FRAMEWORK PROPOSAL FOR BONUS-169
BALTIC SEA SCIENCE PLAN

Assignment concerning BONUS Task 2.5:
Potential Future Transnational Research Schemes (Coordinator: ICES)

By

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SUMMARY:

This document has been prepared as a proposal for a Draft Framework for the BONUS-169 Baltic Sea Science Plan. The document is at this stage simply a proposal and accordingly is intended to be indicative and not definitive, and will form the subject for further consultations regarding the aims and substance of BONUS-169. Further information on this aspect is provided under Section 1.1 Preamble.

BONUS-169

AIMS

BONUS-169 is intended to be a joint programme proposal under Article 169 of the Treaty, involving the eight EU Member States in collaboration with the Russian Federation that together form the contiguous Baltic Sea coastal countries, **aimed at creating a cooperative, well-integrated and focused transnational research programme for the Baltic Sea region, in order to support the sustainable development of the region through the provision of outputs facilitating implementation of ecosystem-based management**, including:

1) ***Better coordinating the region's nationally funded research by more closely promoting, planning, funding, implementing, and publicizing pan-Baltic research.***
2) ***Bridging the gap between science and users by ensuring that the research needs connected with sustainable development of the Baltic Sea better reflects the initiatives and outputs of the region's scientific community, while also better synthesizing and disseminating research outcomes for improved receptivity and utilization in policy and decision-making.***
3) ***Developing capacity to create prudent, long-term, holistic multidisciplinary solutions involving sustainable use of the sea, by:***
    a) ***understanding and quantifying the role of climate change and variability, and its implications for the dynamics of the region's ecosystems and associated impacts on human communities;***
    b) ***understanding the physical, chemical and biological functioning of marine ecosystems, and understanding and quantifying human impacts (e.g. pollution including eutrophication, unsustainable fisheries and aquaculture, and degradation of habitats and ecosystems) on the marine environment and its biodiversity and human well-being;***
    c) ***developing the scientific basis for sustainable use and protection of the marine environment and its associated biodiversity, recognizing the essential benefits arising from socioeconomic development while also realizing the responsibility to conserve, and where appropriate restore, ecosystem health and the production potential of natural capital.***
4) ***Educating and training new generations of young scientists and technicians to apply novel concepts and technologies for the above-mentioned purposes.***

To this effect, BONUS-169 is built up around eight workpackages (WPs) that are summarized as follows:

WP1: NATURAL FORCING AND CLIMATE CHANGE

Investigating the regional effects of natural forcing and climate change, including studies of how changes in the atmosphere, the sea, and the land with the associated watersheds affect the climate of the Baltic Sea region, and the implications for ecosystems and human communities and their activities.

WP2: EUTROPHICATION

Investigating the inputs and origins, dispersion/transport and impacts on ecosystems and human communities of eutrophication in the Baltic Sea region, including evaluating the efficacy of management options to redress the root causes of eutrophication and making proposals for improvements.

WP3: SUSTAINABILITY OF LIVING RESOURCES

Investigating the *sustainability of fisheries and aquaculture in Baltic Sea ecosystems*, including developing and applying scientific methodology, analyses, models and actions/measures furthering the rational exploitation of the utilized living marine resources and aimed also at understanding and limiting the ecosystem effects of fishing and aquaculture activities. In this context it is important also to develop a market and information system for consumers of seafood products that arise from sustainable practices in healthy ecosystems.

WP4: BIODIVERSITY

Applying and further developing methodology, including analytical techniques and models, to describe and quantify the biodiversity of the Baltic Sea region—incorporating the molecular and genetic levels as well as those of species, communities, habitats and ecosystems—with a view to understanding the role of biodiversity in a range of environments spanning from a baseline in relatively pristine ones to those that are more human impacted. This should include determining the effects of naturally and human induced changes on biodiversity, on the goods and services provided by coastal and offshore ecosystems, and providing scientifically-based concepts and tools for monitoring and assessing biodiversity and the associated environment, and applying ecosystem-based actions and measures for conserving and, where appropriate, restoring biodiversity.

