HELSINGIN KAUPUNGIN YMPÄRISTÖKESKUS
MONISTE 4

BOTTOM MACROPHYTE COMMUNITIES IN THE TALLINN AND HELSINKI WATER AREAS AS BIOINDICATORS OF THE COASTAL SEA

Vesikasviyhdyskunnat
Helsingin ja Tallinnan
merialueiden tilan ilmentäjinä

Henn Kukk, Ilkka Viitasalo (eds.)

Proceedings of the Project Seminar
Lohusalu Vacation Centre

January the 9-11th, 1996

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Lukijalle

Helsingin ja Tallinnan ympäristökeskukset ovat vuodesta 1992 alkaen vertailleet rantavesiensä tilaa vesikasveihin, lähinnä merileviin perustuvilla kartoituksilla (biomonitoroinnilla). Menetelmä sopii hyvin alueille, joilla ei ole resursseja käynnistää täydellistä fysikaalis-kemiallis-biologista veden laadun seurantaa. Työtä ovat tukeneen molempien maiden ympäristöministeriöt sekä Helsingin ja Tallinnan ympäristöviranomaiset. Suomessa työtä on valvonut Uudenmaan ympäristökeskus; aiemmin Uudenmaan lääninhallitus.

Tallinnaan on työn aikana perustettu ja koulutettu projektiryhmä, jolla on tiedolliset ja aineelliset valmiudet jatkaa monitorointia itsenäisesti, ylläpitää sen kansainvälistä vertailukelpoisuutta ja tarvittaessa perustaa samanlainen tarkkailuverkosto myös muualle Viroon.

Koska ihmisen toiminta ja vaikutukset kulkeutuvat vesistöön useimmiten rantavyöhykkeen kautta, sitä koskevista tutkimuksista saadaan tärkeätä taustatietoa suunniteltaessa rantojen yleistä käyttöä, uimarantojen ja suojelualueiden sijoittamista jne. Rantavyöhykkeen moninaisuus vaikeuttaa toisaalta koottujen tietojen tulkintaa, mikä edellyttää hyvää yhteistyötä kaikilta tutkimusosapuolilta.

Tässä raportissa on esitetty tulokset Lohusalussa, Luoteis-Virossa tammikuussa 1996 pidetystä tiedonsiirtoseminaarista. Projektin työkielenä on käytetty englantia, jolloin raportit ovat käyttökelpoisia kaikissa Itämeren maissa. Raportti sisältää e.m. biomonitorointia koskevien artikkeleiden lisäksi ensimmäisen perusteellisen katsauksen Tallinnan viemärivesien purkamisesta mereen ja niiden puhdistusmenetelmistä.

Since 1992, biomonitoring of the shoreline waters by macroalgae of the cities Helsinki and Tallin have been conducted in a joint effort between the environmental authorities of both of the cities, universities of Helsinki and Tartu as well as the Estonian Marine Institution. Scientific basis for comparing the results inside and between the sea areas is established.

The littoral zone is important not only to biomonitoring process itself but for the activities of Man's welfare and to the marine ecosystem as well. The complexity of the littoral sea-land interface creates challenges to the researcher which only can be solved by good cooperation and good relationships between the counterparts. This report contains the proceedings from a knowledge transfer seminar of the monitoring project. The Editors wish to thank the Ministries of the Environment in Finland and Estonia as well as the Environmental agencies of Helsinki and Tallinn for the financial and practical support to the project.

Tallinn and Helsinki, spring 1996

Editors

Henn Kukk   Ilkka Viitasalo

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Opening address by Dr **Ahto Järvik**, director, Estonian Marine Institute:

Dr Järvik welcomed the participants to the seminar and to the snowy Lohusalu as well. The bioindicator project has continued for four years. It has staked out waypoints to the common monitoring practices for two most adjacent capitals of the world. Professor Järvik also credited The environment offices of the cities and the environmental authorities of the both countries for the economical and administrative support to the project.

Dr **Pekka Kansanen**, director, Environment Centre of the City of Helsinki:

Dr Kansanen pointed out the importance of the long cooperation traditions between the two countries in the reign of water protection and monitoring. The increasing dealings encourage us to establish stable relationships and *vice versa*. The Helsinki Headquarters in Tallinn has recently moved to new localities, e.g. The bioindicator project has piloted the increasing environmental cooperation. There are other activities in a good beginning, too. The waste management plan of the Port of Tallinn and the environmental auditing of the City of Tallinn, the latter being a joint project between the cities of Tallinn, Turku and Helsinki and supported by the LIFE Fund of the European Union, are good examples.

Dr **Juha Sarkkula**, Environmental Agency of Finland:
GULF OF FINLAND YEAR 1996

The Ministers of the Environment from around the Gulf of Finland will sign the intention protocol in the town of Pskov in 10th of January 1996.

Councillor **Tiiu Raia**, Estonian Ministry of the Environment:

Kindly presented a video record about the Gulf of Finland Year. Among many other interesting topics, the current project was presented, too.

Professor **Åke Niemi**, University of Helsinki:
GULF OF RIGA PROJECT

(APPENDIX 1)

The Gulf of Riga Project was launched and supported since then by the Nordic Council of Ministers in 1993. Up to 25 MDKK is annually allocated to the project. The three main themes are:

A. Climate change research
B. Social science approach on environmental issues
C. Environmental research collaboration

The last theme is divided into six subprojects, all of them dealing with chemical, physical and biological processes of the pelagial and the drainage basin of the Gulf of Riga. The sixth subproject, **production and transport of nutrients in the littoral system and the exchange with the pelagial**, was initiated in 1995 and will be concentrated on process studies in 1996. A detailed information on the organisation and administration of the project is given in the Appendix 1. The project ends in 1997.

Prof. **Erich Kukk**, University of Tartu:
PROBLEMS OF POTENTIALLY TOXIC ALGAE IN THE LITTORAL ZONE.

(APPENDIX 2)

Professor Kukk pointed out the difficult taxonomy of the different algal groups which produce toxic compounds. Recently has genus Prorocentrum invoked attention. Many of them are benthic but may be carried by wind induced turbulence far away to the open sea. The increasing sea transport helps the algae and their cysts spread long distances with ballast water, too. Littoral benthos is frequently visited not only by cattle and fish but crowds of holiday people as well. Risks to different types of poisoning are obvious. Prof. Kukk included a list of potentially toxic plankton algae with comments on their existence in the Baltic Sea.

Henn Kukk*, Viitasalo, Ilkka**:
* Estonian Marine Institute
** Environment Centre of the City of Helsinki

DEVELOPMENT OF THE HELSINKI - TALLINN MARINE ALGAE PROJECT

(APPENDIX 3)

Dr Henn Kukk presented a short summary of the ongoing project. The project was launched in 1992. In 1993, the first wide-scale research was carried out both in the Finnish and Estonian coastal waters of the Gulf of Finland. In 1994, 50 stations in the Tallinn area and 220 stations in the Helsinki area were visited together. In 1995, samples of bottom flora and fauna were collected simultaneously from both sides from about 50 localities.

The results have been presented in scientific journals and symposia. The complete list of the publications is included in Appendix 3.

Anni Turro and Ingrid Jakobson, Environmental Board of the City of Tallinn:

DYNAMICS OF POLLUTION FROM POINT SOURCES IN THE TALLINN BAY

(APPENDIX 4)

Before the 1978, wastewater was discharged via local discharge sewers to the surrounding sea areas. Since then, six collector sewers were put in operation and wastewater was conducted to Tallinn Wastewater Treatment Plant in Paljassaar Peninsula (mechanical treatment). From Paljassaar watewater was discharged to sea via two plastic pipelines about 3 kms north from the coastline. The construction of the biological process began in 1985 and in 1993 partial biological treatment was taken into operation.

The deep-sea outlet operated satisfactorily only for a very short period. The pipeline has been repaired several times because wastewater leaked near the seashore. The last reparation took place in 1993-94.

Detailed history of the municipal and industrial wastewater treatment is included in Appendix 4.

Kukk, Henn*, Viitasalo, Ilkka and Martin, Georg*:**
* Estonian Marine Institute
**Environment Centre of the City of Helsinki

THE ECOLOGICAL STATE OF TALLINN AND HELSINKI COASTAL WATERS BASED ON BENTHIC MACROPHYTES.

(Papers presented in the 14th Baltic Marine Symposium, Pärnu 5-8.sept. 1995; to be published in the Estonian Academy Publications.)

(APPENDIX 5)

Martin, Georg and Kukk, Henn, Estonian Marine Institute:
Benthic algal communities in the coastal sea of the Tallinn Region

The bottom vegetation of the coastal sea of the Tallinn urban area consists of 21 taxa of algae and phanerogarms. On the basis of the structure of benthic algal communities the coastal area was classified in three trophic regions which show certain dynamics in distribution during last three years. Regular monitoring on the benthic algal vegetation in this area could substantially contribute to the assessment of the ecological state of the coastal sea areas in the Tallinn region.

(APPENDIX 6)

Viitasalo, Ilkka, Environment Centre of the City of Helsinki:
Classification of water areas by littoral vegetation in Helsinki

The bottom vegetation was classified into four main algae groups by clustering analysis. The groups could be nominated according to both wastewater load and the location of the sample. The classes resembled more or less the saprobic associations suggested by Häyrén (1924).

Paalme, Tiina, Estonian Marine Institute

PRIMARY PRODUCTION ESTIMATES WITH DIFFERENT MACROALGAL SPECIES IN 1993-1994

(APPENDIX 7)

During 1993 - 1994, *"in situ"* production estimates were carried out with different macroalgal species dominating in algal communities in the Estonian coastal waters of the Gulf of Finland.

Photosynthetic and respiratory performances of annual *Enteromorpha intestinalis* and *Cladophora glomerata* (CHLOROPHYTA), *Ceramium tenuicorne* (RHODOPHYTA), *Pilayella littoralis* and perennial *Fucus vesiculosus* (PHAEOP HYTA) were determined by measuring changes of dissolved oxygen concentration in light and dark bottles using the Winkler titration method or an oxygen meter.

The highest production rates were measured for the green algae *E. intestinalis* and *Cl. glomerata*. The production rate of *C. tenuicorne* was also relatively high, being close to that of the above mentioned green algae. Significantly lower production rates were measured for *P. littoralis* and *F. vesiculosus*.

Comparing the results obtained at experimental stations with different load of human impact the maximal net photosynthetic rates for *E. intestinalis* and *Cl. glomerata* were measured at stations with the highest amount of nutrients in the water.

Kotta, Ilmar and Kotta, Jonne, Estonian Marine Institute:

ZOOBENTHOS OF TALLINN BAY

(APPENDIX 8)

The abundance values of two bivalve species Macoma balthica and Mytilus edulis should be used in order to estimate the concentration of organic matter in sediments (M.balthica) os in water column (M.edulis).

Simm, Mart and Jankovski, Harri, Estonian Marine Institute:

CONCENTRATION OF HEAVY METALS IN THE BOTTOM VEGETATION AT THE SOUTHERN COAST OF THE GULF OF FINLAND

(APPENDIX 9)

Determination of the concentration of toxic substances is not among the goals of the Baltic Sea monitoring program. Opinions available in the litterature differ as to the suitability of bottom vegetation for bioindication. Concentrations of heavy metals in several algae species are tabulated and discussed in the paper.

PLENARY SESSION

Summary and the conclusions of the Seminar

The discussion divided into two parts; the former dealing with the obtained results and the latter the future of the cooperation.

The obtained results can be used in practical monitoring of water quality on both sides. In Helsinki, biomonitoring with aquatic organisms forms an essential part of the routine monitoring programs of water quality. Similar target has been set on the Estonian side.

The meeting recommended to continue the project and proposed the following research plan for the next year:

RESEARCH PLAN 1996

A. Biomonitoring
Macrophyte and zoobenthos monitoring:
Great survey every 3rd year
Minor surveys yearly in important localities
Hygienic indicators: Coliforms > Thermotolerant coli.

B. Heavy metals in biomaterials
Intercalibration and standard material of Fucus
Preparation in Helsinki for heavy metals monitoring in 1997.

C. Macrophyte primary production
Research training in the University of Turku, Seili Biological Station. Publication of the results. Evaluation of the results gained so far after publication.

D. Recruiting
Student exchange
Research training in the University of Helsinki, Tvärminne Zoological Station and in the other institutions as well.

E. Gulf of Finland Year 1996
Extension to St.Petersburg, Wyburg, if supported by governemental authorities.

F. Publications and reports
Year report 1996 to the authorities
City Ecology Symposium in Tallinn 1996
Gulf of Finland Year symposium
CBO-BMB joint symposium on Bornholm, Denmark 1996
BMB-ECSA joint Symposium in Mariehamn, Finland 1997

APPENDIX 1

Niemi, Åke
University of Helsinki

THE GULF OF RIGA PROJECT

The Gulf of Riga Project

In March 1990, the Nordic Council of Ministers agreed upon appointing a committee with the task of preparing proposals for a 5-year "Nordic Environmental Research Programme". At the 39th session of The Nordic Council in 1991, the programme was met covering the period 1993-1997 with an annual maximum budget of DKK 25 million.

The programme was focused on 3 theme areas (projects):
- Reseach on climate changes
- Environmental research-collaboration
- Social science research of environmental policy issues

It was assumed that the second project should be implemented in close collaboration with researchers from the Baltic states. An Expert group with members from the Nordic countries was appointed by the Nordic Council of Ministers. Its secretaiate works in Stockholm (Naturvårdsverket). This group refined and restricted the research topics to studies of processes of importance for the exchange of eutrophying and toxic substances between land and sea in the Baltic Sea area. A concentration of the resources to a geographically limited area was considered essential.The expert Group chose the Gulf of Riga including its drainage area both for environmental and scientific reasons.An essential point of view was the good opportunity to integrate scientists from the Baltic states and the Nordic countries in a common international project.

Outlines of the scientific content

The objective was to study environmental problems in the Gulf of Riga, its drainage area, and its influence on the Baltic proper.The different aspects are presented in Fig. 1. Esthonian and Latvian scientists have already done a lot of valuable work in the area. A comprehensive review has recently been published (edited by Prof. Ewald Ojaveer). The aim of the project is to study those critical processes which control concentrations and distribution features in the Gulf of Riga and the exchange with the Baltic proper. An essential point is to create a common data base and knowledge enough for planning remedial measures for the Gulf of Riga.

As presented in Fig. 1the project is really multidisclipinary. Physicists, chemists, biologists, mathematicians, specialists on modelling etc. from the Nordic and Baltic countries take part in the project. The work is divided i 6 subprojects:

- Drainage basin and the load to the Gulf of Riga
- Pelagic eutrophication and sedimentation
- Sediment and benthos - storage and processes
- Water exchange, nutrients, hydrography and data base
- Budgets of persistent organic polluters and heavy metals
- Production and transport of nutrients in the littoral system and the exchange with the pelagial system

Three years of intense studies and collaboration have elapsed. A lot of scientific materal has been collected. Several reports have been presented on international scientific meetings.
New aspects on the functioning of the ecosystem have been found. After three years intense field studies (1993-1995) the two last years 1996-1997 will be concentrated on analysing af

data,constructing budgets and ecosystem models. The last subproject started at first in 1995 (owing to economical reasons) and will be concentrated on process studies also in 1996.

Administration of the project

The structure of administration is presented in Fig.2. The secreteriate of The Nordic Council of Ministers works in Copenhagen. The Programme Committee (members from all the Nordic countries) meets once a year to decide upon the resources to be divided to the three projects.The chairman and secretary of the Expert Group of each project take part in these meetings to present their work and planning for the next year of their project. They cannot take part in the decision on dividing the resources to the three projects, but they can propagate for the projects which they represent.

The subprojects of the Riga Gulf Project, led by an scientific coordinator, have every year to apply for resources for the next year from the Expert Group. This will evaluate the applications and divide the resources of the year. The Expert Groups aim is to coordinate the work of the Gulf of Riga Project bearing in mind the original aim of the project.

The coordinators of the subprojects have to administrate their subproject, work out the cooperation between Baltic and Nordic scientists and divide and be responsible for the resources of the subproject.When building up the subprojects one rule to be followed is that 50 % of the resources should come from the country or countries the scientists represent, and 50 % from The Nordic Council of Ministers. This rule bring a lot of money to the Gulf of Riga Project. (This rule is not valid for the Baltic countries).

General comments

Establishing a new international cooperation project involving the Nordic countries and the recently liberated Baltic states must encounter a lot of difficulties. The main cooperation problems have derived from the great administrative changes in research structures in the Baltic states. The restructing processis have been difficult while at the same time there has been a drastic reduction of resources for science.The attitude to scientific work and cooperation was different from that in the western countries The lack of cooperation beween Baltic institutions and scientists was a major problem.

Today, more than three years since the project started, a lot has happened. Sixty to seventy people are involved in the Gulf of Riga Project. Three annual meetings have been held for all the participating scientists. The subprojects have arranged their own meetings, workshops and seminars. A great change of scientists between the Baltic and Nordic countries has happened. Several Esthonian and Latvian young researchers have worked in Nordic laboratories or on research vessels. The field studies have chiefly been made using Esthonian and Latvian ships. A lot of money have been directed to Baltic laboratories in order to obtain modern equipments for analytics needed in modern research. A common data base has been established in Tallinn, Riga and Stockholm. Every researcher of the project can use this data base.

Special funds have been allocated from the Nordic Academy of Advanced study (NorFa) for educational aspects, with the aim of strengthening the science base for and recruiting new young researchers. A lot of money were allocated to arranging SCUBA-diving courses for young researchers from the Baltic countries. The NorFa fundings have been of great importance making possible international symposia, mobility-scholarships, international research work and planning meetings and net-work activities. Only by effective cooperation small countries can in science and higher education be comparable with the big Europaean countries. This could be a good step forward for the Baltic and Nordic countries.

author: ÅkeNiemi,The Gulf of Riga Project, chairman of the Expert Group.

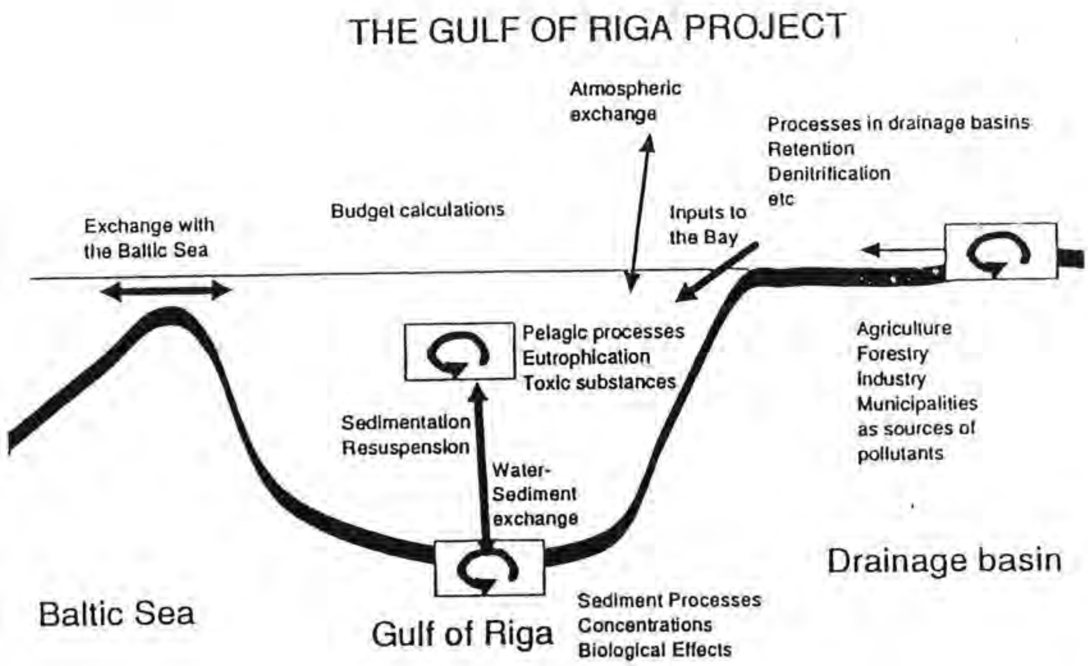

Fig.1. Original multidisclipinary plan for The Gulf of Riga Project. Different processes and objectives to be studied .

