used to explain the suggested isobolic method, are characterized in detail. These are the basin cooler of Ryazan hydroelectric power station, the Pasha River, the Syas River, the Luga River and their inflows.

Chapter 3. Macrozoobenthocoenosis resistance to multifactor impact

The concept of evaluation of macrozoobenthocoenoses resistance to external impact is explained. The criterion is introduced of allocation of those species, which should be regarded as characteristic for macrozoobenthocoenosis during its study and taken into account during a comparative evaluation of species structure exogenic changes. Concepts and attributes of natural habitat conditions and macrozoobenthocoenosis background state are justified. The procedure of describing macrozoobenthocoenosis background state in polytypic habitats is defined. The basic components of the concept and a method of the macrozoobenthocoenosis background condition description, species structure and bioindicatelly significant quantitative characteristics of the coenosis are illustrated through model ecosystems in detail.

The concrete concept and quantitative measure of macrozoobenthocoenosis elastic resistance ("elasticity") to external impact are suggested. Elasticity is treated as an ability of the coenosis to come back to natural condition after impact discontinuance, determined by preservation of species structure, characteristic for this coenosis in its natural state. Accordingly, a proved change of characteristic species structure testifies that the coenosis has lost its elasticity.

The suggested concept allows us to move on to the quantitative description of elasticity saving conditions.

Chapter 4. Quantitative description of macrozoobenthocoenosis resistance preservation conditions in the case of multifactor impact

The system of the interconnected parameters is justified and introduced. They are necessary for the quantitative description of macrozoobenthocoenosis resistance preservation condition in the case of external impact. Methodology and method of the quantitative description of coenosis elasticity are introduced and explained gradually, in process of solved problems complication. At first, the elementary case of one factor action, then - a combination of two factors and, at last, the situation of infinitely complex multifactor interaction are considered one after another. Some results of a quantitative evaluation of macrozoobenthocoenosis elastic resistance at various fresh-water ecosystems, studied by authors are generalized. The maximum permissible level of external impact on the indicator - macrozoobenthos and the ecosystem it represents is described in factor hyperspace as the boundary of the allowed factor value combination area.

All stages of the quantitative description of macrozoobenthocoenosis resistance preservation condition in the case of multifactor impact are shown in detail through particular examples.

Quantitative description of macrozoobenthocoenosis elasticity preservation condition allows us to consider a solution of the following problem: measurement of multifactor impact by comparing its current level with the appropriate maximum permissible level.

Chapter 5. Quantitative evaluation and standard-setting of multifactor anthropogenic impact on macrozoobenthocoenoses

The universal index of resulting multifactor impact level, which is appropriate to all necessary criteria is suggested (chapter 1). This index expresses the rate of excess by impact of macrozoobenthos elastic resistance. The index is proved and entered for three typical situations by the way of their complication (as it was made in chapter 4). At first, one factor action evaluation, then – two factors combination effect and, at last, resulting multifactor impact effect are considered one by one. The all-round approbation of this index is realized:

- the index is really isobolic and it determines changes of major characteristics of biota;

- the index takes into account adequately and flexibly complex factor interaction effect in any combination of this factors;

- the index is dimensionless and it expresses the rate of excess by any complex impact of its maximum permissible level, determined by macrozoobenthocoenosis elastic resistance in the case of this impact.

Bisides, the suggested isobolic index of multifactor impact has some additional advantages. If the impact has not yet caused any loss of macrozoobenthocoenosis elasticity, the index also characterizes "safety factor" of the coenosis (its residual resistance). This index gives exact evaluation of the each factor contribution to their common man-made burden on biota.

Use of the isobolic index allows to analyze, generalize, formalize and typify the basic quantitative laws of fresh-water macrozoobenthocoenosis reaction on various multifactor impacts. The uniform classification and the approach to standard-setting of multifactor anthropogenic impacts on fresh-water ecosystems are suggested.

The evaluation of various complex impacts and different variants of anthropogenic macrozoobenthocoenosis changes are illustrated in details through particular examples.

Chapter 6. Some examples of isobolic method use

Examples of isobolic method practical application are presented to solve the following environmental and nature protection problems:

- the studying and evaluation of multifactor anthropogenic impacts on various aquatic ecosystems;

- the analysis of environmental risk and definition of environmental damage for aquatic objects in the case of multifactor anthropogenic impact;

- the proved choice of effective measures on technogenic impact regulation and expected result predictions.

This book is for specialists in the field of hydroecology, environmental safety, ecological toxicology and zoology. It also can be useful for a broader audience of the readers interested in problems of studying external impacts on biosystems or other system objects.

