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# DEVELOPMENT OF A SPACE-INDEPENDENT BIOINDICATION SYSTEM FOR EVALUATION OF EUTROPHICATION IN COASTAL AREAS OF THE GULF OF FINLAND

## Report of the Gulf of Finland Year 1996 Seminar Tvärminne, November the 25-27th, 1996

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(Editors)

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## PREFACE

During the planning phase of the Gulf of Finland Year 1996 it turned out that the biology of the littoral, or coastal, aquatic zone in the vicinity of big municipalities around the Gulf is not too well understood. These areas are more or less eutrophied by municipal or industrial wastewaters. Local surveys have been made; differences between the methods impede the valid comparison of the results, however.

Recreational activities of the citizens turn mostly to the same areas. Swimming, paddling, winter jigging and other recreational fishing are some of the best examples. A well-balanced ecosystem with high biodiversity is the best guarantee for sustainable existence of these activities.

This report contains proceedings, minutes and recommendations of the seminar **Development of a space-independent bioindication system for evaluation of eutrophication in coastal areas of the Gulf of Finland**, held in Tvärminne Zoological Station, Finland, in November the 25-27th, 1996. The Seminar was the first attempt to compare and harmonize the different biological monitoring methods of pollution near the big cities around the Gulf of Finland. During the Seminar it became obvious that local monitoring work and calculation of biotic indices are on high scientific level. Need for further integration and joint work was acknowledged as well. **A proposal for further activities** which was unanimously accepted by the participants is presented at the end of the plenary session report.

We credit the Finnish Ministry of the Environment for funding the Seminar as well as the skilful staff of the Tvärminne Zoological Station for practical arrangements.

Most of the papers in this report are manuscripts which are to be published elsewhere. It is therefore recommended not to cite the papers without prior reference to the authors.

On Behalf of the Seminar Participants

Editors

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## DEVELOPMENT OF A SPACE-INDEPENDENT BIOINDICATION SYSTEM FOR EVALUATION OF EUTROPHICATION IN COASTAL AREAS OF THE GULF OF FINLAND

Meeting Report and Proceedings of the Seminar
Tvärminne Zoological Station, FINLAND

November the 25-27th, 1996

Opening addresses:

Dr **Jouko Pokki**, station director, University of Helsinki, Tvärminne Zoological Station:

Dr Pokki welcomed all the participants to the Seminar as a station director and on his behalf, too. He gave a brief presentation about the history of the Station. Then he told about the unique situation of the Station by the beautiful fjord-like Pojo Bay and biological features of the area as well. He also presented ongoing scientific activities, facilities and courses, which are held on the Station yearly. He also regretted the dark and cold season, which prevented enjoying the beautiful nature surrounding the Station.

M.Sc. **Ilkka Viitasalo**, project coordinator, Environment Centre of the City of Helsinki:

Ilkka Viitasalo opened the Seminar. Mr Viitasalo pointed out the importance to find new channels to present the results of the research work, transfer knowledge on a personal level and discuss about the international cooperation and even make decisions in developing a common bioindex system for the Gulf of Finland area. He wished we had in future a possibility to compare results of the research work in evaluation and measuring the state of the water quality of the Gulf of Finland. Before this kind of situation is possible we need tools (commonly accepted methods) to create the space-independent bioindication system.

Lectures (complete list of the authors is seen in the appendices):

**Telesh, Irena V.**, Russian Academy of Sciences, Zoological Institute:
WATER QUALITY CLASSIFICATION BASED ON PLANKTON COMMUNITIES

(APPENDIX 1)

1) Planktonic organisms (bacteria, phytoplankton, zooplankton) react to different types of water pollution and this reaction is fast (short life and high reproduction rates). Therefore, plankton can characterize mainly the short-term effects of pollution.

2) Permanent anthropogenic pressure results in the environmental changes which can be well documentated by the long-term data on plankton communities.

3) Parameters of plankton communities, recommended for the water quality evaluation in the eastern Gulf of Finland and Neva Bay:

A) Phytoplankton: species composition, species-indicators, mid-summer density and biomass, production/decomposition rate, primary production and percentage of blue-greens

B) Zooplankton: species composition, species-indicators among dominants, community structure, species diversity, mean summer density and biomass, morphological abnormalities and control of the physiological state of organisms and "artificial mortality"

4) For the adequate evaluation of water quality and the ecosystem changes, a reasonable combination of parameters and methods, including hydrochemical, should be used

**Vuoristo, Heidi**, Finnish Environmental Institute:
WATER QUALITY CLASSIFICATION IN FINLAND

(APPENDIX 2)

Water quality classification project was launched in 1988 and the whole system was planned to be utilization-based (for recreational purposes, for raw water supply and as fishing waters). In general, waters are classified in five categories: excellent, good, satisfactory, fair and bad, but in the classifications for recreational purposes and for fishing waters six classes are used: excellent, good, satisfactory, poor, bad and unsuitable. For raw waters system is more strict consisting of five classes. System also gives a verbal description of the quality classes. The numerical criteria have been given to variables, which can be measured with standardized or commonly accepted analysis methods and which are relevant for the modes of water uses. Some variables illustrate the natural characteristics of water and some indicate the changes caused by waste waters or other human activity. In most cases average or median values are used. Classification results are illustrated by using the coloured maps. Water quality classification is based on the data, which has been collected regularily for decades from all over the country and from different kind of water bodies. All the data is deposited in the water quality data bank of the Finnish Environmental Institute. This classification system does not work perfectly in brackish water, because it is created originally for the fresh waters. If there is a need to classify coastal waters, the criteria should be designed specially for these waters.

**Martin, Georg**, Estonian Marine Institute:
WATER QUALITY CLASSIFICATION IN TALLINN SEA AREA BY LITTORAL VEGETATION

(APPENDIX 3)

The results of the regular monitoring of the state of coastal sea by benthic algal communities in 1996 indicated a change, compared to the earlier situation. The borders of the mesosaprobic zone have also moved from the Viimsi peninsula towards the bottom of Tallinn Bay. The recolonization of *Fucus vesiculosus* was described in the areas close to the Pirita area and northwards along the shoreline of Viimsi peninsula. On the other hand the relative abundance of *Cladophora glomerata* has increased in whole sea area. The development of *Enteromorpha* species was somehow lower than in previous years.

**Hämekoski, Kari**, Helsinki Metropolitan Area Council (YTV):
AIR QUALITY INDEX IN HELSINKI AREA (FINLAND)

(APPENDIX 4)

A simple air quality index (AQI) was introduced for the Helsinki Metropolitan Area in 1993, in order to inform the public about the current air quality in an easily understood way. The pollutants included in the AQI are CO (1 and 8 h), NO2 (1 and 24 h), SO2 (1 and 24 h), O3 (1 h) and PM10 (24 h).

**Panov, Vadim E.**, Russian Academy of Sciences, Zoological Institute:
FUNCTIONAL APPROACH TO THE EVALUATION OF EUTROPHICATION IN THE NEVA ESTRUARY

(APPENDIX 5)

In the process of development of monitoring system is essential to choose the best suitable parameter and sampling plots, as well as to plan carefully sampling programmes of evaluation of eutrophication.

Collected data from Neva Bay shows that the respiration rates in zoobenthos might be an useful indicator of eutrophication or organic pollution in the Neva Estruary. Primary production and respiration in the ecosystem are likely the most appropriate parameters for monitoring of eutrophication. Construction of the detailed carbon budget of the ecosystem allows the accurate quantification of its current trophic status. Long-term data on main parameters of the carbon budget are extremely important for the verification of the simulation models.

The monitoring programmes carried out in coastal ecosystems should be accompanied by the construction of simulation models to describe main carbon flow through the foodweb. These models will contain the actual knowledge on the functioning of ecosystem in a very condensed but integrated form; promote new ideas on the functioning of coastal ecosystems under changing environmental conditions; enhance development of the more effective monitoring programmes; help administrators to decide on specific future management strategies, as "a bridge between science and management". This approach can be considered as a space-independent.

**Viitasalo, Ilkka**, Environment Centre of the City of Helsinki:
ECOLOGICAL CLUSTERS OF MACROPHYTE SPECIES ON THE HELSINKI SEA AREA, GULF OF FINLAND; METHODS AND MAIN RESULTS

(APPENDIX 6)

Macrobenthos data including taxons and their physiological properties (from 3-5 meter wide sampling sites in eulittoral off the Helsinki area) were clustered into groups by using a correlation matrix with Pearson's product moment coefficient and utilized weighted pairing of groups in building the dendrogram. Four following groups of taxa, their properties and functions were detected:

A. Outermost archipelago: e.g. fertile *Fucus* with *Elachista*, *Cladophora* (few epiphytes)

B. Middle archipelago: e.g. sterile *Fucus* without *Elachista*

C. Inner archipelago without wastewater load or convalescent areas: e.g. *Enteromorpha sp., E. compressa, Cladophora* and phanerogams

D. Inner archipelago with wastewater or stormwater load: e.g. mass occurence of *Enteromorpha*, sterile *Ectocarpus*.

Different clusters are supposed to display different kinds of ecological factors e.g. availability of nutrients (eutrophication). S-index (sample biotic index) was calculated based on this information of species, their abundances and values from one sample. After calculations the sampling sites were classified into four classes and a map of different ecological zones was drawn.

**Balushkina, Evgeniya V.**, Russian Academy of Sciences, Zoological Institute:
NEW INTEGRATED INDEX FOR WATER QUALITY EVALUATION BASED ON STRUCTURAL CHARACTERISTICS OF ZOOBENTHOS

(APPENDIX 7)

The following indices for the assessment of water quality of eastern part of the Gulf of Finland, Neva Bay, Neva River and Lake Ladoga were used:

1) Trent Biotic Index, which evaluates structure of benthic community (complexes of species) as whole
2) Index Kch, based on the structure of chironomid communities
3) Goodnigth and Whitley's index, which is the relationship between abundance of oligochaetes and total abundance of zoobenthos
4) Saprotoxic index, which is based on toxicological studies of wastes of industrian enterprices

New Integrated index (IP) includes a set of indices providing the most complete characterization of an animal community as a whole and reflecting specific features of human impact on an ecosystem.

## PLENARY SESSION

Plenum lecture

**Professor Alimov** started the plenary session part of the Seminar with the presentation of the biodiversity indices based on his own studies.

Diversity indices are used as indices of pollution of water bodies and watercourses. From this point of view he studied energy flows and how they act as a basis of the bioindices. When energy flow from the outside is great, many systems are characterized by a low level of species diversity and a high level of development of special adaptive mechanisms used by every species. The wider is the range of available animal resources, the greater is species diversity in animal communities. Species number is related to the width of niches of separate species and the degree of niche overlapping. Predators have also an important role in maintaining species diversity. Therefore availability of resources, competition and predation to a large extent determine the structure of animal communities. When composition of animal communities is assessed simply by the number of species, such important parameter as quantitative relations between them is ignored. Information on the rarity of some species and common occurance of others are lost.

For the quantitative assessement of animal community structure different different kind of diversity indices are used e.g. Shannon index, which summarizes the maximal amount of information on the abundance and composition of organisms, takes into account the number of species and the degree of their predominance. According to the interpretation of the Shannon entropy index in terms of information the diversity is the amount of information per one individual contained in the energy dispersed in species or individuals through trophic relations. Shannon diversity index is borrowed from the information theory and represents formalization widely used for the assessement of complexity of any types of systems. It is therefore most suitable for comparison in the situation when no importance is attached to separate components of diversity. This index reflects the important essence of animal communities. Shannon index is nearly unrelated to sample size and is characterized by normal distribution, since total abundance of all species is always an integral number.

A close relationship between biodiversity index and the ratio of predatory and nonpredatory animals in benthic communities has been shown. The role of the predators in animal communities was assessed according to the ratio of energy assimilated by them (Ac) and ratio of nonpredatory animals (Cn). This ratio shows what portion of energy recorded at the entrance of the system (Cn) is used within it (Ac).

Diversity of communities remains high as long as the value of the ratio Ac/Cn is not lower than 2-3%. An abrupt decline of diversity index when values of this ratio are low, is the most frequently related to water pollution. Elimination of predation pressure brings about instability of the vast majority of communities, there occurring great changes in their species composition.

Pollution causes structural rearrangements, particularly in predominance of eurybiont species. Diversity of communities begins to decline when the ratio of steno- and eurybiont species appears to be less than 60%. The close relationship of diversity index and the ratio of species typical of oligotrophic and eutrophic lakes was shown e.g. zooplakton communities.

Diversity of animal communities is inversely related to their average biomass. There is a distinct relationship between biomass and production of aquatic animal communities. Diversity and productivity of animal communities are also closely connected. Communities with a complex structure are characterized by low production efficiency. Animal populations with low values of P/B coefficients and specific production dominate these communities and vice versa. Therefore diversity indices may reflect emergent properties of animal communities particularly food web structure, biomass and productivty.

Diversity of communities declines with the increase of water bichromate oxidizability, which in many cases is the index of pollution or eutrophication. Diversity of benthic animal communities declines with pollution flow into water bodies, with an increase of the amount of organic matter suspended and dissolved in water, of the amount of sulphates in bottom deposits, size of ground particles, temperature, portion of clay in bottom deposits, change of current and ground in lakes as well as other abiotic factors.

As the structure of communities become simpler the range of seasonal fluctiations of their functional characteristics increase. The range is characterized by the ratio of minimal and maximal biomasses in animal communities per year, which may characterize steadiness of communities under particular conditions. Steadiness declines with increase of productivity, degree of eutrophication or pollution of water bodies. The most specialized species of animals form the communities of the greatest steadiness. Communities with higher diversity show higher stability. The most durable are communities with low stability, i.e. those having large seasonal changes of biomass e.g. eurybiont species with wide ecological spectra, which have developed adaptation to seasonal fluctuations of environment.

## Plenum Summary and the Recommendations of the Seminar

All the participants agreed on the importance of this Seminar especially as a channel in creating international biological "language", which in this case means bioindex system for the coastal polluted areas of the Gulf of Finland. This indicator project was launched in 1996, and this meeting was the very first one. Now the ideas were presented and the development process is started. The following conclusions and the future plans were made during the Seminar:

## A. Present situation:

There are vital biomonitoring programs going on around most of the big cities of the Gulf of Finland. In the TABLE 1 main parameters and properties of the programs are presented.

| | Helsinki A | Helsinki B | St.Petersburg | Tallinn |
|---|---|---|---|---|
| | | | | |
| Monitoring area (sq.km) | 110 | 110 | 1400 | |
| Starting year | 1974 | 1962 | 1982 | 1992 |
| Prevailing salinity range (‰) | 2-6 | 0-6 | 0-6 | 2-6 |
| Organism groups | Macroalgae, phanerogams | Zoobenthos; macrofauna | Chironomidae, Oligochaeta, zoobenthos | Macroalgae, phanerogams |
| No of sampling sites | 220 | 66 | 45 | 40 |
| Present sampling interval | 5 yrs | 5 yrs | 1-2 | 1-2 |
| Classification method | Ecol.groups, abundance, biotic index | Biomass, ecol.groups | Abundance, biomass, species composition, ecol. groups, Integrated Index (Balushkina 1995) | Ecol.groups, saprobic system |
| | | | | |

TABLE 1. Examples of littoral bioindicator programs in urban sea areas of the Gulf of Finland.

Fruitful cooperation between Helsinki and Tallinn has been practiced since 1992. Macrophyte communities have been surveyed on both sea areas with identical sampling and laboratory methods. It has been observed that macrophytes suit well for monitoring purposes (Kukk, Viitasalo and Martin 1995). So far experience is collected from species and communities which need and/or tolerate brackish water. Freshwater communities need further consideration because they mainly receive nutrients both from the sediment and surrounding water. An attempt is underway to analyze heavy metal content of brackish water macrophytes, too.

In St.Petersburg it has been proved that information from different ecological (zoobenthos) groups can be combined into an integrated biotic index. This encourages to employ this method to other areas. Because of the strong spatial and temporal differences of the environmental variables (hydrography, pollution types, salinity, exposition, ice cover etc), additional comparative research is needed between the different polluted areas of the Gulf of Finland.

B. Overall topics:

It is essential to create a "common language" and make an exact definition of terms

Continue intensive research work on a local level

Parameters should be selected carefully e.g. among these presented ones:

Relationship between production and respiration and Shannon Index H'
Relationship between Biomass Min/Biomass Max and H'
Relationship between BOD tot/BOD soluble and H'
Carbon flow versus energy flow
Community indices
Integrated indices
Chemical parameters in biota: Heavy metals, tot-P, tot-N and their relationships

Sessile organism groups, e.g. zoobenthos and phytobenthos were recommended. On the other hand new biotic integrated indices may allow combination of phytoplakton, zooplankton and possibly some chemical parameters

In spite of their importance, fish indicators were not considered in this seminar

Methods should be simple and based on the existing theories. Special character of polluted and semi-polluted water bodies must be taken into consideration.

Results must be presented either as time series or zonation maps.

Filing and reconstruction of historical primary data was considered important. At the same time it was considered that it is time-consuming and contains many sources to errors or misintepretations (methods and units have changed, pollution data is scanty or lacking etc).

It was recognized that the rebirth of the biodiversity concept has revealed gaps in the taxonomy of certain organism groups as well as regrettable shortage in the taxonomical skills of the scientists. International taxonomy courses to younger scientists were recommended.

Old practice of international exchange of sample specimens between expert groups or scientists was encouraged.

C. Recommendations to future work (bioindication, in the vicinity of municipalities):

1. This work should concentrate upon **polluted or semi-polluted coastal areas**. Comparative studies between different areas should continue.

2. **One water area** shoul be selected to a **common pilot field**.

3. In 1997 a **planning workshop** is arranged in order to organize the field study and to introduce the different research teams to the selected area.

4. In 1998, **joint field and laboratory work** is conducted in the selected area with a **concluding seminar** in late autumn 1998.

5. It was considered that an ample pilot area could be the **Wyborg Bay**.

APPENDIX 1

**Telesh, Irena V.**
Russian Academy of Sciences, Zoological Institute:

## WATER QUALITY CLASSIFICATION BASED ON PLANKTON COMMUNITIES

DRAFT

GOF SEMINAR:

## DEVELOPMENT OF THE SPACE-INDEPENDENT BIOINDICATION SYSTEM FOR EVALUATION OF EUTROPHICATION IN COASTAL AREAS OF THE GULF OF FINLAND

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# WATER QUALITY CLASSIFICATION BASED ON PLANKTON COMMUNITIES

**by Irena V. TELESH and Vera N. NIKULINA**

The increasing anthropogenic loading inevitably causes alterations in aquatic ecosystems, resulting in water pollution and often in decrease of natural biological diversity. Along with routine monitoring of polluted zones, professional ecological expertise based on knowledge of general principles of the ecosystem's functioning is of exeptional importance for the control of water quality and protection of biodiversity in stressed ecosystems. Therefore, it is an urgent need of the development of a system of generalized indices which would allow to characterize numerically changes in structure of aquatic flora and fauna in the Gulf of Finland, caused by anthropogenic impact.

Water quality can be assessed by a variety of methods, among which there are hydrophysical, hydrochemical, and biological methods. For the adequate assessment of water quality, a combination of methods should be used, and this would allow to get the statistically reliable results even at the stage of preliminary tests.

In plankton, we can deal with the composition and numerical data on bacteria, algae and animals, keeping in mind that all these three groups of living organisms can characterize different aspects of water pollution.

Thus, increase of the bacterial density witnesses for the organic pollution. The reaction is very fast due to the extremely high growth rates of bacteria. The increase in the biomass of planktonic algae, concentration of Chl "a", growth of primary production and increase of the share of blue-greens in the total phytoplankton biomass - these are the after-effects of the nutrients (mainly phosphorus) loading, which leads to anthropogenic eutrophication. Zooplankton can react on the pollutants by the alterations in species composition, abundance and even by morphological abnormalities. Recently the methods for assessment of eutrophication in lakes basing on the zooplankton data were reviewed by Andronikova (1996).

This report presents the results of our attempts to use data on plankton communities for water quality evaluation in the Neva Bay of the Gulf of Finland which can also be called the upper part of the Neva Estuary.

This fresh water body has the surface area about 400 km2, mean depth 3.5-4.0 m, and mean water residence time 5-6 days (Shiklomanov et al., 1989). High water turbidity and extremely

variable flow regimes are typical for Neva Bay. The city of St. Petersburg and its suburbs are located arround the Neva Bay which suffers greatly from the anthropogenic pressure.
At the Laboratory of Freshwater and Experimental Hydrobiology (Zoological Institute RAS, St.Petersburg), the ecosystem studies of the Neva Estuary have been in progress since early 80-ies till nowadays (see: "Neva Bay: Hydrobiological Investigations", G.G.Winberg and B.L.Gutelmakher (eds), Leningrad 1987; "Communities of freshwater invertebrates...", A.F.Alimov (ed.), Leningrad 1988; and series of other publications). The acquired knowledge of the communities structure, ecological physiology and population dynamics of organisms in the Neva Estuary, as well as progress in elaboration the basic points of the theory of ecosystem functioning (Alimov, 1990) form the background for evaluation of the role of biota in this area, and for the development of methods for bioindication.

## PHYTOPLANKTON

Actually there are very few parameters of planktonic communities that could play the indicative role for the water quality evaluation, *sensu stricta*. However, we can speculate on the ecological state of the water body having the information about species composition, abundance and distribution of planktonic algae.

### Species composition of phytoplankton

Species composition of phytoplankton in the central and northern areas of the Neva Bay is defined by the Lake Ladoga and Neva River, while in the southern areas phytoplankton has different structure (Nikulina, 1987).
Distribution of the dominant phytoplankton species can characterize well the changes in hydrological regime.
For example, the present-day distribution of the algal species indicating the Lake Ladoga water on one hand (*Aulacosira islandica*) and the water of the eastern Gulf of Finland on the other hand (*Sceletonema subsalsum*) - affords to conclude that in the areas located in the Neva Bay close to the storm-surge barrier, the water flow rate is very low, and phytoplankton is accumulated there. Also, species composition of algae witnesses that nowadays brackish waters from the Gulf of Finland can hardly penetrate into the Neva Bay, only via the Sea Shipping Channel (Nikulina, 1996).

### Numbers, biomass and primary production of phytoplankton

In 1982-1984, phytoplankton density and biomass in the Neva Bay were rather low, especially in the southern areas of the bay, mainly due to low water transparency and short water residence time which are two principle factors limiting the phytoplankton growth (Nikulina, 1988). However, the potential productivity of this area was significant because of the development of euglenoides, chlorococcales and filamentous green algae. Thus, inspite of low biomasses, species composition and seasonal dynamics of phytoplankton in the southern Neva Bay were typical of eutrophic conditions.
In the 90-ies, changes in structure of algal assemblages in the Neva Bay were observed, the role of cryptophytes increased from 0.1 to 10% of total phytoplankton biomass (Alimov et al., 1993). Biomass of phytoplankton in the western Neva Bay during the 90-ies was significantly higher than during the previous decade (Fig. 1).

The type of correlation between phytoplankton biomass and water transparency differes in three main parts of the Neva Bay: northern, central and southern areas (Nikulina, 1987). However, primary productivity is correlated directly with water transparency, and this correlation can be used for the prognostic purposes (Gutelmakher et al., 1987)). This is really important because water transparency in the Neva Bay in the 80-ies was low due to dredging activities; nowadays these activities are less intensive.
The rate of production to decomposition of organic matter can reflect eutrophication numerically. During the 80-ies, in the Neva Bay decomposition of organic matter usually exceded primary production, the rate being higher in the southern areas of the bay (Gutelmakher et al., 1987).

**Blue-green blooms**

The relative importance of blue-greens in the total phytoplankton biomass can say much about the water quality (Fig. 2). In the Neva Estuary, the share of blue-greens is usually not high, while in the eastern Gulf of Finland blue-green blooms are very intensive: up till grades 4 and 5 (Tab. 1, Fig. 2).
Thus, the long-term study of phytoplankton in the Neva Estuary and eastern Gulf of Finland showed that:
1) primary productivity is generally correlated with water transparency, therefore the rate of primary productivity can increase to the same extent as the increase in water transparency (Winberg & Gutelmakher, 1987);
2) the increase of the production to decomposition rate witnesses for the progressing eutrophication and can reflect it numerically;
3) evaluation of the ecological situation in the Neva Estuary using the data on phytoplankton can be reliable enough if based on the mid-summer species composition, density and biomass ( which are close to the mid-August data);
4) the best criterion for evaluation of water quality on the basis of phytoplankton is the assessment of the intensity of the blue-green blooms.

## ZOOPLANKTON

**Species composition of zooplankton**

Originally, zooplankton communities in the central part of the Neva Bay are formed by the zooplankton which is brought from the Petrokrepost Bay of Lake Ladoga by the Neva River. The limnetic zooplankton is transformed in the river due to rather high water flow rate and high inorganic turbidity in the up-stream part of the Neva River (Telesh, 1986; Telesh et al., 1987). As a result, in the central area of the Neva Bay rotifers constitute about 50% of the total zooplankton biomass, Infusoria - 28%, Cladocera -20%, Copepoda - 3% (Telesh, 1987). Zooplankton density in the Estuary usually in mid-summer demonstrates 20% increase from east to west.
For water quality evaluation it is extremely useful to control the total species composition of all groups of zooplankters in the water body. However, in practice, it is very difficult because this type of monitoring needs hard work of a skilled taxonomist who knows all the main groups: Infusoria, Rotifera, Cladocera, Copepoda.

In total, about 200 zooplankton species are known from the Neva Estuary nowadays. However, there are only arround 10 - 15 dominant species which form the basis for the total zooplankton biomass and production. These are the most important forms, and their dynamics should be obligatory monitored for the purpose of water quality evaluation.
Nevertheless, it is still essencial to monitor total species composition and diversity, as aquatic organisms are highly susceptible to anthropogenic pressure. Thus disappearance of common species, or mass development of alien species is a good criterion for alteration of the communities.
For example, from the literature data we know that in early 20-th century marine species were rather common and numerous along the south-western and southern shores of the bay (Visloukh, 1913). In 1982, populations of two marine harpacticoid copepods *Ectinosoma melaniceps* and *Dactilopodia vulgaris* were observed in the macrophyte-laden southern zone of the Neva Bay (Telesh, 1987). However, after 1982 nobody ever found any marine copepod species in the Neva Estuary. This can be the clear witness of the fact that marine waters do not any more penetrate into the southern shallow areas of the Neva Estuary.
Another example: a predatory cladoceran *Cercopagis pengoi* (originally from the Kaspian Sea) recently appeared in the Baltic Sea (Ojaveer & Lumberg, 1995), and in 1995 it was first found in the eastern Gulf of Finland (Avinski, pers. com.). Seasonal dynamics, population growth rates and living habits of this alien species in the Gulf of Finland are to be studied very intensively, for we must know the potential effects of this invasion on the natural biodiversity, ecosystem state and water quality in the Gulf. Actually, this work is in progress in our laboratory now.