WP5: POLLUTION AND ECOSYSTEM HEALTH

Conducting investigations to elucidate the inputs and origins, dispersion/transport, and fate of pollutants (*e.g.* heavy metals, persistent organic pollutants and artificial radionuclides) in the ecosystem and the effects on human communities in the Baltic Sea region, including evaluating the efficacy of management options to redress the root causes of pollution and making proposals for improvements.

WP6: SOCIO- AND ECOLOGICAL ECONOMICS

Developing an integrative approach in the field of socio- and ecological economics by analyzing and improving (*e.g.* through cost – benefit considerations) environmental decision-making scenarios and their implications for both the environment and human socioeconomy, by *inter alia*: the elaboration and selection of interlinked environmental and socioeconomic indicators related to measuring the performance of sustainable development; environmental valuation (*e.g.* natural capital arising from ecological goods and services) and 'green' accounting; improvement of environmental policies through fostering the use of economic, regulatory, and institutional instruments for enhancing environmental management; improvement of governance systems leading to better cross-sectoral representation and consensus regarding the integration of environmental issues into decision-making processes regarding coastal zone management, rational utilization of commercially important living resources, and nature

conservation; and not least, the elaboration and provision of educational, capacity-building and outreach activities for emphasizing the dependence of human socioeconomic sustainability on ecological sustainability.

WP7: SYNTHESIS AND DISSEMINATION

A major role of the programme is the synthesis and dissemination of sound and objective scientific information and knowledge, in a timely manner, to a wider public regarding the importance of healthy marine ecosystems and their relation to humanity, as a basis for education and understanding underpinning appropriately informed public opinion, policies and political will for their implementation. This requires focus at all appropriate levels within the programme, as well as interactions between the programme and numerous potential stakeholders using all available media, arrangement of dedicated meetings (e.g. workshops and conferences) and other opportunities. Cooperative education and capacity building schemes, aimed at young scientists and technicians, should figure prominently in the programme.

WP8: MANAGEMENT AND INFRASTRUCTURE

Timely, effective and cohesive management at all levels of the programme, involving internal as well as external affairs, is vital for the success of BONUS-169. This should be achieved by implementation of a devolved yet communally accountable governance model involving the establishment of appropriate leadership structures and mechanisms, including the allocation of unambiguous roles and responsibilities—as defined by clearly formulated protocols and procedures—at the levels of key institutional bodies and personnel. BONUS-169 aspirations, in the context of Article 169 of the Treaty, require agreements and mechanisms to be established permitting comprehensive access to and mobilization of shared infrastructures and facilities in a cost-effective manner, in order to secure both the quantity and quality of scientific outputs at the pan-Baltic level.

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1 INTRODUCTION

1.1 Preamble: BONUS Task 2.5 - the approach used, and structure of the current document.

In December 2003, the International Council for the Exploration of the Sea (ICES) was contracted as Task Leader for BONUS Task 2.5 '**Ideas for potential future transnational research schemes**'. As from 1 May 2005, Professor Christopher Hopkins was engaged by ICES to act as Co-Task Coordinator including drafting the current document.

The Executive Committee of BONUS and the Chair of the Advisory Board, on 21 April 2005 determined that Christopher Hopkins should develop a draft **Framework for the BONUS-169 Baltic Sea Science Plan**, based on the eight workpackages (see **Fig. 1**) that have already been identified for the European Commission. It was noted that '***The plan is supposed to convert the research needs arising from the management bodies into scientific questions, which the science community can respond with research ideas. In practical terms, the Science Plan will be the material for future Calls for Proposals.***'

A Task Steering Group (TSG) for this task was established (BONUS: Members of the Executive Committee and Chair of the Advisory Board; ICES: Reference Group of ICES Professional Secretaries and Chair of the Baltic Committee). The TSG will *inter alia* provide critique and advice on the draft Framework document at the start of the task and at strategically important stages during further development and revision of the document.