CONTENTS

INTRODUCTION

Chapter 1. PROBLEM OF QUANTITATIVE EVALUATION OF MULTIFACTOR ANTHROPOGENIC IMPACTS ON FRESH-WATER ECOSYSTEMS

1.1. Evaluation of ecosystems state and its anthropogenic changes using abiotic parameters

1.2. Bioindication of water environment quality, fresh-water ecosystems state and its anthropogenic changes (by the example of macrozoobenthoscoenoses)

1.3. Evaluation of ecosystems state and its anthropogenic changes using both abiotic and biotic parameters

1.4. Basic results of analysis of quantitative evaluation problem of multifactor anthropogenic impacts on fresh-water ecosystems

Chapter 2. MATERIALS, TECHNIQUES, MODEL HYDROECOSYSTEMS

2.1. Used materials

2.2. Applied techniques of samples gathering and processing

2.3. Brief description of model hydroecosystems

2.3.1. Reservoir - cooler of the Ryazan state district power station (Pronsky dam lake).

2.3.2. The Pasha River, the Kapsha River and the Syas River

2.3.3. The Luga River and its inflows in impact zone of the Limited Liability Company "Industrial Group "Phosphorite"

Chapter 3. MACROZOOBENTHOCOENOSIS RESISTANCE TO MULTIFACTOR IMPACT

3.1. Species composition of coenosis as characteristic species assemblage; evaluation criterion of species composition change

3.2. Choice of confidence level for identification of characteristic macrozoobenthocoenosis species

3.3. Background ecosystem conditions and macrozoobenthocoenosis background state

3.3.1. Concepts of background ecosystem conditions and macrozoobenthocoenosis background state

3.3.2. Description of macrozoobenthocoenosis background state in homotopic and heterotopic habitat

3.4. Concept and measure of macrozoobenthocoenosis resistance to impact

3.4.1. Justification of choice of macrozoobenthocoenosis resistance to impact concept

3.4.2. Justification of choice of macrozoobenthocoenosis elastic resistance criterion and quantitative measure

Chapter 4. QUANTITATIVE DESCRIPTION OF MACROZOOBENTHOCOENOSIS RESISTANCE PRESERVATION CONDITIONS IN THE CASE OF MULTIFACTOR IMPACT

4.1. Biosystems welfare functions; intervals of optimum, suboptimum and resistant values of environmental factors

4.2. Macrozoobenthocoenosis welfare functions as a functions of factors composed impact; intervals of optimum, suboptimum and resistance factor values for macrozoobenthocoenosis

4.3. Quantitative description of macrozoobenthocoenosis resistance preservation conditions in the case of multifactor impact

4.3.1. Description of resistance preservation area in the situation of single-factor impact

4.3.2. Description of resistance preservation area in the situation of two-factor impact

4.3.3. Description of resistance preservation area in the situation of multifactor impact

4.3.4. Some results of quantitative evaluation of various factors synergism power in cause of combined impacts on macrozoobenthos

Chapter 5. QUANTITATIVE EVALUATION AND STANDARD-SETTING OF MULTIFACTOR ANTHROPOGENIC IMPACT ON MACROZOOBENTHOCOENOSES

5.1. Quantitative evaluation of multifactor anthropogenic impacts on macrozoobenthocoenoses

5.1.1. Evaluation of single-factor impact

5.1.2. Evaluation of two-factor impact

5.1.3. Evaluation of multifactor impact

5.2. Laws of macrozoobenthocoenosis reaction on multifactor impact as basis of its standard-setting

Chapter 6. SOME EXAMPLES OF ISOBOLIC METHOD USE

6.1. Analysis of dynamics of multifactor impacts on hydroecosystems

6.1.1. Impact of the Limited Liability Company "Industrial Group "Phosphorite" on ecosystem of the Luga River

6.1.2. Impact of the Joint-stock Company "Boksitogorsky alumina" on ecosystem of the Syas River and its inflows

6.1.3. Technogenic impact on ecosystem of the Plussa River and its inflows

6.1.4. Afteraction of colorful log river drive on ecosystem of the Pasha River and its inflows

6.2. Evaluation of technogenic environmental damage on the basis of the risk-analysis

6.3. Choice of measures of regulation of multifactor impacts on hydroecosystems

REFERENCES

Appendix 1. Chemical water composition of the basin cooler of the Ryazan hydroelectric power station and in background conditions (the Pronya River) (1990 - 1994). Value ranges of parameters

Appendix 2. The list of macrozoobenthos species, found in the basin cooler of the Ryazan hydroelectric power station and in studied stretch of the Pronya River

Appendix 3. Hydrological and hydrochemical characteristics of upper and middle current of the Syas River; results of researches on 6 stations (1997)

Appendix 4. Hydrological and hydrochemical characteristics of the Pasha River (60 kms river stretch - from estuary of the Pit River up to New Village) and the Kapsha River (30 kms river stretch - from Novinka to estuary); summer low-water period, 1992

Appendix 5. Hydrological and hydrochemical characteristics of the Pasha River and the Kapsha River on sample station in summer low-water period (1992-1999)

Appendix 6. The list of macrozoobenthos species, found in the Pasha River, the Kapsha River and the Syas River

Appendix 7. Concentration value range of some substances in waters of the Luga River and its inflows

Appendix 8. The list of macrozoobenthos species, found in the Luga River and its inflows