### Species-indicators

Using species-indicators, mainly Infusoria and Rotifera, the saprobic degree of water can be evaluated. Many zooplankton species are indicators of different types of water, and their mass development in the studied areas can be used as a criterion for the evaluation of water quality. However, this criterion can not be considered as the only absolute.
For example, rotifers from the genera *Brachionus* are indicators of beta-alfa-mesosaprobic conditions (polluted waters). Normally they do not live in the Petrokrepost Bay of Lake Ladoga where there is the source of Neva River. Consiquently, they do not normally live in the central area of the Neva Estuary. Thus, if you observe mass development of Brachionids in the central basin of the Neva Estuary, this will most probably indicate the water pollution.
But in the near-shore macrophyte associations these rotifers can occur very often because they penetrate there from the small waterbodies (ponds and rivers) located on the banks of the Neva Bay. In this case, it is very important to consider the whole species composition of rotifers to be able to say, what is the relative importance of Brachionids. In the Neva Bay we often met places where these Brachionid rotifers were living in the same community with species indicating clean waters.

### Species diversity of zooplankton

Species diversity within aquatic communities is closely related with the trophic state of the water. Earlier Gilyarov (1969) and Alimov (1990) have demonstrated an inverse relationship between the values of the Shannon-Weaver index of species diversity (H') and biomass of

different groups of planktonic and benthic invertebrates in lakes. Data from the Lake Ladoga littoral zone is in general conformity with these observations (Telesh, 1996).
In the Neva Estuary, we analyzed inter-annual dynamics of the Shannon index of species diversity for zooplankton (Table 2). The results show that in the area of the stations 42,43,17,14,6,18 species diversity of zooplankton during the last decade demonstrated a 32% decrease, while in the main part of the central area of the Bay biodiversity of zooplankton community has not been changed (Ivanova & Telesh, 1996).
These results lead to the conclusion that the spatial and long-term dynamics of the Shannon index of species diversity for zooplankton can be used for monitoring the ecological state of the water body.

**Control of "mortality"**

Zooplankters are usually very sensitive to toxic pollution. Therefore during our studies on the Neva River and Neva Estuary we used a technique of vital staining of the zooplankton samples with "aniline blue" for selecting live, damaged and dead animals (Seepersad & Crippen, 1978; Telesh, 1987).
The method allowed to determine that there was a relatively high numbers of dead and damaged zooplankters in the upper Neva River and in the river within the St.Petersburg (up to 50%). In the Neva Bay, average percent of dead organisms was not high (12.4%); highest values were typical for nauplii and rotifers (18-34%). In the turbid stagnant waters of the bay mortality was low, not exceding 7.4%. This means that turbidity itself does not damage planktonic organisms, and that the community in these turbid waters is specific but rather stable. While high degree of mortality in the upper Neva river was most probably due to turbidity combined with high water flow rates. During our studies of diurnal variation in microzooplankton density at two sampling sites in the Neva estuary in June 1992, with sampling interval 2 hours, the method of vital control of the physiological state of the organisms (direct observations) allowed to reveal the case of mass, extraordinary mortality of infusoria in the Bay during night time (data of T.V.Khlebovich). The most probable reason for this case could be the toxic pollution from the local source.

**Numbers and biomass of zooplankton**

Numerical data on zooplankton is known to be highly variable, both in space and time. For example, spatial variation of rotifers density in the Neva Bay was extremely high due to variety of biotopes, each having peculiar structure of the zooplankton community, and it can even exceeded the seasonal variation in rotifer density (Telesh, 1995). However, long-term data on zooplankton can reflect the averaged situation in the water body. For instance, the zooplankton biomass in the Neva Bay averaged for May-September was surprisingly similar in 1982, 1983 and 1984: 1.00-1.06 mg/l, while the range was 0.01-10.00 mg/l (Telesh, 1987).
We can draw at least two conclusions from these results:
1) the zooplankton community in the central area of the Neva Bay has a certain degree of stability; and therefore 2) zooplankton biomass in the Neva Bay averaged for the summer season (May-September), can be used as a criterion for monitoring the ecosystem state of the estuary.

Total values of zooplankton density and biomass depend on the zooplankton community structure. The relative signifacance of Rotifera, Cladocera and Copepoda in the community has an indicative role and is very important for monitoring purposes.
For example, it is well known that in the process of eutrophication the share of rotifers in the total zooplankton biomass increases, and small cladocerans become more abundant, if compared with copepods (Andronikova 1996).
In the Neva Estuary, if we compare share of each of these main groups of zooplankters in June 1984 and 1991, we can see that share of rotifers in total biomass decreased (88% => 78%), and share of copepods increased (5% => 17%) (Alimov et al., 1993). Of course, we can not deny that the eutrophication is in progress in the Neva Bay. However, this result warns that each parameter which we choose for monitoring purposes, should be critically appreciated and considered in concordance with other parameters. In our case, these changes in the zooplankton community structure most probably can be explained by the fact that after the flood barrier construction, the modification of hydrological regime favoured the development of crustacens in the central areas of the bay. Also, as zooplankton community in the Neva Estuary is determined by and originates in Lake Ladoga, the peculiarities od the zooplankton development in the lake could influence the situation in the Neva Bay greatly.

**Morphological abnormalities**

As the effect of toxic pollution, morphological abnormalities can appear in zooplankters, mainly crustaceans. This fact was firstly registered in the Neva Bay in 1986 and described by Silina & Hudoley (1993), though the authors did not publish photographs or schematic drawings of these animals. However, when properly documented and illustrated, these morphological abnormalities can serve as a witness of toxic pollution.

## CONCLUSIONS

1) Planktonic organisms (bacteria, phytoplankton, zooplankton) react to different types of water pollution; this reaction is fast because of relatively short life and high reproduction rates of these organisms. Therefore, plankton can characterize mainly the short-term effects of pollution.
2) Permanent anthropogenic pressure results in the environmental changes which can be well documented by the long-term data on plankton communities.
3) Parameters of plankton communities, recommended for the water quality evaluation in the eastern Gulf of Finland and Neva Bay:

A. Phytoplankton
- -- species composition
- -- species-indicators
- -- mid-summer density and biomass
- -- production/decomposition rate
- -- primary production
- -- percentage of blue-greens

B. Zooplankton
- -- species composition
- -- species-indicators among dominants
- -- community structure

-- species diversity
-- mean summer density and biomass
-- morphological abnormalities
-- control of the physiological state of organisms and "artificial mortality"

4) For the adequate evaluation of water quality and the ecosystem changes, a reasonable combination of parameters and methods, including hydrochemical, should be used.

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Table 1.Intensity of blue-green blooms (modified from: Zhukinski et al., 1976)

| Degree of intensity | Visual characte-ristics | Biomass of algae (g/m3) | Water quality |
|---|---|---|---|
| 1 (initial) | few colonies in the water column | < 1 | normal, ecologically not dangerous |
| 2 (low) | numerous colonies, film of algae appears on the water surface | 1 - 4 | not dangerous, but water quality decreases |
| 3 (moderate) | formation of a layer of floating algae | 5 - 10 | considerable decrease of water quality, undesirable for maintainance of normal productivity |
| 4 (high) | formation of "bloom areas", blue-greens are wind-concentrated | 11 - 50 | ecologically dangerous concentr., cause secondary (biological) pollution and oxigen deficiency |
| 5 (very high) | the layer of blue-greens reaches 5-10 cm | > 50 | toxic concentration |

Table 2. Shannon index of the zooplankton species diversity in Neva Bay, data for June-July 1983, 1984, 1991, 1993 (from: Ivanova & Telesh, 1996). Asterisks mark "polluted" stations.

| Stations | 1983 | 1984 | 1991 | 1993 |
|---|---|---|---|---|
| 7 | 2.66 | 2.81 | 2.92 | 2.79 |
| 12 | 2.63 | 2.23 | 2.59 | 2.44 |
| 42* | 3.16 | – | – | 2.40 |
| 43* | 2.86 | 2.66 | 3.21 | 2.46 |
| 17* | 3.12 | 2.51 | 3.15 | 1.49 |
| 14* | 3.59 | 2.62 | – | 2.26 |
| 13 | 2.90 | 2.68 | 2.93 | 2.80 |
| 9 | 2.84 | 2.91 | 2.81 | – |
| 11 | 2.57 | 3.02 | – | – |
| 6* | 3.23 | 2.99 | 2.85 | – |
| 18* | 3.04 | 2.76 | 1.82 | – |
| River | 2.45 | 2.73 | – | – |
| Average for "polluted" stations | 3.17 | 2.71 | 2.76 | 2.15 |
| "clean" stations | 2,67 | 2.73 | 2.81 | 2.68 |
| Neva Bay | 2.92 | 2.72 | 2.78 | 2.38 |

Fig. 1. Seasonal dynamics of the phytoplankton biomass (mg ww/l) in the western Neva Bay

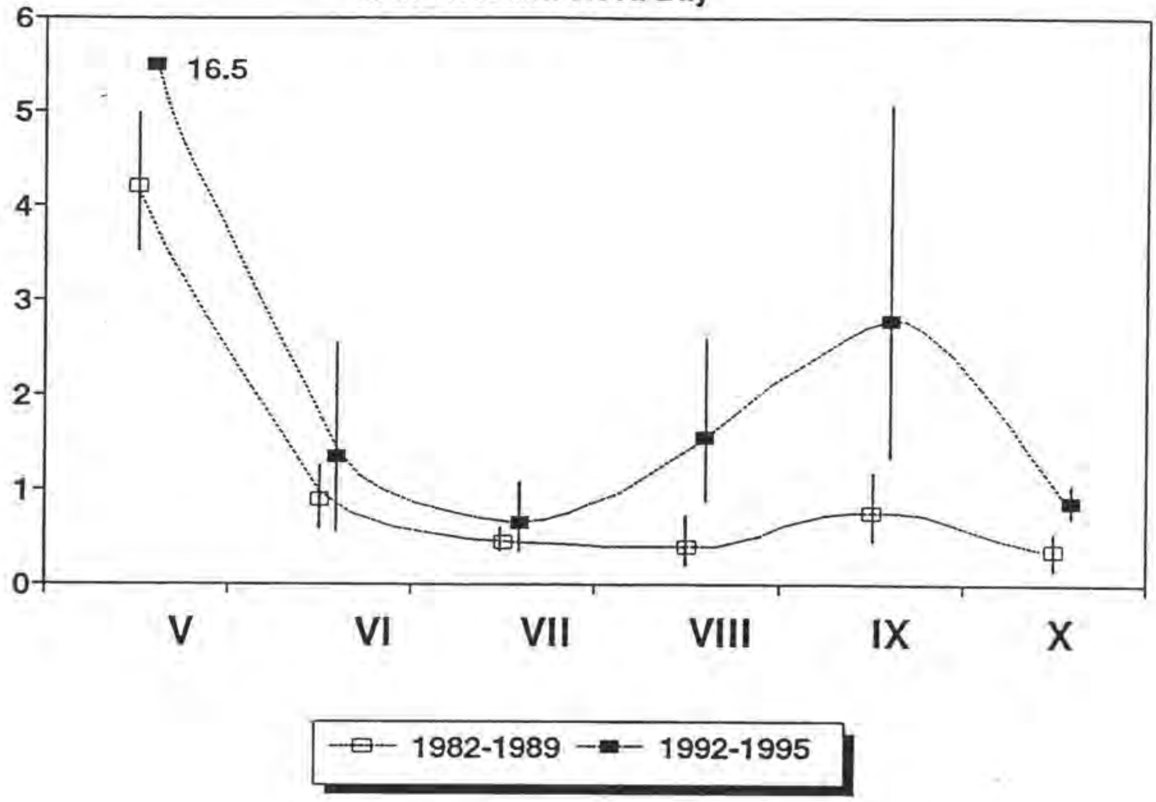
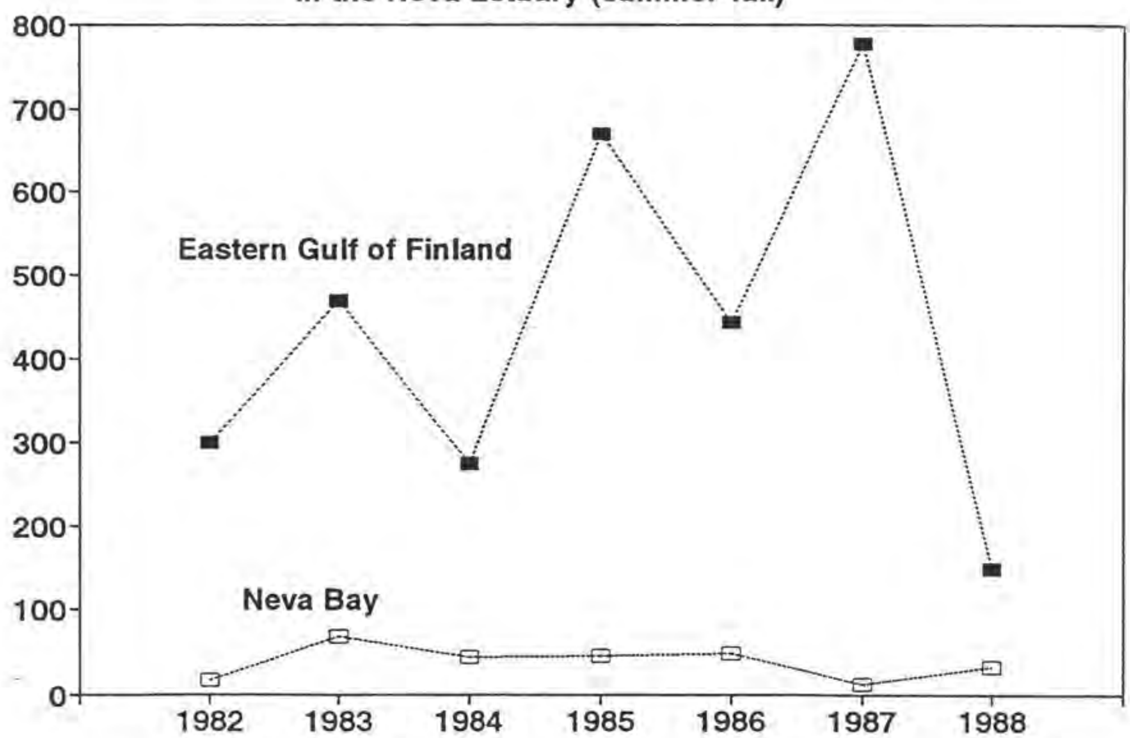



Fig. 2. Mean biomass of the blue-greens (mg ww/m$^3$) in the Neva Estuary (summer-fall)



APPENDIX 2

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## WATER QUALITY CLASSIFICATION IN FINLAND

Tvärminne 26.11.1996

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# WATER QUALITY CLASSIFICATION IN FINLAND

## Introduction

The Finnish Environmental Institute FEI (former Water and Environmental Admistration) has here in Finland rather wide experiences in applying the classificating water quality. The advantages and limitations of using water quality classifications in practice will be discussed based on these experiences.

In 1988, guidelines to classify water quality in inland and coastal waters were published by the Finnish Water and the Enviromental Admistration. The classification system was based originally on a system used in Sweden. Modifications to meet the special characteristics, especially the high humus contents of the Finnish lakes, rivers and coastal waters were made. Water quality requirements on e.g bathing waters set by the Finnish health authorities were taken into consideration. The chosen approach in the classification system is an utilization-based rather than based on an ecological approach. Thus, the criteria were generated from the needs of or demands set to three kinds of uses of the watercourses: for recreational purposes, for raw water supply and as fishing waters. The overall presentation of the suitability of waters, the general water quality classification should be made as a synthesis of the three above mentioned utilization-based classifications. The guidelines give a mathematical model how to calculate general water quality class from the utilization-based classes. To facilitate the dealing of great amounts of data, the general water quality classification has even its own criteria. The general water quality classification has been used rather widely e.g by national or local authorities, by research laboratories etc. The fishing water, raw water or recreational water quality classifications have been used in some special local cases only.

## The structure of the classification system

In the general water quality classification, waters are classified in five categories. They are called excellent, good, satisfactory, fair and bad. In the classifications for recreational purposes and for fishing waters, six classes are used: excellent, good, satisfactory, poor, bad and unsuitable. Raw water classification is more strict consisting of five classes.

In the classification system, very essential items are the numerical criteria for the water quality. However, all characteristics or important parameters for the use of waters are not able to be expressed numerically. Therefore the Finnish water quality classification system also gives a verbal description of the quality classes. In this description the non-measurable variables are used to clarify the typical features of the waters belonging to different usability classes. Examples of the non-measurable variables are e.g. sliming of the fishing nets, algal blooms, presence of abundant macrophytes, the structure of fish population, off-flavour problems in fish, occurence of harmful substances in sediments or biota and risks for the human health. In the raw water classification, the necessary treatment methods in every class are described.

The numerical criteria have been given to variables, which can be measured with standardized or commonly accepted analysis methods and which are relevant for the modes of water uses. When the numerical criteria were designed, all administrative requirements concerning e.g the bathing waters, the raw water or the threshold values of harmful substances in biota were taken into consideration as well as all relevant scientific reseach about e.g the trophic status of the Finnish waters and the distribution of humus contents in Finnish inland waters. Numerical criteria have been given to the following variables:

turbidity
transparency (Secchi disc readings)
suspended solids
colour
total phosphorus concentration
chlorophyll-a concentration
oxygen concentration (saturation %)
oxygen consumption ($COD_{Mn}$)
fecal bacteria
pH and alkalinity (in fishing water classification only)
mercury concentration in fish
heavy metals, mercury and cyanide concentrations in water
Fe, Mn, chloride, sulphate, phenol-, oil-, $NO_3$-, $NO_2$- and $NH_4$-concentrations and conductivity in water (in raw water classification only)

Even lignosulphate concenration is included in the criteria to describe the effects of waste waters from sulphite mills, but this variable is no more relevant because no such mills are nowadays in operation in Finland.

Some of the chosen variables illustrate the natural charasteristics of water (e.g colour, transparency), some indicate the changes caused by waste waters or other human activity ( e.g fecal bacteria).

In most cases average or median values of the variables are used. Depending on the variable, annual average or median values or for the values of critical periods, eg. winter stagnation period, may be calculated as well.

The numerical values of the criteria in the general water quality classification are presented in the annex.

In order to illustrate the results of the classification, recommedations have been given to use coloured maps. The colours have been defined precisely:

| | |
|---|---|
| excellent: | dark blue |
| good: | light blue |
| satisfactory: | green |
| fair: | yellow |
| bad: | red |

It is important to harmonize the ways how the water quality classification maps are published. Therefore, even techical colour codes to be used by the printing houses have been given.

Besides colours describing the different kinds of quality classes, symbols to indicate special problems can be used in the maps, too. E.g. dams in rivers, artificial lakes or severe water level regulation can be shown on the maps as an additional information concerning the state of the classified waters. Acidification should also be indicated with some relevant symbol.

## Data used in water quality classifications

The Finnish Environmental Institute maintains the national monitoring networks for the inland and the coastal waters. The regional Environmental Agencies are responsible for the water sampling and the laboratory analyses. The main networks are as follows:
- water quality in 71 lake deeps
- water quality in 68 rivers
- material input to the Baltic sea at the stations of 30 rivers
- acidification of surface waters, 180 sampling stations in headwaters
- water quality in coastal waters, 12 intensive stations and 94 areal stations

Regional environment centres have their own monitoring networks. The regional monitoring programmes may follow the national programme, but they may also be more like surveys. The number observation stations in these networks exceeds that in the national network.

In addition to the national and regional monitoring networks, the polluted waters in Finland are monitored at the expence of the polluters. This system is called the statutory (or local pollution control) monitoring of waters. It is based on the Water Legislation. There are about 4000 water quality monitoring stations which belong to the statutory monitoring system.

In the national and in the statutory monitoring, both chemical and biological analyses are included.

All the water quality data are deposited in the water quality data bank of the Finnish Environmental Institute. Correspondingly, the plankton data are deposited in the plankton data bank. Theremore, the announcements made about troublesome algal blooms have a data bank of their own. Data banks for bottom fauna and for periphyton data are being planned.

The above mentioned monitoring networks and data banks give a good basis for mapping the quality and suitability of inland and coastal waters. The water quality classification is one of the main ways to make use of the great amouns of data collected every year.

## Experiences gained in classificating inland and coastal waters

Water quality classification in 1985

In Finland, mappings of the water quality classification covering the whole country have been made since 1970's. In the 1970's, the criteria used were a little different from those published in 1987. The early classifications cannot therefore be compared with the latest ones. The guidelines published in 1987 were applied when the situation in Finnish inland and coastal waters in the middle of the 1980's was mapped. Finland is divided into 13 regional environmental agencies. Each of these took care of classifying its own water areas. The map of the water quality in whole Finland was made then in the Finnish Environmental Institute. Negotiations between regional experts and the experts in the Finnish Environmenta Institute were needed to intercalibrate and adjust the results of the classification work. It was found out that great differences between the intepretation of guidelines were possible. Because e.g. common interpretations to the first symptoms of eutrofication were lacking, the lakes showing temporal algal blooms were classified as excellent, good or satisfactory depending on the regional opinion. Another example showing the subjectivity of the classification system was the difficulty to classify rivers where fecal bacteria counts fluctuated strongly. Finally an agreement was reached, and the map was completed.

The map showing the usability of Finnish inland and coastal waters in the middle of the 1980's has been very popular and widely used by decisions makers, authorities, teachers etc. On the other hand, some criticism was also given, because the perceptions of fishermen, swimmers etc. could be very different from the picture given by the classification. Most of criticism was connected with classification of coastal waters. For instance, many questions were addressed to authorities how the open sea areas and coastal waters could be of excellent water quality as massive algal blooms were found by those who sail these high seas.

Water quality classification in the beginning of the1990's

In 1993, the Finnish Environmental Institute started working with mapping the water quality in the beginning of the 1990's. To avoid the difficulties met in the former classification work, it was decided to do the practical work centralized in the FEI. It was hoped that subjectivity could be minimized when a limited group of experts were involved instead of some 13-30 experts working separately in the 13 regional officies. One reason to this solution was the fact, that automatic data management had now become a common tool. In the FEI, a special computer aided program was developed to calculate the classification criteria. It had become possible to deal with great amounts of data rather quickly. Another important decision was made right in the beginning: the coastal waters were not be classified. It was admitted, that the numerical criteria are suitable for inland waters only. Classifying open sea or coastal waters would have required experts familiar with the local aspects and this would have been very time-consuming.

At first, the water quality data bank was used to choose the observation stations to be included in the classification work. Only those which had been monitored at least three times during the years 1990-1993, were included. Lakes smaller than 1 $km^2$ were abandoned, as well as rivers with mean flow smaller than 2 $m^3/s$. About 3800 observation stations met these presumptions. The classification variables were then calculated with the ADM-based program. A group of experts in FEI ( 2-6 persons) made the decision about the quality class. Finally, proposal to the water quality classification was sent to the regional environmental agencies for a check-up, and amendments were made if needed.

In practice, the work was not as easy as hoped in the beginning. It took over two years to get the classification map finished. There were some technical difficulties concerning the use of the water quality data bank and the computer aided program. The production of coloured maps with the help of new GIS (geographical information system) technology did not work before much preliminary work was done. Now these technical difficulties have been mostly overcome, and next efforts to map the water quality may be more successful. A brochure will be made in order to widely distribute the information of the new water quality classification. The information will be channelled to the public via the Internet, too.

In the classification system, there still remains the problem of subjectivity. This becomes very striking especially when data is scarce or when other aspects than chemical quality play an important role in the state and usability of waters. You may have for instance only three measurements of the water quality, and they may differ greatly from each other. To use the average value is not always the right solution - the expert must assess every set of observations separately. You may have adequate water quality data indicating e.g. good water quality, but at the same time, there may be many announcements about algal blooms. How to classify? Another example: the chemical water quality may be good or even excellent, but it is known that, for instance, the sediments are very polluted. Yet, the distribution of the polluted sediments and the significance of this pollution to using the waters is not known. The criteria give no exact limit values for harmful substances in sediments, only a verbal description: " levels are clearly increased above the natural background level" How to classify the water area? Experiences gained in the classification work show, that different expert may have very different kind of opinions in these questions.

**Water quality classification to coastal waters and open sea waters?**

In a mail survey fishermen were asked to report their subjective notions and observations concerning the quality of water in their fishing sites. The recreational fishermen had a strikingly different view of the suitability of coastal waters compared with the general water quality classification of the 1980's (Lappalainen & Hilden 1993). This study was one indication of the failure of the classification system to be applied for coastal waters.

The water quality criteria were originally developed for the inland waters. The limit values for total phosphorus and a-clorophyll have proved to be too high for the coastal waters. Some criteria, for instance colour are not be able to be used at all because they are relevant only for the inland waters. The changes in water quality may be very rapid in the coastal waters and the concept of the average water quality cannot be used. When coastal waters have in some local cases been classified, this classification reflects the opinion of experts about the degree of pollution and is based mostly on the verbal description rather than on the numerical limit values.

If there is a need to classify coastal waters, the criteria should be designed specially for these waters. Aspects to be taken into consideration are for instance: eutrophication, oxygen condition in deep waters, the degree of pollutation in sediments, the influence or river waters to eg. the turbidity of the coastal waters. The dynamics of the coastal waters may make it very difficult to find any nationally or internationally applicable way to classify these waters. Maybe one solution would be to concentrate in the efforts to create a classification to illustrate only the degree of pollution in near-shore waters.

**Water quality classification: advantages and limitations**

In summary, the water quality classification is a rough generalization of the state and usability of water areas. Some of its major limitations are subjectivity and hiding of detailed information gained through numerous observations. On the other hand, it is an effective way to integrate huge amounts of data into an easily understood presentation. The water quality classification gives possibilities to compare eg. in a nation-wide scale water areas with each other. It may even be used to follow the effects of water pollution control measures in watercourses. The FEI has serious plans to develop the water quality criteria and the whole classification system including the new tools which the computer aided systems provide.