In carrying out the task and preparing the current Framework document, **the author emphasizes the following**:

- ***When developing a science plan for the future, it is extremely important for the success of the plan that top-down planning*** (*i.e.* the problem-oriented themes included in the preliminary framework) ***and bottom-up input*** (*i.e.* question-driven priorities of scientists and research organizations) ***are effectively coupled***. The ***Framework document is intended to be a living manuscript*** that will be periodically revised, amended and further adapted and focused: ***it is not the final product, but one of several steps in a progression (i.e. a stepwise process) towards reaching the concluding stage***. This procedure will ***take into account critique, feedback and good advice from an extensive consultative process***, for example, through making the document available to the BONUS-related community on the web, and the scheduling of national and transnational consultations and workshops involving a range of stakeholders. These consultations should include the scientific community, project managers, research funders and coordinators, and the advisory, management and regulatory sectors. The process should ***lead to consensus regarding the basis for a Call for Proposals***. In due course, there will be a need to compare and contrast the received project Proposals with the general intentions of the Call, with a view to matching the 'map and the terrain' including deciding how to deal with specific gaps where responses to the Call are viewed as disappointing.
- ***It is essential to mobilize a critical mass of the scientific community working on Baltic Sea issues. The Framework should be inclusive rather than exclusive, and indicative rather than definitive, so that it may attract interest, discussion and eventually a high number of responses to the Call.***
- ***With respect to assessing information on research needs and activities, the reference material used by the author has included a wide range of documents from peer-reviewed publications*** (*e.g.* in international scientific journals and books) ***to the so-called grey literature*** (*e.g.* study/working group and workshop reports emanating from international organizations). These have included access to literature searches on Biological Abstracts for 2003 – 2005, and searching the Baltic Sea Marine Environment Bibliography and Database <http://www.baltic.vtt.fi/>. Information and documents have also been consulted arising from the Baltic Marine Biologists (BMB), European Commission (EC), European Environment Agency (EEA), Helsinki Commission (HELCOM), International Baltic Sea Fishery Commission (IBSFC), International Council for the Exploration of the Sea (ICES), International Maritime Organization (IMO), and ERA-NET BONUS (*e.g.* BONUS 2005a, b). Additionally, the Abstracts from the November 2001 4th Baltic Sea Science Congress (BSSC) (Stockholm, Sweden) and the Abstracts from the June 2005 5th BSSC (Sopot, Poland) have been reviewed. ***At the 2005 BSSC, a 'BONUS Task 2.5 Workshop – Development of a Baltic Sea Science Plan for BONUS-169' was held***

on 20 June 2005, as an initial step in consulting with the science community. ***A series of follow-up consultation mechanisms are planned*** in national and international forums.

- ***Account has been taken also of policy drivers***, such as international Conventions, agreements and instruments including European Community Directives and the European Marine Strategy (*c.f.* **Tables 1 & 2**.). Such policy drivers traditionally play an important role in focusing EC Research and Technological Development (RTD) programmes.
- As mentioned earlier, ***a wide range of consultation, collaboration and inputs are necessary with a view to further developing and improving this Framework document***. The author firmly urges that a timetable for this consultative process, at the national and international levels, is developed by the BONUS leadership.
- Finally, the author is fully aware of the enormity of the task that he has been asked to conduct almost single-handedly, *viz.* start the process for developing a Baltic Sea Science Plane covering a wide range of natural/physical and social sciences. Even with the best of intentions, human frailty undoubtedly has resulted in several important topics being inadvertently overlooked in this draft document, and the author apologizes in advance for these omissions. ***Thus, the current draft document should be seen as a 'strawman'***[1] ***that invites substantial improvement.*** The author looks forward to redressing the failings in this document through the forthcoming consultation process.

Structure of the current document: Besides a comprehensive ***Introduction*** (Section 1), the ***BONUS-169 structure*** (Section 2) provides an outline of the eight workpackages (WPs). For the majority of WPs, the document has sub-sections entitled:

a) ***Potential BONUS-169 research and application issues*** which provides a Summary of the main aims of the particular Workpackage, followed by an unranked bulleted list of relatively specific activities that merit consideration with respect to guiding an eventual Call. Each of the entities in the bulleted list has been formulated in a '*term of reference*' style in order to be viewed as a realizable 'to-do' activity. Several of these bulleted entities can be further ***sorted and clustered together***, thereby forming more substantial work units. It is anticipated that the bulleted list will be critiqued and modified during the consultation process with the intention of achieving a robust list of research topics for the programme to address. This will, after a process of comprehensive consultations that should be embarked upon, eventually lay the grounds for a system of agreed priority issues to form the backbone of an eventual future Call for Proposals;

b) ***Background,*** which sets the scene *inter alia* on policy and management matters as well as highlighting the status and trends regarding the Baltic marine environment including its ecosystems and living resources.

c) ***Major international collaborative activities of relevance to the Workpackage***, which provides an overview of a range of international activities that may be further built on in BONUS-169's collaborative networking.