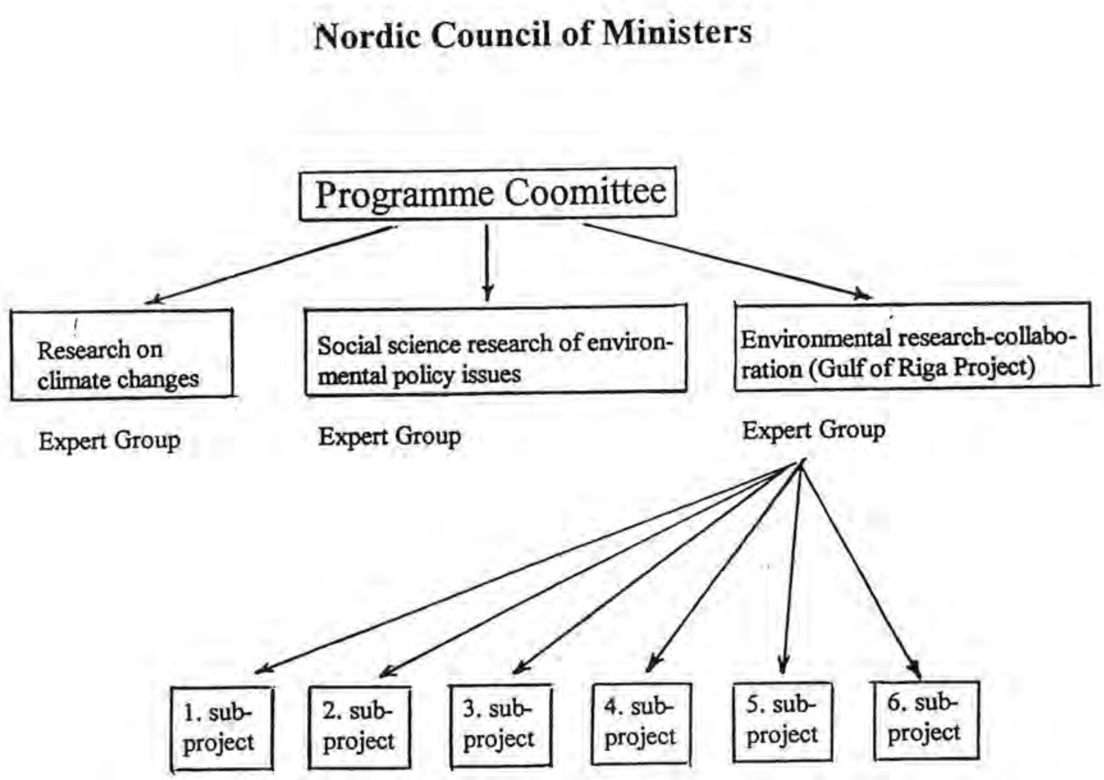

Fig.2. The organization of the Nordic Environmental Research Programme including the Gulf of Riga Project.

APPENDIX 2

Kukk, Erich
University of Tartu, Inst. of Botany and Ecology, Lai 40 Str, Tartu, Estonia

PROBLEMS OF POTENTIALLY TOXIC ALGAE IN THE LITTORAL ZONE

POTENTIAALISTEN MYRKKYLEVIEN ONGELMISTA MEREN LITORAALISSA.

E. Kukk

Meren rantavyöhyke, missä ovat muuttuvaiset ympäristöolot, on suotuisa alue myös useille levälajeille. Aalokko nostaa pohjasta yleensä siellä eläviä lajeja, irroittaa päällyskasvustosta asukkaita ja näin voivat ne jäädä pitkälti keijumaan planktoniin. Kaiken sen takia on litoraalin plankton paljon monipuolisempi kuin avoveden plankton, usein myös arvaamattomampi.

Monta vuotta sitten, tutkiessa Orissaaressa Maasilinnan rannikovedesta kerättyä planktonin näytettä, oli mikroskoopin alla semmoinen levä (k 1). Todennäköisesti on se tuttu monellekin tuolta ajalta. Mutta kaikesta huolimatta en voi vielä nytkin varmasti sanoa, niin kuin on tehnyt monet virkaveljet, onko tämä laji *Prorocentrum scutellum* tai ei. Mielenkiintoinen se löytö oli ja tästä alkoi kuin ketjureaktio ja loppua ei ole näkyvissäkin. Yritän seuraavassa kertoa, minkälaista tietoja on kerääntynyt kolmen vuoden aikana ja minkälaisia ongelmia on syntynyt.

Jo ensimäinen koskeutus *Prorocentrum* sukun kanssa näytti, että kysessä on sekä taksonomisesti että ekologisesti kiinnostava ja omaperäinen ryhmä. Koko suvusta, missä on lähes viisikymmentä lajeja, on vaan pari lajeja makeanveden asukkaita. Kymmenenkunta lajeja ovat erittäin myrkyllisiä. Puhumatta nyt tässä myrkyistä haluaisin sittenkin korostaa, että Kanadan tutkijoiden (Ewen, Todd et al., 1993) mukana on vuosien 1880 - 1990 välillä myrkylliset litoraalinlevät aiheuttanut 96 sairauskohtausta (yhteensä 524 ihmistä) ja kuoli 32 ihmistä. Itämeren planktonlevien luettelossa (Edler, Hällfors, Niemi, 1984) on panssarilevien joukossa 16 sellaista, mistä voimme kirjallisuuden perusteella sanoa, että tämä laji on jossakin paikassa ollut myrkyllinen. Vielä yksi mielenkiintoinen havainto - Sanna Tanskasen yleiskatsauksesta Itämereen myrkkylevistä v. 1990 oli luettelossa 23 myrkyllista ja niistä 9 esiintyi myös Itämeressä. Nyt (vuonna 1995) on myrkyllisten lajien määrä jo 49 ja niistä 16 on myös Itämeressä.

Mistä on kysymys? Maailmassa ovat lisääntynyt tutkimustyöt, mutta valitettavasti se ei koskee meidän vesiä. Toiseksi on hyvin todennäköistä, että lisääntynyt laivaliikenne vetää painolastiveden kanssa kymmeniä lajia valtavien välimatkojen taakse ja on mahdollista, että monetkin niistä löydävät uusissa paikkakunnissa itselleen suotuisat eksistenssiehtot. Vuosina 1989 ja 1990 Japanin ja Australian välillä matkustaneet 80 tarkistetusta laivasta oli 30 laivan painolastivedessä panssarilevien kysteja , niistä viidessä myrkyllisten lajien *Alexandrium catenella* ja *A. tamarensis*- kystejä (Hallegraeff & Bolch, 1991).

Useat isot panssarilevät ovat pohjaläheisen vesikerroksen asukaita. Aalokko nosta he päällysveteen ja kuten Pienen - salmen tutkimuksesta ilmenee voivat montakymmentä mikronia läpimitassa *Prorocentrum* solut ajautua litoraalista kilometrien taakse avoveden aluelle, missä voivat muodostaa olennaisen osan biomassasta. kun ei ole tuulta eikä aalokkoa sitten pysyvät levät rantaläheisessä vedessä, missä he myrkyllisyyden tapauksessa ovat vaara kaikille. Tässä kehotus kaikille lomarantojen ja karjankasvatusrantojen omistajille sekä kampelakalastusalueiden käyttäjille - ennen huippukäyttöä ja sen aikana täytyy periodisesti kontrolloida eikö ole planktonissa tai pohjaläheisessä vesikerroksessa vaarallisia lajeja. Pärnun lahden ja Väinameren kokemuksen perusteella tulee tarkistusta aloittaa silloin kun veden lämpötila on +15°. Näyttää näin, että semmoisessa lämpötilassa pohjalla sijaitsevien kystien itämiskyky aloittaa toimintansa, solut lähtevät liikkeelle ja levät tulevat veteen. Näytteitä tulisi ottaa mahdollisimman matalasta vedesta ja heti elossa olevina mikroskopointia.

Erikoisongelmaksi on mahdollisesti myrkyllisten panssarilevien esiintyminen avomeren planktonissa. Edellisten vuosien havaintokirjojen luetteloissa on edustajia semmoisista suvuista mitkä eivät ole määritetty lajin asti, mutta missä on mahdollisesti myrkyllisia lajeja. Tätä tulee vakavasti tuomita. En tietää, oliko aikaa tai ainestoa vähän tai ei ollut tutkija pätevä. Kun suvusta on tietää yksikin myrkyllinen laji tulisi yrittää kaikin voimin määrittää kaikki tämän suvun edustajat lajin asti (vaikka jää kysymysmerkkejä). Näin olisi hälytystilassa (sairauskohtaukset, eläimiem kuolema) helpompi etsiä syitä.

Ehkä tulisi vaivautua ja laatia kokonaan uusi lajilista, missä ovat kaikki myrkylliset levät, mitä tietämme tänään ja levittää sitä levätutkijoiden joukossa, että he niitä lajeja erikseen kontrolloivat. Ehkä tulisi perustaa kokonaan pieni työryhmä, kenen tehtäväksi olisi tutkia ainoastaan rantaläheisten mahdollisesti myrkyllisten levien taksonomiaa ja ekologiaa. Seuraava askel olisi niiten levien eristäminen ja työ viljelyn kanssa myrkyllisyyden määrittämiseksi. Tätä työtä tuntevat suomalaiset tutkijat hyvin (ennenkaikkea sinilevien osalta).

Kun myrkytys sinilevien puolesta esintyy veden kukintakaudella, sitten panssarilevien osalta tämä lainmukaisuus ei toimi niin varmasti. Syyksi on tämä seikka, että panssarilevillä ovat kystit myrkyllisempiä vegetatiivisista soluista. Syksyllä veden viilentymisen aikana voi vesi olla jo hyvin läpinäkyvä, mutta sittenkin voi siellä olla vaarallisessä määrässä leväkystejä. Tästä syystä myrkylliset panssarilevät ovatkin vaarallisia siihen asti kun kystit ovat vajonnut pohjaan.

Lopuksi - tässä on myrkyllisten panssarilevien nimistö (k 2) kirjallisuuden perusteella v. 1995 alussa. Tässä on niitä lähes puolisata, mutta ei ole tropiikistä löytettyjä lajeja. Ilmeisesti tuovat lisää v. 1995 julkaisut. Näin on mistä ajatella ja kuinka toimia.

Vetikaliik		Toksilisuse või mürgi tüüp
Alexandrium (Gonyaulax)	acatenella	PSP
–	catenella	PSP
–	cohorticula	PSP
–	lusitanicum	PSP
–	minutum	PSP
–	monilatum	PSP
–	ostenfeldii	PSP
– (incl. G. excavata)	tamarense*	PSP
Amphidinium	carterae	hemolüütiline, ihtüotoksil.
–	klebsii	" "
–	rhynchocephalum	?
Dinophysis	acuminata*	DSP
–	acuta*	DSP
–	fortii	DSP
–	norvegica*	DSP
–	rotundata*	DSP
Dinophysis	sacculus	?
–	tripos*	?
Gambierdiscus	toxicus	ciguatera toksiin
Glenodinium	danicum*	glenodiniin
Gonyaulax	monilata	PSP, ihtüotoksil.
–	polyedra*	PSP, ? ciguatera toks.
Gymnodinium	catenatum	PSP
–	mikimotoi	?
–	nagasakiense	mürgine keriloomadele, ihtüotoks.
–	nelsoni	?
–	sanguineum	ciguatera toksiin
–	veneficum	vees lahustuv neurotoksiin
Gyrodinium	aureolum*	?
–	spirale*	?
Heterocapsa	triquetra*	?
Noctiluca	scintillans*	? mürgine limustele ja kaladele
Ostreopsis	heptagona	?
–	lenticularis	?
–	ovata	?
–	siamense	?
Peridinium	polonicum	glenodiniin, ihtüotoksiline
Prorocentrum	balticum*	?
–	concavum	ciguatera toksiin, hemolüütil.,ihtüot.
–	hoffmannianum	?
–	lima*	ciguatera toksiin, DSP
–	mexicanum	ciguatera toksiin
–	micans*	?DSP
–	minimum*	VSP
–	– v. mariae-lebouriae	VSP
–	triestinum	?
Ptychodiscus	(Gymnodinium) brevis	NSP
Pyrodinium	bahamense v. compressa	PSP
–	phoneus	PSP

Tärniga (*) tähistatud liigid on leitud ka Läänemeres. Küsimärk mürkide tulbas märgib, et mürk kas on üldse identifitseerimata või on tema koostis ebaselge.

PSP – Paralytic Shellfish Poisoning
DSP – Diarrhetic Shellfish Poisoning
NSP – Neurotoxic Shellfish Poisoning
VSP – Venerup Shellfish Poisoning

APPENDIX 3

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DEVELOPMENT OF THE HELSINKI - TALLINN MARINE ALGAE PROJECT

The project was launched in 1992 when funding for research from the Ministry of Environment was obtained. The first stage of the project addressed harmonization of the methods. In view of the aims of the project, samples of bottom vegetation both from the Helsinki and Tallinn regions were collected using the same technique. The discussion of the study results took place in autumn 1992 in Tvärminne, Finland. At the meeting it was concluded that the methods were entirely suitable for the research to be started in 1993.

In 1993, a wide-scale research was carried out both in the Finnish and Estonian coastal waters of Helsinki and Tallinn, Gulf of Finland. The results obtained were reported on the seminar at Roosta, Estonia. The participants resolved to continue the project. They pointed out the progress so far made and stressed the need for expansion of studies in the field of microbiology and nutrients.

In 1994 , the samples of bottom vegetation were collected at 50 stations in the Tallinn area and at 220 stations in the Helsinki-Espoo area. The results of the studies were reported on the seminar at Jollas, Finland. The participants found that the bottom fauna as a good bioindicator should be included in the project. It was also agreed that the concentration of heavy metals in the bottom vegetation of areas with different load of pollution should be studied.

In 1995, the samples of bottom fauna were collected at 50 stations in the Tallinn area. In parallel, samples of the bottom flora were taken also in the Helsinki area.

The results obtained in the limits of the project have been presented in reports and published in the following papers.

Kukk, H., Kotta, J., Kotta, I., Martin, G., Viitasalo, I. (1994).
The present status of benthic communities in the Gulf of Finland. Proc. of Int. Meeting "The Urbanisation and the Protection of the Natural Biocoenoses in the Baltic Coasts, Juodkrante, 11-12.

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We would like to thank the Finnish Government and the Head of the Uudenmaa District, the Centre of the Environment of the City of Helsinki and the Environmental Board of the City of Tallinn for the financial support owing to which our working group has succeeded in reaching thus high level in applying bioindication to the assessment of the state of environment.

APPENDIX 4

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DYNAMICS OF POLLUTION FROM POINT SOURCES IN THE TALLINN BAY

The city of Tallinn, located on the coast of the Tallinn Bay is closely connected to the sea.

The Tallinn Bay is a part of the southern area of the Gulf of Finland. It stretches from Suurupi peninsula in the west to Viimsi peninsula in the east. An imaginary line connecting the tips of Naissaare, Aegna and Kräuli islands forms its northern border. The geographical Tallinn bay consists of four smaller bays (Kakumäe, Kopli, Paljassaare and the so called Tallinn Bays) and open part of the Bay /Figure 1/. The open area of the

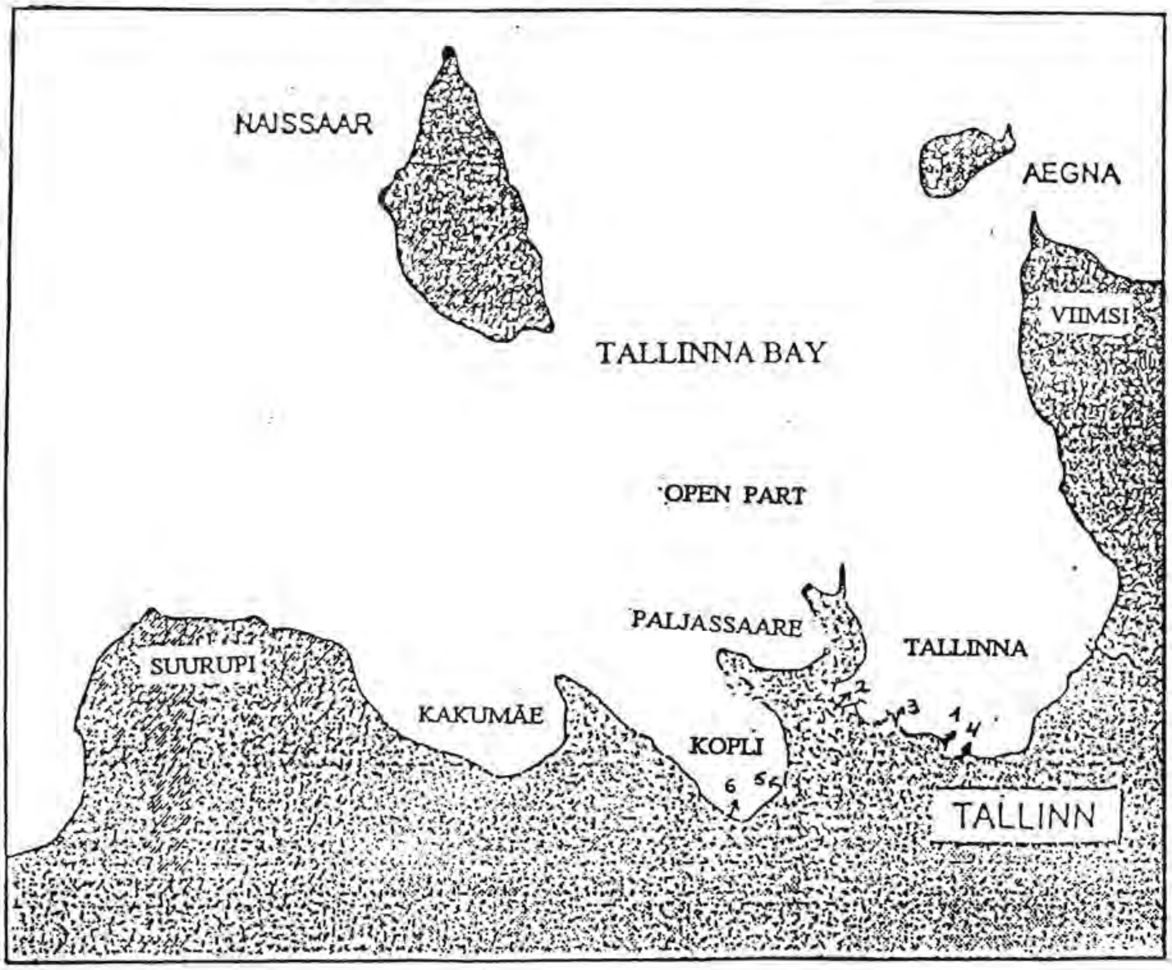

Figure 1 Tallinna Bay

bay covers 250 km^2 and the maximum depth is 90 m /Suursaar Ü., 1991/.

The water quality in the Tallinn Bay is affected by the input of pollution from land-based sources, by meteorological and hydrological conditions of the bay. /Changes in the water quality..., 1990/.

The ecological condition of the bay is dependant upon the discharges of industrial and domestic wastewater, precipitation and pollutants carried into the bay by the Pirita River from its catchment area.

Before January 1978 when the main collector No.1 was put into operation, the wastewater from Tallinn was discharged through different outlets into the Kopli and Tallinn bays /Figure 1/.

Discharges into the Tallinn Bay:

1-	Härjapea collector	up to	121.0 thousand m^3/day
2-	Collector No.2	up to	34.0 thousand m^3/day
3-	Salme street collector	up to	13.4 thousand m^3/day
4-	Pulp Mill collector	up to	39.3 thousand m^3/day

Discharges into the Kopli Bay:

5-	Seevald collector	up to	95.0 thousand m^3/day
6-	Oismäe collector	up to	17.3 thousand m^3/day

Some of the enterprises discharged their wastewater (ca 10 thousand m^3/day) into the sea through individual outlets.

Untreated wastewater is still discharged into the sea /Figure 2/:

into the Tallinn Bay by:

Central Prison	up to	250 m³/day
Patarei dwelling area	up to	180 m³/day

into the Paljassaare Bay by:

Neeme dwelling area	up to	150 m³/day
Tram Depot	up to	20 m³/day.

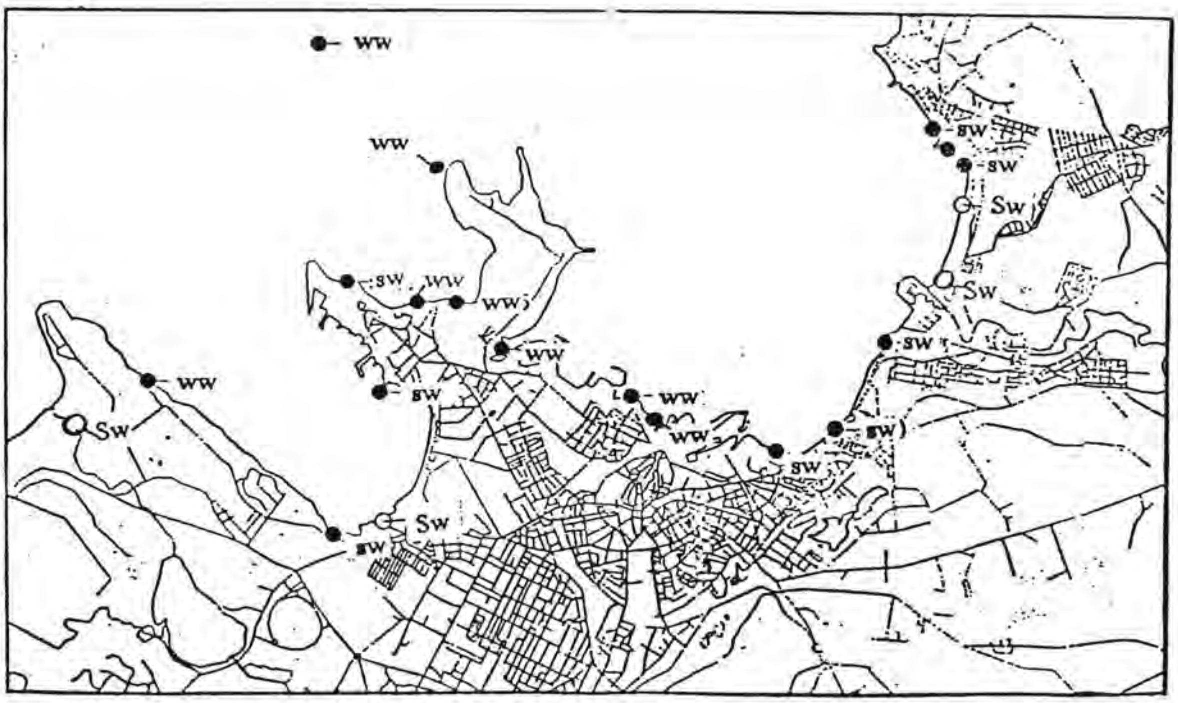

Figure 2 Pollution points
Sw - surfase water, sw - stormwater, ww - wastewater

Härjapea, Salme and No.3 collectors were closed down after the main pumping station started operation. Wastewater discharges into the Kopli Bay ended after collector No.3 was placed into operation in April 1979. This increased the pollution load placed on the deep-sea outlet.