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ANNEX

## WATER QUALITY CLASSIFICATION

## THRESHOLD VALUES OF THE GENERAL WATER QUALITY CLASSES

| | |
|---|---|
| **CLASS I<br>EXCELLENT** | * COLOUR < 50 MG Pt/l<br>* TRANSPARENCY > 2,5 m Secchi disc<br>* TURBIDITY < 1,5 FTU<br>* FECAL BACTERIA < 10 cfu/ 100 ml<br>* MEAN a-CLOROPHYLL IN THE GROWING SEASON < 3 µg/l<br>* TOTAL PHOSHORUS < 12 µg/l |
| **CLASS II<br>GOOD** | * $O_2$ IN EPILIMNION 80-100%, NO OXYGEN DEPLEPTION IN HYPOLIMNION<br>* COLOUR VALUE 50 - 100 mg Pt/l (NATURAL HUMUS WATERS < 200)<br>* TRANSPARENCY 1 - 2,5 m<br>* FECAL BACTERIA < 50<br>* MEAN a-CLOROPHYLL IN THE GROWING SEASON < 10 µg/ l<br>* TOTAL PHOSPHORUS < 30 µg/ l |
| **CLASS III<br>SATISFACTORY** | *$O_2$ IN EPILIMNION 70-120%, NO OXYGEN DEPLETION IN HYPOLIMNION<br>* COLOUR VALUE < 150 mg Pt/l<br>* FECAL BACTERIA < 100<br>* MEAN a-CLOROPHYLL IN THE GROWING SEASON < 20 µg/ l<br>* TOTAL PHOSPHORUS < 50 µg/l<br>* IN AREAS POLLUTED WITH PULPING EFFLUENTS NaLS 2 -5 mg/l |

| | |
|---|---|
| CLASS IV<br>POOR | * $O_2$ IN EPILIMNION 40-150%, CLEAR OXYGEN DEPLETION IN HYPOLIMNION<br>* FECAL BACTERIA < 1000<br>* MEAN a-CLOROPHYLL IN THE GROWING SEASON 20 - 50 µg/l<br>* ALGAL BLOOMS FREQUENTLY RECORDED<br>* TOTAL PHOSPHORUS 50 - 100 µg/l<br>* IN AREAS POLLUTED WITH PULPING EFFLUENTS NaLS 5 -10 mg/l<br>* As < 50, Hg < 2, Cd < 5, Cr < 50, Pb < 50, total cyanide < 50 µg/l<br>* OFF-FLAVOURS FREQUENTLY OBSERVED IN FISH |
| CLASS V<br>BAD | * MAJOR DISTURBANCES OF OXYGEN CONDITIONS, THE SATURATION LEVEL IN EPILIMNION MAY EXCEED 150% IN SUMMER, BUT ON THE OTHER HAND, TOTAL OXYGEN DEPLETION MAY ALSO BE OBSERVED IN THE HYPOLIMNION<br>* MEAN a-CLOROPHYLL IN THE GROWING SEASON > 50µg/l<br>* TOTAL PHOSPHORUS > 100 µg/l<br>* IN AREAS POLLUTED WITH PULPING EFFLUENTS NaLS > 10 mg/l<br>* HEAVY METAL CONCENTRATIONS EXCEED THE MAXIMUM THRESHOLD VALUES OF CLASS IV<br>* Hg CONCENTRATION IN FISH > 1 mg/kg<br>* OIL FILM OFTEN OBSERVED ON THE WATER SURFACE |

APPENDIX 3

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## WATER QUALITY CLASSIFICATION IN TALLINN SEA AREA BY LITTORAL VEGETATION

**Monitoring of the state of the coastal sea in Tallinn area in 1993-1996 by littoral macroalgae.**

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**Introduction:**

The earliest data concerning the bottom vegetation of Tallinn Bay is available from the year 1849 published by E. Eichvald. In his work he mentioned the presence of red algae *Furcellaria fastigiata* = *F. lumbricalis, Polysiphonia nigrescens* and *Ceramium sp*. From the brown algae *Chorda filum* and from the marine phanerogarms *Zannichellia martima* = *Z. palustris* and *Potamogeton pectinatus* were mentioned. Chr. Gobi, a Russian professor of St. Petersburg (1874, 1977 ), was the next to study marine algae in Tallinn Bay. He described the benthic flora of Tallinn Bay and nearby bodies of water. E. Häyren (1929) collected data about species composition of the macrophytobenthos of this region from stranding on seashore. Thereafter the investigations came to a standstill until in 1975 they were revived by H.Kukk who collected samples of benthic algae from 127 stations all over Tallinn Bay. Besides, in 1976 he took samples from 35 stations. The obtained results were presented and long-term changes analysed (1979). In 1978, 19 samples were taken from this region and in 1984, 36 more samples were examined. All the data obtained were published in 1986. Already in 1984 certain changes became evident compared to earlier years. So in Kopli Bay *Zostera marina* had considerably expanded its distribution. The same pattern was registered for *Fucus vesiculosus*. Some species (*Sphacellaria arctica, Furcellaria lumbricalis, Coccotylus truncatus*), previously absolutely lacking in the bottom vegetation of the area, occurred in the bay. At the same time serious decline of *Fucus vesiculosus* was registered east of Tallinn Bay at the coast of the Viimsi Peninsula. The above changes were thought to be caused by starting of the new waste water purification system (Kukk 1986). During the last few years, since 1991, a regular monitoring has been carried out in the area. On the basis of this programme the bottom vegetation of the area is mapped each year and changes in the communities have been recorded (Kukk, et. al. 1994).

**Material and Methods.**

Material for the present study was collected during the field work in June-July of 1993, in July of 1994 and in August of 1995 and August of 1996. Each year 30 stations from Kopli, Paljassaare and Tallinn Bays were sampled. All samples were collected from a depth of 0.2 - 2 m by a special scraper. The character of substrate and depth were recorded at each location. The samples were preserved in Strasburger solution (45% alcohol, 30% glycerol and 25% formalin). In each sample the species composition and relative abundance (percentage of the wet weight of each species from the total wet weight of the sample) were studied. Relative abundance was later treated as a quantitative measure in statistical processing. The classification of benthic algal communities was established by cluster analyses using the MVSP package where the similarity measure was Squared Euclidean Distance.

**Results and Discussion.**

Out of the 21 taxa of macroalgae and phanerogarms identified in the samples of this area 7 species were PHAEOPHYTA, 4 species RHODOPHYTA, 5 species CHLOROPHYTA, 1 species CHAROPHYTA and 4 species MAGNOLIOPHYTA. The bottom vegetation of the Tallinn area is somewhat different from that of the Helsinki area. Comparison of the sampling results in 1993 showed that only 14 species of bottom vegetation occurred in both areas, while 24 species were found either in the Tallinn or in the Helsinki area. In the Tallinn area the share of CLOROPHYTA was the biggest in terms of biomass, whilein the Helsinki area the PAEOPHYTA was the most abundant group of bottom vegetation. These differences are caused most probably rather by the geomorphology of the coastline and the type of the substrate than by salinity conditions or the character of human impact.

To find out the regularity in the distribution pattern of the bottom vegetation in the Tallinn area the methods of classification by cluster analyses was applied. As a result, three groups of communities with a very specific structure of communities were determined. The figure shows the relative abundances of six main species of benthic algae in these communities. It is important to note that all six species are present in each of the three communities, but the in share is considerably different. In the first group of vegetation communities the green algae *Cladophora glomerata* is hardly dominating the vegetation while the abundances of other species are very low. The second group of vegetation communities is characterized by codominance of four key species *Cl. glomerata, Enteromorpha intestinalis, Ceramium tenuicorne* and *Pilayella littoralis*. The third group of communities is dominated by the brown algae *Fucus vesiculosus*. On the basis of the structure of the communities, these three groups could be classified to three different trophic levels of the coastal sea water in the area. The first group of communities inhabits the areas with the highest trophic level of the coastal environment. The second group is characterizing the moderate trophic level of the coastal sea. The third group, dominated by the bladder wrack with its epiphytes, is representing the areas of the coastal sea with natural background trophic conditions not influenced by human activities. According to the distribution of these three groups of benthic algal communities the areal classification of the coastal sea in the Tallinn area was established. The validity of this classification is proved also by the distribution of the dominant species of bottom vegetation along the coast of the Tallinn area. It is obvious that the urban area of the coastal sea in the Tallinn region is surrounded from the east and west by the benthic communities dominated by bladder wrack (*F. vesiculosus*). These communities inhabit the areas west of Kopli Bay, the coastal sea of Naissaar Island and the waters east of the Viimsi Peninsula. The inner part of the urban area is dominated mostly by two species of green algae *Cladophora glomerata* and *Enteromorpha intestinalis*. The abundant occurrence of *E. intestinalis* is recorded for the most polluted coastal areas of the Paljassaare Peninsula and harbour region of Tallinn Bay.

The results of regular monitoring of the state of coastal sea by benthic algal communities in the region show some dynamics of the distribution of the tropic level of the coastal sea. In 1993, the inner part of the coastal sea of the Tallinn urban area was covered by mesosaprobic vegetation. By 1995 the mesosaprobic zone had diminished considerably; being replaced, for the most part, by the oligosaprobic vegetation, it had preserved only in the areas close to the Paljassaare Peninsula and the innermost part of Kopli Bay. The area of distribution of katarobic vegetation has not changed much since 1993. This phenomenon could be explained by the effect of introducing modern waste water treatment system at the Tallinn Waste Water Treatment Plant in 1994.

In 1996 the situation has changed also. The borders of the mesosaprobic zone have also moved from the Viimsi peninsula towards the bottom of Tallinn bay. The recolonisation by *Fucus vesiculosus* was described in the areas close to the Pirita area and northwards along the shoreline of Viimsi peninsula. On the other hand the relative abundance of *Cladophora glomerata* has increased in whole sea area. The development of *Enteromorpha species* was somehow lower than in previous years.

APPENDIX 4

**Hämekoski, Kari**
Helsinki Metropolitan Area Council (YTV):

## AIR QUALITY INDEX IN HELSINKI AREA (FINLAND)

# AIR QUALITY INDEX IN HELSINKI AREA, FINLAND

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## ABSTRACT

A simple air quality index (AQI) was introduced for the Helsinki Metropolitan Area in 1993, in order to inform the public about the current air quality in an easily understood way. The pollutants included in the AQI are CO (1 and 8 h), $NO_2$ (1 and 24 h), $SO_2$ (1 and 24 h), $O_3$ (1 h) and $PM_{10}$ (24 h).

## INTRODUCTION

The Helsinki Metropolitan Area Council (YTV) is responsible for air quality monitoring as well as planning, research, education and providing information on air pollution control in the area i.e. the cities of Helsinki, Espoo, Kauniainen, and Vantaa. Helsinki is situated next to the Baltic sea at a latitude of 60°N. The population of the largest urban are in Finland is 850,000. Air quality is monitored in order to observe changes in air quality, to evaluate the effects of different sources on air quality, to evaluate the air pollution control measures taken and to inform the public of the air quality. The Air Pollution Control Act requires municipalities to be aware of the air quality within their territory.

There has been a great deal of interest internationally to develop environmental indicators and/or indices as a tool to inform the public and to measure changes and trends in environmental quality.

## AIR QUALITY MONITORING AND GUIDELINES

Air quality has been monitored periodically in the Helsinki area since the late 1950s. An automatic $SO_2$ monitoring network was constructed in 1975, and since then several parameters have been added, and the network has been expanded to cover all four cities in the metropolitan area.

The current Finnish air quality guidelines (Table 1) were established by the Council of State in 1996 based on report of a working group on air quality guidelines (Ohjearvotyöryhmän mietintö 1993). Guidelines were based on the latest scientific information of the effects of pollutants on health and nature.

Air quality is fairly good in the Helsinki area by comparison with several other cities of similar size around the world. TSP, $PM_{10}$ and $NO_2$ concentrations, however, exceed the new guidelines. There is some evidence that fairly low pollutant concentrations combined with the cold climate might cause adverse effects on health in the area (Pönkä 1990).

## AIR QUALITY INDEX

Air quality index (AQI) was developed in 1993 in order to inform the public in layman's terms about the current state of the air pollution situation. It was decided that the AQI should be simple to calculate, clear enough for the public and have a sound scientific basis. Even though the AQI is mainly based on acute health effects, long term effects on nature and man-made structures are also considered. The development was partly based on work conducted in the USA and Canada, for example by Ott and Hunt (1976) and Mignacca and others (1991). The current AQI version is used on an on-line, daily and monthly reporting basis.

The pollutants included in the AQI are CO (1 and 8 h), $NO_2$ (1 and 24 h), $SO_2$ (1 and 24 h), $O_3$ (1 h) and $PM_{10}$ (24 h). Sub-indices are calculated hourly for all pollutants and for the given hour the highest sub-index becomes the AQI. Moving averages are used for 24 and 8 hour averages.

The AQI incorporates a segmented linear function consisting of 4 breakpoints (Table 2) joined by straight line segments. The index level of 100 is based on the new guidelines in Finland. The allowed exceedances are not taken into account. The AQI errs on the side of public safety. The recommendation of WHO (1987) is used for ozone. There are no guidelines for ozone in Finland. The index level of 150 is defined as 1.5 * concentrations associated with the AQI level of 100. As far as $O_3$ is concerned the index level of 50 is 50 % of 1 h WHO guideline. The AQI level 10 is based on background levels of pollutants. It has, however, no use in urban or suburban areas due to continuously elevated pollutant concentrations.

Each AQI index category is associated with characterisation of health and other impacts as well as colour and descriptive word (Table 3). Combined effects of different air pollutants are not included as there is not yet enough scientific evidence for this with the exception of combined effects of $SO_2$ and particulate matter (WHO 1987). This has not been included in the AQI because the new Finnish guidelines for $SO_2$ and $PM_{10}$ are stricter than the WHO guidelines for combined exposure.

## RESULTS AND DISCUSSION

The AQI has been routinely calculated since 1993 for urban traffic environment in the centre of Helsinki (Töölö station) and for suburban environments (a combination of Tikkurila and Leppävaara stations). AQIs are published in a newspaper, on local radio and on colour on-line display in Helsinki. The AQI is also in use in several other cities in Finland.

With very few exceptions the highest index values are found in the centre of Helsinki. The average of daily maximum for centre of Helsinki in 1994 was 80, and 66 for suburban areas. The highest AQI values are caused by 24 hour $PM_{10}$ and $NO_2$ concentrations. In 1994 the highest recorded value in the centre of Helsinki was 227 caused by 24 hour $PM_{10}$ concentration and in suburban areas 129 also caused by $PM_{10}$. Both values were recorded in spring when particulate matter concentrations were typically high due to resuspension caused by traffic and wind after the street sanding, and the use of studded tires in winter. On the average the pollutant responsible for the daily maximum index value is usually 24 hour $NO_2$ concentration.

## CONCLUSIONS

A simple, understandable air quality index has been found to be a very useful tool for presenting and interpreting air quality data for the public in the Helsinki Metropolitan Area. The Air quality index will be further developed when new data on the effects of pollutants on man, nature and materials, valid for the climatic and other conditions in the Helsinki area, become available. As the environmental indices are becoming popular, more international cooperation are needed in development work.

## ACKNOWLEDGEMENTS

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Table 1. Current Finnish guidelines.

| Pollutant | Averaging time | Proposal | Allowed exceedances |
|---|---|---|---|
| $SO_2$ µg $m^{-3}$ | hour | 250 | 1 %/month |
| | 24 hour | 80 | 1/month |
| | year | 20 | - |
| $NO_2$ µg $m^{-3}$ | hour | 150 | 1 %/month |
| | 24 hour | 70 | 1/month |
| | year | 30 ($NO+NO2_2$)[1 | - |
| TSP µg $m^{-3}$ | 24 hour | 120 | 2 %/year |
| | year | 50 | - |
| $PM_{10}$ µg $m^{-3}$ | 24 hour | 70 | 1/month |
| CO mg $m^{-3}$ | hour | 20 | - |
| | 8 hours | 8 | - |

[1 as $NO_2$

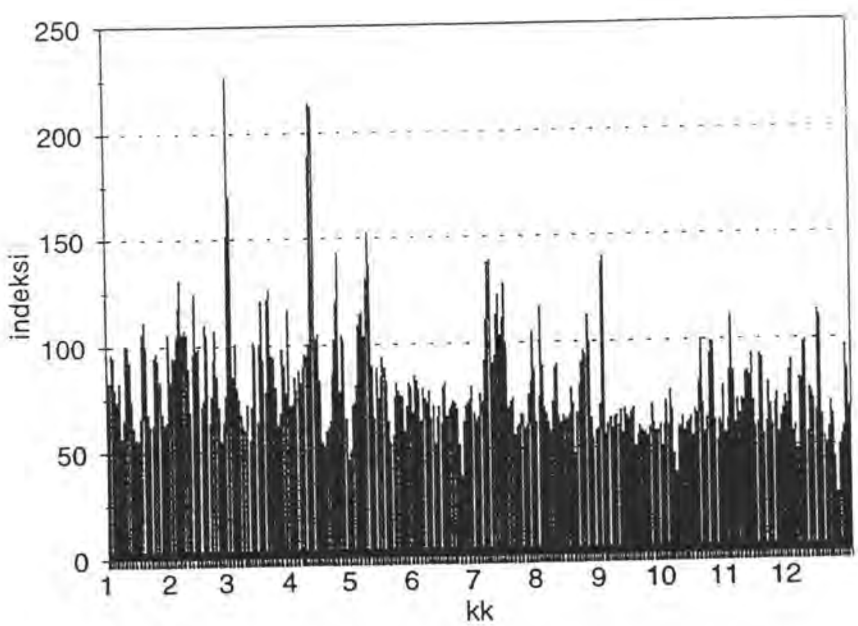
Table 2. Comparison of AQI values with pollutant concentrations, µg $m^{-3}$, CO mg $m^{-3}$

| Index | CO 1 h | CO 8 h | $NO_2$ 1 h | $NO_2$ 24 h | $SO_2$ 1 h | $SO_2$ 24 h | $O_3$ 1 h | $PM_{10}$ 24 h |
|---|---|---|---|---|---|---|---|---|
| 10 | 0.5 | 0.5 | 7 | 7 | 4 | 4 | 50 | 10 |
| 50 | 4 | 4 | 35 | 35 | 40 | 40 | 75 | 35 |
| 100 | 20 | 8 | 150 | 70 | 250 | 80 | 150 | 70 |
| 150 | 30 | 12 | 225 | 105 | 375 | 120 | 225 | 105 |

Table 3. AQI categories.

| Index | Colour | Definition | Health effects | Other effects (long term) |
|---|---|---|---|---|
| -50 | green | good | no effects | slight effects on ecosystems |
| 51-100 | yellow | fair | adverse effects improbable | effects on nature, effects on materials |
| 101-150 | orange | passable | adverse effects possible on sensitive individuals | marked effects on vegetation, effects on materials |
| 150- | red | poor | adverse effects possible on sensitive subpopulation | marked effects on nature, effects on materials |

Figure 1. The highest daily index values in the centre of Helsinki in 1994.



APPENDIX 5

**Panov, Vadim E.**
Russian Academy of Sciences, Zoological Institute:

## FUNCTIONAL APPROACH TO THE EVALUATION OF EUTROPHICATION IN THE NEVA ESTRUARY

**DRAFT**

Gulf of Finland Year 1996 International Seminar:
Development of a Space-Independent Bioindication System for Evaluation of the Eutrophication in Coastal Areas of the Gulf of Finland

November 25-27th, 1996
Tvärminne Zoological Station
Hanko, Finland

## Functional Approach to the Evaluation of Eutrophication in the Neva Estuary

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Eutrophication, defined as increased growth (primary production) of algae and higher plants due to increasing load of nutrients, is considered as the main environmental problem for the Baltic Sea. Effects of eutrophication are more obvious in the coastal zone, especially in sheltered areas such as lagoons, semi-enclosed bays, archipelagos and estuaries. Biological effects of eutrophication in the Gulf of Finland coastal zone are the following:

1. Development of blue-green algae in phytoplankton
2. Foliaceous perennial macroalgae (Fucus) to be overgrown and eventually replaced by filamentous, annual forms (Cladophora) and depth distribution of macroalgae to became shallow. Increasing role of wetland associations due to the spread of reed (Phragmites) beds
3. Increase in zooplankton biomass
4. Increase in zoobenthic biomass in areas not influenced by oxygen deficiency, and degradation of benthic communities in areas with low oxygen concentrations (oxygen depletion in stratified waters is a secondary consequence of the eutrophication process).

In the process of development of the coastal zone monitoring programmes three main questions arise:

1. Which parameter to monitor in order to evaluate eutrophication?
2. Where the sampling plots for a monitoring programme should be located in

a ecosystem, so that changes in species composition or in processes can be documented?

3. How frequently the samples should be taken?

The first question is likely the most important. Species composition of plant or invertebrate communities, abundance (coverage of plants) and biomass are usually considered as obligatory parameters for monitoring in coastal waters.

Changes in biomass and other structural characteristics of planktonic and benthic communities in coastal areas can be referred to eutrophication, and some of them considered as useful bioindicators of eutrophication in the Neva Estuary (see reports of Telesh, Nikulina and Balushkina for details). Description of biological indicators, mainly structural in their nature, is a traditional approach to the biological state assessment for aquatic ecosystems. Application of different structural indicators (indices) often resulted in the controversal estimations, because ecological state of certain components in the ecosystem (or community) can be different. Summation of the state of certain components on the basis of some complex indices (see Balushkina) allows to make more or less reliable estimations of the ecosystem state. But such estimations usually fail to differ eutrophication effects and organic pollution.

Because of dynamic nature of coastal areas and multivariate human impact, invertebrate communities in coastal ecosystems are affected by a complex set of abiotic, biotic and anthropogenic factors. This impose a serious limitations for the application of biological indices, based on structural characteristics of invertebrate communities, for the evaluation of eutrophication. Main factors, influencing invertebrate communities in the Neva Estuary, are shown in Figure 1. Effects of eutrophication on the community level are masked in the Neva Bay (freshwater upper part of the estuary) and easternmost Gulf of Finland (brackish water part) by the influence of such powerful abiotic factors as hydrodynamics and salinity. Sedimentation of inorganic matter, contamination and organic pollution are also important. Changes in total number of benthic species of macroinvertebrates and species diversity index along Neva Estuary have a clear relationship with the salinity gradient (Figure 2).

Local eutrophication effects in the Neva Estuary are apparently more obvious in sheltered shallow areas, especially in the Neva Bay, where extensive macrophyte beds have been developed. In such spatially complex habitats biotic interactions are likely the most important structuring factors for invertebrate communities. As it has been shown for the Neva Bay, predation by invertebrates, mediated by the habitat complexity, is the main factor, affecting structural characteristics of the macrophyte-associated fauna (Alimov, 1988). As shown in Figure 3, total number of species was significantly higher in macroinvertebrate communities in macrophyte zone, then in those located in open areas. Comparatively, low level of predation (estimated as the ratio of consumption rate of predators to secondary production of non-predatory macro-invertebrates - Cp/Pnp, see Fig.3) resulted in the fast growth in the isopod *Asellus aquaticus* population and, consequently, in the unusually low value of species diversity index (H=1.9).

Biotic interactions within natural communities in the Gulf of Finland coastal zone can be seriously altered by the invasions of exotic species. The zebra mussel, *Dreissena polymorpha*, the Caspian predacerous cladoceran *Cercopagis pengoi*, Baikalian amphipod *Gmelinoides fasciatus* are the examples of the most recent invaders to the Gulf of Finland. Established populations of these species can cause drastic changes in structural characteristics of invertebrate communities. These changes can result in the extinctions of aborigen species, in the increase (or decrease) of total community biomass and simplification of food webs. Thus, effects of such "biological pollution" can be similar to ones observed under eutrophication or organic pollution. Besides the direct effects of the introduced species on the community structure of invertebrates, the successful invaders can cause indirect effects on phytoplankton in the coastal zone, promoting its development whether by enhancing excretion of nutrients (*Dreissena*), or by controlling grazing zooplankton (*Cercopagis* and *Gmelinoides*).

Structural approach to the evaluation of eutrophication by means of structural indices do not consider a system nature of an ecosystem, which can result in different response to the stress in the ecosystem, depending on its the spatial and functional organization. So decision-making and effective management of the degraded areas is impossible without understanding how the ecosystem is functioning, and which factors are important for the ecosystem structural-functional organization.

Functional indicators allow to estimate the ecosystem state not only at the short temporal scale, but they allow to reflect ecosystem processes in their dynamics. Respiration rate of benthic macroinvertebrates can be useful functional parameter, reflecting changes in local loading of organic matter, derived both from enhanced sedimentation due to eutrophication and organic pollution sources. Existed information on the respiration rates of macroinvertebrates, allowed to evaluate respiration rates of the Neva Bay zoobenthic communities in terms of organic carbon for different periods. In the early 1980's, less than 30% of waste waters were treated, and those treated waters were released in the easternmost Neva Bay. As a result, most particulated organic matter sedimented in this area, which was indicated by the extremely high respiration rates of benthic macroinvertebrates, up to 3000 mgC/m2day in August, but in the western areas of the Neva Bay respiration rates were less than 50 mgC/m2day. At present more than 70% of sewage waters are treated, and a half of them are released at the northern Neva Bay. Respiration rates in zoobenthos changed dramatically: more than one order decrease in eastern Neva Bay (less than 50 mgC/m2day in August), and obvious increase in the south-western, western and north-western parts (up to 100 mgC/m2day). Increase in respiration of macrobenthos in the south-western areas, first revealed in 1995, was attributed to the accelerating eutrophication due to significant increase in water transparency after termination of dredging activity in south-eastern area of the Bay. Following studies on phytoplankton biomass and primary production conducted here in 1996 supported this suggestion.

The seasonal respiration of zoobenthic community is positively related with the seasonal primary production, and this relationship for freshwater lakes and reservoirs can be described by linear regressions. As it has been shown by Alimov (1989), such a linear regression for reservoirs has significantly higher slope, that those for lakes (Figure 4). This difference can be attributed to the external loading of reservoirs by dissolved and particulate organic matter (DOM and POM). Calculated values of seasonal respiration of zoobenthos in Neva Bay in 1983-1985 are extremely high, and that is reflected in the unusual high position of the 1983-1985 Neva Bay in the plot (Figure 4). Respiration of the Neva Bay zoobenthos in 1995-1996 fits the regression line for reserviors quite well due to decrease in POM and DOM loading and elevated primary production. Respiration of zoobenthos in the eastern Gulf of Finland in the middle of 1980's occupies the intermediate position between lakes and reservoirs in the plot, and respiration values in macroinvertebrates associated with macrophyte beds in the Neva Bay in 1983 are highest in the studied range, and fit regression for reservoirs (Figure 4). In the last case the "reservoir"-like position can be likely attributed to the accumulation of decaying higher plants on the bottom .

Above data show that respiration rates in zoobenthos might be an useful indicator of eutrophication or organic pollution in the Neva Estuary. But only the monitoring of respiration rates in zoobenthos still do not allow to distinguish clearly eutrophication and organic pollution effects in coastal zone.

The most important functional charateristics of an ecosystem are the primary production, and the ratio of primary production (P) and decomposition (=respiration, R) of organic matter in the ecosystem. Primary production is a fundamental quantitative estimate of eutrophication. Respiration in the ecosystem can be measured directly, or quantified by the summation of metabolic requirements of biota within the community. P/R ratio reflects changes in the ecosystem functioning under eutrophication or organic pollution. Then P/R ratio close to 1, the processes of production and decomposition of organic matter are balanced due to effective mineralization of organic matter, or due to removal of organic matter and nutrients from the system. P/R > 1 reflects accumulation of organic matter in the system due to eutrophication, and P/R < 1 reflects degradation of the system due to organic pollution.

Primary production and respiration, one of the few readily measurable integrative properties of ecosystem, can be measured from diel changes in free-water dissolved oxygen (D'Avanzo et al., 1996). We measured community metabolism in two locations in the Neva Bay, in the bulrush (*Scirpus lacustris*) beds. In one location at the south shore (station South300), close to local waste water discharge, P/R ratio for periphyton and total community were less than 1, but in the another one at the north shore these parameters were significantly higher than 1 (Figure 5). In the first case the organic pollution was clearly indicated by the low P/R ratio, and prevailing eutrophication was reflected by high P/R ratio in the northern location. In the last case processes of production of organic matter obviously exceeded its decomposition. Accelerating accumulation of organic matter along the shoreline in the northern Neva Bay can cause replacement of aquatic habitats by terrestrial ones. Some visible changes in northern areas during last decade support this suggestion.

As it has been shown recently (D'Avanzo et al., 1996), primary production and respiration of such dynamic coastal ecosystems as shallow estuaries can be monitored on the daily basis by the deployments of automated oxygen meters, and that would allow to quantify differences in metabolic rates between ecosystems as whole units (and likely between parts of ecosystem) in response to nutrient enrichment.