1.2 The Baltic Sea: Outline of environmental status and geopolitical perspectives

The Baltic Sea is one of the world's largest brackish water bodies, occupying about 413 000 km^2 and having a volume of about 21 600 m^3 (HELCOM 2002). Although there are nine Baltic Sea coastal States (*i.e.* Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russian Federation, and Sweden), the Baltic Sea's drainage basin includes a population of about 90 million people from a catchment area covering about 1.7 million km^2 in a total 14 nations, *i.e.* the above-mentioned nations plus Belarus, Czech Republic, Norway, Slovakia, and Ukraine (GIWA 2005). Nearly 15 million people live within 10 km of the Baltic Sea coast and about 30 million people live within 50 km of the coast (Sweitzer *et al.* 1996; HELCOM 2001). Important human activities are connected with a range of industries including iron and steel, chemicals and petrochemicals, mining, and pulp and paper, agriculture, fishing, and shipping (GIWA 2005; Palmer 2005).

The Baltic Sea is a semi-enclosed water body connected with the North Sea by narrow and shallow sounds that limit water exchange, particularly inflows of more saline oxygen-rich water (Voipio 1981; Mälkki

[1] A crude plan or document serving as the starting point in the evolution of a project. The strawman is not expected to be the last word; it is refined until a final model or document is obtained that resolves all issues concerning the scope and nature of the project.

1985). The Baltic Sea ecosystem is characterized by natural fluctuations connected with infrequent and sporadic flushing of the deeper basins with more oxygenated water from outside, followed by stagnation periods frequently lasting many years with declining levels of oxygen (Fonselius & Valderrama 2003). During stagnation periods, eutrophication—caused by excessive nutrient loads—builds up with associated oxygen depletion (hypoxia and anoxia) and the production of poisonous hydrogen sulphide (H_2S) eventually causing 'dead areas' lacking the characteristic biological production needed for supporting commercially exploitable living marine resources such as fish (Leppäkoski & Mihnea 1996). The low biodiversity, associated the brackish water being too salty for most freshwater species and too fresh for most marine species, and the short ecological history of the Baltic, places many plant and animal species near the periphery of their physiological and ecological tolerance, making them particularly vulnerable to pollution and other human-caused stresses (Wallentinius 1991; Elmgren & Hill 1997). The delicate ecological balance of the coastal and offshore areas of the Baltic Sea is greatly influenced by climatic and oceanographic variation, including the frequency and magnitude of saltwater intrusions causing flushing and increased oxygenation in the deeper basins, as well as by the volume and quality of run-off connected with the effects of leaching and dispersal of nutrients and pollutants (Graham 1999; Jansson & Dahlberg 1999; MacKenzie *et al.* 2000).

Until about 1940, the Baltic Sea was a nutrient-poor (oligotrophic) water body with relatively low biological production and clear water (Jansson & Dahlberg 1999). Since then, excessive inputs from human activities in the catchment area—combined with the long residence time in the system—have raised the loads of nutrients and toxic and hazardous pollutants, giving rise to symptoms of advanced 'ecosystem pathology' (Leppäkoski & Mihnea 1996). Overfishing has seriously depleted commercial fish stocks and also adversely affected vulnerable species and habitats in the ecosystem (HELCOM 2002; GIWA 2005). The impacts of pollution on coastal and marine ecosystems are all too evident, including the effects of advanced eutrophication, hazardous substances and oil spills (HELCOM 1996a, 2002). Contaminants, such as persistent organic pollutants (POPs such as DDT, PCBs and dioxins) and heavy metals, have *inter alia* accumulated via the food web causing health problems in several biota (*e.g.* benthos, birds and marine mammals), and levels of some pollutants in seafood (*e.g.* fatty fish and shellfish) may constitute a health risk for humans (Jensen *et al.* 1969: Helander *et al.* 1982; Blomqvist *et al.* 1993; Skerfving *et al.* 1995; Bengtsson *et al.* 1999; Backman *et al.* 2003; MacKenzie *et al.* 2004; Selin & VanDeever 2004). These degradations in ecosystem health have resulted in detrimental socioeconomic impacts (GIWA 2005).