The mechanical treatment plant with the capacity of 250 000 m^3/day was put into operation at Tallinn Wastewater Treatment Plant (TWTP)in Paljassaare at the end of 1980 in order to improve the ecological situation of the Tallinn Bay. Full capacity was reached during 1981. The treatment efficiency was as follows:

suspended solids	-29 to 64% (average 44.5%)
BOD_5	-13 to 21% (average 17.5%).

The construction of the plant continued and mechanical-chemical treatment plant with the capacity of 370 000 m^3/day started operation in December 1983. The treatment efficiency (suspended solids 50 - 60% and BOD_5 30 - 35%) achieved through the introduction of the mechanical-chemical treatment method was unsatisfactory and did not meet HELCOM recommendations.

The construction of the biological treatment plant with the capacity of 440 000 m^3/day began in 1985 and in 1993 partial biological treatment of the wastewater was introduced. The construction of the treatment plant is continuing.

It should be noted that the deep-sea outlet operated satisfactorily for a very short period. The first leaks were noticed in 1983. Wastewater was discharged into the sea at the distance of 180 meters from the shore from November 1984.From then on the full length of the outlet pipeline has been in operation only periodically. In the fall of 1988 due to the breakdown the deep-sea outlet could not be operated and wastewater was discharged into the Paljassaare Bay through an outlet located on the coast. Great amount of money has been used for the repairs of the deep-sea outlet and for the investigation of reasons for the breakdown. The last repairs were made in 1993 and 1994 during the spring-fall period. The breakdown of the deep-sea outlet and periodic discharges of wastewater into the sea in the vicinity of the shore create a situation whereby wastewater does not reach the area it should. Instead it floats on the surface and is carried by the sea currents to the coast of Viimsi peninsula and further between Aegna and Kräuli islands into the open sea area.

Tallinn Pulp and Paper Mill (TPPM)has for years been one of the major polluters of the Tallinn Bay. In October 1989 TPPM discharged its technological wastewaters into the municipal sewerage system. In cases of emergency wastewater from TPPM was discharged into the sea in the vicinity of Tallinn Port (near Kadriorg). The manufacturing operations in the mill ended due to bankruptcy and it ceased to contaminate the Tallinn Bay.

Since 1992 decrease in the volume of wastewater has been noted /Figure 3/.

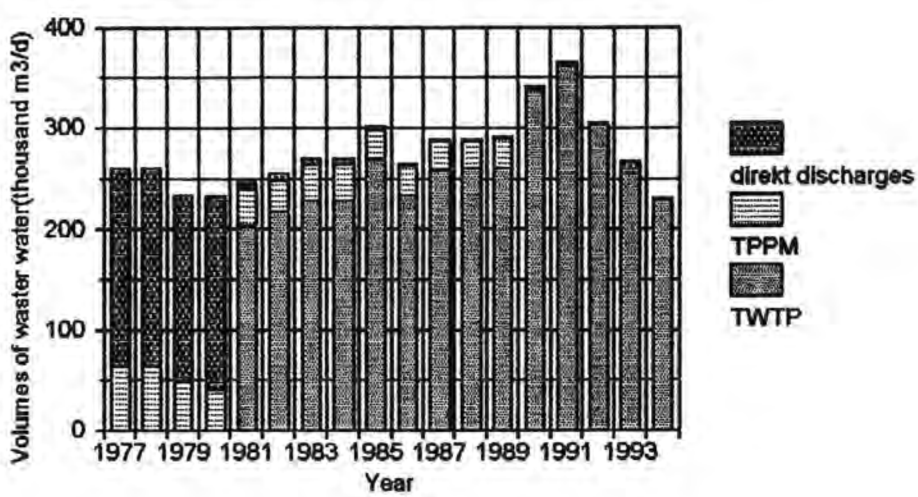

Figure 3 Dynamiks of wastewater volumes

Wastewater volumes have decreased due to the recession. The close- down of TPPM alone reduced the volume of wastewater by 25-30 thousand m³/day.

Next we shall focus on the changes in the load placed on the Tallinn Bay by pollutants (organic matter expressed as BOD_7, P_{tot}, N_{tot}).

The phasing-in of wastewater treatment and close-down of TPPM reduced notably the pollution load placed on the Tallinn Bay by organic substances expressed as BOD_7 /Figure 4/. BOD_7 input has been measured since 1990. Before 1990 only BOD_5 content had been determined. 1.15 was taken for the correlation coefficient for BOD_5 and BOD_7.

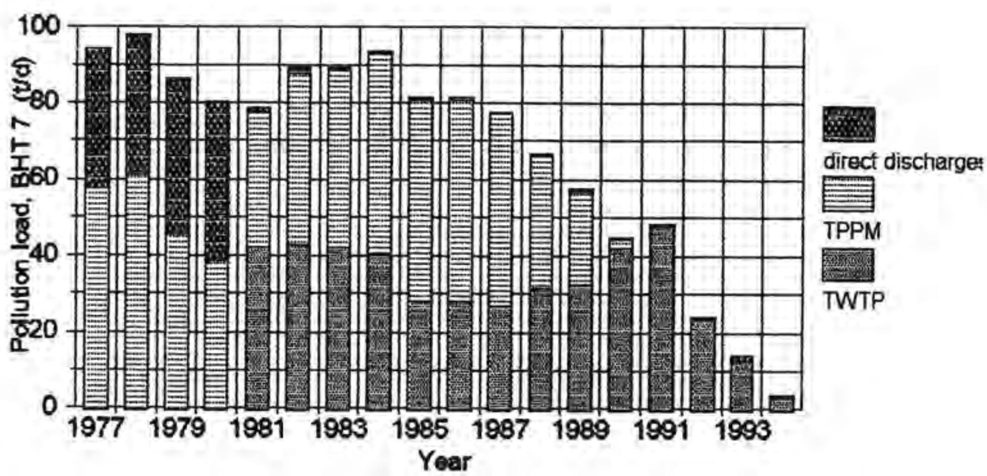

Figure 4 Dynamiks of BOD_7 loads

The ecological state of the Tallinn Bay is influenced by the amount of nutrients as well as their ratio in seawater.

The dynamics of phosphorus load has been presented in Figure 5.

Treatment of wastewater from Tallinn PPM in the municipal treatment plant caused significant changes in the treatment process. The coagulation and phosphorus removal processes were hampered by the presence of specific suspended solids in the wastewater. As a result the phosphorus load increased in the effluent discharged into the Tallinn Bay. The treatment process was stabilized in the treatment plant and phosphorus load decreased notably after the liquidation of the pulp manufacturing process. The introduction of the biological treatment method in the treatment plant notably reduced phosphorus load. The average annual phosphorus concentration is at present below 1.5 mg/l and this value meets HELCOM recommendations.

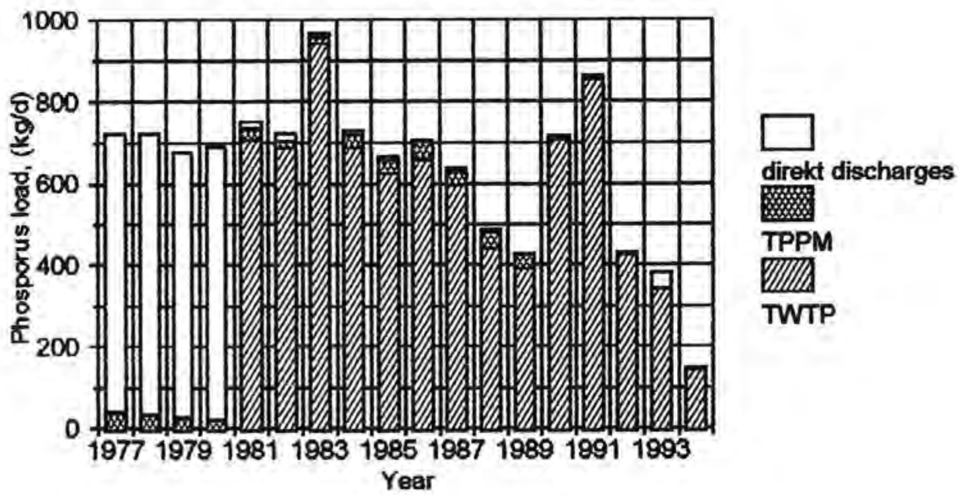

Figure 5 Dynamiks of P_{tot} loads

The determination of total nitrogen in wastewater was introduced in 1990. Earlier the concentrations of ammonium, nitrate and nitrite ions had been measured. Inorganic nitrogen is composed of the sum of those ions. Total nitrogen consists of inorganic and organic nitrogen. Data on the content of organic nitrogen in wastewater are lacking and for this reason it is not possible to estimate long-term changes in total nitrogen load. The dynamics of total nitrogen from 1990 onwards is presented in Figure 6.

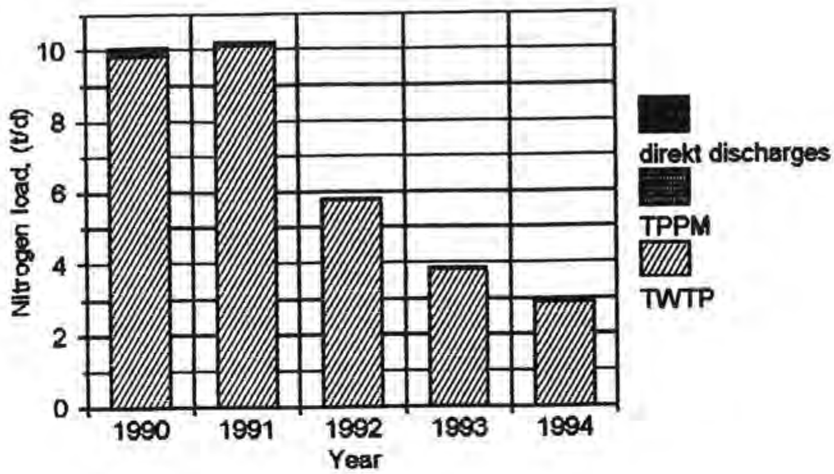

Figure 6 Dynamiks of N_{tot} loads

Besides industrial and domestic wastewater also precipitations pollute the water in the Tallinn Bay. Various substances may be incorporated into precipitations when they travel through the atmosphere or flow on the ground.

Pollutant pick-up by precipitations in the atmosphere does not depend only on local conditions and for this reason it cannot be reduced by introducing measures which have only local impact.

However, major part of pollutants are picked up while stormwater is flowing on the ground. The characteristics of the ground depend on local conditions. The qualitative composition of the surface runoff varies and it contains a great amount of organic and inorganic suspended solids, nitrogen and phosphorus compounds, oil products etc. The concentrations are dependent on many circumstances and fluctuate within a great range /Determination of the permissible..., 1988, Pollution levels..., 1991/.

The importance of stormwater as the carrier of pollutants into the Tallinn Bay increased after the reduction of the load by wastewater /Figures 7,8,9,10,11,12/. The Pirita River plays a major role in the pollution of the Tallinn Bay (up to 20%, especially nitrogen compounds)/Transfer of Tehnologi...,1994, 1995/.

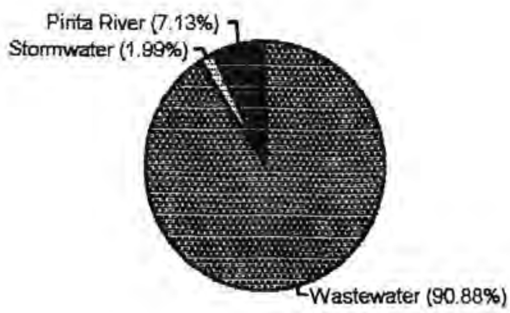

Figure 7 Distribution of BOD_7 loads in1993

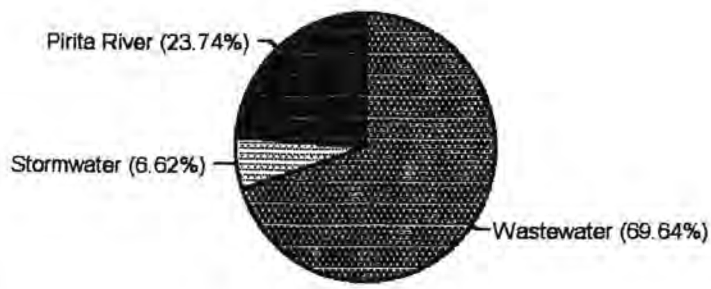

Figure 8 Distribution of BOD_7 loads in 1993

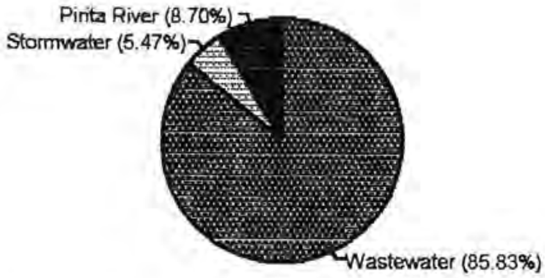

Figure 9 Distribution of P_{tot} loads in 1993

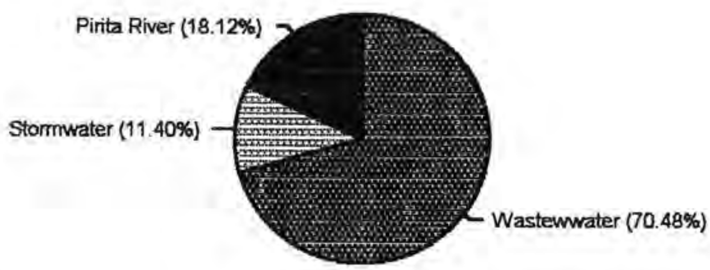

Figure 10 Distribution of P_{tot} loads in 1994

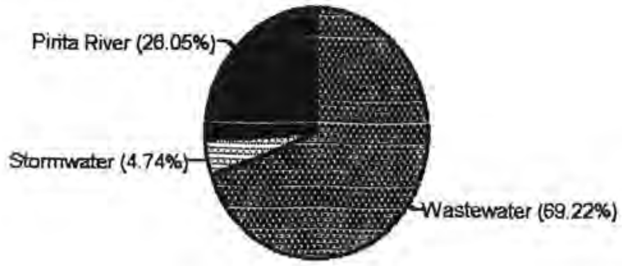

Figure 11 Distribution of N_{tot} loads in 1993

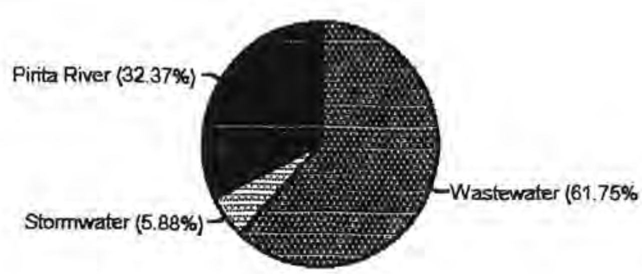

Figure 12 Distribution of N_{tot} loads in1994

The division of pollutant load by bays is not even. Figures 14,15,16 present the pollution load by bays by BOD_7 and nutrients according to data for 1993.

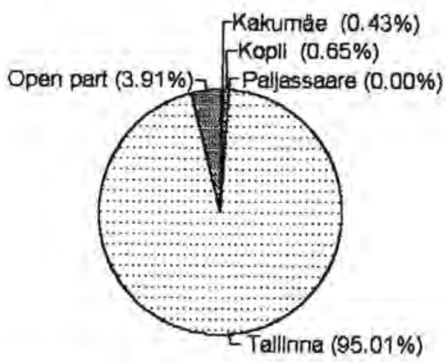

Figure 13 Distribution of water volumes in different bays

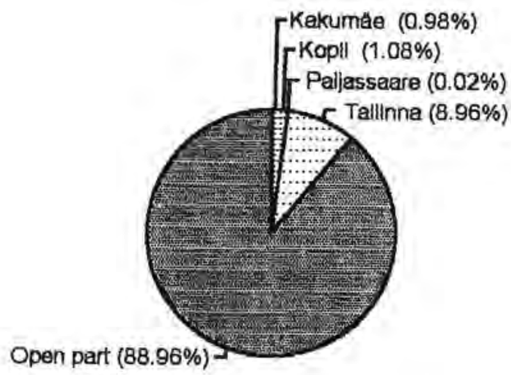

Figure 14 Distribution of BOD_7loads

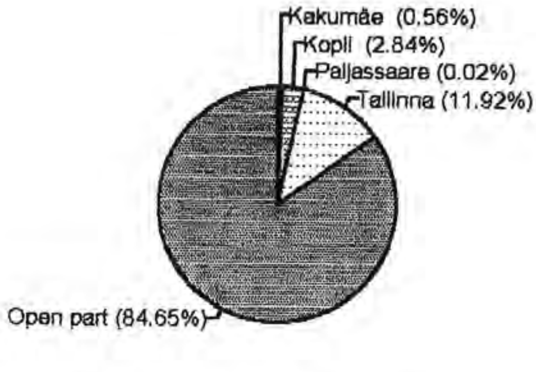

Figure 15 Distribution of P_{tot} loads

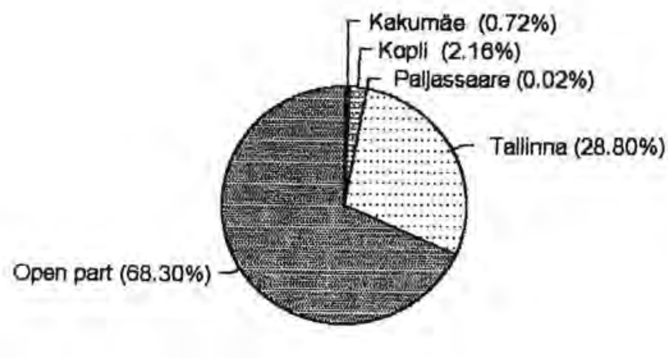

Figure 16 Distribution of N_{tot} loads

CONCLUSIONS.

1.The Tallinn Bay is contaminated by wastewater from Tallinn and by precipitation.

2.The Pirita River plays a major role in the pollution of the Tallinn Bay (up to 20%, especially nitrogen compounds).

3.The operation of Tallinn Wastewater Treatment Plant in Paljassaare has improved the state of the marine environment in the Kopli and the Tallinn Bays.

4.Tallinn Pulp and Paper Mill finished its activities and contamination of the Tallinn Bay in 1992. Water quality in the Kadriorg region improves very slowly since the pollutants from the mill were slowly decomposing organic matter.

5.The wastewater pollution load (BOD, P) decreased notably after the introduction of the biological treatment method in 1993.

6.The reduction in the pollution load cannot be simultaneously reflected in seawater quality changes since the marine environment is a comparatively inert system.

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APPENDIX 5

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BENTHIC ALGAL COMMUNITIES IN THE COASTAL SEA OF THE TALLINN REGION

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. Each year 30 stations from Kopli, Paljassaare and Tallinn Bays were sampled (Fig. 1). 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 (Fig. 2). 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 (Fig. 3). 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 (Fig. 4). 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 (Fig. 5,7). 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 (Fig. 6). 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 (Fig 5, 7). 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.