Primary production and respiration in the ecosystem are likely the most appropriate parameters for monitoring of eutrophication. But only knowledge of the dynamics of these integrative functional characteristics will not inevitably result in the complete understanding how the ecosystem function, and how to manage it. Construction of the detailed carbon budget of the ecosystem is much more time consuming, but allows the accurate quantification of its current trophic status, and promote more reliable understanding on the ecosystem functioning. The main parameters of the seasonal carbon budjet for the Neva Bay and the eastern Gulf of Finland in 1980's are shown in Figures 6-7. Heavy DOM and POM loading resulted in elevated respiration in plankton and benthos, which significantly exceeded primary production. P/R ratio for plankton and total community were significanly less than 1 in both parts of the estuary (Figures 6-7).

Construction of the detailed carbon budget and the knowledge on functional relatioships between hydrological and biological characteristics allowed to propose prognostic scenario of the ecosystem responses on the changing load of nutrients, DOM and POM (Winberg, Gutelmakher, 1987; Shishkin et al., 1989). Later this knowledge has been integrated into the simulation model of the Neva Bay (Umnov, 1996). Long-term data on main parameters of the carbon budget are essential in understanding how ecosystem function and correcting interpretation of the observed changes. These time series data are extremely important for the verification of the simulation models.

Studies in 1995-1996 revealed significant changes in the Neva Bay functional characteristics (Alimov et al.,1996). Gradual decrease in the Neva Bay loading with DOM and POM during last decade, as well as substantial increase in water transparency after termination of dredging activity, resulted in enhanced primary productivity (especially in the southern Bay) and decrease in the respiration of plankton and benthos, P/R ratio increased significantly (Figure 8). Elevated biomasses of phytoplankton in the western Neva Bay during last years (see Telesh, Nikulina) also indicated increasing eutrophication of the Bay. Construction of the detailed carbon budgets for Neva Estuary in 1990's is constrained by the absence of the essential functional characteristics of plankton and benthos.

As a result of heavy eutrophication, an extensive macrophyte beds (mainly emergent phanerogams) have been developed in the Neva Bay coastal zone during the recent decades, extending up to 500 m from the shoreline in some locations. Development of emergent macrophytes in the lower estuary are limited by wave disturbance, but filamentous green algae (Cladophora) are prolificated vigorously on hard substrates in the Neva Estuary during summer. Development of both emergent macrophytes and

*Cladophora*-mats damage beaches, causing serious problems for recreation in the area. Reliable information on the long-term changes of structural and functional characteristics of the littoral communities is scarce, in spite of obvious eutrophication effects in littoral zone. Available information and existed ideas on the functioning of littoral zone in the Neva Bay and the eastern Gulf of Finland can be expressed in the form of generalized relationship between primary productivity of phytoplankton, macrophytes and periphyton (attached algae) in ecosystems of increasing fertility (Figures 9-10). This relationship for the Neva Bay is close to observed in shallow lakes (Wetzel, 1979), and likely general for the sheltered areas in the Baltic Sea coastal zone. Prolification of attached algae in the exposed littoral of the Gulf of Finland with increasing fertility is a general fenomenon for large, deep lakes. Obtaining of essential data on littoral zone functional parameters is an important step before the construction of the simulation models as tools for decision-making.

To conclude, the monitoring programmes carried out in coastal ecosystems should be accompanied by the construction of simulation models to describe main carbon flow through the foodweb (de Jonge, DeGroodt, 1989). These models will:

1. contain the actual knowledge on the functioning of ecosystem in a very condensed but integrated form;
2. promote new ideas on the functioning of coastal ecosystems under changing environmental conditions;
3. enhance development of the more effective monitoring programmes (to justify the choice of sampling areas and frequency at which samples should be taken - answer on the questions 2 and 3 above);
4. help administrators to decide specific future management strategies, as "a bridge between science and management" (Lindeboom et al., 1989).

This approach can be considered as a space-independent.

Because environmental degradation in the Gulf of Finland coastal zone is primarily a consequence of eutrophication derived from local pollution sources, efforts to reduce local discharges of substances that cause eutrophication are likely to have positive environmental effect in the coastal zone (Cederwall, Elmgren,1990). Thus the management strategies should be a space-dependent.

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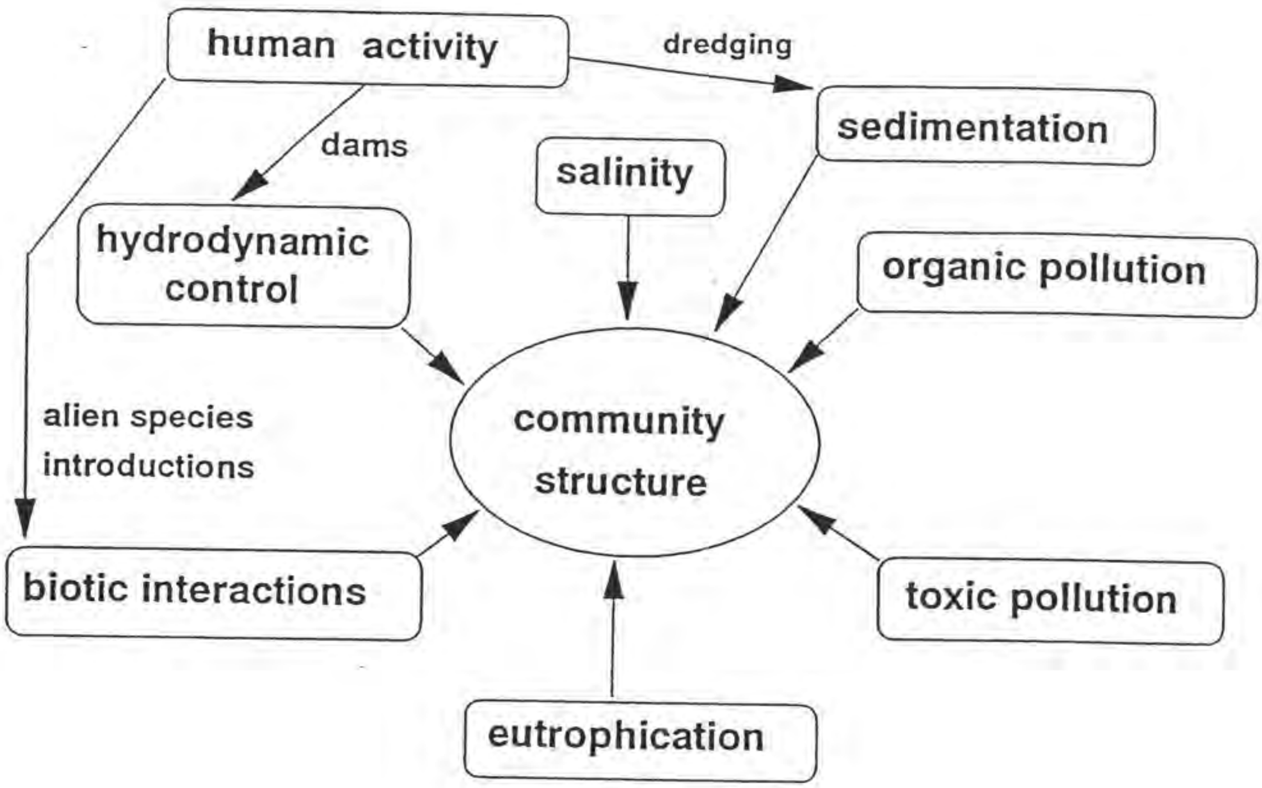


Fig. 1

Main factors, influencing the invertebrate communities structure in the Neva Estuary

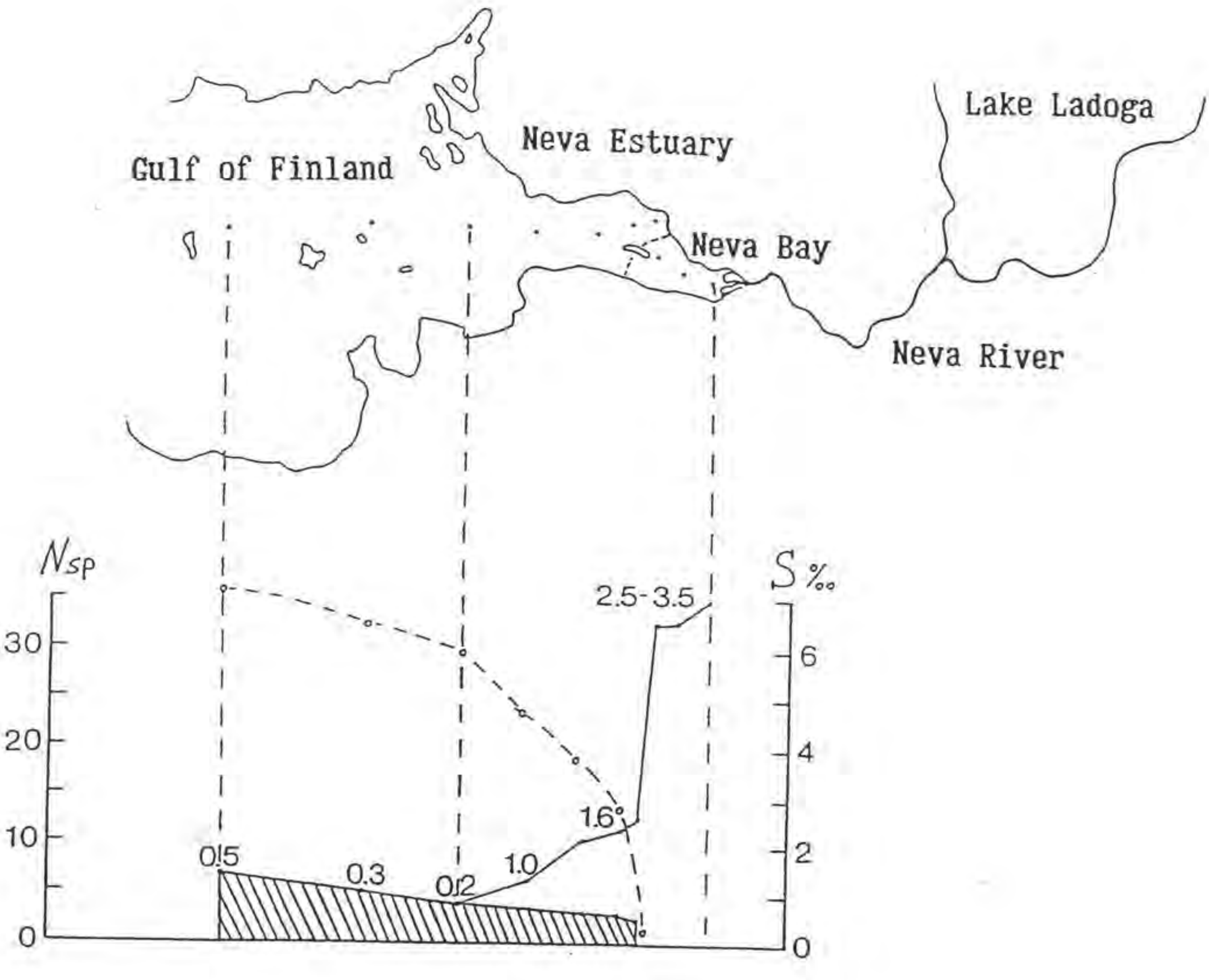


**Fig. 2**

Number of benthic macroinvertebrate species in the Neva Estuary along the salinity gradient. Stripped colour - marine and brackish-water species. Numbers indicate values of Shannon's species diversity index. Salinity estimates shown by open circles (modified from Shishkin et al., 1989).

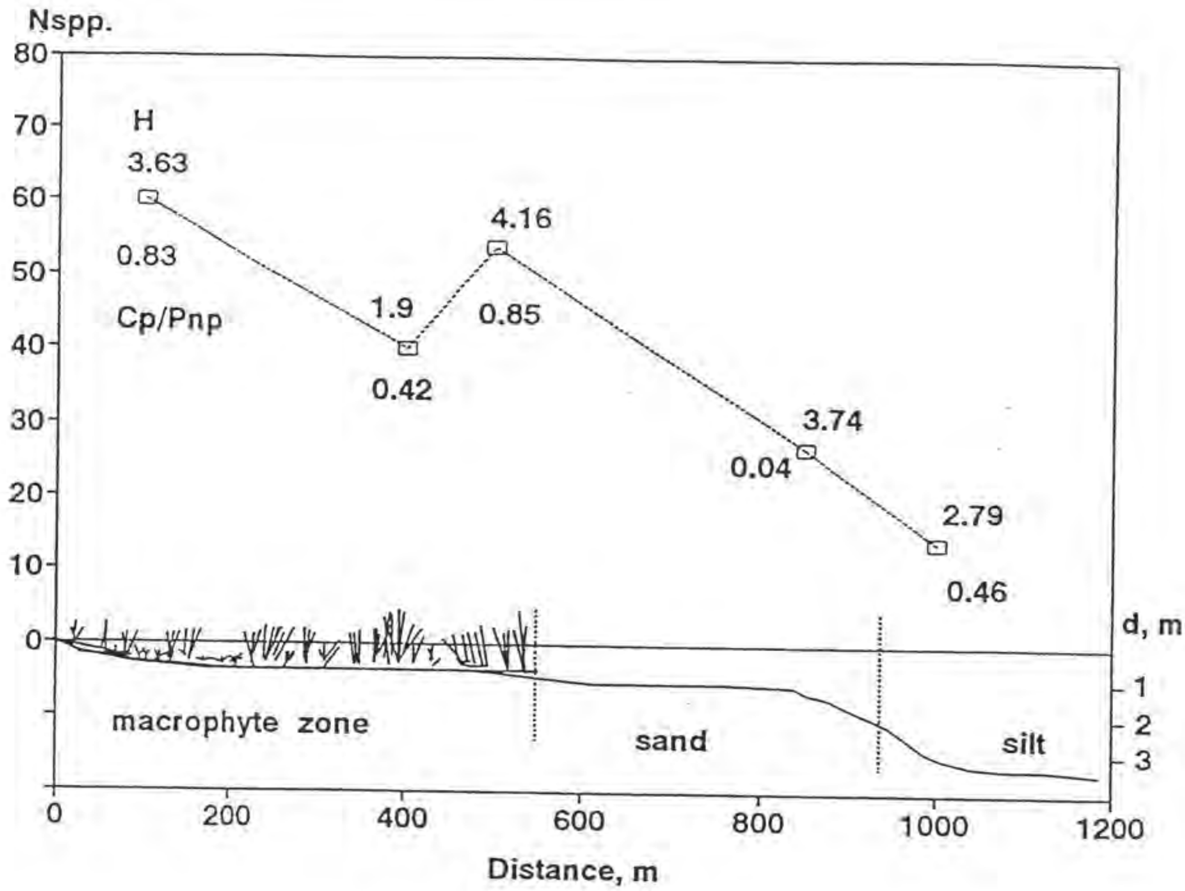


Fig. 3

Number of benthic macroinvertebrate species along littoral transect in the northern Neva Bay (see text for detailes)

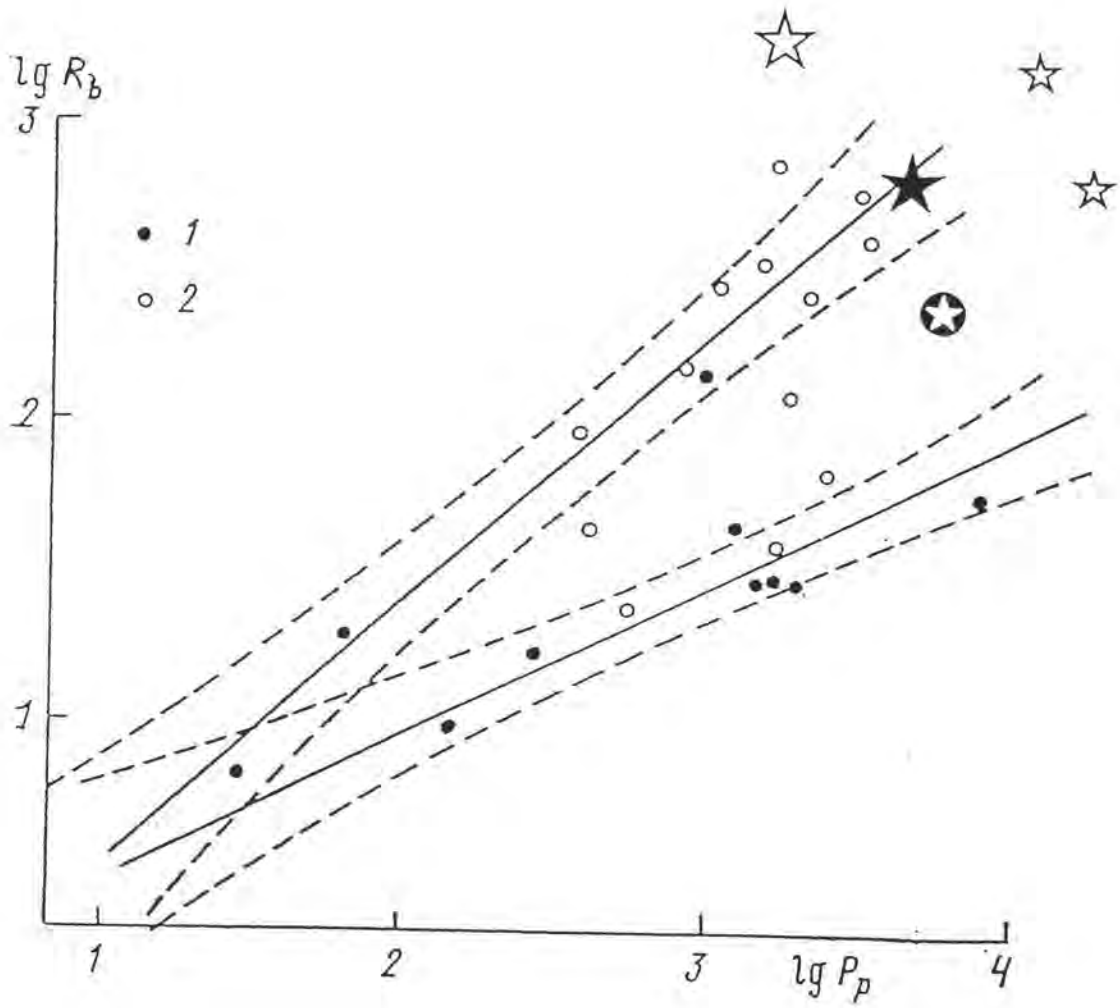


**Fig. 4**

Relationship between seasonal zoobenthic community respiration and seasonal primary production in lakes (1), reservoirs (2), open Neva Bay in 1983-85 (open large asterisk) and in 1995-96 (filled asterisk), Eastern Gulf of Finland in 1984 (open asterisk in filled cicle), and in littoral macrophytes in 1985 (open small asterisks) (modified from Alimov, 1989).

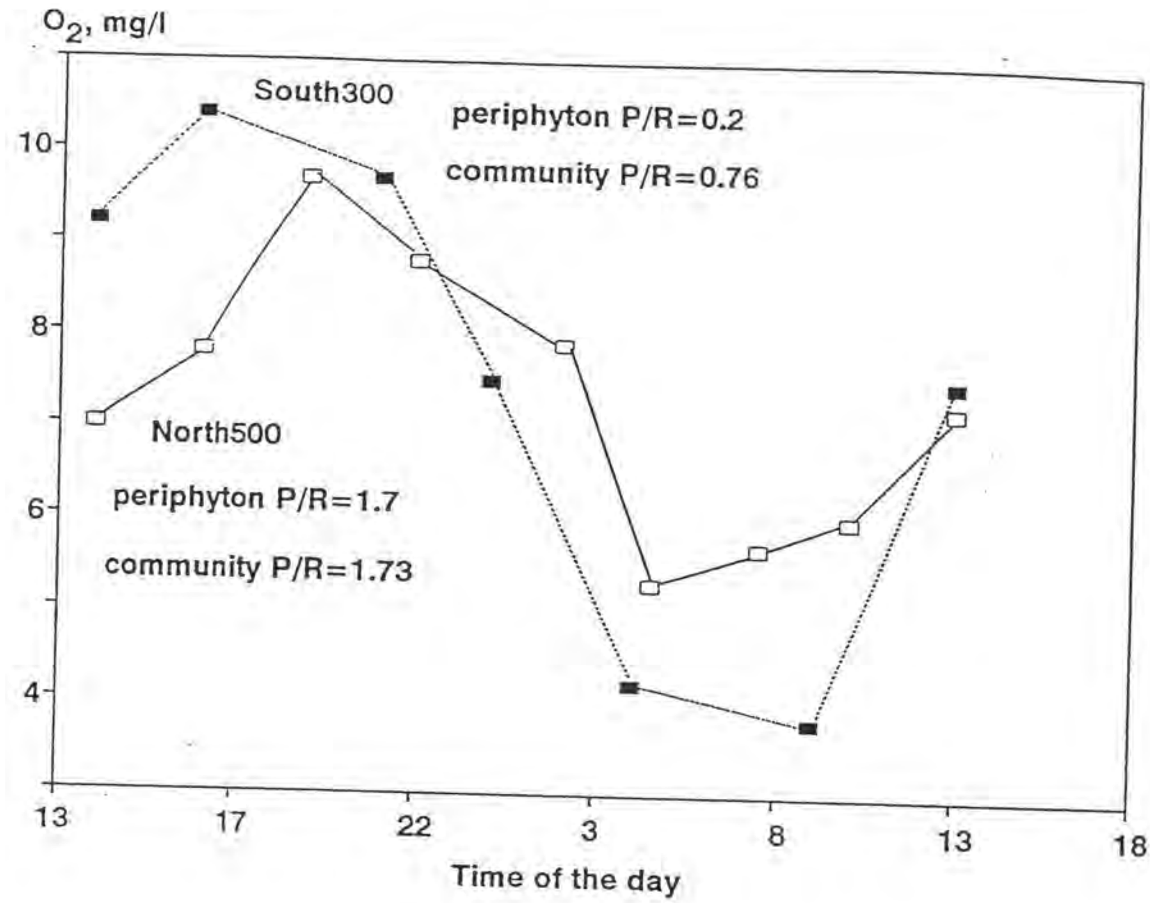


**Fig. 5**

Daily changes in the dissolved oxygen concentration in bulrush beds in two locations of the Neva Bay littoral zone.

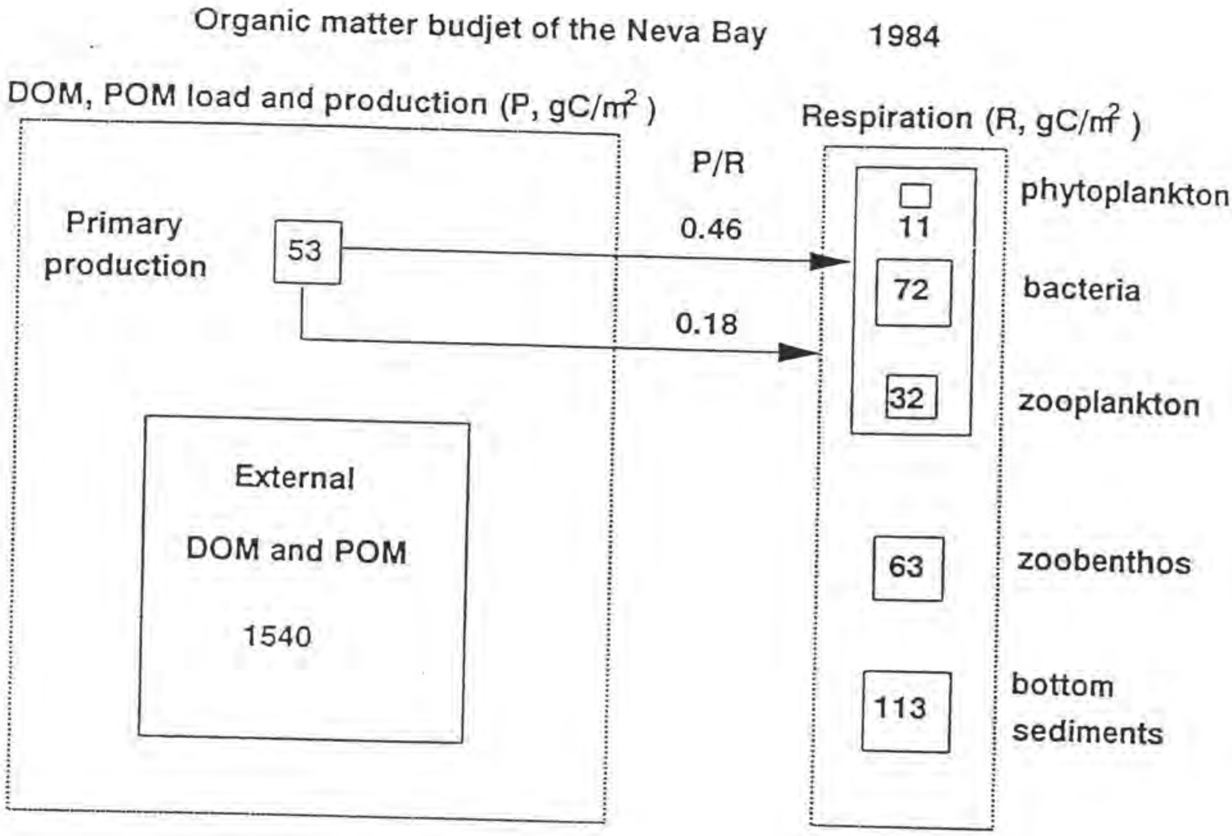


Fig. 6

Organic carbon budjet for the Neva Bay, 1984 (Modified from Shishkin et al., 1989)