A major geopolitical development has been the accession to the European Union (EU) in 2004 by Estonia, Latvia, Lithuania and Poland, leaving the Russian Federation as the sole non-EU coastal Baltic State. This enlargement of the EU has significant implications on the land, coastal and marine policies of the States of the Baltic Sea region, especially regarding the application of various policies and strategies concerning agriculture, transport, environment, fisheries, water resources and scientific research. The EU must face the challenge of developing and applying a more proactive strategy for collaboration with the Russian Federation in environmental management, research, and monitoring and assessment to achieve improved conservation and restoration of the environment and the living resources of the Baltic Sea, and to insure the sustainable development of the region.

The Baltic Sea is among the most thoroughly scientifically investigated sea areas in the world. In recent years extensive studies have been undertaken concerning the environmental conditions, issues and priorities in the drainage basin and coastal zone in relation to the Baltic Sea. Major programmes to address environmental management and ecological restoration of the Baltic Sea are under implementation through the complementary activities of the Helsinki Commission, Baltic 21 and other initiatives. ***However, the capability to survey, monitor, assess and manage the marine environment and its living resources, including fisheries, varies greatly among the coastal Baltic Sea States. The research and development (R&D) capacity, necessary for these purposes and to operationalize the ecosystem approach to management*** (see section 1.4.2 for definition) ***must be enhanced on a pan-Baltic scale. As the complexity of the issues is increasing, there is a strong need to build, mobilize and further integrate 'core science' capabilities in order to underpin the sustainable development of the Baltic Sea as a whole with regard to ecosystem-based management. In this context, the States in economic transition require assistance in capacity building, both in terms of human resources development and facilities. In addition, research institutions should be encouraged to further coordinate their use of infrastructure, network building and collaboration with a view to enhancing capacity interchange in the region.***

Although much has been accomplished over the last decade to improve environmental conditions in the drainage basin, coastal zone and marine environments of the Baltic Sea region, much remains to be done. There is no cause for complacency: existing problems and emerging issues need to be actively addressed and resolved.

1.3 ERA-NET BONUS and evolution to BONUS-169

1.3.1 ERA-NET BONUS for the Baltic Sea – Network of Funding Agencies

BONUS is a European Community 6th Framework Programme (FP6) ERA-NET project with a total funding of € 3.03 million for 2004 - 2007. The project brings together the key research funding organizations in all the European Union (EU) Member States (*i.e.* Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, and Sweden) and the Russian Federation around the Baltic Sea. The current BONUS ERA-NET intends to '***form a network and partnership of key agencies funding research with the aim to deepen the understanding of conditions for science-based management of environmental issues in the Baltic Sea***'. BONUS operates in close connection with the scientific and management actors. **The strategic purpose of BONUS is to gradually and systematically create conditions for a joint Baltic Sea research and researcher-training programme**.

The ERA-NET BONUS programme is composed of a total of 12 partners: 11 research funding organizations from the Baltic coastal States and one intergovernmental organization connected with the coordination of marine science in the Baltic Sea region. In addition, BONUS links six funding organizations as Observers, thereby increasing the number of involved organizations to 18. Further information on BONUS is found at: <http://www.bonusportal.org/>.

1.3.2 BONUS-169

Objectives and participating States and institutions

BONUS-169 is an initiative, responding to Article 169[2] of the Treaty (EC 2001), with a view to creating a joint, transnational programme in the field of Baltic Sea research as originally anticipated by the FP6 ERA-NET BONUS programme.