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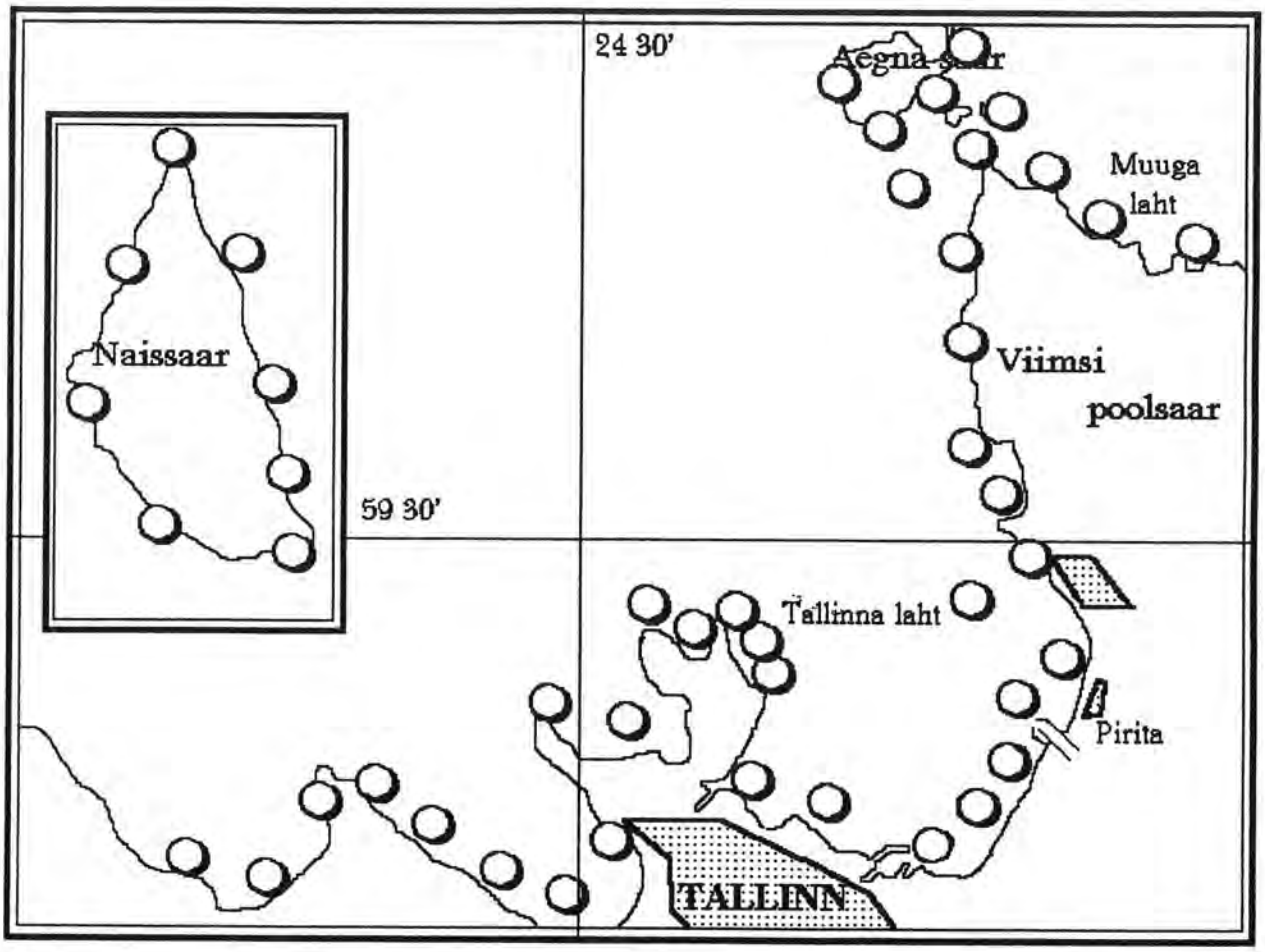

Figure 1. Location of the sampling sites in Tallinn area.

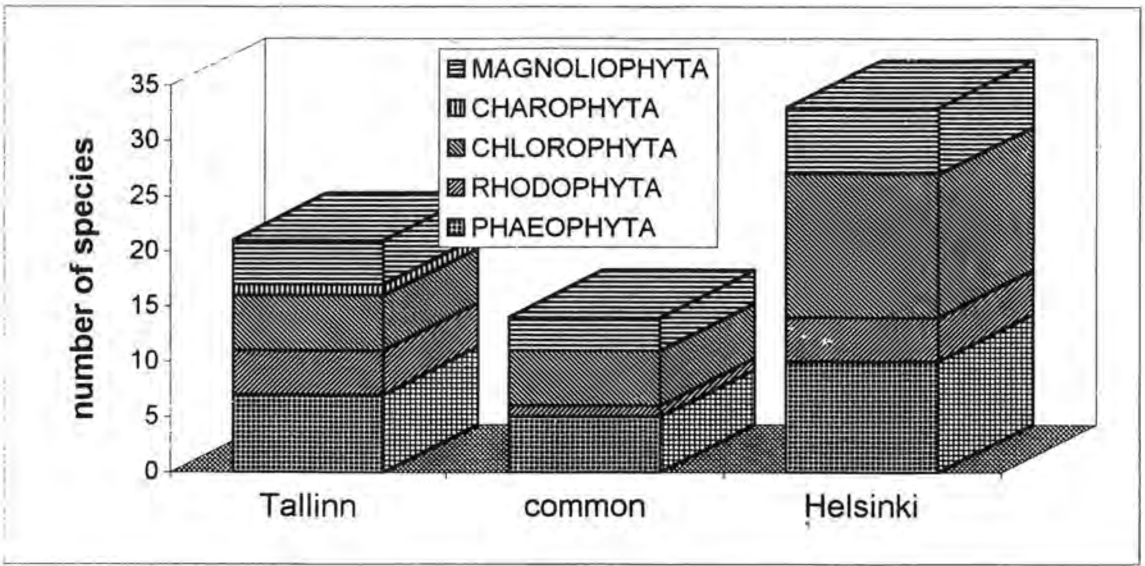

Figure 2. Number of species of bottom vegetation in Tallinn and Helsinki areas.

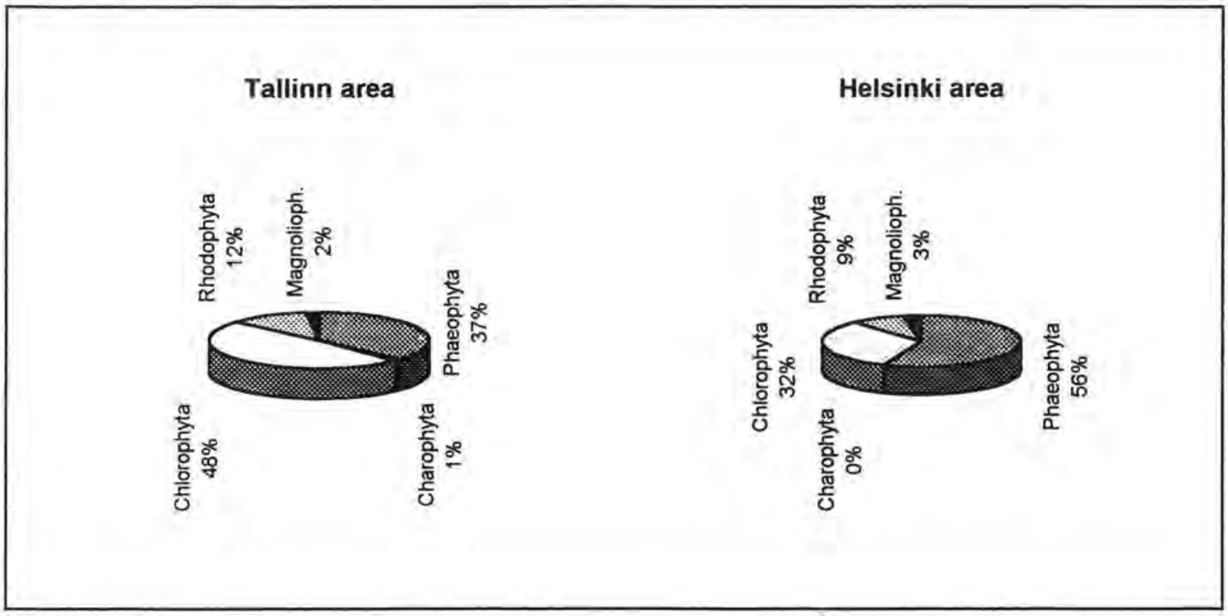

Figure 3. Relative abundance of different taxa in bottom vegetation of Tallinn and Helsinki areas

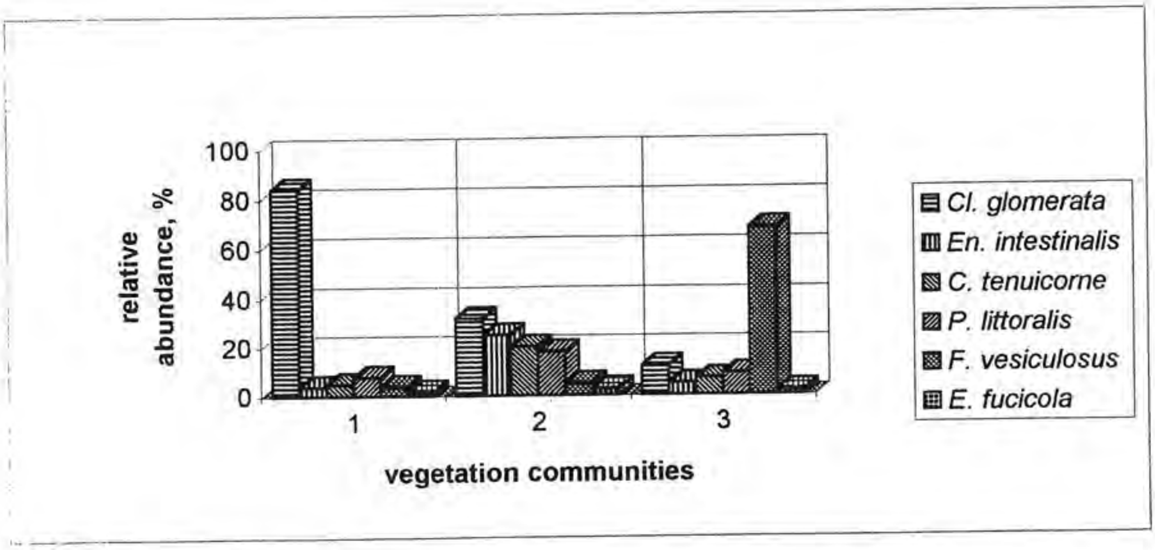

Figure 4. Structure of bottom vegetation communities in Tallinn area.

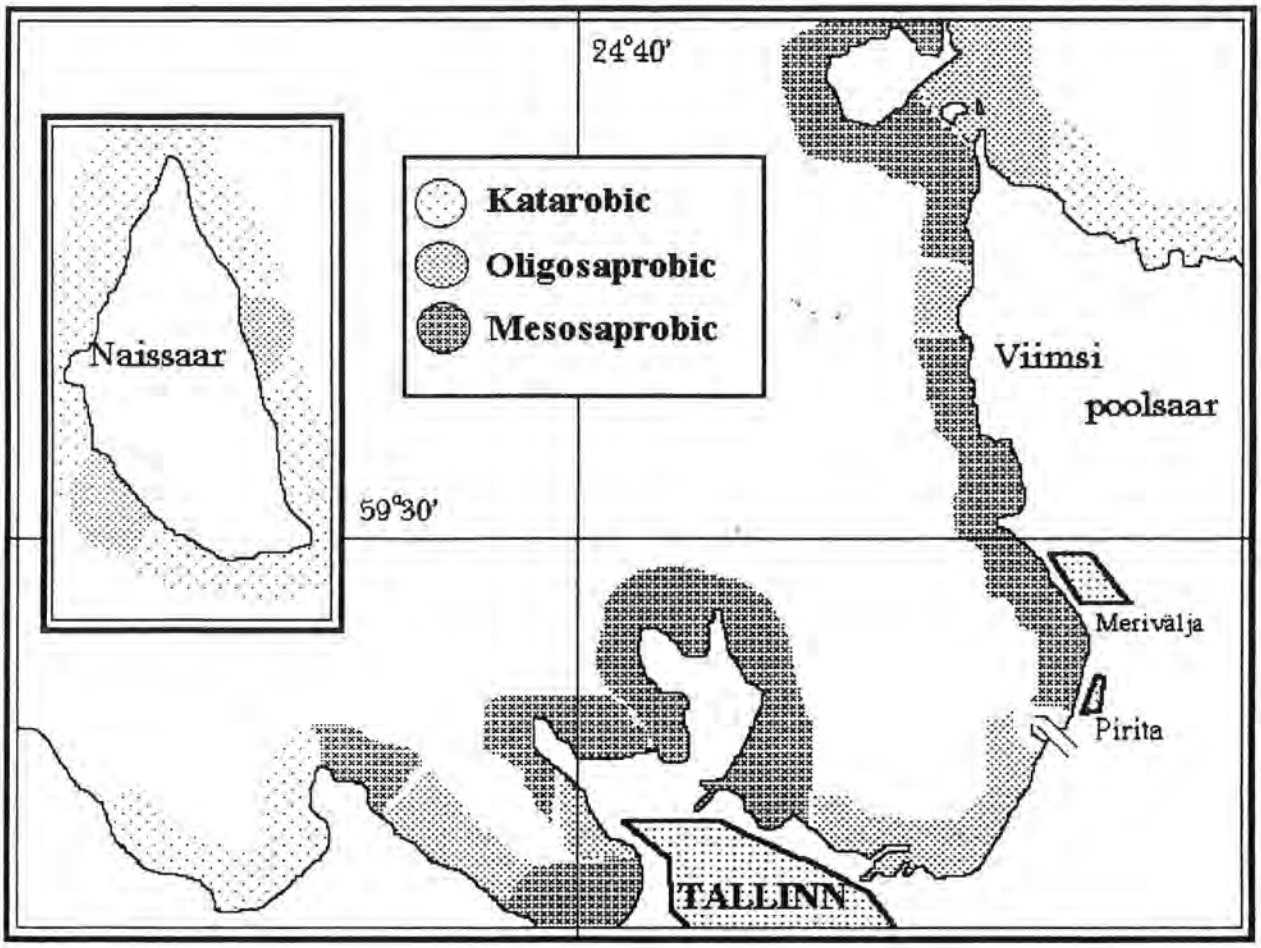

Figure 5. Distribution of trophic zones in Tallinn area in 1993.

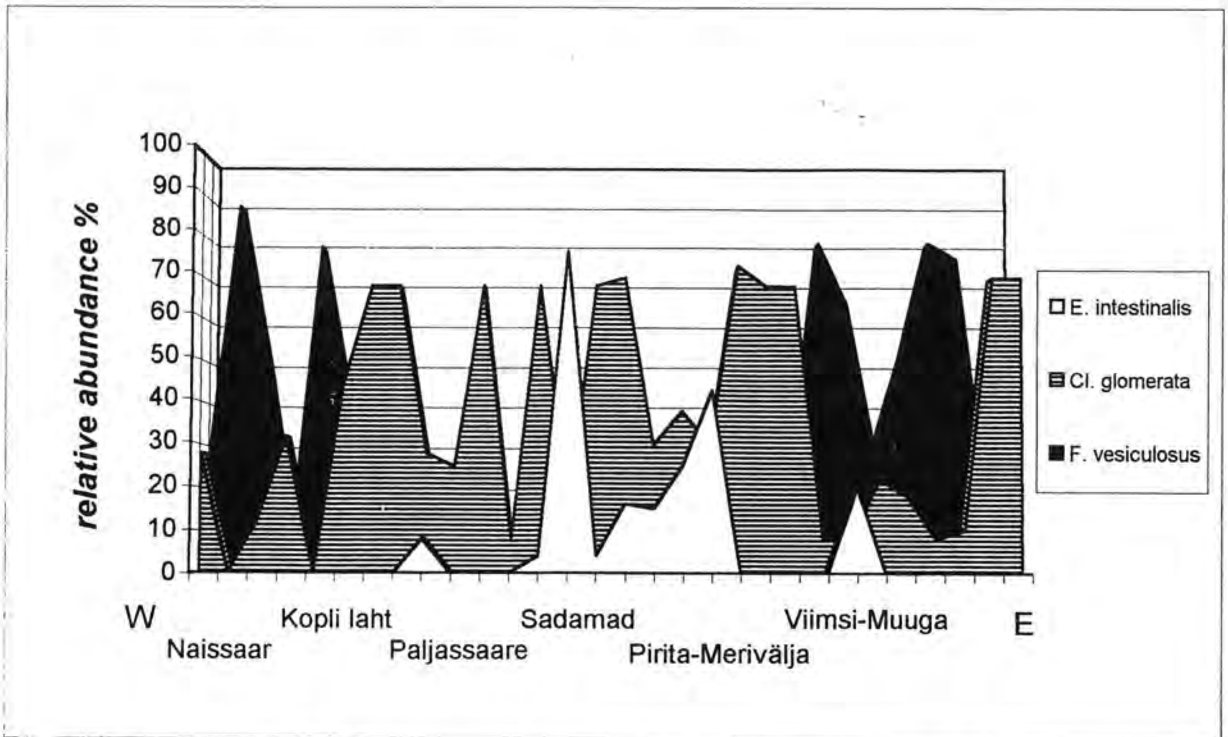

Figure 6. Distribution of relative abundance of dominant species of bottom vegetation along the coastline in Tallinn area

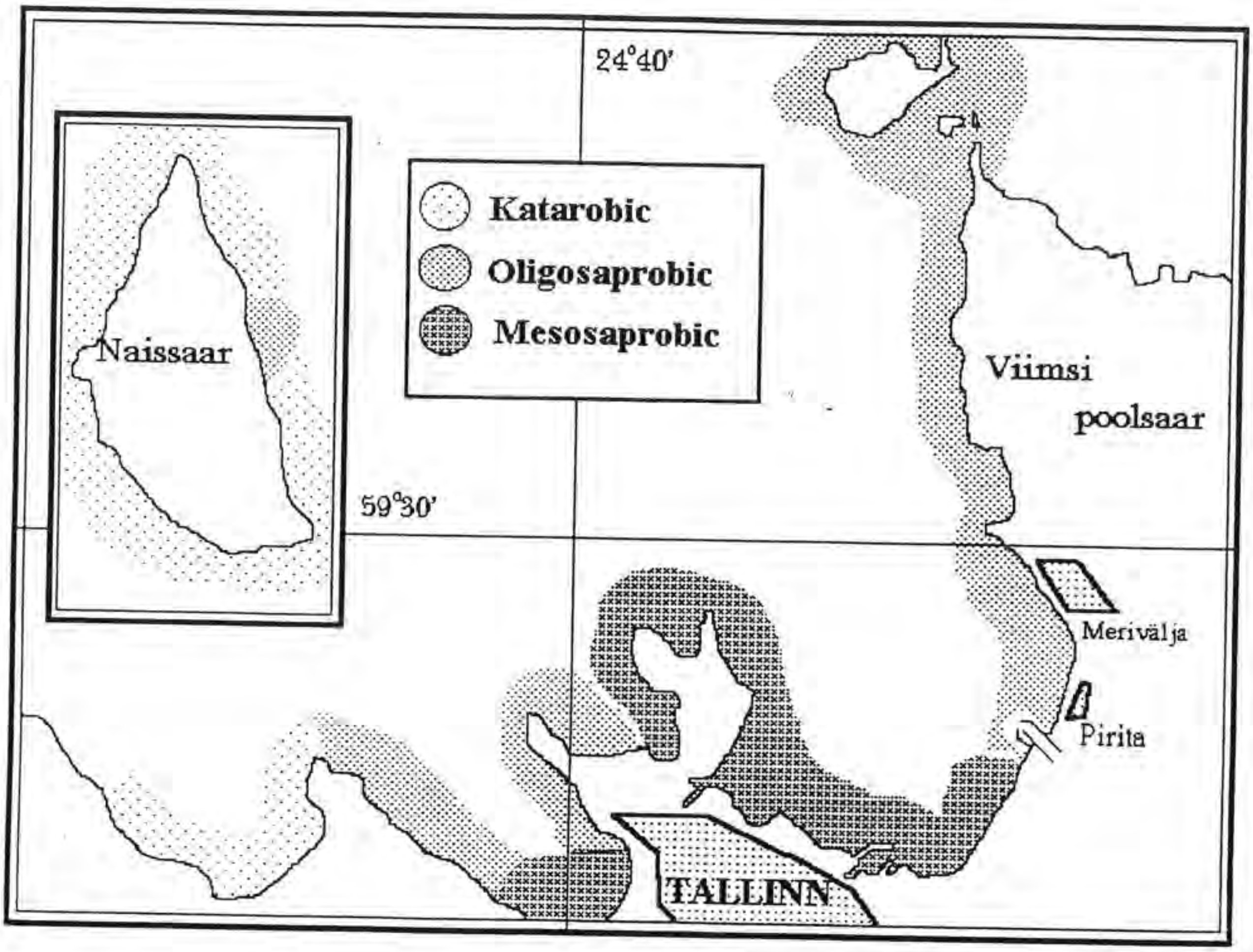

Figure 7. Distribution of trophic zones in Tallinn area in 1995.

APPENDIX 6

Viitasalo, Ilkka, Environment Centre of the City of Helsinki

THE CLASSIFICATION OF WATER AREAS BY LITTORAL VEGETATION IN HELSINKI

The cities of Tallinn and Helsinki are located almost across the Gulf of Finland, Baltic Sea, the distance being 85 kms. Both coasts have been frequently studied for bottom vegetation; the most recent samples have been taken in 1992-94.

The growth of macrophytes is dependent on different environmental parameters. Tide is almost lacking from the Baltic Sea. Sea level varies according to the cyclonic activity and precipitation; the lowest water levels occur mainly in spring and early summer. Local wave exposure, ice shearing and the quality of substrate are the most important 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 are concentrated into sublittoral zone under 1,0 - 1,5 m depth because of ice shear. Annual macrophytes; mainly green 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.

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 both of the coasts.

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 as well.