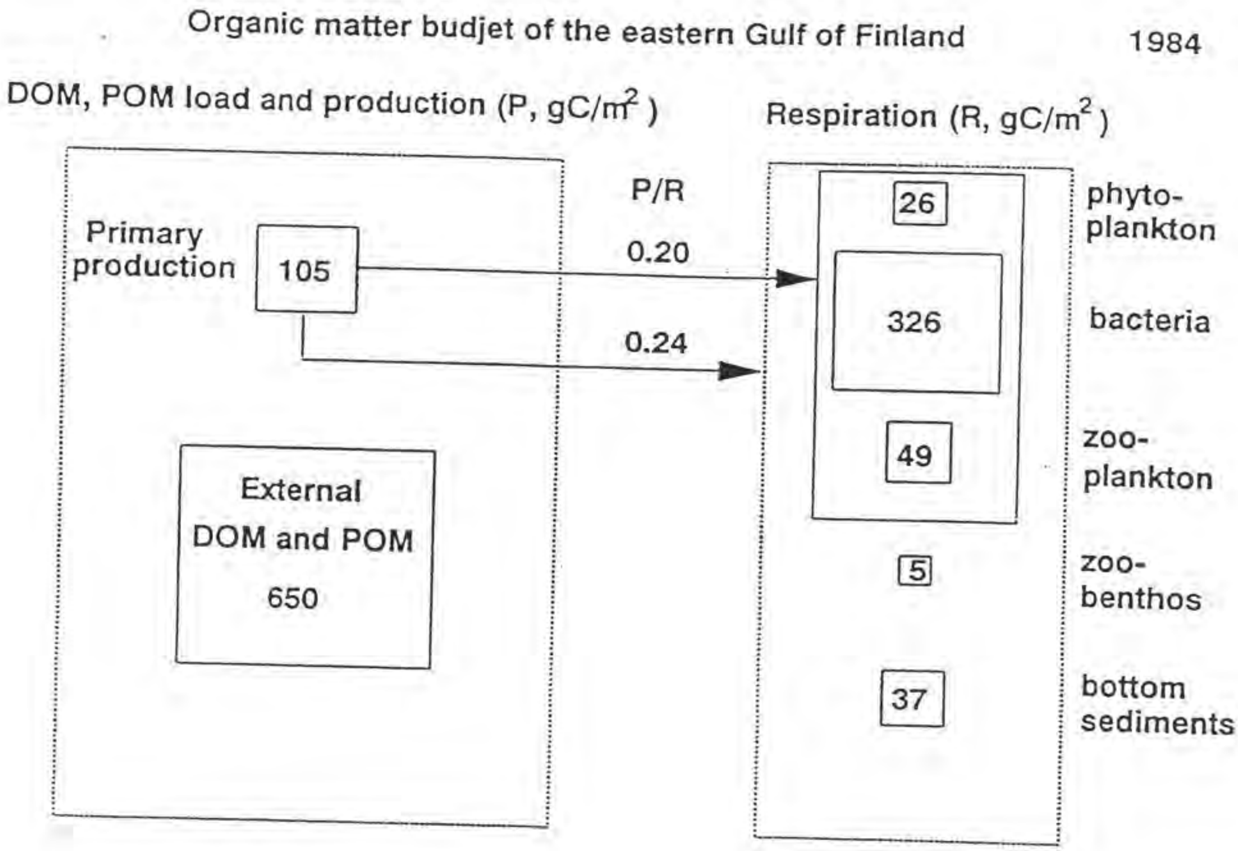


Fig. 7

Organic carbon budjet for the Eastern Gulf of Finland, 1984 (modified from Shishkin et al., 1989)

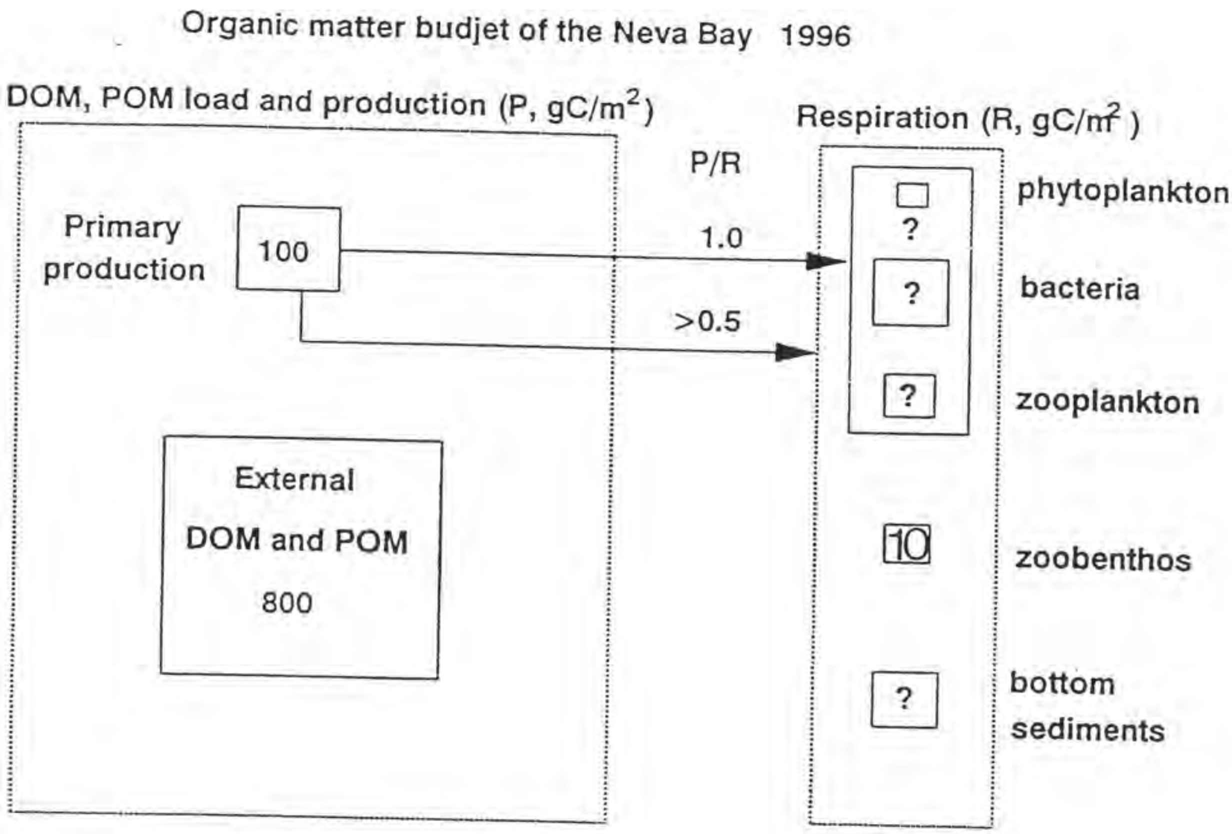


Fig. 8

Organic carbon budjet for the Neva Bay, 1996

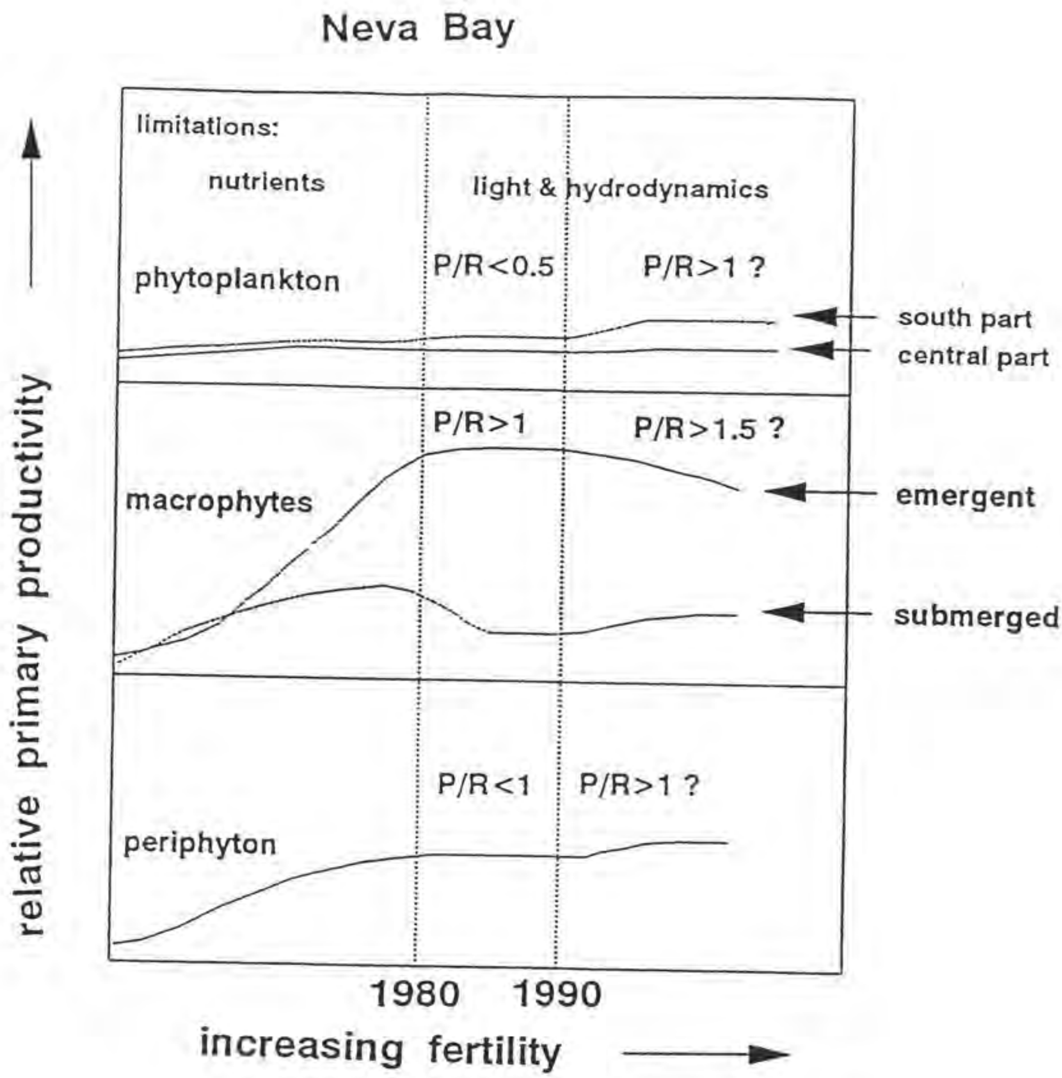


Fig. 9

Generalized relationship between primary productivity of phytoplankton, macrophytes and attached algae in the Neva Bay under increasing fertility (modified from Wetzel, 1979)

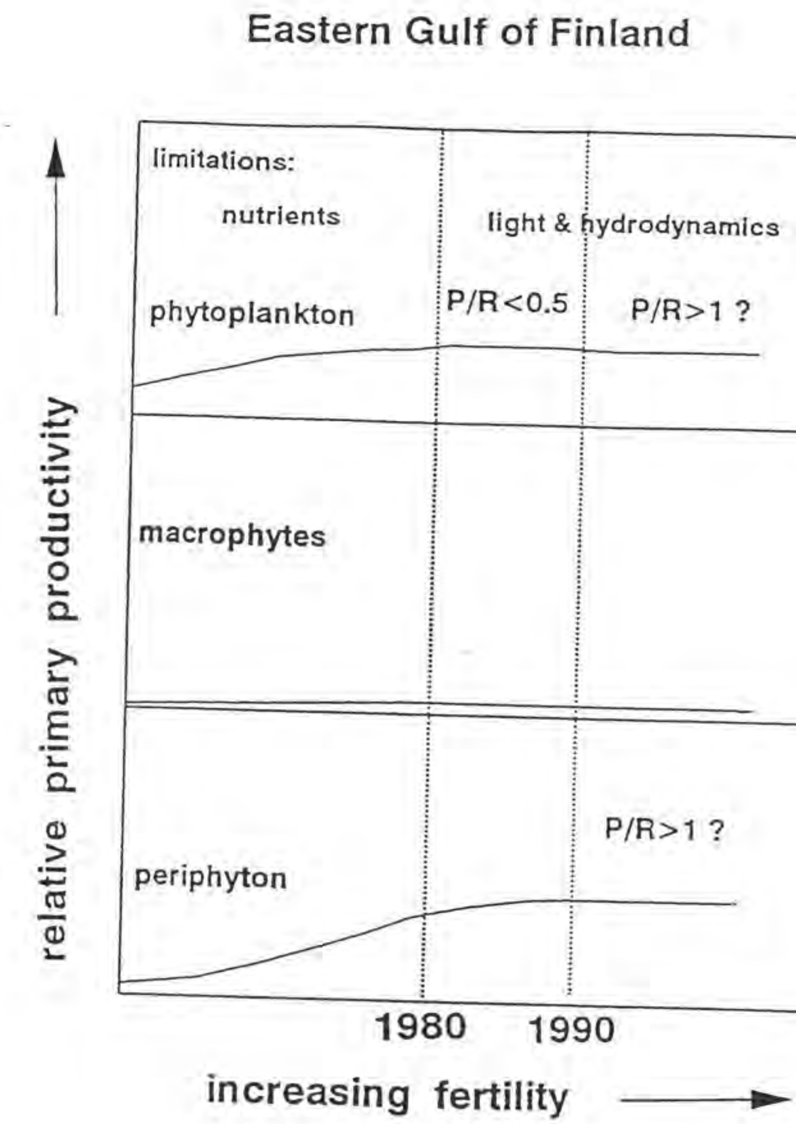


Fig. 10

Generalized relationship between primary productivity of phytoplankton, macrophytes and attached algae in the Eastern Gulf of Finland under increasing fertility (modified from Wetzel, 1979)

APPENDIX 6

**Viitasalo, Ilkka**
Environment Centre of the City of Helsinki:

## ECOLOGICAL CLUSTERS OF MACROPHYTE SPECIES ON THE HELSINKI SEA AREA, GULF OF FINLAND; METHODS AND MAIN RESULTS

THE GULF OF FINLAND YEAR 1996 SEMINAR:
DEVELOPMENT OF A ASPACE-INDEPENDENT BIOINDICATION SYSTEM FOR EVALUATION OF EUTROPHICATION IN COASTAL AREAS OF THE GULF OF FINLAND

Tvärminne Zoological Station, Finland 25-27. Nov. 1996

Viitasalo, Ilkka: WATER QUALITY CLASSIFICATION IN HELSINKI SWA AREA BASED ON MACROALGAE; METHODS AND MAIN RESULTS

Part of the paper:

> H.Kukk, I.Viitasalo and G.Martin (1995): The ecological state of Tallinn and Helsinki coastal waters based on benthic macrophytes. -Paper presented in 14th Baltic Marine Biologists Symposium, Pärnu 1995.

The growth of macrophytes is dependent on different environmental parameters. Tide is almost absent in the Baltic Sea. Sea level varies according to the cyclonic activity and runoff; the lowest water levels occur mainly in spring and early summer. Salinity is affected by runoff, upwelling and irregular movements of water layers. Wave exposure, ice shearing and the quality of substrate are the most important local abiotic factors to macrophytes. Growth period is limited by ice cover, temperature and solar radiation; most of the primary production taking place in June-September. Perennial macrophytes inhabit the sublittoral zone under 1,0 - 1,5 m depth because of ice shear. Annual macrophytes; mainly green and brown algae, colonize the eulittoral zone from 0 to 1-3 meters depth. If ice period is delayed, some of them inhabit the uppermost water line in the dark season, too. Due to low water temperature, secondary production is slow. Thus they are able to stay in the waterline without being decomposed by grazer organisms or bacteria.

Besides the above-mentioned factors, inorganic nutrients are essential growth promoters for macrophytes. Plankton algae compete directly with them by using the same nutrients and indirectly by shading deeper water layers. The riverine and human input of nutrients is remarkable in the Gulf of Finland. Even if the Gulf is open towards the Baltic proper, local high concentrations of nutrients, mainly nitrogen anf phosphorus, are frequently recorded along the coastline.

The study was concentrated to the upper (eu)littoral zone which is mainly populated by annual green algae and phanerogams. The uppermost part of the *Fucus* belt (down to 2.0 - 2.5 m depth) was included, too.
Samples were taken in July-August when the annual algae have reached full length but before they begin to cease, decompose and detach from the substrate. Sampling took place from a outboarder boat with a shaft rake, equipped with a cutting edge and a net bag. Sample sites were 3-5 m broad strips of the eulittoral zone. Prior to sampling, the site was viewed and documented for substrate type and vegetation cover. By raking several times from one site a representative collection of the macrophyte cover was obtained. The sample was preliminary surveyed onboard and different algal groups or species were subsampled to an one liter plastic container with the ambient sea water. The subsamples were preserved (fixed) with Strassburger solution for later microscopy in the laboratory. Sampling took place on both sides of the Gulf by the same crew. Laboratory work was made by the same personnel, too.

Besides taxonomical determinations, different physiological parameters were recorded for *Cladophora glomerata* and *Fucus vesiculosus*. A compilation of the parameters is presented in Table 1.

| | | |
|---|---|---|
| | | |
| | | |
| *Cladophora glomerata* | Height | 1-12 cm<br>10-30 cm |
| | Abundance of epiphytes (3 classes, visual observation) | Class 0 (no epiph.)<br>Class 1-2<br>Class 3 (abundant) |
| *Fucus vesiculosus* | Height<br>Gas vacuoles<br>Fertility<br>*Elachista* as an epiphyte[1] | (cm)<br>(y/n)<br>(y/n)<br>(y/n) |
| | Hydrozooic epiphytes[2] | <10 % of surface<br>>10 % of surface |
| | | |

Remarks: [1] The most common obligate epiphyte on *Fucus* in the Baltic.
[2] Mainly *Membranipora crustulenta* and *Balanus improvisus*.

Table 1. Physiological and vegetative properties recorded in this study.

So far the field and laboratory operations have been succesfully intercalibrated.

Data handling and results; Helsinki

The most extensive field work in Helsinki and adjacent areas was conducted in 1993. 225 sample sites were visited in two weeks at the end of July (Viitasalo et al. 1994). Here we report some of the methods and core results from this field period.

The taxons and their physiological properties were clustered into groups which occur most likely together in same samples. The clustering process used a correlation matrix with Pearson's product moment coefficient and utilized weighted pairing of groups in building the dendrogram (Kowach 1993, Lance and Williams 1966). Some of the taxa were rare and their clustering affinities were not clear. The following groups of taxa, their properties and functions were detected, however (see FIGURE 1):

A. Group of the outermost archipelago (s=-2):

Fertile *Fucus* with *Elachista* but few zooic epiphytes.
*Cladophora* with few (diatomic) epiphytes.
*Pilayella* and *Dictyosiphon chordaria* near the surface.
*Ceramium, Cladophora rupestris* and *Furcellaria* under *Fucus*.

B. Group of the middle archipelago (s=-1):

Sterile *Fucus*; mainly without *Elachista* and older parts of the thallus covered by epiphytes.
*Ectocarpus siliculosus, Polysiphonia violacea* on stones, *Dictyosiphon foeniculaceus* also on *Fucus*.
*Chorda filum, Ranunculus baudotii* in more sheltered localities.

C. Group of inner archipelago without wastewater load or convalescent areas (s=+1)

Constant occurrence of small amounts of *Enteromorpha sp*. (abundance under 2 %).
*Enteromorpha compressa*.
Constant growth of *Cladophora* in different forms.
Rich populations of phanerogams; *Potamogeton pectinatus, P.perfoliatus, Ceratophyllum sp, Myriophyllum sp*.
Zannichellia.

D. Group of inner archipelago with wastewater or stormwater load (s=+2):

More than one species of *Enteromorpha* or mass occurrence (abundance > 60 % in the sample) of *Enteromorpha sp*.
Most frequent species were *E. prolifera, E. ahlneriana, E. intestinalis*.
Sterile *Ectocarpus* with long hairy branches (*Ectocarpus confervoides* typus *fluviatilis*, sensu Waern 1952, p.116).

Remarks on the groups:

*Cladophora glomerata* occurred frequently in the groups A and D, too. The clustering process can "sell" one taxon only once into a group with the highest affinity. Thus an ubiquitous species like *Cladophora* suffers from this type of grouping method.

Many rare species confuse the clustering tree rather than show any indication properties. Further work is needed to evaluate whether or not they deserve attention in respect to eutrophication.

The overall nutrient concentrations are well documented in the area. Different clusters (and taxa inside them) are supposed to display different ecological factors, one of them being the availability to nutrients (eutrophication). All taxa in a certain cluster were assigned with integer values which were called s-values (s-indicator values). These values are not necessarily connected to eutrophication in the outer fringe of the archipelago.

The information of different taxa, their abundances and svalues from one sample were collected into a sample biotic index ("S-index") according:

$$S = \frac{\sum (s \times a_{100}^{1/3})}{\sum (a_{100}^{1/3})}$$

where S = sample S-index
s = taxon s-value
$a_{100}^{1/3}$ cubic root of the abundance of a taxon in a sample.

Comment: Taxa with s = 0 were excluded.

Because the S-index is an average-like function of all taxa in a sample, it is less sensitive against local variation than the observations of individual taxa alone. The abundances were handled by cubic root transformation. It favours small-sized species with permanently low abundances, which, however, may be as important indicators as the big ones (Williams and Stephenson 1973).

There are many different biotic indices. The present method is based mainly on Pantle and Buck (1955), Chutter (1972) and Sladecek (1961). All of them have suggested indices where the abundances are weighed by different subjective quality values of the same taxa. As is well known, the distribution of algae species is mainly dependent on natural environmental variables (salinity, light, temperature etc). Thus care must be taken when conclusions of their reactions against eutrophication are drawn.

After the calculation of the sample S values, the sample sites were classified into four classes and a map of different ecological zones was drawn (FIGURE 2).

The question arises, to which extent the sample S values alone mirror eutrophication. Man-induced effects upon an ecological association are always hard to separate from the natural variety of circumstances and localities. Long-lasting monitoring of the same areas with identical methods, however, may help to detect and explain the changes.

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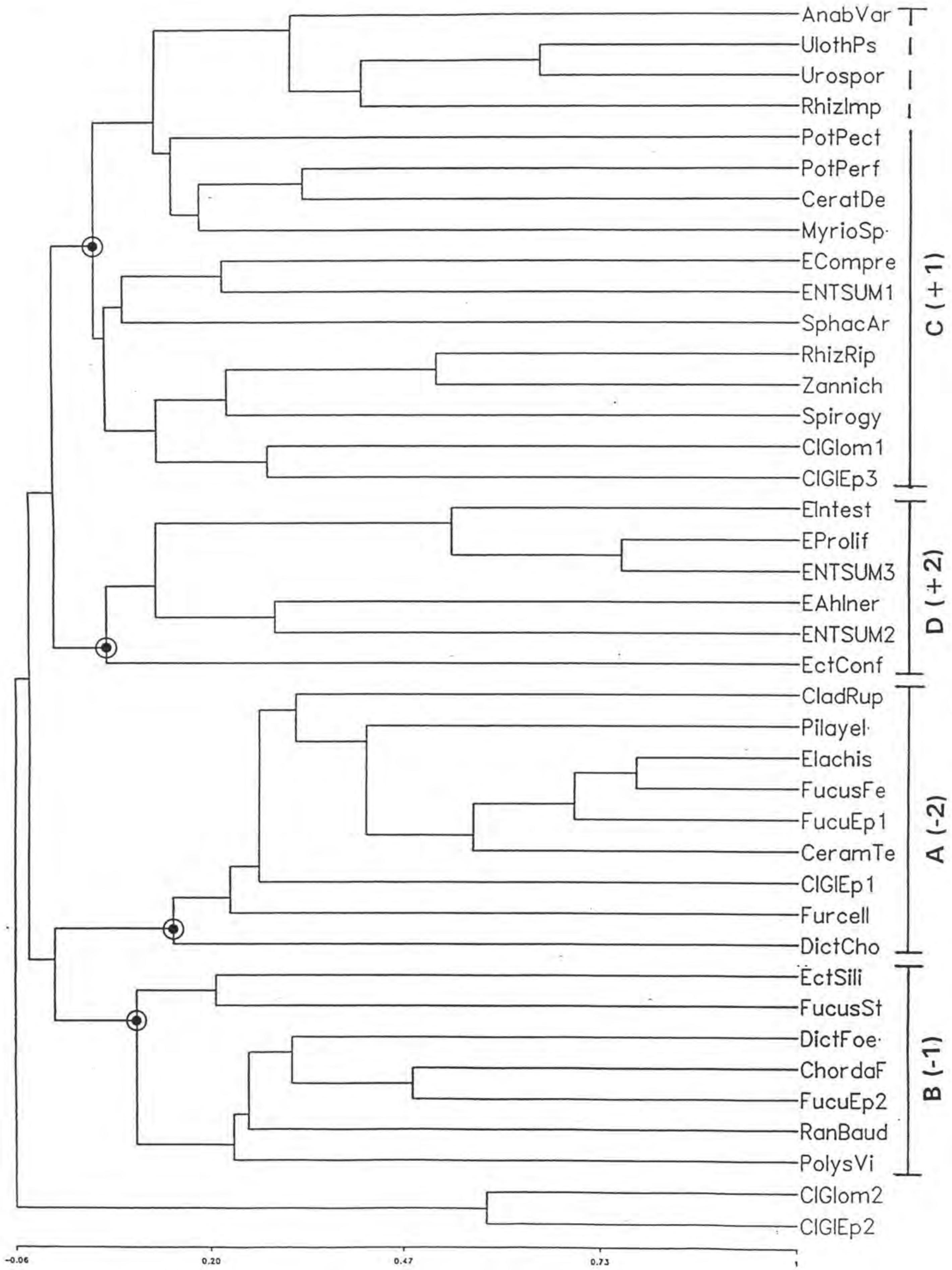


Figure 1. Clusters of different aquatic macrophyte taxons in the Helsinki Metropolitan Sea Area in 1993.

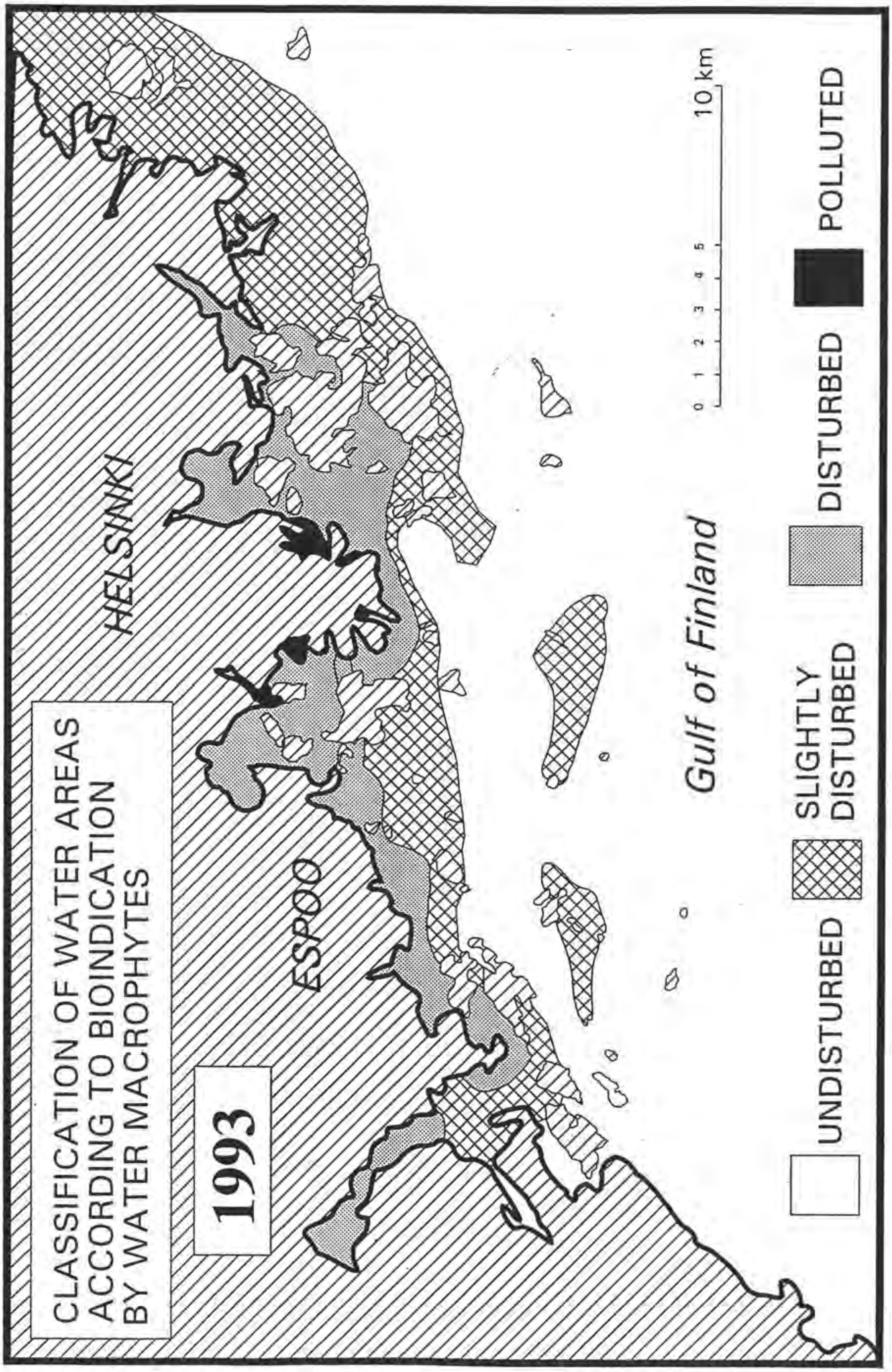


Figure 2. Distribution of different aquatic macrophyte groups in the sea areas of the Helsinki Metropolitan Area in 1993.