The participating funding organizations ('consortium') in BONUS-169 are partners of the running ERA-NET *BONUS for the Baltic Sea – Network of Funding Agencies.* It involves all nine Baltic coastal States (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russian Federation and Sweden) and one intergovernmental organization (International Council for the Exploration of the Sea):

- Danish Research Agency (Danish Natural Science Council);
- Estonian Science Foundation;
- Academy of Finland;
- Forschungszentrum Juelich - Projekttraeger Juelich, Germany;
- Latvian Council of Science;

[2] Article 169 enables the European Community to participate in research programmes undertaken jointly by several Member States, including participation in the structures created for the execution of national programmes. Article 169 is potentially a very powerful instrument facilitating the integration of a) national programmes, and b) individual performer's research in Integrated Projects and Networks of Excellence. Article 169 is adopted by a co-decision process between the European Parliament and the Council. The novelty of Article 169 is that the proposal for its employment comes from the Member States. The political players are the policy-makers and the operational players are the programme managers of national programmes. The European Commission is responsible for transforming each initiative into a formal proposal of Article 169 to the Council and Parliament who then decide through the co-decision process. The basic criteria for the selection of the proposals are: 1) involvement of enough Member States to obtain a significant structuring effect and critical mass; 2) the topic is of great interest to the Community and fits with the thematic properties of the Framework Programme; 3) the principles of co-funding by Member States and Community, and of additionality are respected; 4) there is sufficient European value-added; and 5) Article 169 is the only way the project/programme could be implemented.

- Ministry of Education and Science of the Republic of Lithuania;
- Ministry of Scientific Research and Information Technology, Poland;
- Foundation for Strategic Environmental Research, Sweden;
- Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning;
- Swedish Environmental Protection Agency;
- Russian Foundation for Basic Research;
- International Council for the Exploration of the Sea.

The consortium has signed the 'Letter of Interest' regarding a joint Baltic Sea research programme under Article 169, and firmer commitments are negotiated within respective ministries. More funding organizations will be invited to join the initiative in the near future.

In the Baltic Sea States, only Germany and Russia have long-term national research programmes in the field of marine research. Finland, Sweden and Poland have shorter, more specific Baltic Sea research programmes that will either end, or be near their end, before the start of the planned joint programme. In these States, earmarking of funds will be made for the joint Baltic Sea programme instead of for separate national programmes. Latvia, Lithuania and Estonia do not have research programmes – this issue is specifically addressed in the ongoing BONUS ERA-NET Task *Durable integration of national marine research funding schemes in New Member States into the ERA*.

Scope and activities of the joint programme

The joint programme aims at integrating national Baltic Sea research into a joint transnational programme in order to support the sustainable development of the Baltic Sea with regard to environmental, fisheries and ecosystem-based management.

There are already a number of international, European and regional Conventions, agreements and other instruments aiming at facilitating sustainable development of the Baltic Sea region, *inter alia*: Helsinki Convention — Convention on the Protection of the Marine Environment of the Baltic Sea Area (1974/1992), under the auspices of HELCOM – Baltic Marine Environment Protection Commission; Gdansk Convention — Convention on Fishing and Conservation of the Living Resources in the Baltic Sea and the Belts, under the auspices of IBSFC – Baltic Sea Fishery Commission (1973); MARPOL Convention on Marine Pollution from Ships (1973/1978), and the International Convention for the Control and Management of Ships' Ballast Water and Sediments (2004), under the auspices of IMO - International Maritime Organization; and numerous European Community policies and directives, including the Common Fisheries Policy (1983 and subsequent reforms), Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (92/43/EEC), Water Framework Directive (2000/60/EC) and the European Marine Strategy (EMS, COM(2002) 539 final)). More information on these and other instruments is provided in **Tables 1 & 2**.

However, the ***funding of Baltic Sea research and development (R&D) is nationally scattered, and has limited regional coordination and focus regarding sustainability issues connected with environmental, fisheries and ecosystem related matters. The research needs arising from the goal of sustainable development for the Baltic Sea insufficiently reflects the initiatives and outputs of the region's scientific community, and* vice versa*. Furthermore, synthesizing and disseminating research outcomes for management and policy purposes needs to be improved and better focused. Accordingly, the BONUS-169 programme aims to promote, closely integrate and better focus the national Baltic Sea R&D with a view to facilitating sustainable development of the Baltic Sea***.