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 10-30 cm
	Abundance of epiphytes (3 classes, visual observation)	Class 0 (no epiph.) Class 1-2 Class 3 (abundant)
Fucus vesiculosus	Height Gas vacuoles Fertility *Elachista* as an epiphyte[1]	(cm) (y/n) (y/n) (y/n)
	Hydrozooic epiphytes[2]	<10 % of surface >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. The work towards unified data processing and classification methods is going on and the results are reported elsewhere. Here we describe statistical methods and the results from both sides of the Gulf of Finland separately.

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 load is well documented in the area. Different clusters (and taxa inside them) are supposed to display different nutrient load intensities (eutrophication). All taxa in a certain cluster were assigned with integer values which were called s-values (s-indicator values).

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

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

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 pollution zones was drawn (FIGURE 2).

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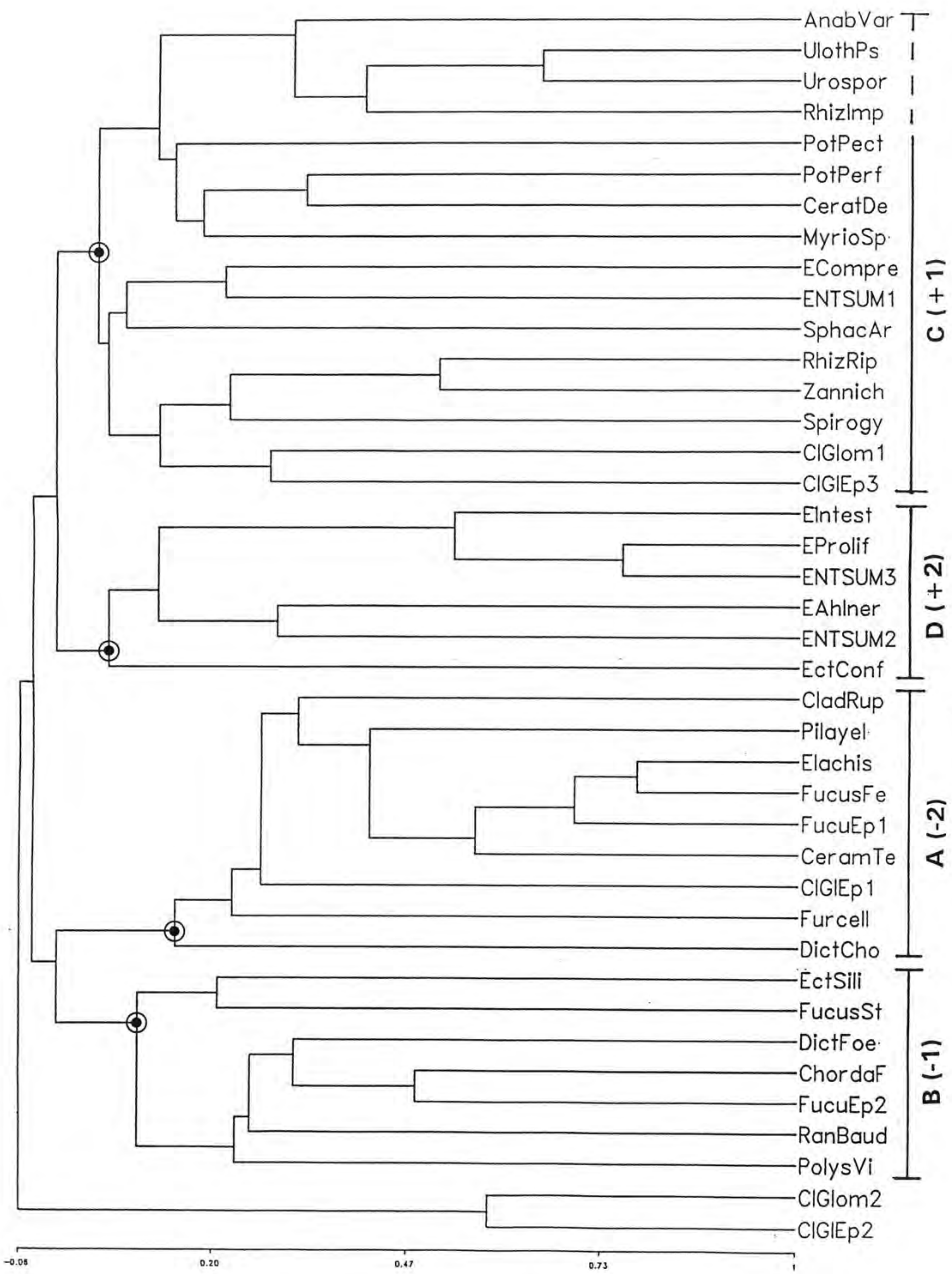

Figure 1. Dendrogram according to species found in the Helsinki region in 1993

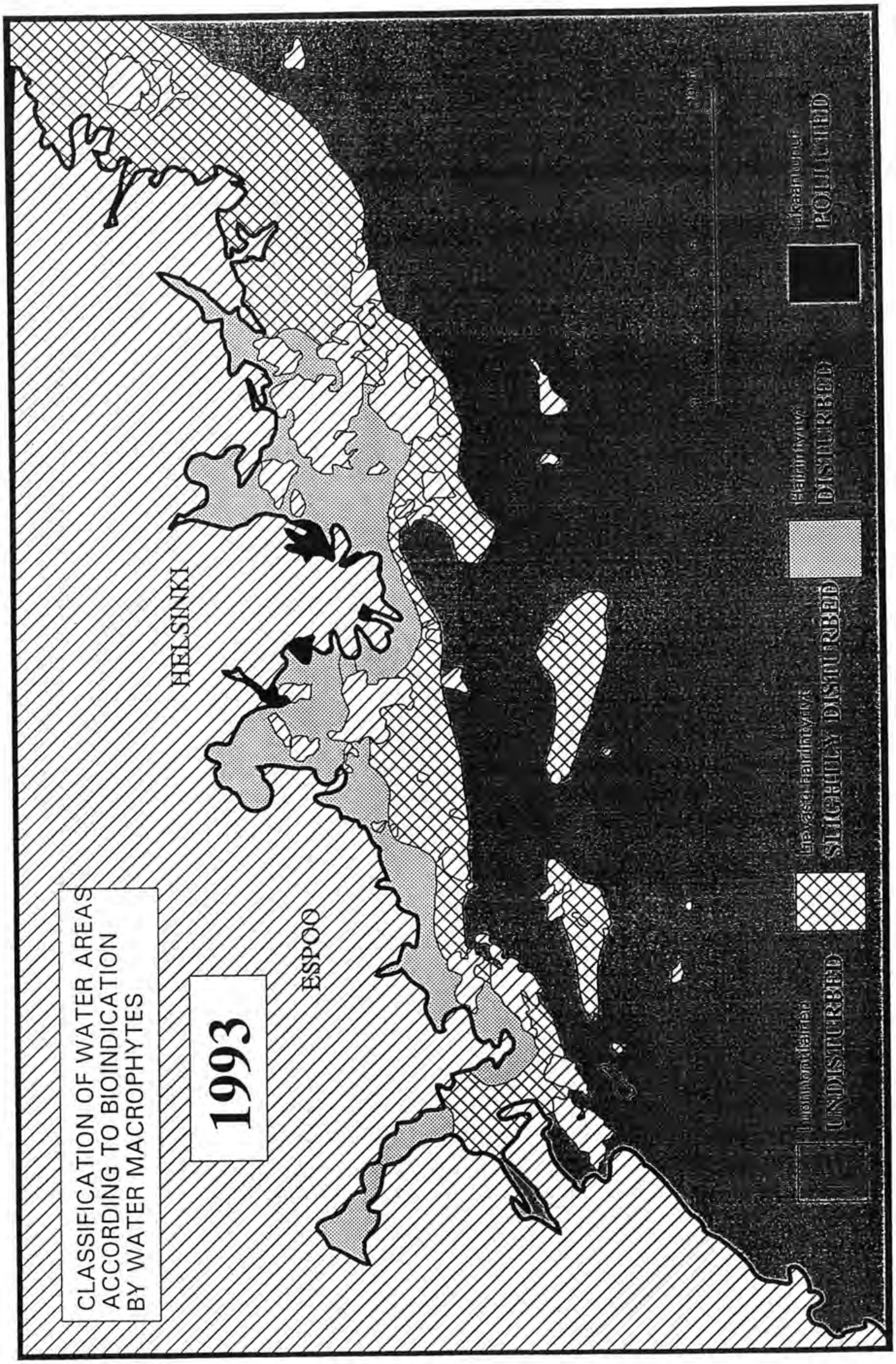

Figure 2. The extent of the different eutrophication classes according to macrophyte groups in the Helsinki region in 1993.

APPENDIX 7

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PRIMARY PRODUCTION ESTIMATES WITH DIFFERENT MACROALGAL SPECIES IN 1993-1994

Abstract

During 1993 - 1994, *"in situ"* production estimates were carried out with different macro-algal species dominating in algal communities in the Estonian coastal waters of the Gulfof Finland.

Photosynthetic and respiratory performances of annual *Enteromorpha intestinalis* and *Cladophora glomerata* (CHLOROPHYTA), *Ceramium tenuicorne* (RHODOPHYTA), *Pilayella littoralis* and perennial *Fucus vesiculosus* (PHAEOPHYTA) were determined by measuring changes of dissolved oxygen concentration in light and dark bottles using the Winkler titration method or an oxygen meter.

The highest production rates were measured for the green algae *E. intestinalis* and *Cl. glomerata*. The production rate of *C. tenuicorne* was also relatively high, being close to that of the above mentioned green algae. Significantly lower production rates were measured for *P. littoralis* and *F. vesiculosus*.

Comparing the results obtained at experimental stations with different load of human impact the maximal net photosynthetic rates for *E. intestinalis* and *Cl. glomerata* were measured at stations with the highest amount of nutrients in the water.

Key Words

Primary production, net photosynthesis, dark respiration, *Enteromorpha intestinalis, Cladophora glomerata, Pilayella littoralis, Ceramium tenuicorne, Fucus vesiculosus*;

Introduction

The data presented in this paper are based on *"in situ"* macroalgal primary production estimates carried out in 1993 and 1994.

In 1993, the main interest focused on changes in net photosynthetic and dark respiration rates of different macroalgae during the vegetation period. Five species of macroalgae - annual *Enteromorpha intestinalis* and *Cladophora glomerata* (CHLOROPHYTA), *Ceramium tenuicorne* (RHODOPHYTA), *Pilayella littoralis* and perennial *Fucus vesiculosus* (PHAEOPHYTA), which dominate in algal communities in the Estonian coastal waters of the Gulf of Finland were subject to studies.

In 1994, an attempt was made to compare during three months (May, June and July) the net photosynthetic rates of the two fast growing green algae *E. intestinalis* and *Cl. glomerata* at experimental stations with different load of human impact.

Material and methods

Study area (Fig.1) In 1993 the production estimates were carried out in Muuga Bay near the tip of the Viimsi Peninsula at one experimental station (in 1994 station 3) where the algal vegetation was dominated by *F. vesiculosus*. In spring and early summer *E. intestinalis* and *P. littoralis* and in July-August *Cl. glomerata* were the most abundant annual algal species growing there.

In 1994, basing on recent investigations of the ecological situation in the coastal waters of Tallinn Bay, as a result of which the geographical distribution of macrophytobenthos according to saprobic level was established (Kukk et al. 1994), location of two new experimental stations in this area was chosen. Station 1 was situated near the Port of Tallinn and station 2 in the area between the mole of Merivälja and the Miiduranna harbour, in the vicinity of the outflow of the domestic sewage from the local settlement into the sea. Both stations were prevailed by algal communities, in which *E. intestinalis* and *Cl. glomerata,* the pecies of green algae favouring eutrophic areas, dominated. At station 3 , situated in a relatively undisturbed area in Muuga Bay at the tip of the Viimsi Peninsula *F. vesiculosus* dominated in algal communities.

Photosynthetic and respiratory performances of algae were determined by measuring changes in dissolved oxygen concentration in "light and dark" bottles with Winkler titration method (1993) or using the oxygen meter OXI 92, which also measured the water temperature (1994).

The algal material was collected from natural populations growing in the vicinity of the experimental stations and transferred to 300 ml (light and 250 (dark, wrapped in aluminium foil) glass bottlescompletely filled with natural sea water. About 0.05 - 0.5 g (depending on species) dry weight of algal material was added to an incubation bottle for a period ranging from 1.0 to 1.5 hours. Bottles were incubated (dark and light ones separately) horizontally on special trays at a depth of 0.5 m.

The obtained oxygen values were converted to mgC_g dry wt^{-1}_h^{-1} by standard methods (Strickland, 1960) assuming a photosynthetic quotient of 1.2 and respiratory quotient of 1.0 for expression of rates of net photosynthesis and dark respiration (each of the results is a mean at least of three replicates).

Dry weight of the algal material was determined at the temperature of 60°C.
The environmental factors measured at the time of the experiment were solar radiance (kW_m^{-2}) above water surface and the water temperature (°C). For the further laboratory analysis of nutrients content water samples (250 ml each) were taken.

Results and discussion

In 1993 the experimental station (station 3 on Fig. 1) was visited altogether 29 times during the investigation period which lasted from 20 April until 9 November, and net photosynthetic (NP) and dark respiration (DR) rates for five most abundant algal species in the area - *Enteromorpha intestinalis, Cladophora glomerata, Pilayella littoralis, Ceramium tenuicorne* and *Fucus vesiculosus* - were measured.

The above-mentioned values, measured for different species, displayed remarkable differences between species and also showed temporal variation within the same species during the investigation period.

The highest NP and DR rates were measured for short lived annual green algae *E. intestinalis* and *Cl. glomerata* , as might have been expected, supporting our earlier results and those of other investigators (Jannson 1974, King and Schramm 1976, Wallentinus 1976,1978). There were no remarkable differences in magnitude of NP rates between *E. intestinalis* and *Cl. glomerata* (0.4-3.9 and 0.2-3.8 mgC_g dry wt^{-1}_h^{-1} ,accordingly) but a certain temporal variation in occurrence of maximal NP values was observable (Fig. 2 and 3).

The highest vernal NP rate for *E. intestinalis* - 3.3 mgC_g dry wt^{-1}_h^{-1} , was measured at the beginning of May, while the maximal NP rate was obtained in August - 3.9 mgC_g dry wt^{-1}_h^{-1} . Remarkable high NP rate, close to those mentioned above could be obtained even as late as October.

For *Cl. glomerata* the highest NP rate - 3.8 mgC_g dry wt^{-1}_h^{-1} was measured in September. High NP rates close to the maximal rate were obtained in the second half of July and in August, accompanied with luxuriant growth of this algae in the study area.

One reason for the observed temporal variation in the occurrence of maximal NP between *E. intestinalis* and *Cl. glomerata* could be different adaptation to water temperature. *Cl. glomerata* seems to prefer somewhat higher temperatures than *E. intestinalis*.

In literature there are several data available on the direct effects of temperature on the production rates of *Cl. glomerata*. According to Whitton (1967), maximum growth takes place at temperatures between 15 and 25 °C, the lowermost limit being 6 °C. Jansson (1974) has observed a visible growth of *Cl. glomerata* at the temperature of water not exceeding 4 °C.

The water temperature measured at our experimental station varied during the investigation period between 0.7 and 18.5 °C. As seen from Figure 7, highest temperatures occurred in July - August when, as already mentioned, high NP values for *Cl. glomerata* were obtained, i.e. the water temperatures was higher than 14 °C. Low NP was observable at water temperature 5 °C.

E. intestinalis unlike *Cl. glomerata* was capable of fast growth already in early spring under relatively low temperature conditions. The highest vernal NP for *E. intestinalis* obtained at the temperature of water 8 °C was close to maximal NP measured at 18 °C, while considerable NP were observed with water temperatures below 5 °C.

Compared to other algal species in our *"in situ"* experiments, the above-mentioned green algae had higher DR rates. In *Cl. glomerata* DR rates were somewhat higher than in *E. intestinalis*. DR was roughly estimated to be 32 per cent of gross photosynthesis for *Cl. glomerata* and 26 per cent of gross photosynthesis for *E. intestinalis*.

According to our investigation results, *C. tenuicorne* was the third algal species with relatively high NP rates (0.5 - 2.6 mgC_g dry wt^{-1}_h^{-1}) though the maximal NP was a bit lower. (Fig. 4). As is seen from the figure, the highest NP rates were measured in August. DR was found to be 25 per cent of gross photosynthesis.

Significantly lower NP rates were obtained for perennial brown algae *F. vesiculosus* below 0.6 mgC_g dry wt^{-1}_h^{-1} (Fig. 5). In the event of *F. vesiculosus* the absolute DR rates and the percentage of DR from gross photosynthesis (20 %) were also the lowest.

Unexpectedly low NP rates below 0.8 mgC_g dry wt^{-1}_h^{-1} and relatively high DR (on the average 40 per cent of gross photosynthesis) rates during the study period in 1993 (27.04. - 10.08.) were exhibited by *P. littoralis* (Fig. 6).

NP values obtained by us at the same station in 1994 were higher - up to 1.7 mgC_g dry wt^{-1}_h^{-1} (DR rate 30 per cent of gross photosynthesis) while at station 1 and station 2 (Fig.1) the maximal NP measured were accordingly 2.4 and 1.8 mgC_g dry wt^{-1}_h^{-1} (obtained at the end of June). For comparison, I. Wallentinus (1978) reported that the production rate of *P. littoralis* in "in situ" measurements with ^{14}C ranged between 0.6 and 6.1 mgC_g dry wt^{-1}_h^{-1}.

According to the above presented results, the algal species used in "*in situ* " experiments in 1993 can be divided roughly at least into two groups. The first group will include the species with high net photosynthetic(production) rates, such as *E. intestinalis, Cl. glomerata* and *C. tenuicorne*, the second one - the species with low net photosynthetic (production) rates - *P. littoralis* and *F. vesiculosus*.

In 1994, the primary production estimates were concentrated on primary production of *E. intestinalis* and *Cl. glomerata* , the two fast growing green algae very common in algal communities of shallow coastal areas. During three months, from May to July changes in their NP rates were measured altogether ten times and an attempt was made to compare the corresponding values obtained at the same time at different experimental stations (Fig. 1). Our experimental data, on figures 8 and 10 show differences in NP rates of *E. intestinalis* and *Cl. glomerata* from different stations. At the same time, a certain temporal shift of the occurrence of NP maxima measured for the above-mentioned algae between stations is evident.

Unfortunately, the data available are too scanty and do not allow any definite conclusion to be drawn to explain these differences. In May the water temperature (as seen from figure 9 there are remarkable differences in water temperature between stations) seems to control NP rates of algae used in our experiments. In June after unification of water temperature other environmental as well as physiological (incl.age of the algae) factors must be taken in consideration to explain differences in NP rates between stations.

It cannot be excluded that besides other factors differences in nutrient content in the water of experimental stations are to a certain extent responsible for these discrepancies.

The highest rates of net photosynthesis were obtained both for *E. intestinalis* and *Cl.glomerata* at station 1, where during the investigation period relatively higher concentrations of NO_3^- and PO_4^{3-} were measured (Fig. 11 and 12).