APPENDIX 7

**Balushkina, Evgeniya V.**
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# NEW INTEGRATED INDEX FOR WATER QUALITY EVALUATION BASED ON STRUCTURAL CHARACTERISTICS OF ZOOBENTHOS

# New Integrated index for water quality evaluation based on structural characteristics of zoobenthos.

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The establishment of hydrobiological service for water quality control began in our country about 20 years ago. Many parameters and indexes were created on the basis of observations in bodies of water in Europe. They were tested therefore in some of our bodies of water, watercourses and then partially recommended for usage. But the necessity to adapt these methods to conditions in bodies of water of our country was emphasized.

For zoobenthos it appeared impossible to use the method of indicator organisms because of significant distinction of benthic fauna in many regions of our country and Europe and because of absence of experts, who could develop a system of benthic indicator organisms.

Results of application of different methods for the assessment of water quality in the north-western region from zoobenthic animals are presented in works by N.P. Finogenova, A.F. Alimov, (1976) and E.V. Balushkina (1976).

Results of long-term researches carried out abroad along these lines are reviewed in the book Freshwater biomonitoring and benthic macroinvertebrates (1992). The chapter devoted to criteria of assessments of ecosystem health emphasizes that distribution, structure and benthic community dynamics is the key to understanding the state and changes in the functioning freshwater ecosystem (Reice, Wohlenberg, 1992).

It should be taken into account however, that many indices were created for the assessment of the degree of pollution by organic matter; their behaviour under conditions of a heavy toxic pollution is poorly known. The impact of toxic and organic pollution on aquatic ecosystems (including bodies of water studied by us) brings about conditions leading to complicated rearrangements in benthic animal communities; different explanations of these rearrangements have been proposed. Methods of saprobic analysis permit the assessment of water quality in ecosystems subject to organic pollution. The mixed character of pollution by organic and toxic substances gaining in importance with the development of industry in our region required the development of system for the assessment of their impact on the biota.

The interpretation of changes in community structure in order to provide characterization of water quality under conditions of anthropogenic impact may be more or less successful depending on specific features of external effects, characteristics of the ecosystem (morphometry, drainage), degree of changes, occurring in benthic communities, systems of assessment. The more comprehensive the characterization of the animal community and changes caused by human impact the more adequate the assessment of water quality.

Therefore we have to pass from the controversial assessment of water quality based upon different indices to an integrated one including a set of indices providing the most complete characterization of an animal community as a whole and reflecting specific features of human impact on an ecosystem.

Selection of parameters for the assessment of conditions in the studied watercourses and bodies of water from zoobenthos was based upon the following principles.

The parameter should reflect: 1) the impact of pollution of organic and toxic substances on benthic animals 2) changes in the dominant and subdominant groups of benthic of animals, 3) changes of the structure of the community as a whole.

Therefore we used the following indices for the assessment of water quality:

1) Trent Biotic Index (Woodiwiss, 1964), 2) Index Kch, based on the structure of chironomid communities (Balushkina, 1976), 3) Goodnigth and Whitley's index (Goodnigth, Whitley 1964), 4) Saprotoxic index (Jakovlev, 1987).

Biotic index (or TBI - Trent Biotic Index ) incorporates availability of animal groups that can be regarded as indicators of water quality. The "group" includes species or complexes of species, the index significance of which is evaluated depending on the total number of groups of animals in a sample. The biotic index, therefore evaluates structure of a community as whole. The insufficient correlation of "group" with the numbers of animals constituting it can be regarded as one of its drawbacks. It is necessary to keep in mind that under conditions of impoverished fauna particularly on clean sand one should select more samples in order to reflect the variety fauna under these conditions. In the opposite case the significance of a very small "group" can be overestimated.

Oligochaetes is a predominant group of benthic animals in many studied bodies of water, and therefore change in their numbers can be useful for the assessment of their condition. The index of relationship between abundance of oligochaetes and total abundance of zoobenthos (No / Nc ), ( Goodnight, Whitley,1961) reflects to a greater degree pollution with organic matter and nutrients, accumulation of mineral particles on the bottom of a body of water; pollution in this case can be considered to be less toxic because of low sensitivity of oligochaetes to toxic pollution.

One of its drawbacks is that showing the tendency of a benthic community towards monoculture the index does not incorporate species diversity of oligochaetes and possible presence of species requiring clean water among them.

Chironomids occurred in nearly all bodies of water studied. Larvae of chironomids of the genus Chironomus frequently formed aggregations near places of inflow or domestic wastes. In places of significant accumulation of heavy metals in water and ground they were either predominant or remained the only inhabitants of the bottom.

Index Kch for determining water quality on the basis of Chironomid communities has been developed:

$$Kch = \frac{\alpha t + 0.5\alpha ch}{\alpha o}$$

where $\alpha_{ch}$ is $\alpha$ Chironominae, $\alpha_o$ is $\alpha$ Orthocladiinae and Diamesinae, $\alpha_t$ is $\alpha$ Tanypodinae, where $\alpha$ = N+10, where N is relative abundance of individuals of all species of this subfamily expressed as percentage of the total numbers of individuals of all chironomids. Kch index values from 0.136 to 1.08 characterize clean waters, 1.08 - 6.05 moderately polluted waters, 6.05 - 9.0 polluted waters, 9.0 -11.5 dirty waters.

Kch index value in the rivers of Leningrad, Kaliningrad and Moscow regions and in the eastern part of the Gulf of Finland shows a close correlation with the content of dissolved oxygen, ammonium, amount of saprophytes and phosphates, species diversity index ( Balushkina, 1976,1987).

The Yakovlev index (Yakovlev, 1987) is developed based on data for a large number of bodies of water and watercourse of the Kola north, from results of comparative toxicological studies of wastes of industrial enterprises of different profiles (Yakovlev, 1988)

$$St = \frac{\sum(St_i * n_i)}{N},$$

Where $(St_i * n_i)$ is the sum of products of values of saprotoxicity index of separate species by the number of individuals - $n_i$.
N - number of individuals of all indicator species.

This formula reflects diversity and quantitative relationship of certain indicator species. The index of saprotoxicity is equal to 1.0-1.5 in an oligosaprotoxic zone to 1.5-2.5 - in $\beta$- mesosaprotoxic zone, 2.5-3.5 in $\alpha$ - mesosaprotoxic zone, 3.5-4.0 in polysaprotoxic zone.

The table of indicator species totals about 150 species of zooplankton and zoobenthos with quantitative assessment of their indicator valency. The indicator valency of species was established on the one hand on the basis of indicators saprotoxicity (i.e. organic pollution) and on the other hand on the basis of high sensitivity of separate animal species to different toxic substances entering in large amounts with organic toxic substances in regions with developed industry and often impeding usages of systems of saprotoxicity in connection with change in indicator valency of separate species under the influence of toxic substances.

We can apply saprotoxicity index to both bodies of water and watercourses. The index is highly sensitive and is adequate for usage in ecosystems of north-western Russia. It permits characterization of the waterbody from the degree of mixed toxic and organic pollution, which is particularly important under conditions of industrially developed regions.

Each of the four indices mentioned above incorporates quantitative characterization and water quality scale (Fig. 1).

With the increase of pollution values of indices ST, No / Nc and Kch grow, values BI are reduced. Values of a No / Nc index are expressed as percentage, which hampers comparison of results of assessment by index. Therefore we expressed the value of BI index by an inverse value ( 1 / BI ). Values of the index will increase with the increase of pollution from 0.1 to ...1. In this case index BI acquires the same directionality as the other three indices. Different dimensionality of the indices also hampers comparison of their absolute values.

Therefore the parameters ST, Kch and 1 / BI were expressed as percentage of their maximal values (Fig. 2).

The scale of new Integrated Index sums the data of these four indices. A new integrated IP index may be used for determining water quality of ecosystems with mixed pollution - organic and toxic.

We accepted gradations of water quality according to recommendations of Bylinkina and co-authors (Drachev, 1964), i.e. 1st class of waters - very clean, 2nd class - clean, 3-rd class - moderately polluted, 4-th class - polluted, 5-th class - dirty, (Table 1).

It should be emphasized that in this case the conventional division on five classes of waters is accepted only for the purpose of obtaining comparable characteristics. The character of IP scale permits quantitative characterization of continuous changes of water quality brought about by anthropogenic impact.

The application of integrated index can be demonstrated by the example of the system Ladoga - Neva River - Neva Bay - eastern part of the Gulf of Finland.

For the characterization of zoobenthos in the system Ladoga Lake - Neva River - Neva Bay - eastern part of the Gulf of Finland sampling data for 1994 and 1995 and also results of long-term observations in the Neva Bay and the Ladoga Lake were used . In 1994, 1995 we studied two stations on the Ladoga Lake close to Petrokrepost' settlement, the Neva River in its middle part and in the area close to the Tuchkov Bridge (centre of St. Petersburg), mouth areas of tributaries of the Neva River, Tosno River, Izhora, Slavyanka, four stations at the Neva Bay, two stations at the Kopora Bay, eight stations in the eastern part of the Gulf of Finland, one station in the Vyborg Bay, one station in the Luga Bay. Samples of zoobenthos were selected with Petersen bottom grab with sampling area? of 0.025 m2 (two bottom grabs at each station) in the autumn, in the end of September - beginning of October when emergence of insects is over and all groups of benthic animals are present in the body of water. A scheme of stations' location is presented in Fig. 3.

Moreover, data obtained earlier for the rivers of the Leningrad Kaliningrad and Moscow Regions (Methods ..., 1976).

Collection and examination of zoobenthos samples by animal group was conducted by experts from the Institute of Lake Research?, RAS, T.D. Slepukhina, M.A. Barbashova and by an expert from the Zoological

Institute, RAS, A.M. Pavlov. The identification of animals to a species was performed by specialists from the Zoological Institute, RAS, and the Institute of Lake Research? N.P. Finogenova identified oligochaetes, Ya. I. Starobogatov identified molluscs, E.V. Balushkina identified chironomids, T.D. Slepukhina identified amphipods.

Moreover, data on chemistry of water and bottom sediments were used. The data were obtained by specialists from the Institute of Lake Research, RAS, G.T. Frumin, G.F. Raspletina, L.I. Frumin and A.G. Sveshnikov a specialist from State St. Petersburg University.

As the Integrated Index was being developed, it was discussed with my colleagues Prof. A.F. Alimov and N.P. Finogenova.

The first results obtained with the IP were published in a joint work with Prof. A.F. Alimov.

Table 2 contains results of the assessment of water quality by four indices where stations are arranged in the order of increase of sums of Integrated index (IP) and, accordingly, in the order of deterioration of water quality.

The role of each parameter in the assessment of water quality is more clearly demonstrated in Fig. 4.

Table 3 contains results of the assessment of water class by each of the four parameters. As follows from the data obtained cases of a complete discrepancy in the assessment of water quality were extremely rare, e.g. station of Pregolya River - Pr.3. Such discrepancies were caused as a rule by the fact that value of the parameter was close to boundaries of a particular class of waters, the separation into classes being conventional.

In the assessment of water class the greatest coincidence with other indices is shown by Biotic Index (44 cases of coincidence), Balushkina Index showed coincidence in 41 cases, Yakovlev Index showed coincidence in 36 cases; Goodnight-Whitley Index showed minimal coincidence in 28 cases.

Results of the assessment of water quality at stations studied in 1995 are presented in Table 4.

As is seen from Table 5, combining data for two years, water of the highest quality, in 1994 and in 1995 were noted for the Ladoga Lake in the region of Petrokrepost' (stations 112, 114) and in eastern part of the Gulf of Finland (st. 3, 4).

From IP values it is possible to characterize them in general as "moderately polluted ". Waters in the middle part of the Neva River (station 161 (1) ) can be also evaluated " moderately polluted " by three from four parameters used (Table 5). Zoobenthos community in these waters is characterized by lowest portion of oligochaetes, comparatively low values of saprotoxicity indices, low values of Kch indices because of a relatively high portion of clean water orthocladiins among chironomids and a considerable species diversity. The deterioration of water quality is observed slightly further downstream in the area of station 161. Within the limits of St. Petersburg (st. NT - Neva River near the Tuchkov Bridge) waters of the Neva River can be characterized as "polluted". This station differs from the area of Petrokrepost' by an abrupt increase in the portion of oligochaetes and increase of the saprotoxicity index, species diversity of zoobenthic community in that area remains sufficiently high (Table 4, 5).

Waters of tributaries of the Neva River (mouth areas ) of the rivers Mga, Tosno, Izhora and Slavyanka (stations M, T, 172 and S respectively ) are evaluated by the integrated parameter as "polluted", water quality in mouths of the rivers Tosno, Izhora and Slavyanka is similar to the boundary values of "dirty" waters (Table 2).

Waters on all stations of the Neva Bay can be characterized as "polluted" (Table 2, 4). Only separating those areas the evaluation of which coincided according to the data of 1994 and 1995 (IP: 234.98-253.47) we can characterize the regions of ... (st. 9) and st. 14 as the least polluted in the class of "polluted" waters. Species diversity in benthic animal communities was the highest among those studied by us in the Neva Bay in 1994 through 1995.

Analysis of condition of separate parts of the Neva Bay in 1982-83 and 1994 shows significant changes in the structure of benthic communities near Kotlin Island.

In 1982-83 26 species of benthic animals were noted off northern coast of the Kotlin Island. In 1994 only 11 species were noted in that area, the value of the Shannon Index decreased (Table 6).

In 1994 such indicators of polluted waters as Isochaetides newaensis were not observed near the Kotlin Island, indicators of dirty waters Limnodrilus hoffmeisteri became predominant.

In the 1980's abundant population of Spirosperma ferox inhabiting central and western parts of the Neva Bay and also in mouths of tivers Izhora and Slavyanka included 10 % of individuals with derformities, whereas in 1994 this species was represented by 90% of abnormal forms (Balushkina, Finogenova, Slepukhina, 1996). Individuals with abnormalities of separate morphological structures were noted in 1994 also among chironomid larvae.

The degree of toxicity of waters surrounding the Kotlin Island can be characterized by biological indices as α-meso-, polysaprotoxic (St) and as a whole (IP) as polluted and dirty, (Table 7).

Waters in the eastern part of the Gulf of Finland on the stations 19, 20, 21, 24, and 26 are characterized in general by data for two years by values of the IP index as "polluted". Of these station 19 is subject to pollution to the least degree; its IP index value is 231.95-256.31. The Species Diversity Index at stations of the eastern part of the Gulf of Finland (20, 21, 24, and 26) is much lower than at the studied areas of the Ladoga lake and Neva Bay. Moreover, these stations show higher values of saprotoxicity indices (Table 2, 4).

The studied parts of the Kapora Bay (St. 3k) are characterized as "polluted" and "dirty" (St. 6k). In spite of the great differences in the animal community in the Kopora Bay according to the data for two years, values of water quality obtained as result of evaluation from its structure coincided completely. The area of station 6k is characterized by extremely low species diversity and high values of saprotoxicity indices (Table 2, 4).

Water condition in the studied area of the Luga Bay (St. 61) is evaluated according to IP as "polluted".

Comparing the evaluation of water quality at the same stations in 1994 and 1995 we can note good agreement of values of the integrated parameter, in spite of considerable aggregation in the distribution of zoobenthos in the investigated areas (Fig. 5). Indices of species diversity at the stations investigated 1994 and 1995 showed the tendency towards decrease as the degree of water pollution increased (Fig. 6).

In comparison with the Neva Bay habitation conditions of animals in the eastern part of the Gulf of Finland are most unfavourable. Water salinity of 5-7% observed there has a negative impact both freshwater and brackish water organisms (Khlebovich, 1974). This impact is aggravated by abrupt salinity fluctuations occurring at irregular intervals. Oxygen deficit has been noted for many years in the lower parts of the relief where heavier salt waters are accumulated (Shishkin and others, 1989).

The eastern part of the Gulf of Finland can be divided conventionally into a shallow, resort zone (st. 19, 20, 21, 26) and a deep water zone (st. 61, 6k, 3k, 1, 2, 3, 4).

In the shallow zone abundance, biomass and diversity of species is much higher than in the deep water zone. The fauna is most diverse off the northern coast. More than 20 species and forms of invertebrates inhabit in that area. Their abundance in 1995 attained 19580 specimens per m2. As would be expected, the number of species inhabiting there is much lower as compared to the Neva Bay (Balushkina,Finogenova, Slepukhina, 1996). Oligochaetes are predominant in our collections from the shallow zone in numbers and biomass; chironomid larvae sometimes have an important role.

At these stations zoobenthos consisted of freshwater species. Abundant species are: Tubifex ignotus (Stolc), Spirosperma ferox Eisen, Cladotanytarsuys mancus (Walker), Chironomus plumosus L., Limodrilus hoffmeisteri Clap., Potamothrix moldaviensis Vejdovsky.

The number brackish and marine species penetrating the bay increases westwards and with the increase of depth. At st. 24 (depth 20 m) brackish water Paranais frici Hrabe becomes predominant and marine oligochaete species Paranais litoralis (Muller).

Our data for 1994-1995 indicate further impoverishment of bottom population. At st. 1, 2, 3 (depth 26-50 m) total biomass of benthos was very low, varying from 0.126 per m2 to 2.74 g per m2. Only Saduria (=Mesidotea ) entomon ( L. ) was noted besides oligochaetes, spherids and amphipods. Apparently zoobenthos differs in its structure from impoverished biocenoses of the shallow zone by predominance of marine and brackish water species Macoma balthica L., Marionina argentea ( Mich. ), Amphichaeta sannio Kallstenius, Paranais litoralis ( O.F.Muller ) and others (Balushkina,Finogenova, Slepukhina, 1996) .

At st. 4 close to Gogland Island biomasses of benthos are still high (26.389 per m2 ). However besides amphipods constituting 79.9% of abundance and 28 % of biomass of benthos, only oligochaetes Nais elinguis O.F.Muller and tubificids inhabit that area.

Therefore, the Gulf of Finland in the region of st. 1, 3, 4 and the Vyborg Bay differ from other areas studied by higher salinity and, as a result, by total absence of chironomid larvae in bottom fauna. Therefore water quality was assessed there without taking into the Kch index (Table 4). As a whole waters of the Vyborg Bay are evaluated as "dirty", waters near st. 1, which is the closest to the coast as "polluted". Stations 3 and 4 show a considerable decline in the portion of oligochaetes and zoobenthos community and the lowest saprotoxicity indices.

It is possibly not quite correct to assess brackish waters using indices developed for freshwater ecosystems. There is a need to develop special methods for the assessment of the state of brackish waters.

To analyse relations of integrated parameter with chemical charactersitics of water and bottom deposits is rather difficult. Different chemical indices were measured at different time. Reasonably large sets of data are available for a few indices.

As we noted in 1994 concentration of total phosphorus in water increase with the increase of the integrated parameter and this relationship can be described by the equation:

$$\log Ptot = -8.783 + 3.249 \log IP, \; r = 0.656, \; P - 0.99, \quad (1),$$

where Ptot is expressed in mgP/l, (Fig. 7).

The increase of concentration of total phosphorus with the increase of the integrated index noted by us in 1994 was observed also in 1995 although in 1994 phosphorus concentration in the zone of "polluted waters" was on the average considerably above that of 1995 (Fig. 8).

One can see in Fig. 9 that BOD5 values also increase with an increase of integral parameter. This relationship can be described by an equation of linear regression:

$$\log BOD5 = -0.814 + 0.528 \log IP, \; r= 0.510, \; P - 0.99, \; (2),$$

where BOD5 is expressed in mg O per l.

There is a clearly defined relationship between the integrated index (Fig. 10), which is suggested by a higher correlation coefficient:

$$\log NH4 = -5.628 + 2.358 \log IP, \; r = 0.627, \; P - 0.99, \quad (3),$$

where NH4 is expressed in mg of N per litre.

As can be seen in Fig.11 and 12, heavy metal concentration in water and bottom deposits increased with increases with the increase of the values of integrated parameter.

The level of abundance and biomass of benthic animals in the system Ladoga - Neva - Neva Bay increases with the increase of water pollution (Fig. 13, 14). It has been shown before, however, that an increase in the numbers of animals occurs only up to the boundaries of the class of "dirty" waters. In the class of "dirty" waters abundance of benthic animals declines apparently because of the critical increase of the degree of toxic and organic pollution. At the same time the level of quantitative development of benthic animals to a large extent depends on total phosphorus concentration in water (Fig. 15, 16).

The growing impact of human activity on aquatic ecosystems is accompanied by changes and disturbances in biocenoses that were formed as a result of evolution, decrease of species diversity, decrease of the ecosystems ability of self-purification. As a result their gradual degradation occurs.

Benthic animal communities accumulating information about their habitat conditions (chemical characteristics of water and bottom) respond to the changes of its quality by rearrangements in the structure and change of qualitative development. Species composition and structure of benthic communities reflect the state of the ecosystem for a relatively long period characterizing its regime. Concentrations of chemical elements normally used for the assessment of water quality may be related to episodical waste discharge and characterize the state of a particular body of water at the given moment.

The relationship of predominant groups of animals, species composition of the saprotoxicity indicators, structure of chironomid community as a whole forming the basis of IP gave a relatively accurate account of the state of the ecosystem in spite of the notable variation in biomass, species diversity of benthic animals in different years.

Similar results obtained at the same stations in different years permit us to conclude that water quality assessment can be performed on the basis of one-time field sampling in late September - early October.

The Integrated index (IP) is related to many chemical characteristics of water and bottom deposits. The relationships shown belong to weak, but significant correlations because the separate indices incorporated into the IP are related in different ways to chemical characteristics of water and bottom deposits. For this particular reason the evaluation of the state of ecosystems from the IP (unlike the separate indices incorporate into it) reflects the relations of integrated characterization of benthic communities and the totality of biotic and abiotic characteristics of the ecosystem. In the future investigations the relationships obtained may become the basis for the assessment of condition of aquatic ecosystems and ecological normalization of anthropogenic impact.

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1) BI

10--------------------------------------------------------0

---- encrease of pollution ------------->

2) Kch

0.14-----------1.08------------6.5-------------9---------11.5

clean　moderately polluted　polluted　dirty

3) No/Nc

0--------------60--------------------------------80---------100

clean　doubtful clean　dirty

4) St

1--------------1,5-------------2,5-------------3,5----------4

oligosaprotoxic　$\beta$-mesosaprotoxic　$\alpha$-mesosaprotoxic　polysaprotoxic

Fig.1. Scales of evaluation of condition of waters by indexes: 1) Trent Biotic Index (Woodiwiss, 1964), 2) Index Kch (Balushkina, 1976), 3) Goodnigth and Whitley's index (Goodnigth, Whitley 1964), 4) Saprotoxic index (Jakovlev, 1987).

1) BI

10---------------20------------33.3-------------50---------100

clean | moderately polluted | polluted | dirty

2) Kch

1.22------------9.4------------56.5----------78.26---------100

clean | moderately polluted | polluted | dirty

3) No/Nc

0--------------50------------60----------------80----------100

clean | moderately polluted | polluted | dirty

4) St

25-------------37.5----------62,5-------------87,5--------100

clean | moderately polluted | polluted | dirty

Fig. 2. Scales of evaluation of quality of waters by indexes: 1) Trent Biotic Index (Woodiwiss, 1964), 2) Index Kch (Balushkina, 1976), 3) Goodnigth and Whitley's index (Goodnigth, Whitley 1964), 4) Saprotoxic index (Jakovlev, 1987)BI in a modified form.

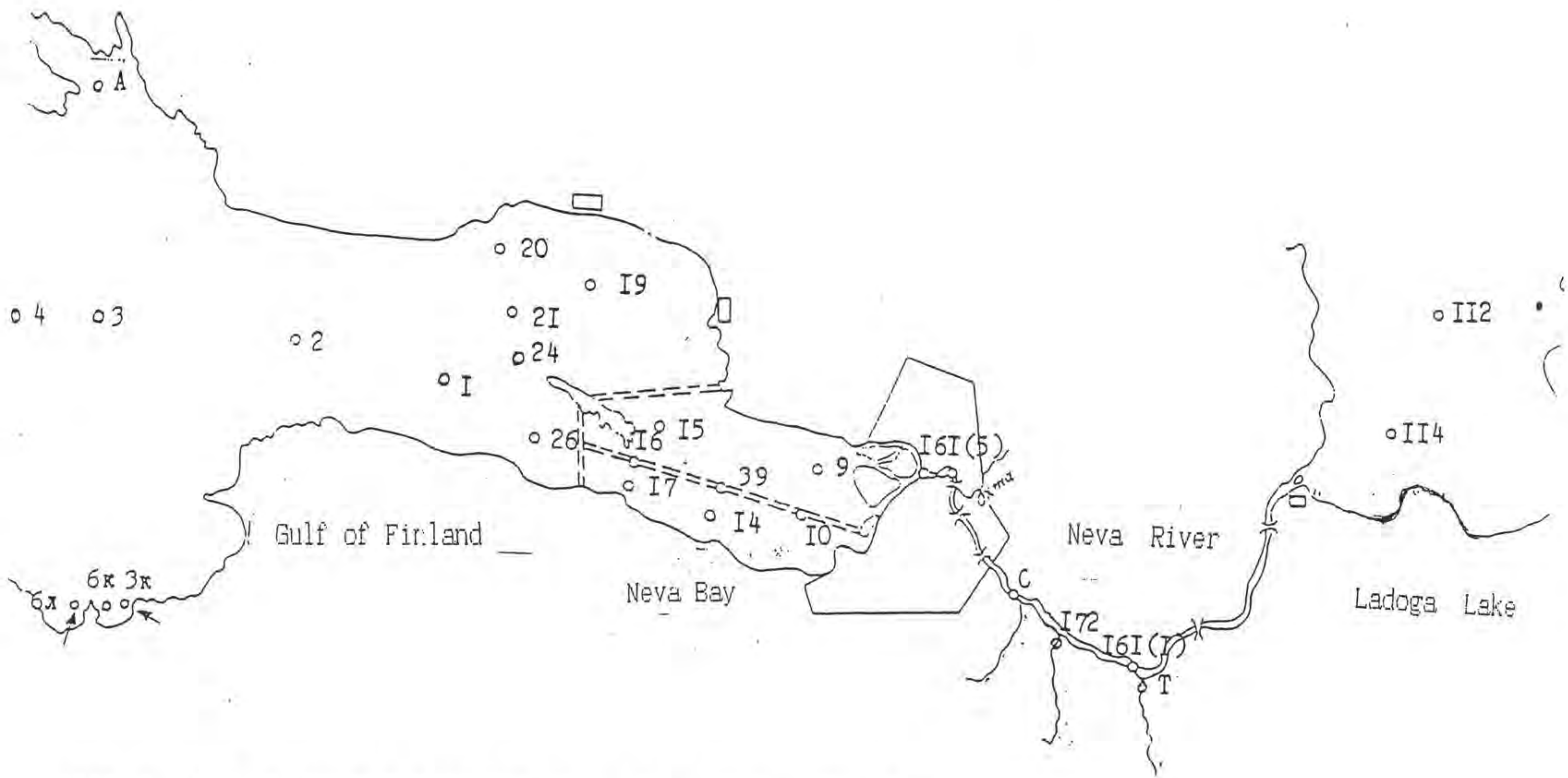



Fig. 3. Map of the system Ladoga lake - Neva River - Neva Bay - eastern part of the Gulf of Finland and the sampling stations .