The activities of BONUS-169 are organized in eight work packages (see **Fig. 1**) reflecting research related to redressing the major environmental, fisheries and ecosystem-related challenges in the Baltic Sea. Special emphasis is placed in a workpackage focusing on the synthesis and dissemination of information concerning findings and products. The above-mentioned challenges in the Baltic Sea region are inherently linked to socioeconomic activities, *e.g.* agriculture, fisheries, coastal industries, power generation, coastal engineering and land reclamation, sand and gravel extraction, dredging and dumping of materials including litter and garbage, oil and gas exploration and production, shipping, and military activities. Thus, a special work package is dedicated to 'Socio- and ecological economics' that encourages interdisciplinary research approaches concerning socioeconomic development and the sustainable utilization and conservation of ecological ‘goods and services’.

The BONUS-169 work packages are:

1) Natural forcing and climate change;
2) Eutrophication;
3) Sustainability of living resources;
4) Biodiversity;
5) Pollution and ecosystem health;
6) Socio- and ecological economics;
7) Synthesis and dissemination; and
8) Management and infrastructure.

Workpackages 1, and 6-8 are cross-cutting, while workpackages 2-5 are thematic pillars.

The Marine Board of the European Science Foundation has acknowledged the importance of the Baltic Sea scientific studies for understanding overall ocean processes and for developing examples of marine ecosystem management in support of international Conventions. It also supports the scientific approach to these issues through regional programmes.

Organizational issues, including governance and dedicated management.

The governance and management structure for a joint programme involving national funds has already been agreed to within the ongoing BONUS ERA-NET (BONUS Publications No. 2: Joint *Baltic Sea Research Programme – Best Practice, Possibilities and Barriers*). It consists of the following three levels (mandates indicated in parentheses):

1) Funding organization (earmarks the funds, appoints the representative to the Steering Committee, makes the funding decision on the basis of the recommendations by the Steering Committee);
2) Steering Committee (agrees on themes/topics, launches calls, determines the communication strategy, organizes the evaluation, provides the funding recommendation to the national funding organizations, makes the funding decisions concerning the EC funds, appoints the programme management). An Advisory Board consisting of high-level experts and stakeholders will support the Steering Committee;
3) Programme management (supports the Steering Committee, coordinates and implements decisions, implements the communication strategy, *etc.*)

The programme will be open for research groups and institutes from the participating countries. In cases when the need for specific high-quality expertise, not existing in the Baltic Sea countries, is demonstrated in a project application, collaborative consortia with participation of research groups and institutes from other countries can be accepted. As the Article 169 BONUS-169 initiative is intended to be a model for collaboration in research related to the ecosystem-based management of other European regional seas, then it is important that scientists and organizations are engaged through workshops and other joint planning activities so that they can both learn from the initiative and contribute their perspectives.

There are several options under examination for dedicated structure. The possibility of using an already existing structure (*e.g.* HELCOM) is also being considered.

Duration, budget and governance.

BONUS-169 is proposed to have a duration of five years (*i.e.* 2007 – 2011).

The estimated budget regarding Member State contributions is € 50 - 75 millions. These contributions include earmarked research funds and 'in kind' contributions, such as ship time and other research infrastructures and facilities.

A contribution of € 100 million is requested from the Commission.

Thus, the total budget for the joint programme is estimated at € 150 – 175 millions.

1.4 International collaborative mechanisms for research, monitoring and regulation in the Baltic Sea region, and policy drivers for environmental, fisheries and biodiversity issues

1.4.1 Conventions, agreements and other instruments regarding environmental, fisheries and biodiversity issues

Numerous international conventions, agreements and other instruments contribute to the protection of coastal and offshore environment and biodiversity of the Baltic (**Table 1**). In 2004, Estonia, Latvia, Lithuania, Latvia and Poland acceded to the EU, joining Denmark, Finland, Germany and Sweden. Thus, all the Baltic coastal countries with the exception of the Russian Federation are members of the European Community (EC). Accordingly, many EC directives apply to the marine environment, and living marine resources including fisheries and biodiversity, in Community waters (**Table 2**)