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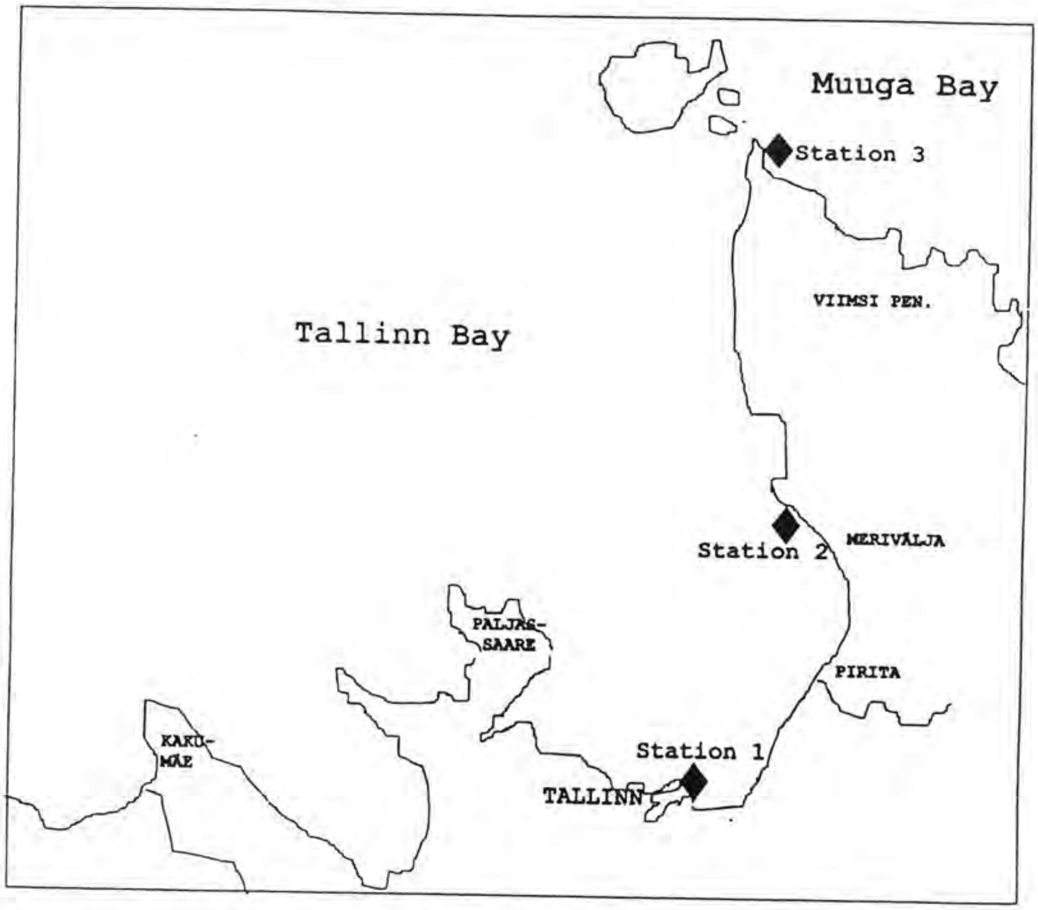

Fig. 1 Location of experimental stations

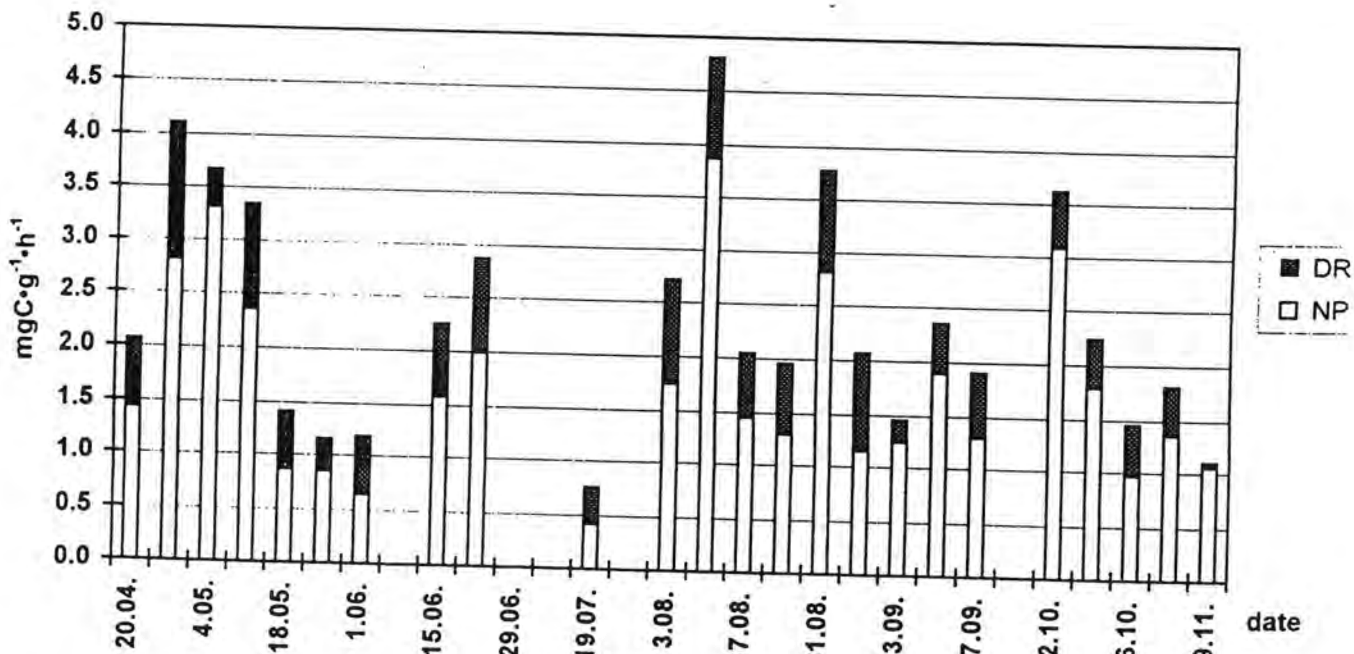

Fig. 2 Net photosynthetic and dark respiration rates of *Enteromorpha intestinalis*

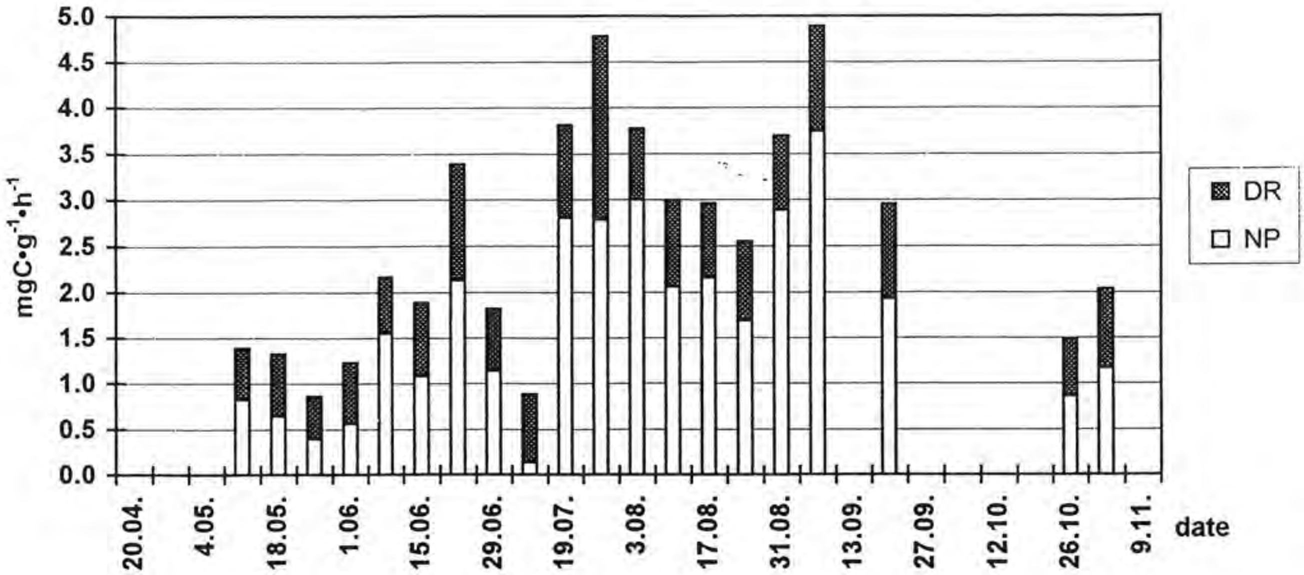

Fig. 3 Net photosynthetic and dark respiration rates of *Cladophora glomerata*

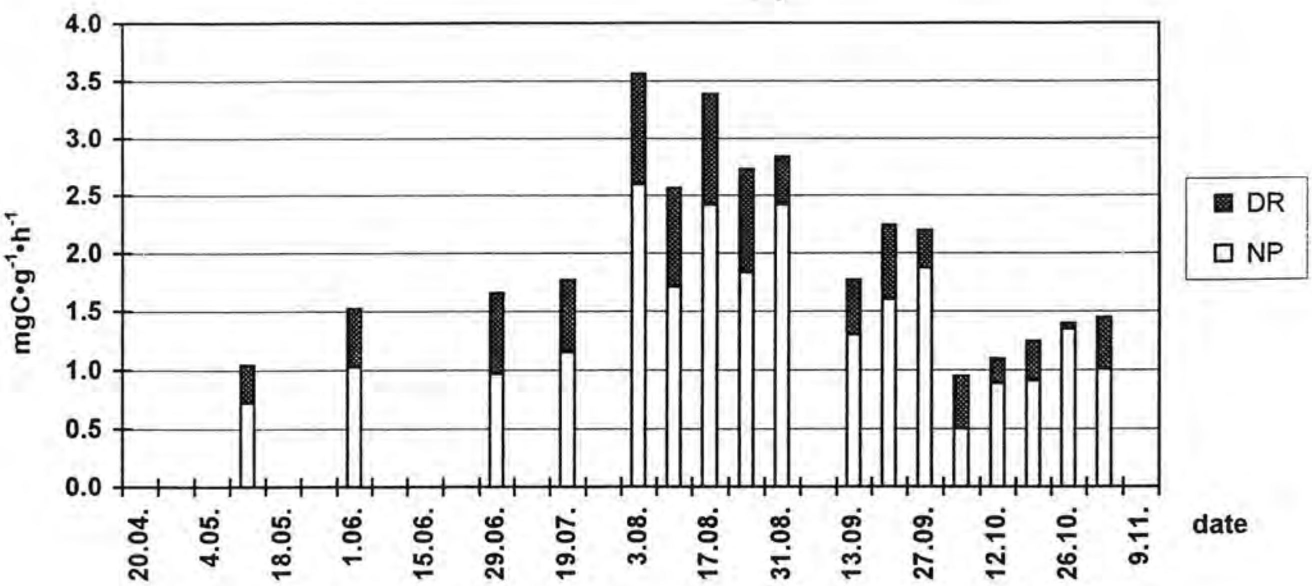

Fig. 4 Net photosynthetic and dark respiration rates of *Ceramium tenuicorne*

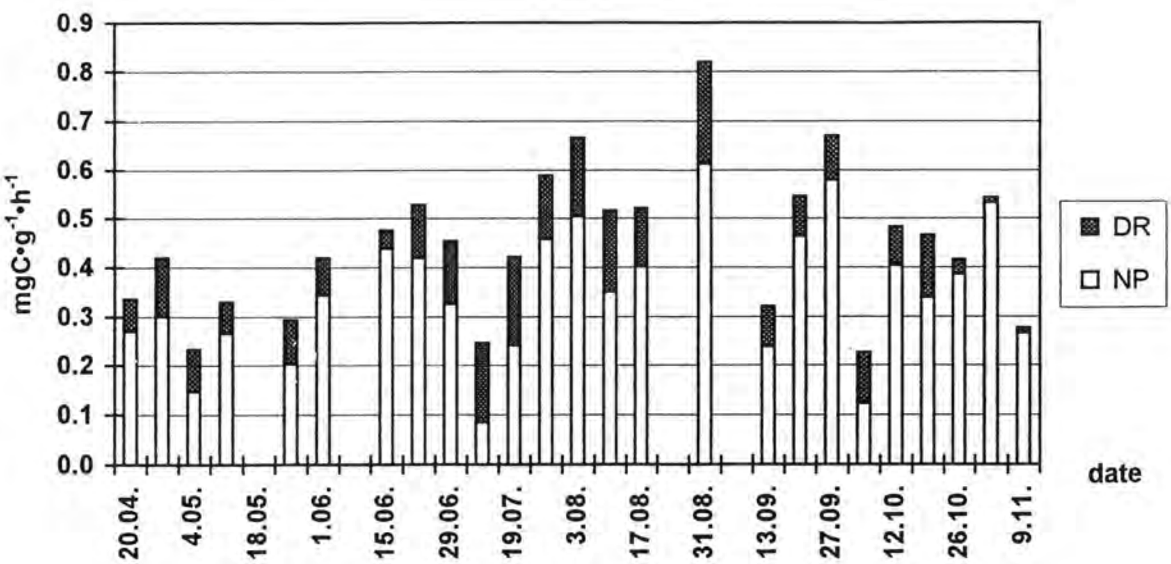

Fig. 5 Net photosynthetic and dark respiration rates of *Fucus vesiculosus*

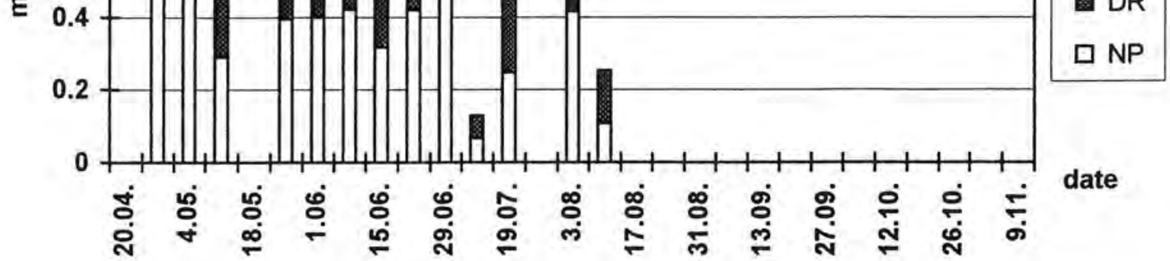

Fig. 6 Net photosynthetic and dark respiration rates of *Pilayella littoralis*

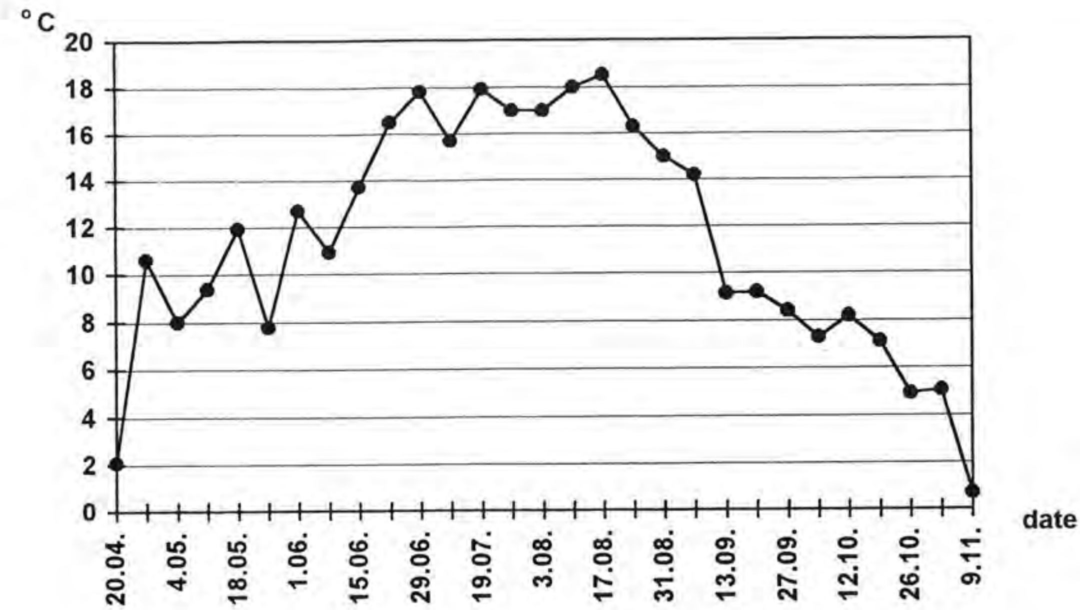

Fig. 7 Water temperature

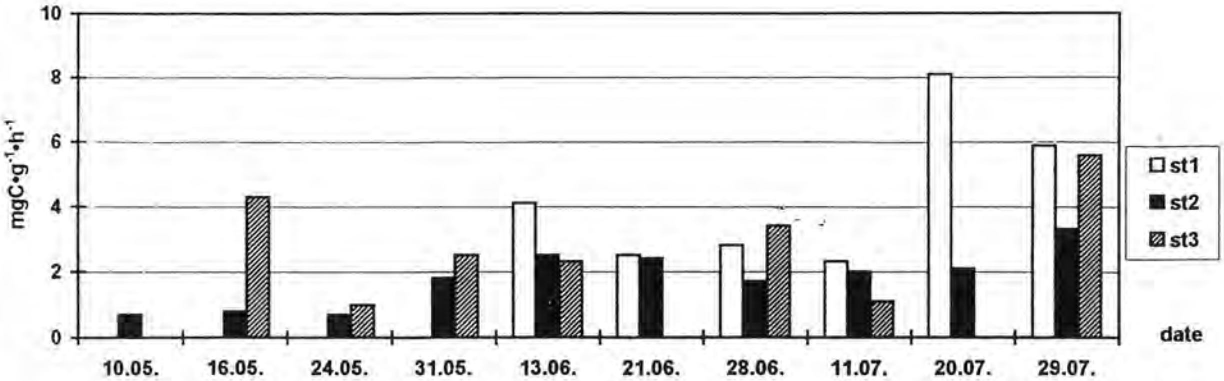

Fig. 8 Net photosynthetic rates of *Cladophora glomerata*

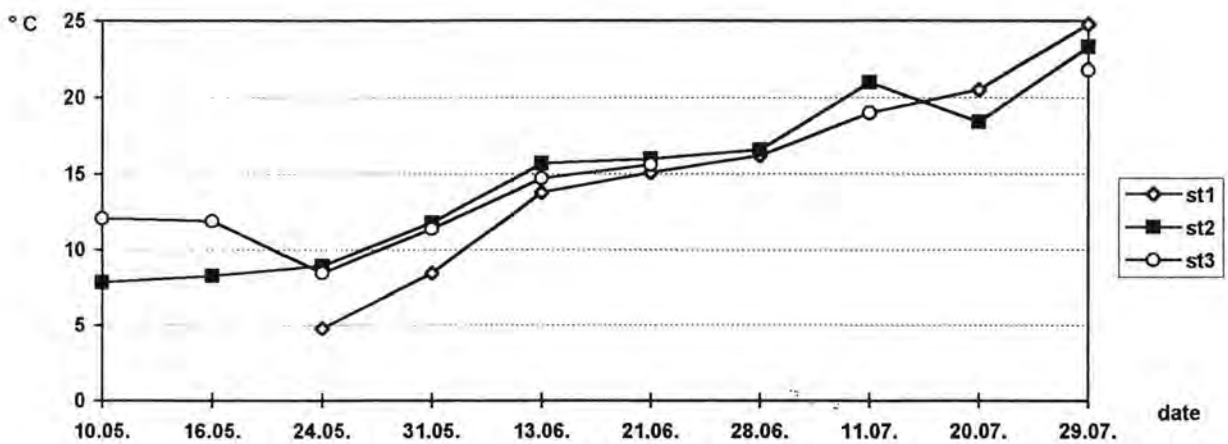

Fig. 9 Water temperature at different stations

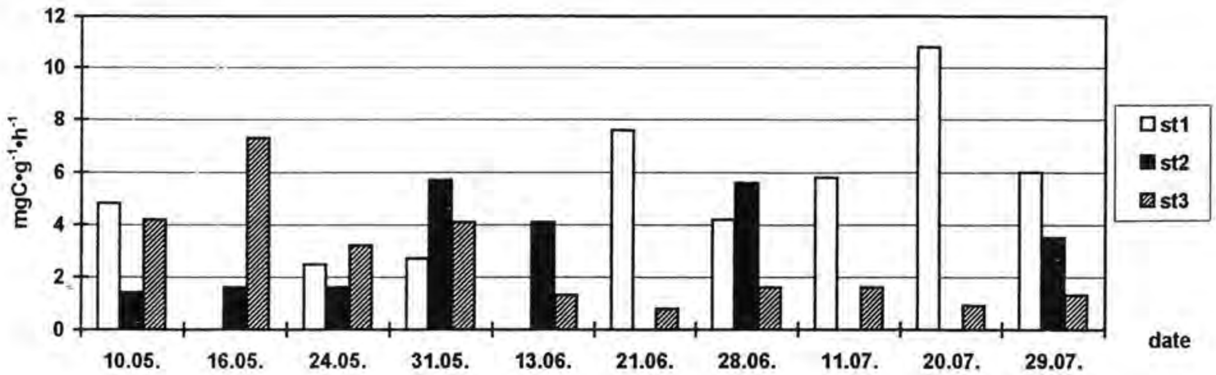

Fig. 10 Net photosynthetic rates of *Enteromorpha intestinalis*

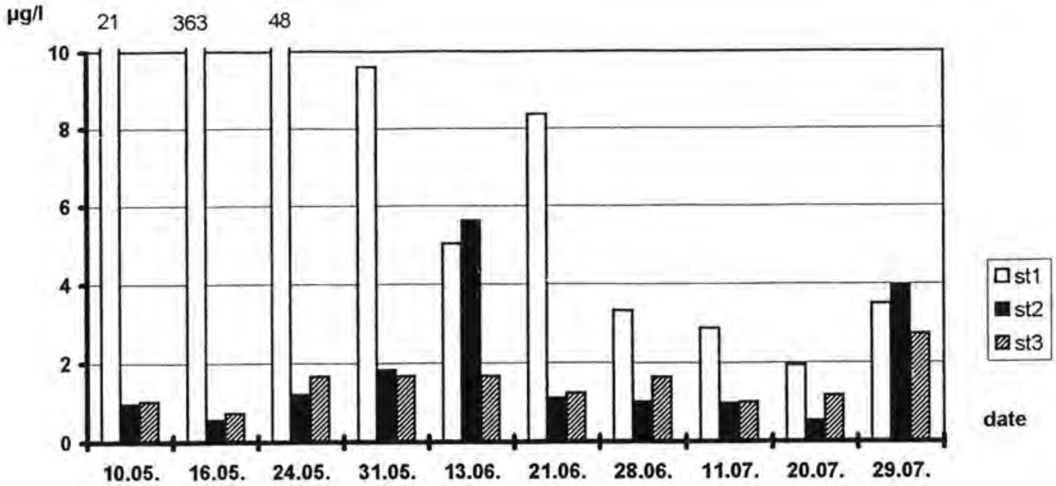

Fig. 11 NO_3^- content of the water at different stations

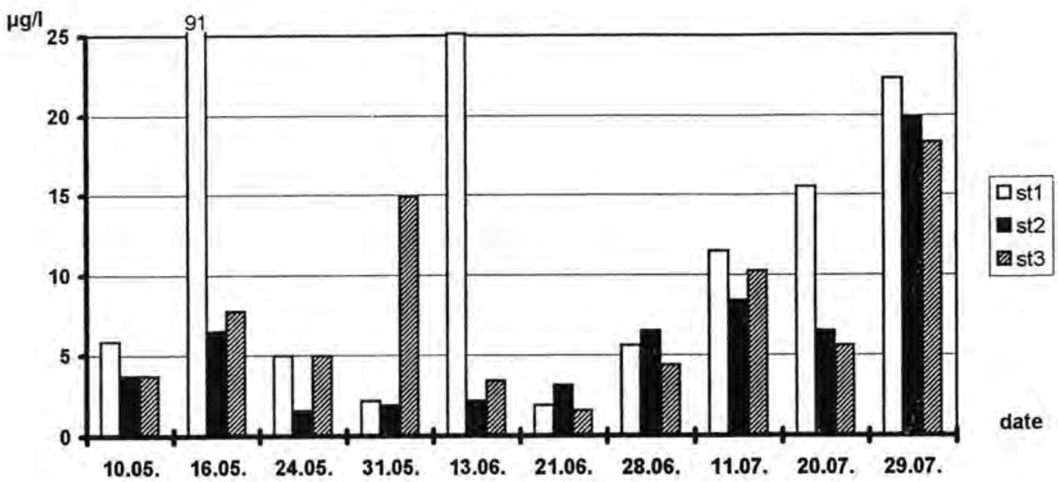

Fig. 12 PO_4^{3-} content of the water at different stations

APPENDIX 8

Kotta, Ilmar and Kotta, Jonne, Estonian Marine Institute:

ZOOBENTHOS OF TALLINN BAY

Introduction

The distribution of a zoobenthic species is highly related to depth values. Depth correlates with several environmental parameters, such as sediment type, salinity, temperature, oxygen concentration and presence or absence of benthic vegetation which control the development of a particular zoobenthic community.