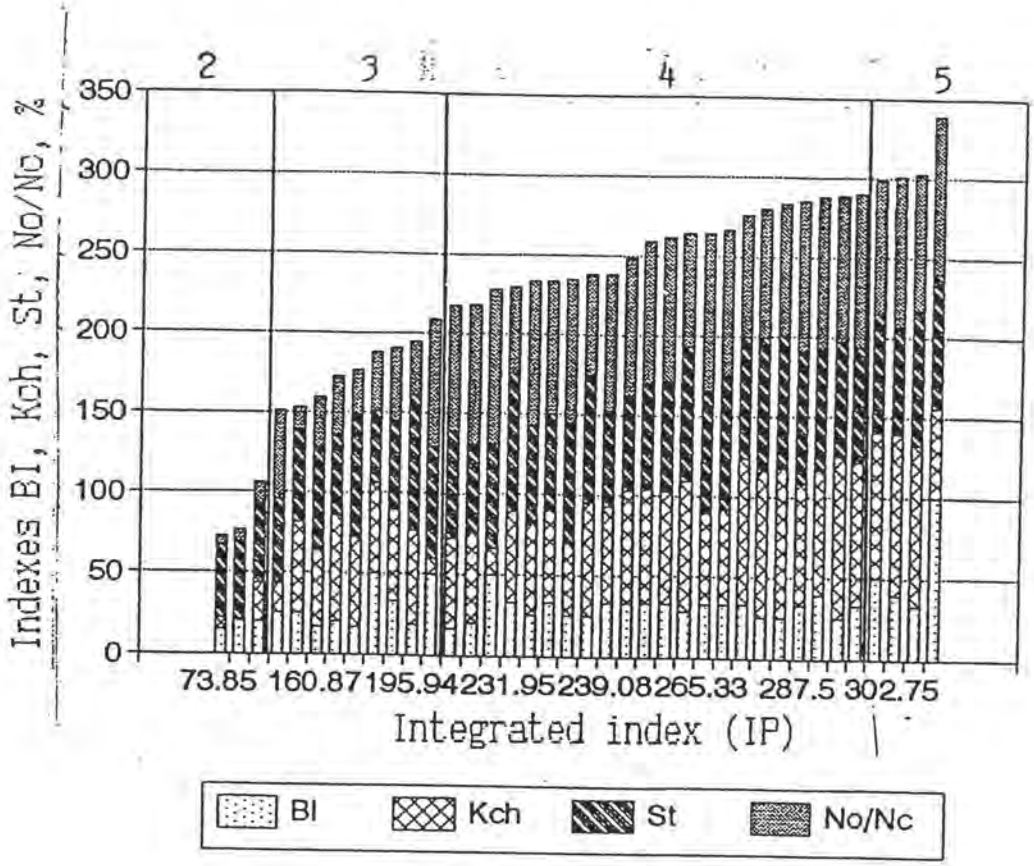



Fig.4. Evaluation of water quality by indexes BI, Kch, St, No/Nc.

X axis -- evaluation of water quality at the stations (label): Mo1, Izh1, Pi1, 112, 114, In1, Pr4, Mo2, Mo6, La1, Lu1 r. c., Vu3, Pr1, Pr3, Nt,19, Lu1 l.c., 9, 15, M, Pr2, Pr5, 16, 14, Izh3, 39, 20, Izh4, 3, T, 17, Mo4, 172, S, Mo5, Mo3, 6, 26. Mo1-Mo6 - Moccwa River, Iz1-Iz4 - Izhora River, Pr1-Pr5 - Pregolya River, In1 - Instruch River, Pi1 - Pissa River, La1 - Lava River, Lu1 r.c. - Luga River (rigth coast), Lu1 l.c. - Luga River (left coast), Vu3 - Vuoksa River, 112,114 - station on the Ladoga Lake close to Petrokrepost' settlement, NT - Neva River in the area close to the Tuchkov Bridge (centre of St. Petersburg), mouth areas of tributaries of the Neva River, T - Tosno River, Iz - Izhora River, S - Slavyanka, 172 - mouth of Izhora River, 14, 15, 16, 17 - stations at the Neva Bay, 3k, 6k - stations at the Kopora Bay, 19,20,26 - stations in the eastern part of the Gulf of Finland.

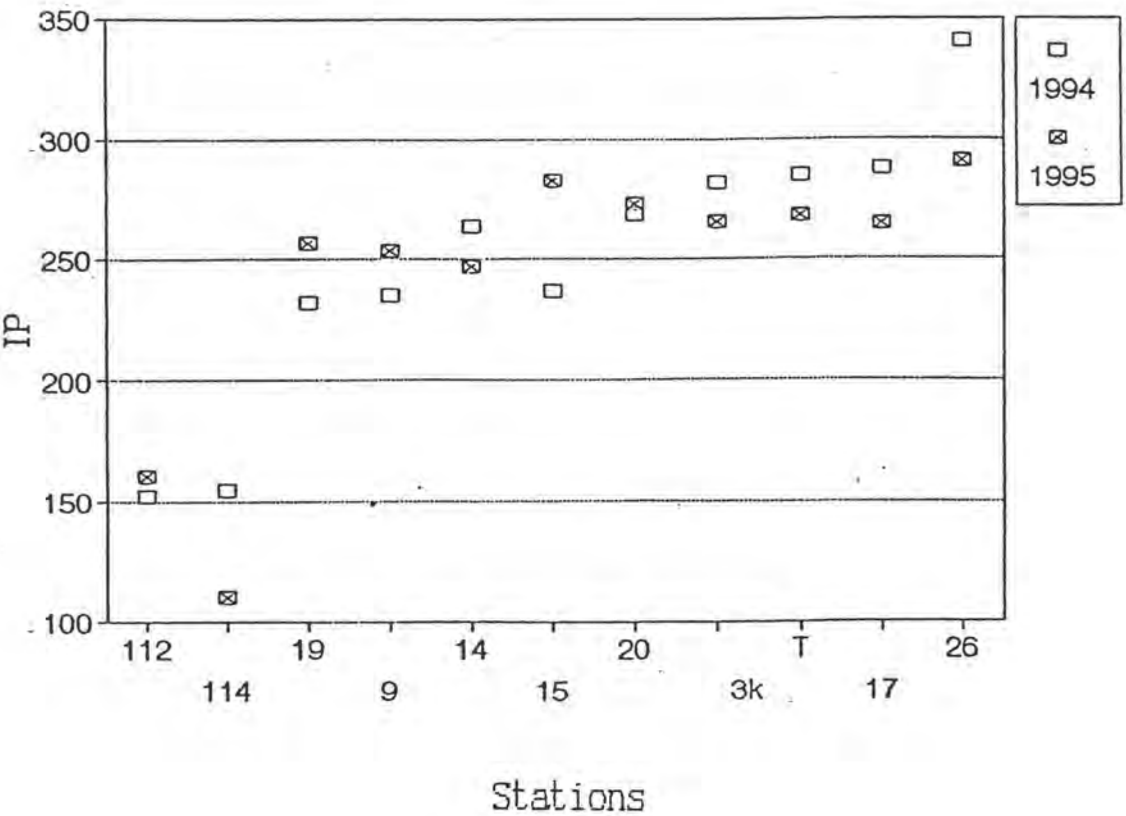



Fig.5. Evaluation of water quality by Integrated index ( IP ) in 1994, 1995.

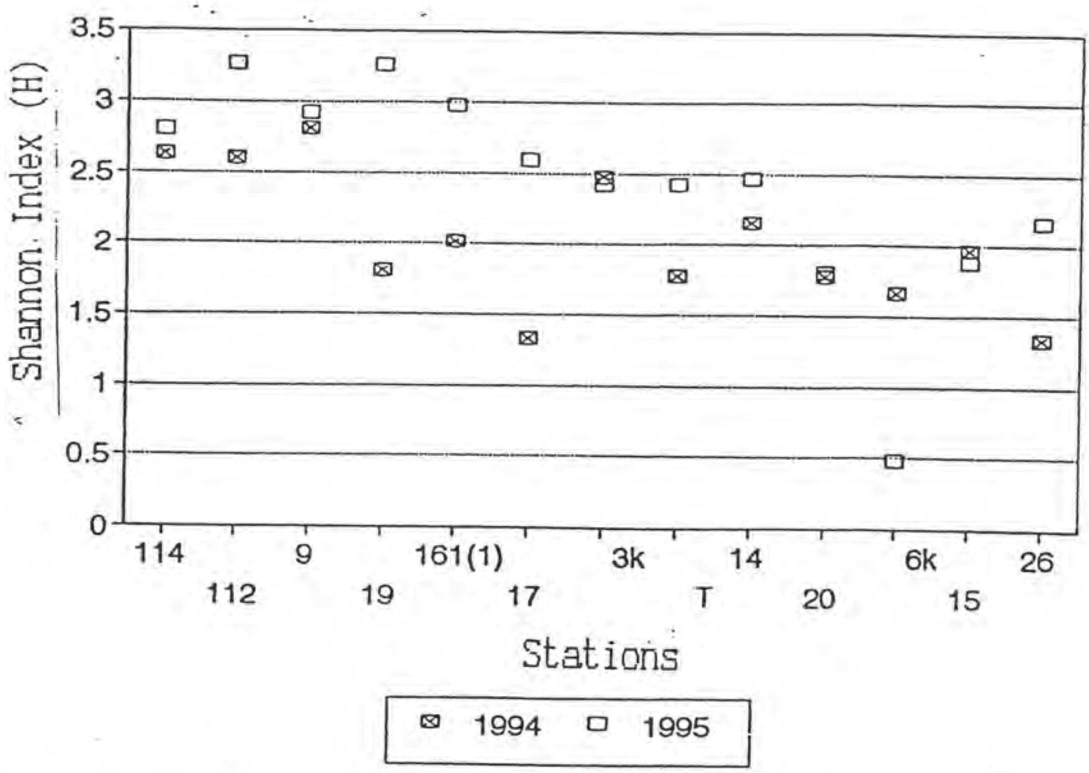



Fig.6. Values of the Shannon Index 1994, 1995. (species diversity) (H) in 1994, 1995.

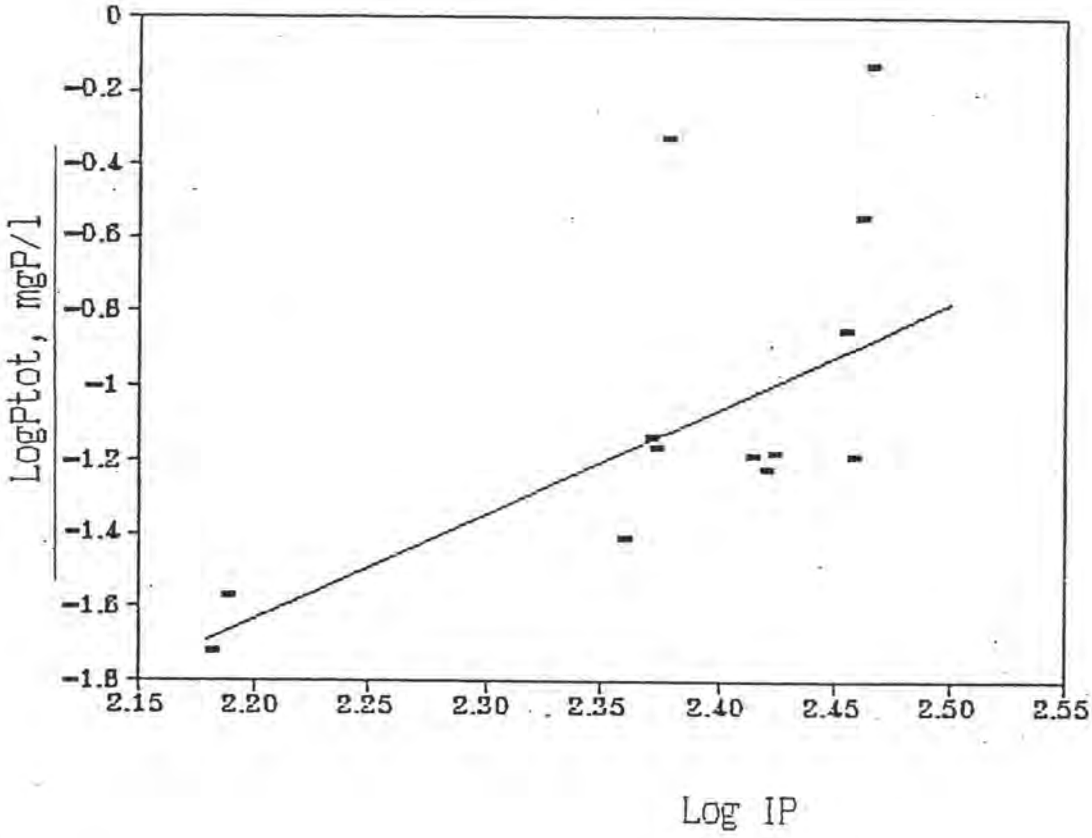



Fig.7. Relationship between the total phosphorus concentration ( log Ptot ) and value of Integrated index ( log IP ).

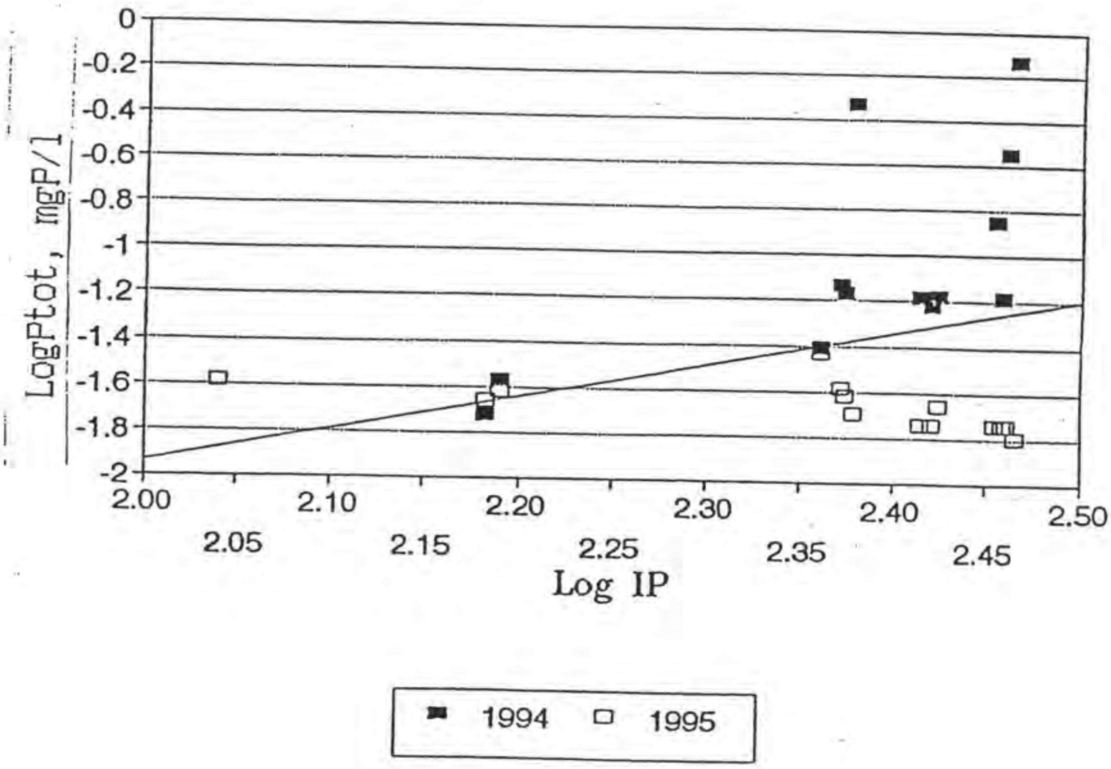



Fig.8. Relationship between the total phosphorus concentration ( Ptot ) and value of Integrated index ( log IP ) in 1994, 1995.

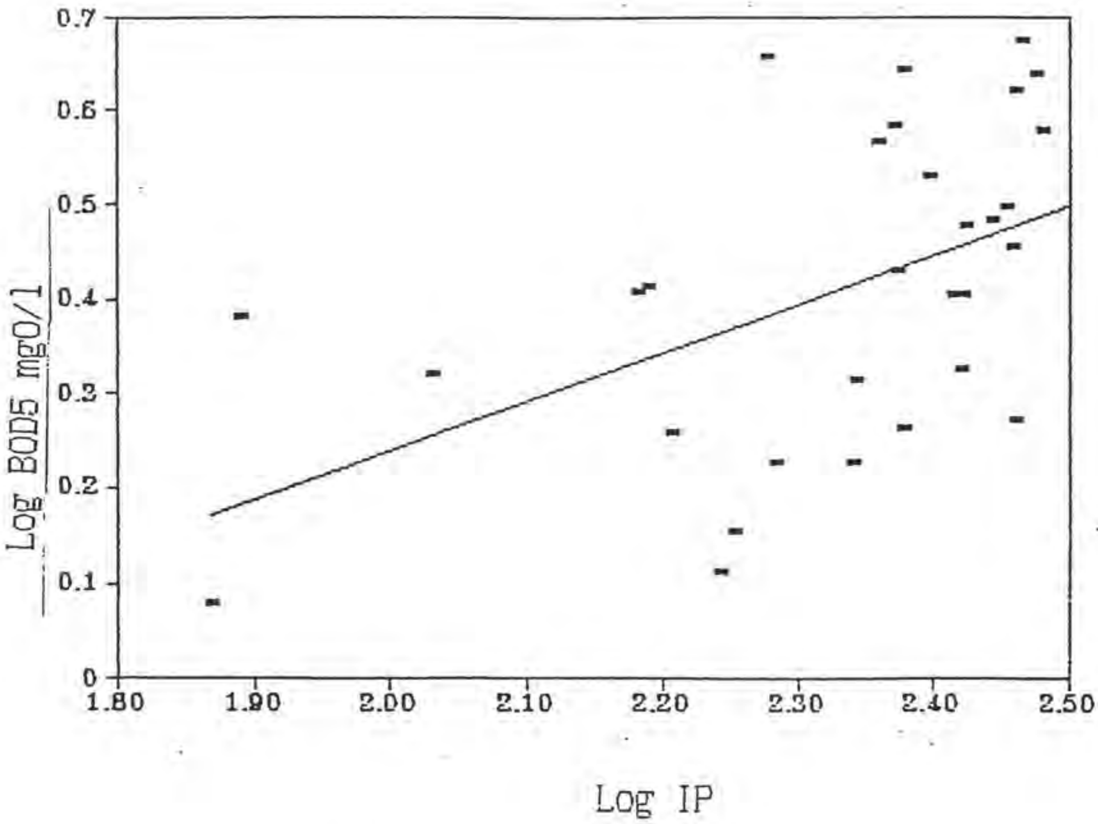



Fig.9. Relationship between BOD5 ( log BOD5 ) and value of Integrated index ( log IP ).

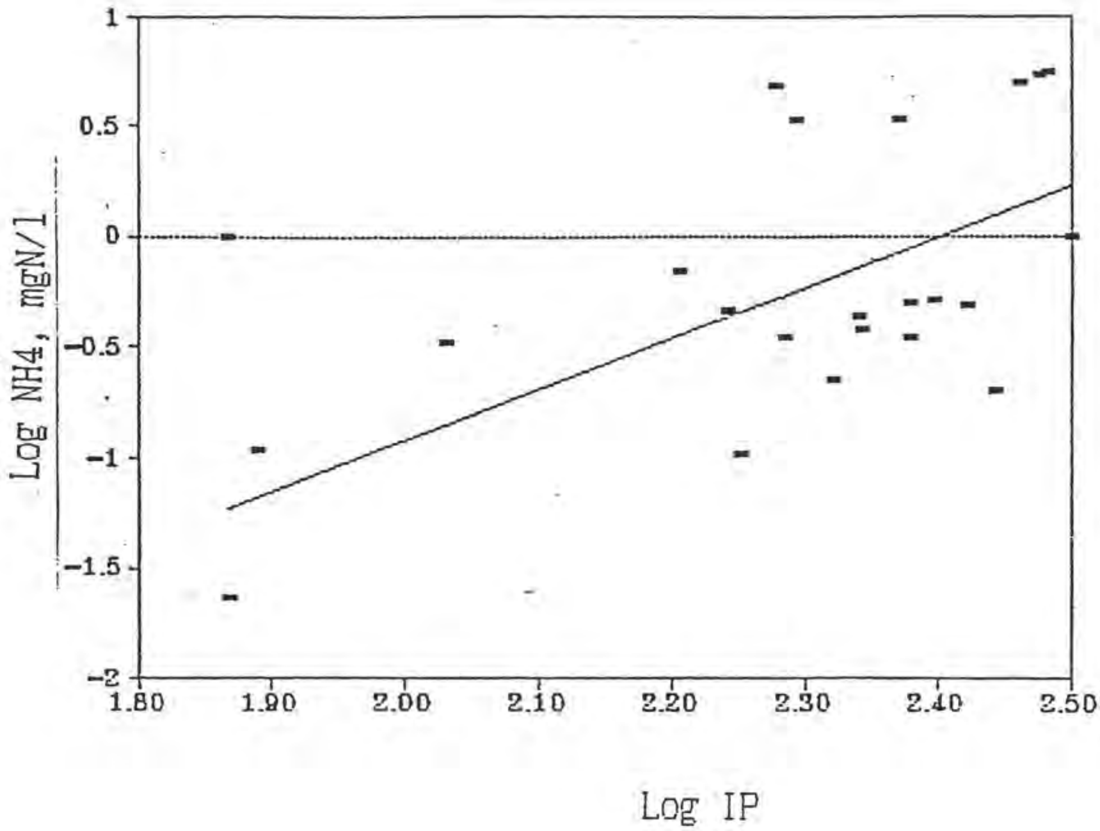
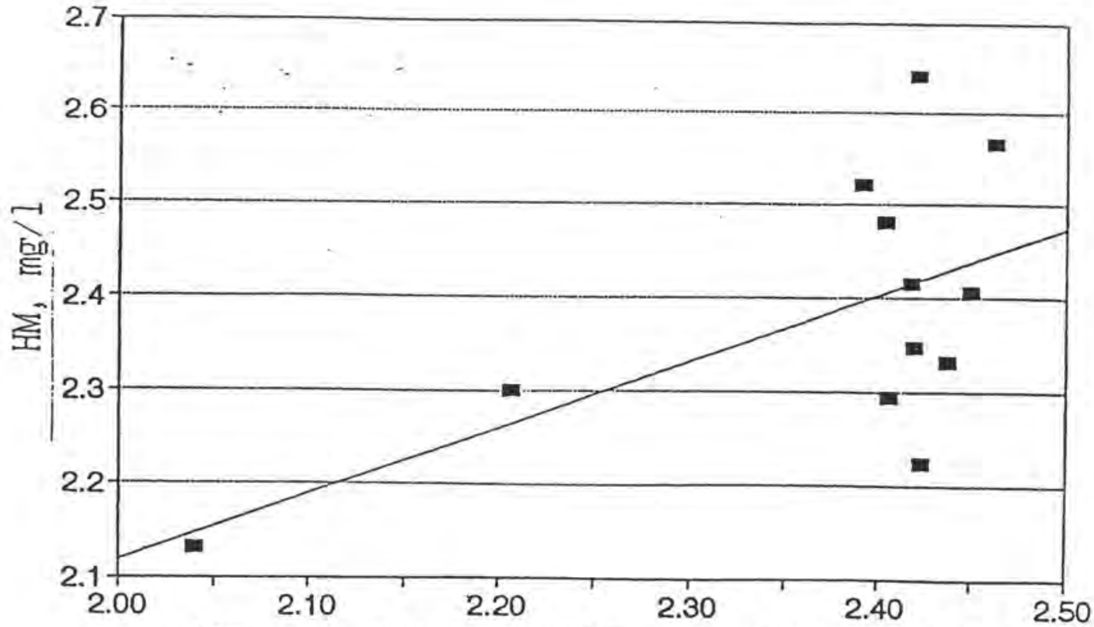



Fig.10.Relationship between concentration of ammonia (log NH4) and value of Integrated index ( log IP ).