Sediment type affects the total abundance of macrozoobenthos. Each sediment type is characterized by certain zoobenthic species which have become adapted to this sediment. Benthic fauna in the littoral zone has high biomasses on hard substrate (stone, sand) and abundances on muddy sediment. In the deeper areas more abundant communities are found on muddy clay bottoms.

Low salinity results in low values of species diversity in the Gulf of Finland. Fresh water species may occur at salinity less than 4-5 ‰ but these are few in number.

"Cold - addicted" species colonize deeper sea areas (depth < 30 m) where water temperature is stable throughout a year (+ 6 °C). On the other hand, benthic invertebrates which tolerate high fluctuations of temperature inhabit shallower regions.

Both the species diversity and abundances are higher in the areas where abundant benthic vegetation occurs. Low oxygen concentrations may limit the development of zoobenthic communities in very shallow and isolated areas or similarily in the relatively deep sea regions (depth > 100 m).

The factors which relate to the "civilization" should be integrated to the previous list. Increase in organical particles in sea water and the occurrence of predominantly muddy sediments are typical features of the areas which experience strong human influence. From the biological point of view, decrease of species diversity and increase in the abundance of bivalves (both suspension and deposit feeders) are observed.

Open bays of the Estonian coastal area are mostly inhabited by the bottom community of *Macoma balthica* or *Mytilus edulis*. Because of their polytopic and eurysaprobic character they are not suitable for being used as the indicators of the degree of organic pollution of mild toxicity (Järvekülg & Kukk, 1985).

During this study we aimed at investigating the impact of pollution load to the benthic fauna in the vicinity of Tallinn city. It is the first attempt to study the zoobenthic communities in the shallowest zone of Tallinn Bay, though, the systematical surveys of the bay started already in the 1960s (Järvekülg, 1970; Järvekülg, 1979).

Material and methods

The material was collected from the littoral zone (depth between 1.5 and 8 m) of Tallinn, Kopli, Paljassaare and Muuga Bays as well as from the surroundings of Naissaar Island in 1995 (fig. 1). Depth values and sediment type were recorded at every station. In this study we may presume the effect of temperature, salinity, oxygen concentration to be negligible. Petersen bottom grab (catching surface 0.017 m^2) was used for sampling. Samples were sieved through nylon net bag with the mesh size of 0.25 mm. Animals were fixed in 4 % buffered sea water formaldehyde solution. Animals were picked up under stereo-microscope. Abundance and wet weight values of each species were determined.

Results

The species composition of macrozoobenthos was relatively rich in the littoral zone of Tallinn Bay in 1995 (table 1). Worms were represented by *Turbellaria, Halicryptus spinulosus, Oligochaeta, Nereis diversicolor*, crustacean by *Bathyporeia pilosa, Corophium volutator, Gammarus spp., Balanus improvisus, Jaera albifrons, Idothea baltica, I. viridis, Monoporeia affinis; Insecta larvae* by *Chironomidae; Mollusca* by *Macoma balthica, Mytilus edulis, Cerastoderma lamarcki, Mya arenaria, Hydrobia spp., Potamopyrgus jenkinsi, Theodoxus fluviatilis.* Besides the individuals of

Hydrozoa and *Ostracoda* were found but none of these were determined to species level.

In Tallinn Bay the mean abundance and biomass of zoobenthos were 5240 ind/m² and 61.9 g/m², respectively. *Mytilus edulis* dominates both in numbers and biomass in the shallower areas (depth between 0.5 and 2 m). Three most common species in the deeper parts (depth between 2 and 8 m) are *Hydrobia spp.* and *Macoma balthica*.

The mean biomass and abundance were considerably lower in Kopli Bay, Muuga Bay (close to the Viimsi Peninsula) and around Naissaar Island. These values were correspondingly 820 ind/m² and 33.4 g/m², 14 ind/m² and 21.5 g/m², 122 ind/m² and 21.5 g/m². *Mytilus edulis* and *Gammarus spp.* had higher abundances in shallower areas, *Theodoxus fluviatilis* and *Macoma balthica* in deeper areas.

Tallinn Bay is among the most highly polluted sea areas at the Estonian coast. Previous figures depict the amount of the increase in the "carrying capacity" of an environment after the influx of pollutants in the course of several decades.

The impact of sewage water on the species composition and the abundance of dominants is quite remarkable (fig. 1). The extreme abundance and biomass values of Tallinn Bay come from the thriving of two mollusc species - *Macoma balthica* and *Mytilus edulis*, which prefer the sediments high in organic matter, and the suspended-particle-rich water column above sediment.

The densest colonies of *M. edulis* occur at the Cape of Paljassaare and in the north-eastern part of Tallinn Bay (fig. 2). These are explained by the vicinity of deep-water sewage output and dominant currents. Quite dense populations of *M. edulis* (> 5000 ind/m²) are equally found in the innermost part of Kopli and Muuga Bays. In Kopli Bay it is due to the sewage pipeline (closed in 1979), while in Muuga Bay it is related to the dredging works (the early 80s). This indicates that the previous equilibrium state may never be reached even if the impact of a factor which had destabilized the community, reverted.

Usually the individuals of *M. balthica* are missing at depths less than 5 m in the Gulf of Finland because of unfavourable sediment type in this zone. But the abundance of *M. balthica* exceeds > 400 ind/m² in the coastal area of Tallinn Bay, the region where muddy sediments rich in organic matter accumulate.

Conclusions

It may be concluded that the abundance values of two bivalve species- *M. balthica* and *M. edulis* - should be used in order to estimate the concentration of organic matter in sediment (*M. balthica*) or in water column (*M. edulis*) in Tallinn Bay. But special attention should be payed to the populations of *M. edulis* which having been artificially created, has persisted as a natural stable system of considerably higher abundance level over several decades.

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Table 1. Species list of macrozoobenthos in Tallinn Bay and the vicinity in 1995.

TAXA	Kopli Bay	Eastern part of Tallinn Bay	Western part of Tallinn Bay	Eastern part of Muuga Bay
Turbellaria		+	+	
Oligochaeta		+	+	+
Halicryptus spinulosus		+		
Nereis diversicolor		+	+	
Corophium volutator	+		+	
Gammarus spp.	+	+	+	+
Bathyporeia pilosa	+			
Jaera albifrons		+		
Idothea viridis	+	+		
I. baltica				+
Monoporeia affinis			+	
Chironomidae l.	+		+	
Potamopyrgus jenkinsi		+	+	
Hydrobia spp.	+	+	+	+
Theodoxus fluviatilis	+	+	+	+
Lymnaea peregra		+	+	
Macoma balthica	+	+	+	+
Mytilus edulis	+	+	+	+
Mya arenaria	+	+	+	
Cerastoderma lamarcki	+	+	+	

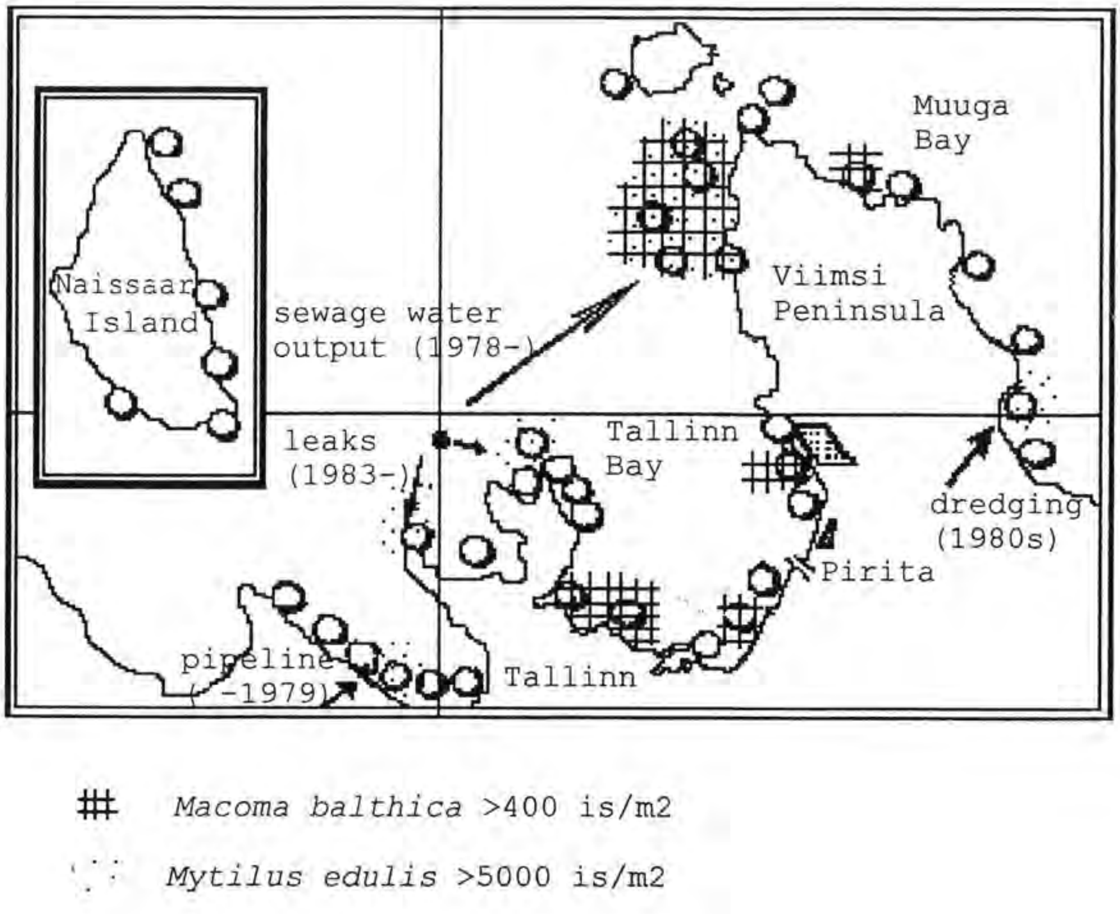

Figure 1. Sampling stations of macrozoobenthos in Tallinn Bay and surrounding areas in 1995. Arrows represent main sources of pollution. Extremely high abundances of *Macoma balthica* (hatched area) and *Mytilus edulis* (dotted area) are drawn.

APPENDIX 9

Simm, Mart and Jankowski, Harri, Estonian Marine Institute:

CONCENTRATION OF HEAVY METALS IN THE BOTTOM VEGETATION AT THE SOUTHERN COAST OF THE GULF OF FINLAND

The project "Bottom vegetation communities as a bioindicator of the state of coastal sea on the example of the Tallinn and Helsinki areas" addresses determination of heavy metal concentration in different species of bottom vegetation. For this purpose, in 1995 algae were collected from the areas with different pollution load in the vicinity of Helsinki. The analysis of the samples is in progress and the results to be obtained, including the data on the algae of the Tallinn area, will be published next year. In earlier years researchers of the Marine Chemistry Department studied the concentration of heavy metals in the bottom vegetation in different parts of the Baltic Sea. Below we shall give a survey of the relevant studies conducted at the southern coast of the Gulf of Finland.

Our data about the concentration of heavy metals in the bottom vegetation, including also that of the Gulf of Finland, have been published in a series of papers (Pôder, 1981; Jankovski, Pôder, 1981; Jankovski et al., 1984; 1987; 1988; 1989). The concentrations of copper, lead, cadmium and zinc were determined mainly in the species of macroalgae widespread in the Baltic Sea - *Fucus vesiculosus, Cladophora glomerata* and *Enteromorpha intestinalis*. The data on *Cladophora rupestris, Dictyosiphon foeniculaceus, Ceramium tenuicorne, Furcellaria lumbricalis* and *Rhodomela confervoides* is somewhat scanty. Most of the material was collected and analysed during 1983-1988.

Determination of the concentration of toxic substances is not among the goals of the Baltic Sea monitoring programme. Opinions available in literature differ as to the suitability of bottom vegetation for bioindication. For instance, relations between heavy metal concentrations in bottom vegetation and sediments have been analysed. Some authors maintain that the concentration of metals, first of all copper and zinc in the bottom vegetation correlates with the concentration of these metals in sediments (Luoma et al., 1982; Brix et al., 1983; Greger, Kautsky, 1992 a.o.). Others deny this kind of connection (Aulio , 1986). Discrepancies may be due to the purity of the studied material, i.e. the presence of mineral substances and other particles, including epiphytes in the sample (Barnett et al., 1985; Szefer et al., 1988; Söderlund et al., 1988 a.o.). Despite these difficulties, the studies on bottom vegetation have allowed local differences in the spread of heavy metals to be described quite successfully (Brix et al., 1983; Kangas, Autio, 1986; Söderlund et al., 1988; Barnett et al., 1989 a.o.).

The concentration of heavy metals in the bottom vegetation varies with species. The concentration of copper in the red algae (15.3 ± 3.0 $mg*kg^{-1}$) is higher than in the green and brown algae (8.7 ± 5.8 and 5.0 ± 3.0 $mg*kg^{-1}$, respectively). Table 1 shows that the concentration of copper is higher (more than 10 $mg*kg^{-1}$) in the red algae *Ceramium tenuicorne, Furcellaria lumbricalis* and *Rhodomela confervoides,* but also in the brown alga *Dictyosiphon foeniculaceus.* The concentration of lead in the green algae (3.0 ± 1.9 mg * kg^{-1}) is somewhat higher than in the red and brown algae (1.4 ± 0.8 and 1.2 ± 1.1 mg * kg^{-1}, respectively). The species *Cladophora rupestris, Cladophora glomerata* and *Enteromorpha intestinalis* are also relatively high in lead (Table 1). The content of cadmium and zinc in the brown algae (4.45 ± 3.60 and 60 ± 35 mg * kg^{-1}) is much higher than in the red (0.84 ± 0.53 and 16 ± 9 mg * kg^{-1}) and green (0.47 ± 0.30 and 20 ± 7 mg * kg^{-1}) algae. In the event of cadmium, this is due to the extremely high concentration in *Fucus vesiculosus* , while in *Dictyosiphon foeniculaceus*, which was another brown alga studied, the concentration of cadmium is rather low (Table 1). The concentration of zinc in both above-named species is higher than in other analysed algae, however, in *Fucus vesiculosus* it is still higher than in *Dictyosiphon tortilis.*

In view of the heterogeneity of data (material collected from different areas was put together), the above conclusions should be considered as approximate. More detailed studies in different areas, however, support these conclusions. In three different parts of the Gulf of Finland (Fig. 1), the concentration of copper in *Enteromorpha intestinalis* is much higher than in *Cladophora glomerata* and *Fucus vesiculosus.* Figure 2 shows that in four different study areas the concentration of copper in red algae (*Ceramium tenuicorne, Furcellaria lumbricalis, Rhodomela confervoides)* is higher than in the other species studied. In the area of Kaberneeme, Vergi and Toolse (Fig. 1) the concentration of lead is somewhat higher in the green algae *Cladophora glomerata* and *Enteromorpha intestinalis*, and lower in *Fucus vesiculosus.* The same is valid for the Suurupi area, but in the vicinity of Osmussaar Island the concentration of lead is highest in *Fucus vesiculosus* (Fig. 2). In all study areas the concentration of cadmium and zinc in *Fucus vesiculosus* is much higher than in the other species analysed.

In analysing the concentration of heavy metals in the bottom vegetation besides species also several other biological-physiological and ecological factors must be taken into consideration. There are sufficiently data showing the relation between the content of heavy metals and the age of plants. Our data on *Fucus vesiculosus* show that the concentration of copper and cadmium in the older parts of the thallum is somewhat higher than in the younger parts (Table 2). The same results have been obtained through the studies on *Fucus vesiculosus* in the Tvärminne area (Kangas, Autio, 1986). However, at the same time, in the specimens of *Fucus vesiculosus* collected from the Gulf of Bothnia this holds true only for zinc, while in the event of copper, cadmium and lead no dependence between their concentrations and the age of the plant has been observed (Söderlund et al., 1988). Let us analyse the impact of biological-physiological factors on the accumulation of heavy metals in the bottom vegetation on the basis of two species - *Ceramium tenuicorne* and *Ceramium rubrum*. In the specimens of *Ceramium tenuicorne* growing in the area of Ruhnu island in the Gulf of Riga the concentration of copper and cadmium (13.7 and 0.62 mg * kg^{-1}, respectively) was almost twice as high as in *Ceramium rubrum* (6.2 and 0.29 mg * kg^{-1}). There were no remarkable difference in the concentration of lead (3.36 and 3.33 mg * kg^{-1}, respectively). Differences in the concentrations of copper and cadmium were evidently due to the circumstance that *Ceramium rubrum* unlike *Ceramium tenuicorne* is covered with cortical layers.

Regional differences in the heavy metal concentration in different parts of the Gulf of Finland were assessed on the basis of the three species of the bottom vegetation - *Fucus vesiculosus, Cladophora glomerata* and *Enteromorpha intestinalis*. Difficulties are due to the circumstance that the samples of *Fucus vesiculosus* have been collected from 15 areas (the species does not occur east of the island of Seskar), *Cladophora glomerata* from ten and *Enteromorpha intestinalis* only from five areas. In *Fucus vesiculosus* the concentration of copper is highest in the easternmost area, i.e. in the vicinity of Seskar island. It is relatively high also in the Kaberneeme region. As to *Cladophora glomerata,* the concentration of copper is high in plants growing in the vicinity of Sosnovy Bor and Sillamäe . In *Enteromorpha intestinalis* it is high in the Sillmäe area. The above provides a basis for the conclusion that the concentration of copper is higher in the bays of Narva and

Neva in the eastern Gulf of Finland.

The concentration of lead (Fig. 4) in *Fucus vesiculosus* is high in the vicinity of Aegna and Mohni islands, in *Cladophora glomerata* in the area of Vergi and Sosnovy Bor and in *Enteromorpha intestinalis* in the Sillamäe region. In *Fucus vesiculosus* the concentration of lead is higher in the Mohni than in the Vergi area, while in *Cladophora glomerata* it is much higher at Vergi than in the region of Mohni. The concentration of lead in the specimens of *Enteromorpha intestinalis* collected in the Sillamäe area is about three times as high as in the plants from the vicinity of Vergi. Thus, the data on the concentrations of lead is contradictory and do not allow local differences to be described. The concentration of cadmium in all the above three species is essentially higher in the eastern part of the Gulf of Finland, starting from Narva Bay and the coastal waters of the island of Gogland (Fig. 5).

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Table 1. Erinevates põhjavetikate liikides määratud raskemetallide kontsentratsioonid (mg * kg $^{-1}$) Soome lahe rannikul.

Liik	n	Vask	Plii	Kaadmium	Tsink
Enteromorpha intestinalis	20	9.4 ± 7.2	2.6 ± 1.5	0.29 ± 0.17	29 ± 3
Cladophora glomerata	55	8.2 ± 5.6	3.1 ± 2.0	0.42 ± 0.18	15 ± 5
Cladophora rupestris	12	9.1 ± 1.6	3.2 ± 1.9	1.06 ± 0.21	24 ± 6
Fucus vesiculosus	108	4.6 ± 2.4	1.2 ± 1.2	4.67 ± 3.57	64 ± 35
Dictyosiphon foeniculaceus	8	11.6 ± 3.4	1.8 ± 0.3	0.41 ± 0.12	31 ± 19
Furcellaria lumbricalis	6	13.4 ± 0.2	0.6 ± 0.0	0.24 ± 0.04	18 ± 1
Ceramium tenuicorne	29	15.1 ± 3.3	1.6 ± 0.8	0.99 ± 0.55	18 ± 11
Rhodomela confervoides	7	17.7 ± 0.2	1.6 ± 0.5	0.75 ± 0.03	11 ± 0

Table 2. Concentration (mg per kg dry weight) of copper and cadmium in different parts of thalli of *Fucus vesiculosus.*

Area	Part of thalli	Copper	Cadmium
Kaberneeme	apical	7.8	4.62
	basal	8.4	4.17
Vergi	apical	2.5	1.86
	basal	2.9	4.73
Suurupi	apical	1.9	1.85
	basal	2.2	2.03
Riguldi	apical	7.0	1.90
	basal	8.6	3.09

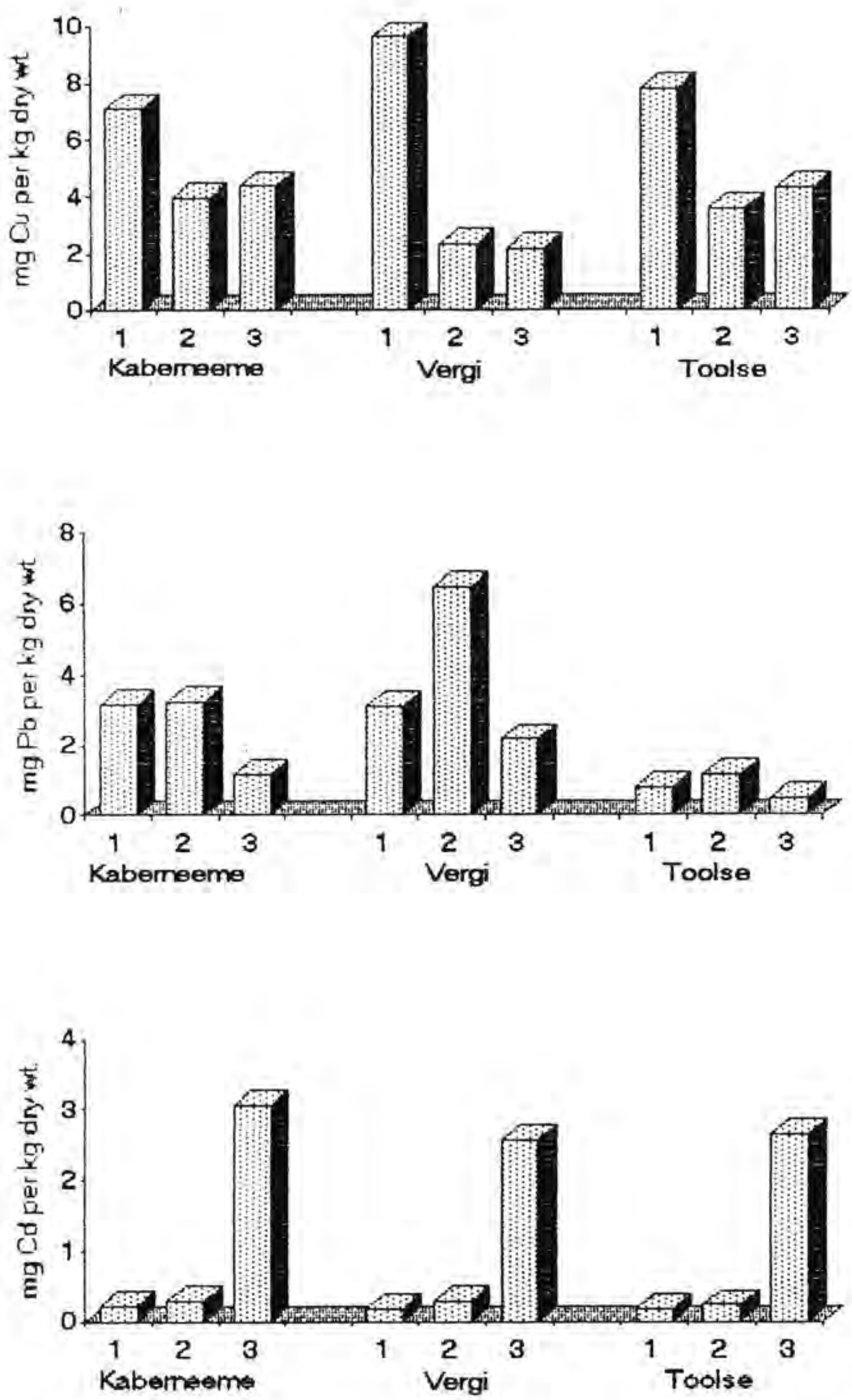

Figure 1. Concentration of copper, lead and cadmium in some benthic macrophytes at three sites of the southern coast of the Gulf of Finland.

1 - *Enteromorpha intestinalis*; 2 - *Cladophora glomerata*; 3 - *Fucus vesiculosus*.

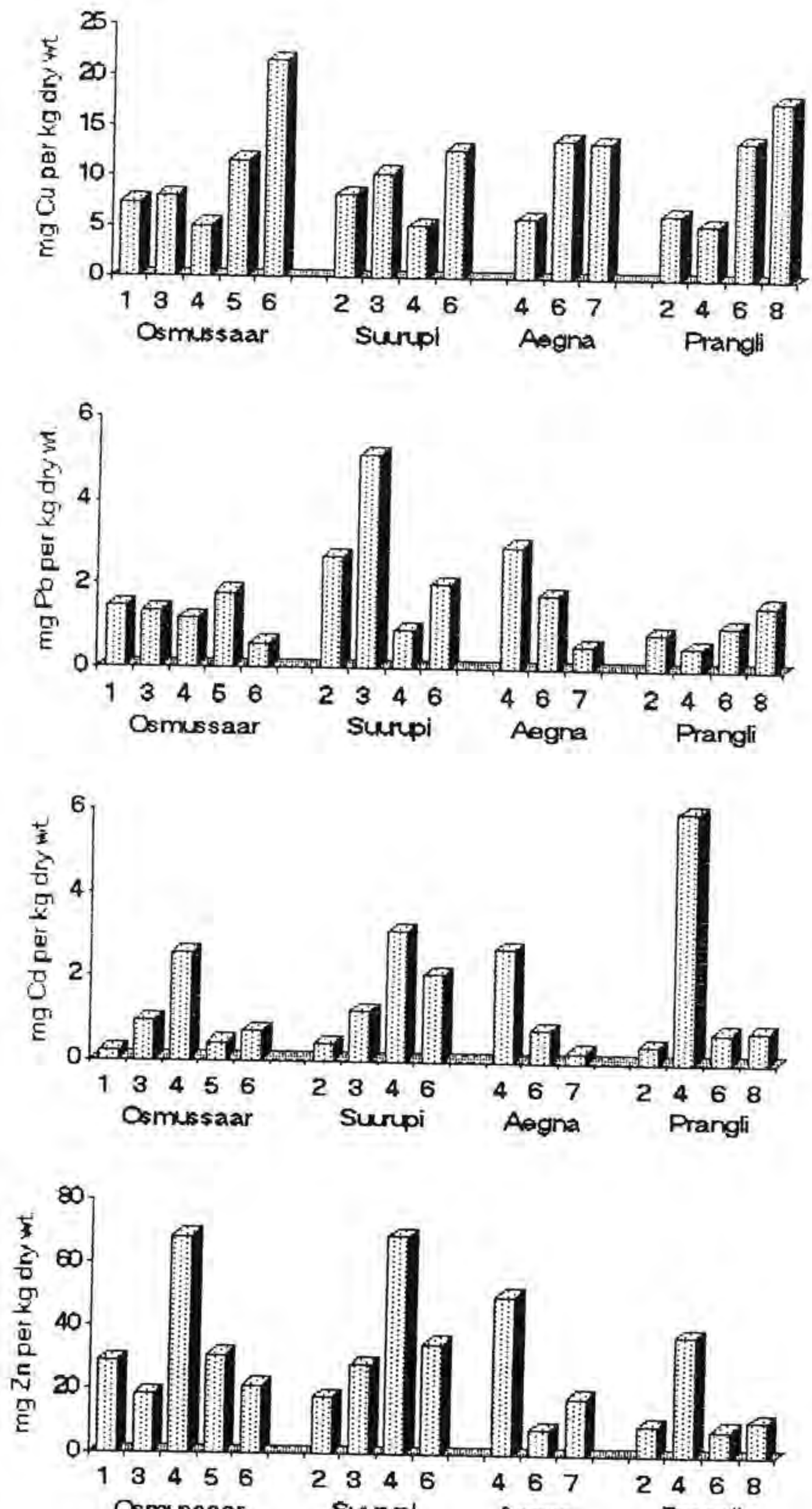

Figure 2. Concentration of trace metals in different species of macrophytes at some areas of the southern coast of the Gulf of Finland.

1 - *Enteromorpha intestinalis*; 2 - *Cladophora glomerata*; 3 - *Cladophora rupestris*; 4 - *Fucus vesiculosus*; 5 - *Dictyosiphon foeniculaceus*; 6 - *Ceramium tenuicorne*; 7 - *Furcellaria lumbricalis*; 8 - *Rhodomela confervoides*.

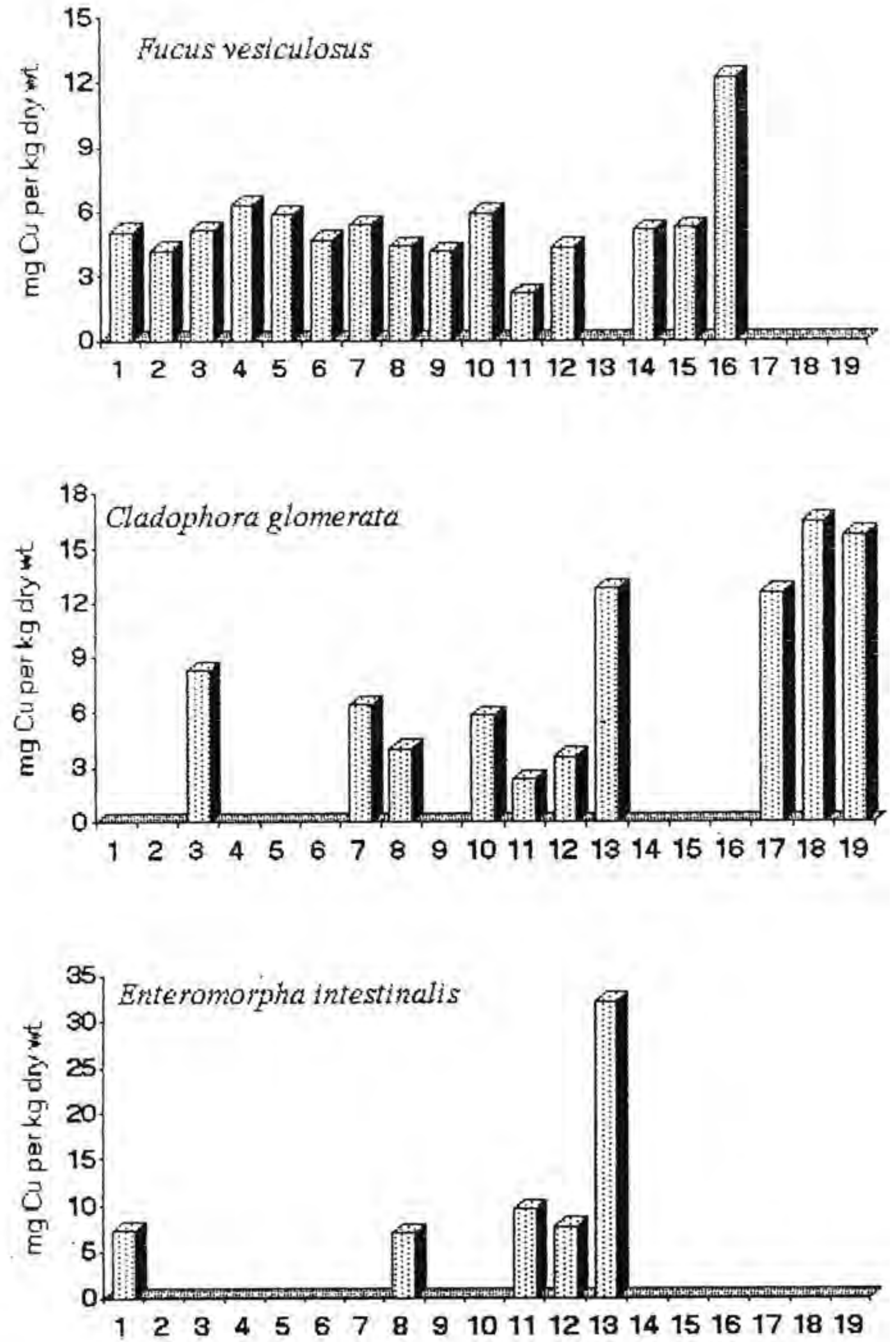

Figure 3. Concentration of copper in some species of macrophytes at different areas of the Gulf of Finland.

1 - Osmussaar; 2 - Lahepera; 3 - Suurupi; 4 - Meriválja; 5 - Aegna; 6 - Keri; 7 - Prangli; 8 - Kaberneeme; 9 - Kolga; 10 - Mohni; 11 - Vergi; 12 - Toolse; 13 - Sillamäe; 14 - Gogland; 15 - Moshnoi; 16 - Seskär; 17 - Kokpolovka; 18 - Sosnovoi Bor; 19 - Bolshaja Izhora.

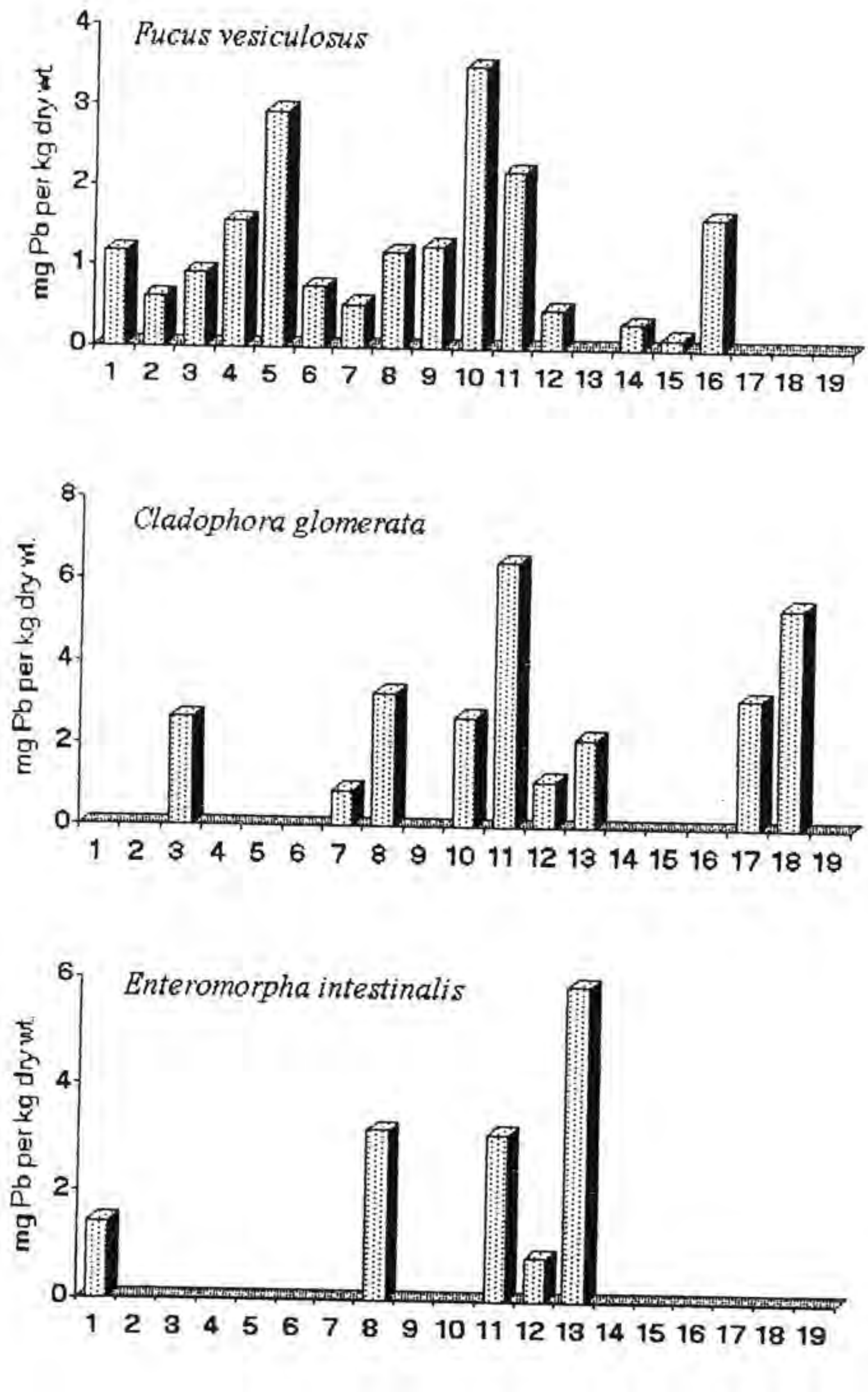

Figure 4. Concentration of lead in some species of macrophytes at different areas of the Gulf of Finland (numbers of areas are the same as in Fig. 3).

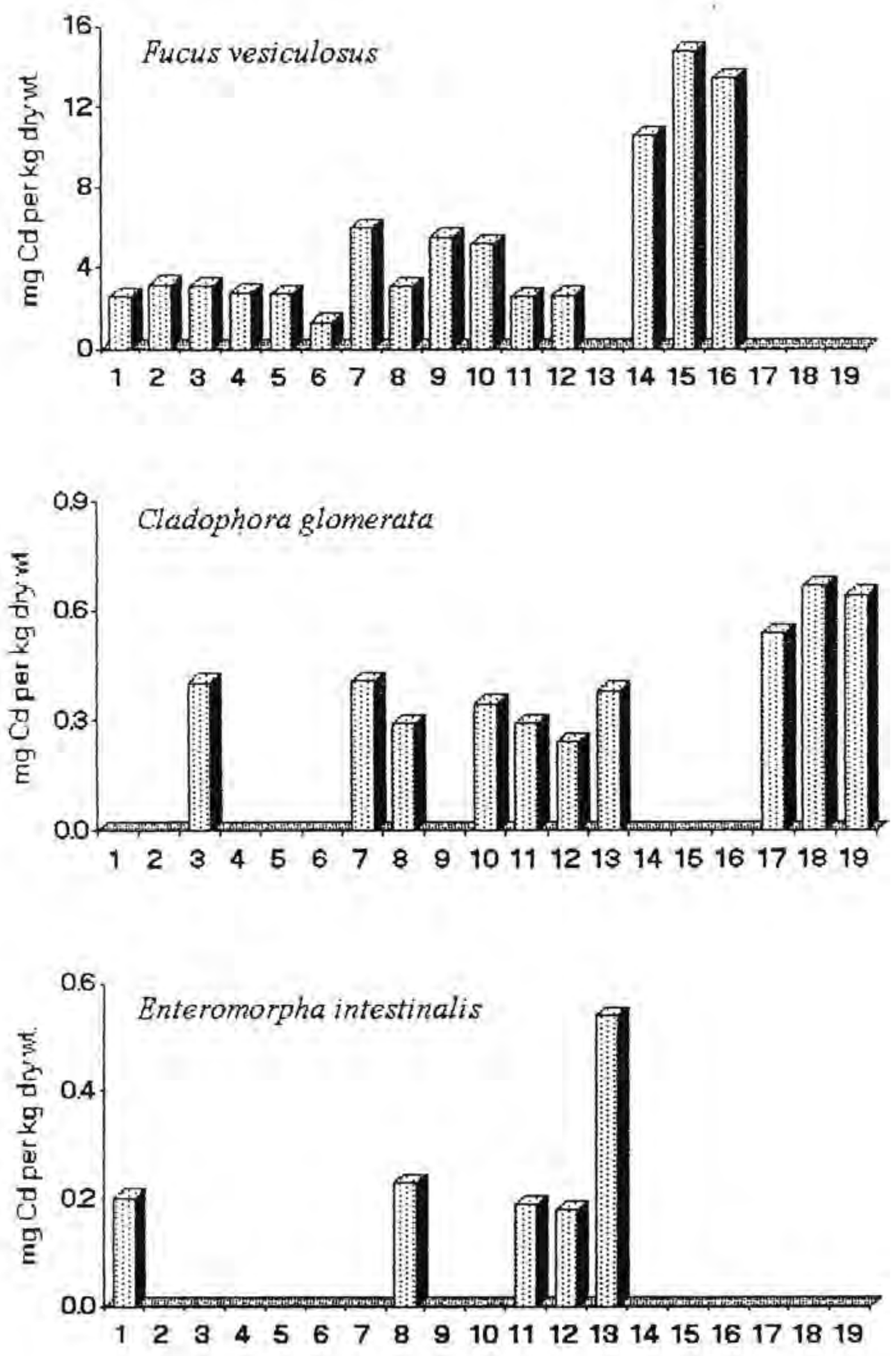

Figure 5. Concentration of cadmium in some species of macrophytes at different areas of the Gulf of Finland (numbers of areas are the same as in Fig. 3).