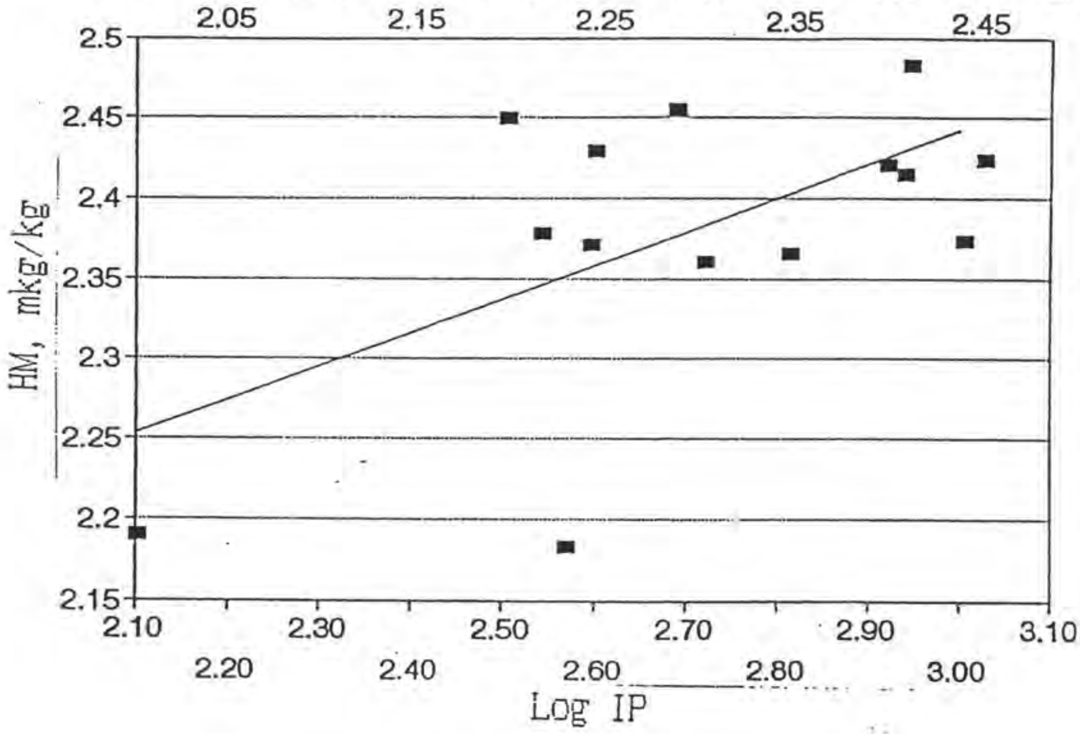
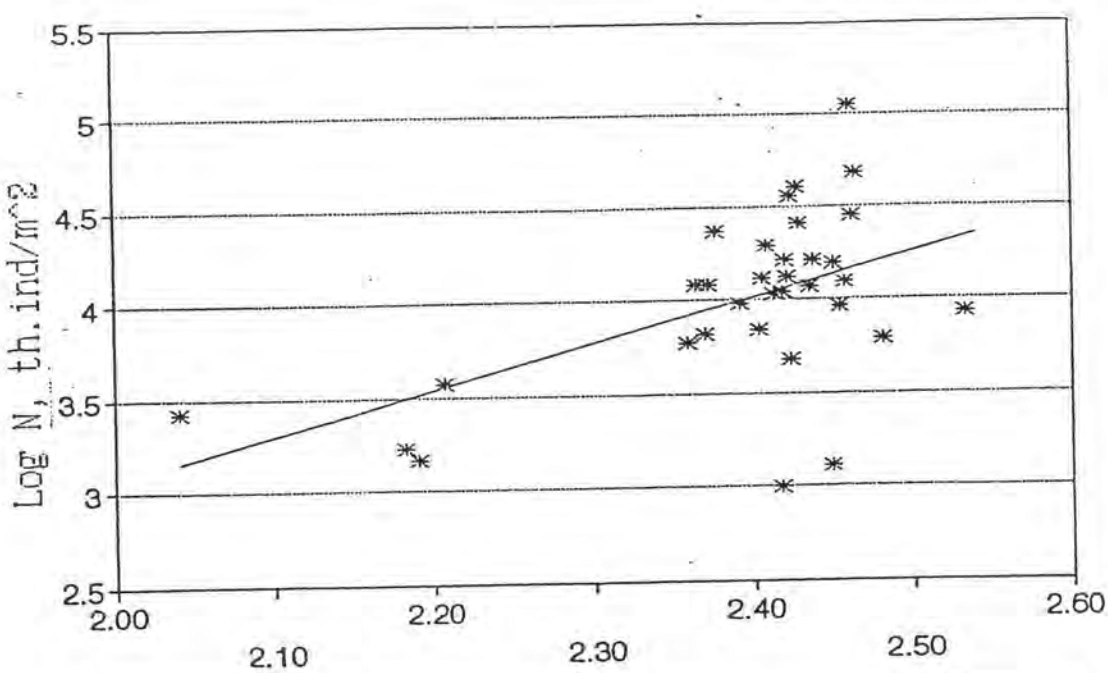




Fig.11. Relationship between concentration of heavy metals (HM) in a water and value of Integrated index (log IP).

Fig.12. Relationship between concentration of heavy metals in bottom sediments from value of Integrated index (log IP).



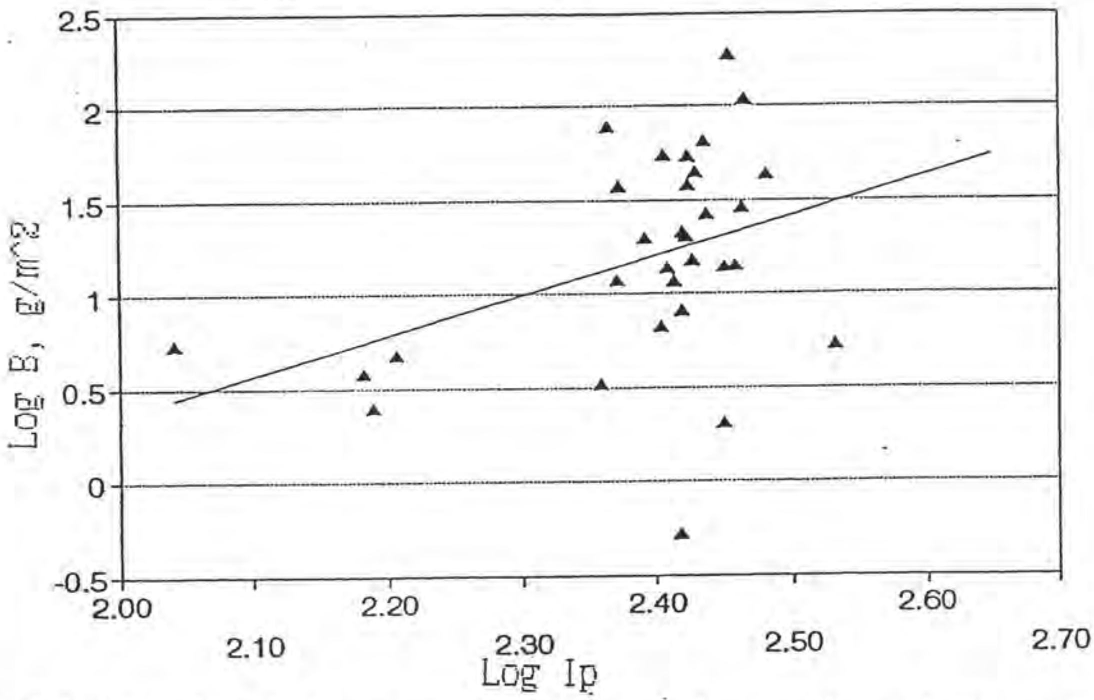
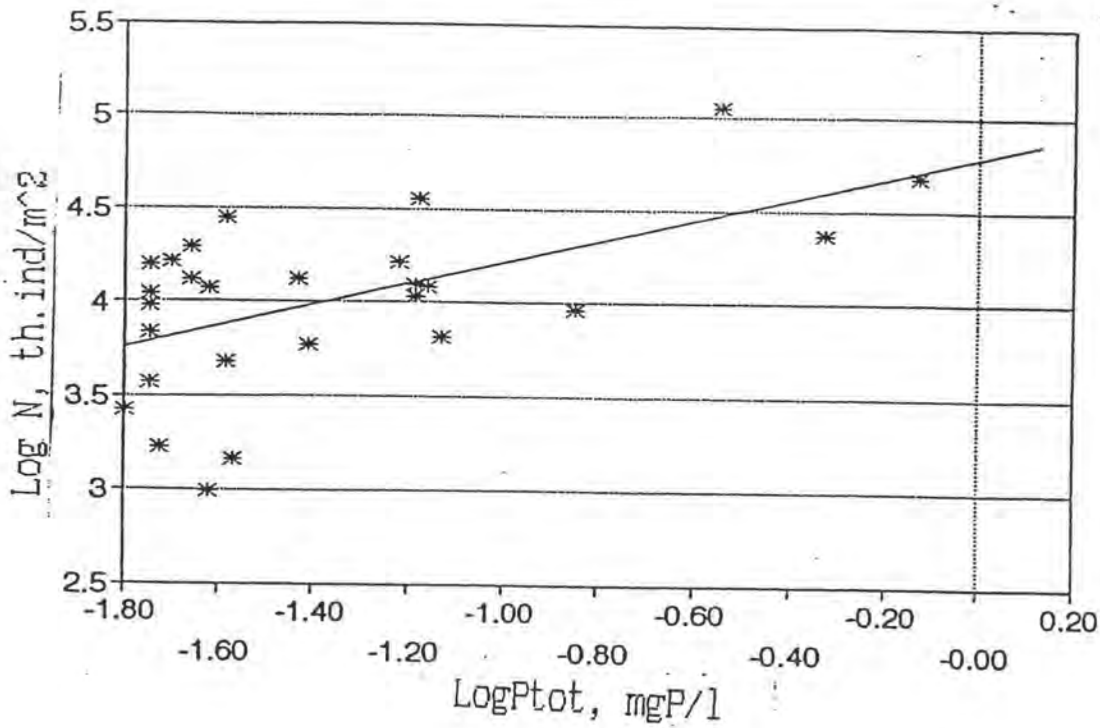




Fig.13. Relationship between zoobenthos numbers (N) and IP value of Integrated index (log IP).

Fig.14. Relationship between biomass of zoobenthos (B) and value of Integrated index (log IP).



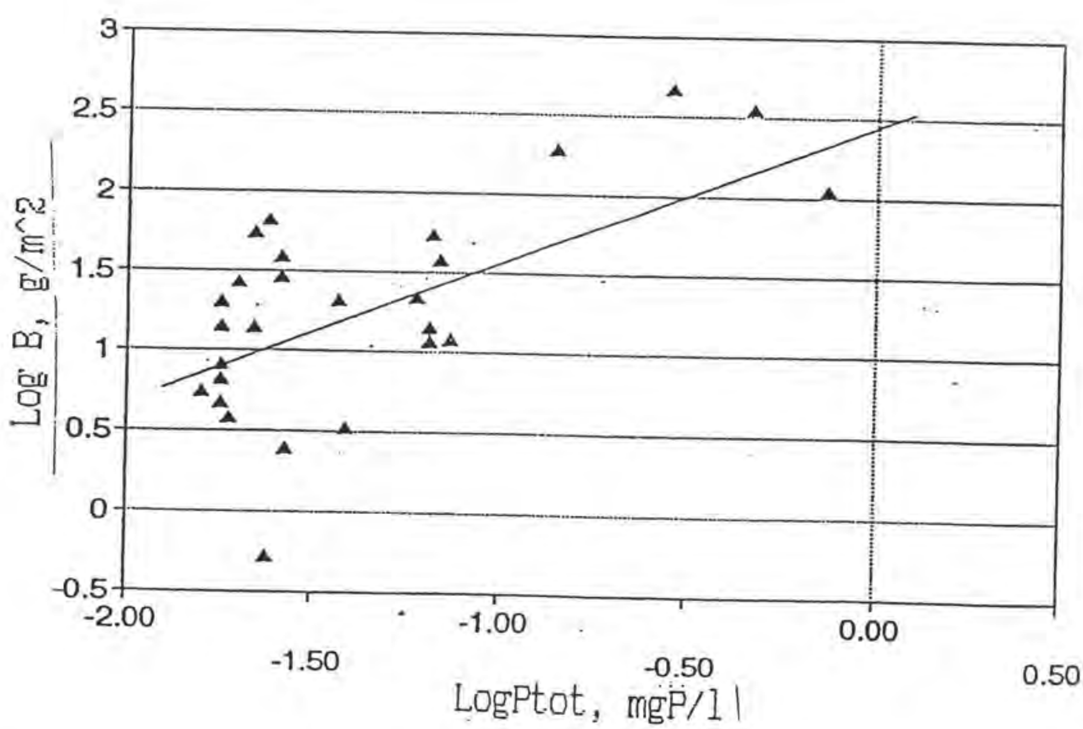




Fig.15. Relationship between zoobenthos numbers (N) and total phosphorus concentration ( Ptot ).

Fig.16. Relationship between zoobenthos biomass and total phosphorus concentration (Ptot).

Table 1

Classes of water quality by zoobenthos indices St, No/Nc, Kch, BI and integrated IP index

| St | No/Nc | Kch | BI | IP | Classes of waters |
|---|---|---|---|---|---|
| | | | | | very clean |
| 25 | 0 | 1.22 | 10 | 36.22 | |
| | | | | | clean |
| 37.5 | 50 | 9.4 | 20 | 116.9 | |
| | | | | | moderately polluted |
| 62.5 | 60 | 56.5 | 33 | 212 | |
| | | | | | polluted |
| 87.5 | 80 | 78.26 | 50 | 295.76 | |
| | | | | | dirty |
| 100 | 100 | 100 | 100 | 400 | |

Table 2

Values of indices BI, St, Kch, No/Nc, IP and the assessment of water quality at different stations (data for 1994).

| Sta-tions | BI | Kch | St | No/Nc | IP | Classes of water |
|---|---|---|---|---|---|---|
| | in percent of maximum value | | | | | |
| Mo1 | 14.29 | 7.56 | 46.125 | 5.87 | 73.85 | Clean |
| Iz1 | 20 | 1.91 | 47.75 | 8 | 77.66 | -"- |
| Pi1 | 20 | 24.35 | 49.5 | 13.5 | 107.35 | -"- |
| 112 | 25 | 17.91 | 53.25 | 56 | 152.16 | Moderately |
| 114 | 25 | 56.52 | 59.5 | 13.7 | 154.72 | polluted |
| In1 | 16.67 | 46.96 | 65.25 | 32 | 160.87 | -"- |
| Pr4 | 20 | 66.09 | 50.75 | 37.5 | 174.34 | -"- |
| Mo2 | 16.67 | 56.52 | 76.5 | 29 | 178.69 | -"- |
| Mo6 | 50 | 56.52 | 45 | 37.8 | 189.32 | -"- |
| La1 | 33.33 | 56.52 | 56 | 46.5 | 192.36 | -"- |
| Lu1r.c. | 18.18 | 58.26 | 85.5 | 34 | 195.94 | -"- |
| Vu3 | 50 | 9.83 | 70 | 80 | 209.83 | -"- |
| Pr1 | 16.67 | 56.52 | 66.75 | 79 | 218.94 | Polluted |
| Pr3 | 20 | 56.52 | 55.75 | 88 | 220.27 | -"- |
| NT | 50 | 16.61 | 64.42 | 98 | 229.03 | -"- |
| 19 | 33.33 | 56.52 | 87.1 | 55 | 231.95 | -"- |
| Lu1l.c. | 25 | 56.52 | 61.25 | 91.8 | 234.57 | -"- |
| 9 | 33.33 | 56.52 | 61.12 | 84 | 234.98 | -"- |
| 15 | 25 | 45.22 | 75.65 | 90.5 | 236.36 | -"- |
| M | 25 | 70.78 | 79.25 | 63.8 | 238.8 | -"- |
| Pr2 | 33.33 | 60 | 59.75 | 86 | 239.08 | -"- |
| Pr5 | 33.33 | 69.56 | 60.5 | 86 | 249.4 | -"- |
| 16 | 33.33 | 70.43 | 66.4 | 89.4 | 259.56 | -"- |
| 14 | 33.33 | 69.74 | 69.68 | 90.5 | 263.25 | -"- |
| Iz3 | 28.57 | 80.52 | 84.25 | 70.95 | 264.29 | -"- |
| 39 | 33.33 | 56.52 | 76.78 | 98.7 | 265.33 | -"- |
| 20 | 33.33 | 58.43 | 83.95 | 92.9 | 268.62 | -"- |
| Iz4 | 33.33 | 91.3 | 76.5 | 76.53 | 277.67 | -"- |
| 3k | 25 | 91.3 | 83.85 | 81.2 | 281.35 | -"- |
| T | 25 | 93.82 | 82.75 | 83.4 | 284.97 | -"- |
| 17 | 33.33 | 75.83 | 83.35 | 95 | 287.5 | -"- |
| Mo4 | 40 | 77.39 | 76.5 | 95.5 | 289.39 | -"- |
| 172 | 25 | 100 | 72.8 | 91.7 | 289.5 | -"- |
| S | 33.33 | 88.61 | 73.68 | 96.6 | 292.22 | -"- |
| Mo5 | 50 | 90.43 | 74.625 | 84 | 299.06 | Dirty |
| Mo3 | 40 | 100 | 68.25 | 94.5 | 302.75 | -"- |
| 6k | 33.33 | 100 | 84.28 | 86 | 303.61 | -"- |
| 26 | 100 | 56.52 | 84.78 | 99.5 | 340.8 | -"- |

Mo1-Mo6 - Moskva River, Iz1-Iz4 - Izhora River, Pr1-Pr5 - Pregolya River, In1 - Instruch River, Pi1 - Pissa River, La1 - Lava River, Lu1 r.c. - Luga River (right coast), Lu1 l.c. - Luga River (left coast), Vu3 - Vuoksa River, 112,114 - station on the Ladoga Lake close to Petrokrepost' settlement, NT - Neva River in the area close to the Tuchkov Bridge (centre of St. Petersburg), mouth areas of tributaries of the Neva River, T - Tosno River, Iz - Izhora River, S - Slavyanka River, 172 - mouth of Izhora River, 14, 15, 16, 17 - stations at the Neva Bay, 3k, 6k - stations at the Kopora Bay, 19,20,26 - stations in the eastern part of the Gulf of Finland.

Classes of water quality by zoobenthos indices St, No/Nc, Kch, BI and integrated index (IP) in different stations

| Stations | BI | Kch | St | No/Nc | IP | Classes of water |
|---|---|---|---|---|---|---|
| | in percent of maximum value | | | | | |
| Mo1 | 2 | 2 | 3 | 2 | 2 | Clean |
| Iz1 | 2 | 2 | 2 | 2 | 2 | -"- |
| Pi1 | 2 | 3 | 3 | 2 | 2 | -"- |
| 112 | 3 | 3 | 3 | 3 | 3 | Moderately |
| 114 | 3 | 4 | 3 | 2 | 3 | polluted |
| In1 | 2 | 3 | 4 | 2 | 3 | -"- |
| Pr4 | 2 | 4 | 3 | 2 | 3 | -"- |
| Mo2 | 2 | 4 | 4 | 2 | 3 | -"- |
| Mo6 | 4 | 4 | 3 | 2 | 3 | -"- |
| La1 | 4 | 4 | 3 | 3 | 3 | -"- |
| Lu1rc | 2 | 4 | 4 | 2 | 3 | -"- |
| Vu3 | 4 | 3 | 4 | 4 | 3 | -"- |
| Pr1 | 2 | 4 | 4 | 3 | 4 | Polluted |
| Pr3 | 2 | 4 | 3 | 5 | 4 | -"- |
| NT | 4 | 3 | 4 | 5 | 4 | -"- |
| 19 | 4 | 4 | 4 | 3 | 4 | -"- |
| Lu1lc | 3 | 4 | 3 | 5 | 4 | -"- |
| 9 | 4 | 4 | 3 | 5 | 4 | -"- |
| 15 | 3 | 3 | 4 | 5 | 4 | -"- |
| M | 3 | 4 | 4 | 4 | 4 | -"- |
| Pr2 | 4 | 4 | 3 | 5 | 4 | -"- |
| Pr5 | 4 | 4 | 3 | 5 | 4 | -"- |
| 16 | 4 | 4 | 4 | 5 | 4 | -"- |
| 14 | 4 | 4 | 4 | 5 | 4 | -"- |
| Iz3 | 3 | 5 | 4 | 4 | 4 | -"- |
| 39 | 4 | 4 | 4 | 5 | 4 | -"- |
| 20 | 4 | 4 | 4 | 5 | 4 | -"- |
| Iz4 | 4 | 5 | 4 | 4 | 4 | -"- |
| 3k | 3 | 5 | 4 | 5 | 4 | -"- |
| T | 3 | 5 | 4 | 5 | 4 | -"- |
| 17 | 4 | 4 | 4 | 5 | 4 | -"- |
| Mo4 | 4 | 4 | 4 | 5 | 4 | -"- |
| 172 | 3 | 5 | 4 | 5 | 4 | -"- |
| S | 4 | 5 | 4 | 5 | 4 | -"- |
| Mo5 | 4 | 5 | 4 | 5 | 5 | Dirty |
| Mo3 | 4 | 5 | 4 | 5 | 5 | -"- |
| 6k | 4 | 5 | 4 | 5 | 5 | -"- |
| 26 | 5 | 4 | 4 | 5 | 5 | -"- |

Table 4

Values of indices BI, St, Kch, No/Nc, IP and the assessment of water quality at different stations (data for 1995).

| Sta-tions | BI | Kch | St | No/Nc | IP | Classes of water |
|---|---|---|---|---|---|---|
| | in percent of maximum value | | | | | |
| 114 | 20 | 2.78 | 47.5 | 39.39 | 109.67 | Clean |
| 112 | 20 | 8.26 | 67 | 65.59 | 160.85 | M. polluted |
| 14 | 33.33 | 69.83 | 75 | 68.62 | 246.78 | Polluted |
| 9 | 33.33 | 56.52 | 75.25 | 88.37 | 253.47 | -"- |
| 21 | 33.33 | 56.52 | 85.25 | 79.91 | 255.01 | -"- |
| 19 | 33.33 | 81.7 | 75.5 | 65.78 | 256.31 | -"- |
| 6L | 50 | 59.04 | 87.5 | 65.31 | 261.85 | -"- |
| 161 | 33.33 | 60.14 | 79 | 90.35 | 262.82 | -"- |
| 17 | 33.33 | 74.52 | 81.75 | 74.58 | 264.18 | -"- |
| 3k | 50 | 56.52 | 76 | 82.77 | 265.29 | -"- |
| T | 33.33 | 59.63 | 79.25 | 95.5 | 267.71 | -"- |
| 20 | 50 | 56.52 | 86 | 80.38 | 272.9 | -"- |
| 24 | 33.33 | 56.52 | 85.25 | 99.02 | 274.12 | -"- |
| 15 | 50 | 56.52 | 80.5 | 95.26 | 282.28 | -"- |
| 26 | 50 | 70.31 | 84.5 | 85.49 | 290.3 | -"- |
| 4 | 25 | | 40.25 | 1.49 | 66.74 | Clean |
| 3 | 25 | | 40 | 25 | 90 | -"- |
| 1 | 25 | | 85 | 69.56 | 179.56 | Polluted |
| 6k | 20 | | 85 | 100 | 205 | Dirty |
| Vyb. B. | 50 | | 85 | 100 | 235 | -"- |

112,114 - station on the Ladoga Lake close to Petrokrepost' settlement, 161 - Neva River in its middle part, NT - Neva River in the area close to the Tuchkov Bridge (centre of St. Petersburg); mouth areas of tributaries of the Neva River: T - Tosno River; 14,15, 17 - stations at the Neva Bay; 3k, 6k - stations at the Kopora Bay; 19,20,21,24,26,1,3,4 - stations in the eastern Gulf of Finland; Vyb. B. - station in the Vyborg Bay; 6L - station in the Luga Bay.

Table 5

The assessment of water quality in the system
Ladoga - Neva - Veva Bay - eastern part of the Gulf of Finland
by the IP integral index.

1994

| Stations | IP | Classes of water |
|---|---|---|
| 112 | 152.16 | Moderately |
| 114 | 154.72 | polluted |
| HT | 229.03 | Polluted |
| 19 | 231.95 | -"- |
| 9 | 234.98 | -"- |
| 15 | 236.36 | -"- |
| M | 238.8 | -"- |
| 16 | 259.56 | -"- |
| 14 | 263.25 | -"- |
| 39 | 265.33 | -"- |
| 20 | 268.62 | -"- |
| 3к | 281.35 | -"- |
| T | 284.97 | -"- |
| 17 | 287.5 | -"- |
| 172 | 289.5 | -"- |
| C | 292.22 | -"- |
| 6к | 303.61 | Dirty |
| 26 | 340.8 | -"- |
| | | |
| 1 | 234.22 | -"- |
| 161(1) | 89.85 | Moderately polluted |

1995

| Stations | IP | Classes of water |
|---|---|---|
| 114 | 109.67 | Clean |
| 112 | 160.85 | M.polluted |
| 14 | 246.78 | Polluted |
| 9 | 253.47 | -"- |
| 21 | 255.01 | -"- |
| 19 | 256.31 | -"- |
| 6л | 261.85 | -"- |
| 161 | 262.82 | -"- |
| 17 | 264.18 | -"- |
| 3к | 265.29 | -"- |
| T | 267.71 | -"- |
| 20 | 272.9 | -"- |
| 24 | 274.12 | -"- |
| 15 | 282.28 | -"- |
| 26 | 290.3 | -"- |
| 4 | 66.74 | Clean |
| 3 | 90 | -"- |
| 1 | 179.56 | Polluted |
| 6к | 205 | Dirty |
| Выб.г. | 235 | -"- |

Table 6

Numbers of benthic animals and the Shannon Index at stations near the Kotlin Island

| Stations | | Numbers ind/sq.м | Shannon Index |
|---|---|---|---|
| 17 | 1982 | 2820 | 2.17 |
| 42 | 1982 | 6423 | 1.94 |
| 42 | 1983 | 2866 | 1.95 |
| 15 | 1983 | 3959 | 2.94 |
| 15 | 1994 | 12060 | 1.95 |
| 16 | 1994 | 10780 | 2.15 |
| 17 | 1994 | 12340 | 1.33 |
| 26 | 1994 | 8500 | 1.33 |

Table 7

Values of indices BI,St,Kch,No/Nc,IP and the assessment of water quality at different stations

| Stations | Years | St | Kch | No/Nc | BI | IP | Classes of water |
|---|---|---|---|---|---|---|---|
| 15 | 1994 | 75.7 | 45.2 | 90.5 | 25 | 236.4 | polluted |
| 42 | 1982 | 57.25 | 88.96 | 87 | 25 | 258.21 | polluted |
| 16 | 1994 | 66.4 | 70.4 | 89.4 | 33.3 | 259.5 | polluted |
| 17 | 1982 | 63.5 | 100 | 82.27 | 20 | 265.77 | polluted |
| 15 | 1983 | 80 | 85.56 | 89.74 | 16.67 | 271.97 | polluted |
| 17 | 1994 | 83.3 | 75.8 | 95 | 33.3 | 287.4 | polluted |
| 42 | 1983 | 77.5 | 99.39 | 96.9 | 50 | 323.79 | dirty |
| 26 | 1994 | 84.8 | 56.5 | 99.5 | 100 | 340.8 | dirty |

## HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUKSEN MONISTEITA 1995

1. Helsingin ja Espoon merialueiden velvoitetarkkailu vuosina 1987 - 1994

2. Tuoreen kalan laatu tukkuportaasta vähittäismyyntipisteeseen kesällä 1994

3. Kestävää kehitystä mittaamaan - selvitys indikaattorihankkeista

4. Meluesteiden tehokkuusmittaukset Helsingissä

5. CFC-yhdisteiden käyttö kylmäaineina ja liuottimina Helsingissä

## HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUKSEN MONISTEITA 1996

1. Ilmaääneneristävyyden vaihtoehtoisten mittaustapojen vertailu

2. Päiväkotien ilmanvaihtolaitteiden epäpuhtaudet

3. Helsingin ympäristökysymykset lehtien palstoilla

4. Bottom Macrophyte Communities in the Tallinn and Helsinki Water Areas as Bioindicators of the Coastal Sea

5. Katajaluodon jätevesitunnelin tukkeutumisen aiheuttama seuranta Helsingin vesialueilla ja Viikin-Vanhankaupunginlahden luonnonsuojelualueella

## HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUKSEN MONISTEITA 1997

1. Helsingin ympäristökeskuksen tekemät tutkimukset Pietarhovin palatsialueen vesijärjestelmästä vuosina 1995 - 1996

2. Development of a space-independent bioindication system for evaluation of eutrophication in coastal areas of the Gulf of Finland. Report of the Gulf of Finland year 1996 Seminar, Tvärminne, Nov. the 25-27th, 1996

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