The 1992 Helsinki Convention, supported by its governing body the Helsinki Commission (HELCOM), has as its main goal the protection of the marine environment of the Baltic Sea from all sources of pollution, and to restore and safeguard its ecological balance. The Contracting Parties include all nine Baltic coastal countries (Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Sweden and Russia) as well as the European Community. HELCOM, besides the Heads of Delegation, comprises five operational groups: Response (HELCOM RESPONSE); Monitoring and Assessment (HELCOM MONAS); Maritime (MARITIME); Land-based Pollution Group (LAND); and Nature Protection and Biodiversity (HABITAT). These, in turn, organize working groups and projects, seminars, symposia and informal expert meetings. The 'ecosystem approach' to management (see below for definition), adopted by the 2003 Joint HELCOM/OSPAR Ministerial Meeting, obliges HELCOM to assess the pressures as well as the resulting state and impacts on the marine environment and to use this as the foundation for priority actions. The new HELCOM Monitoring and Assessment Strategy, adopted in 2005 by the Helsinki Commission, aims *inter alia* to: a) facilitate the implementation of the ecosystem approach, b) to show the interlinkage and interdependence of activities on land, in coastal areas and at sea, c) coordinate monitoring activities for Baltic species issues of concern, and d) produce targeted environmental assessments for regional specific management purposes by also making use of data and information produced by Contracting States and other forums[3]. The HELCOM monitoring programmes (*e.g.* COMBINE – Cooperative Monitoring in the Baltic Marine Environment) cover eutrophication, hazardous substances and elements of biodiversity. Baltic Sea Protected Areas (BSPAs) provide building blocks for nature conservation assessments. Since 1981, HELCOM has conducted a series of periodic assessments of the status of the Baltic marine environment. In June 2005, HELCOM agreed to develop by 2007 a strategic Baltic Sea Action Plan (BSAP) to further reduce pollution in the Baltic Sea and repair the damage done to the marine environment. The development of the plan will require input and active participation from all major stakeholder groups in the region in order for it to be relevant and eventually implemented. The consultation and involvement of stakeholders as well as the drawing up of the BSAP will be carried out between the latter part of 2005 and 2007. The finalized plan is expected to be adopted at a special HELCOM Ministerial Meeting. The Action Plan will ensure that every possible step is taken to improve the state of the Baltic Sea, through safeguarding the region's natural ecosystems while also allowing valuable marine resources to be used sustainably in the future. The social and economic effects of the measures proposed for the plan will be carefully assessed, as well as their beneficial impacts on the environment. The ongoing HELCOM work to develop ecological objectives for the Baltic will provide the foundation for the BSAP. The ecological objectives and associated indicators will be

[3] *Inter alia*: EC Directives and other instruments (*e.g.* Water Framework Directive, Urban Waste Water Treatment Directive, Nitrates Directive, Habitat Directive, Dangerous Substances Directive, Integrated Pollution Prevention Control (IPPC) Directive, European Marine Strategy), European Environment Agency, International Atomic Energy Authority, ICES, Organization for Economic Cooperation and Development, and UN Environment Programme.

used to evaluate the efficiency of the existing environmental measures and to provide guidance for the development of future management measures for the region. The BSAP will form an important contribution to the European Marine Strategy, which foresees a separate action plan for each European regional sea. Further information concerning HELCOM is found at: <http://www.helcom.fi/>

Since establishment of the Gdansk Convention in 1973, with all nine of the Baltic coastal countries as Contracting Parties, fisheries have been internationally managed via the International Baltic Sea Fisheries Commission (IBSFC). There are currently six Contracting Parties to the IBSFC, namely the European Community, Estonia, Latvia, Lithuania, Poland and the Russian Federation. Following the enlargement of the European Union on 1 May 2004, in accordance with Article 6 (12) of the Act of Accession of 2003, the four new Member States have an obligation to take the necessary steps to withdraw from the Gdansk Convention at the date of their accession or at the earliest possible date thereafter. According to the rules of the Gdansk Convention a withdrawal notified to the Depositary Government (Poland) during 2004 will take effect on 31 December 2005. Following these withdrawals, there will remain only two Contracting Parties, namely the European Community and the Russian Federation. Effectively, the organization will be redundant and will be superseded by a bilateral Agreement between the EC and Russia Federation on the management of Baltic Sea fisheries. Further information on IBSFC is found at: <http://www.ibsfc.org/>

The International Council for the Exploration of the Sea (ICES) was established in 1902 and currently has all of the coastal countries of the Baltic except Lithuania among the 19 Contracting Parties to its Convention. ICES focuses on international cooperative studies and the provision of scientific information and advice involving the mutual interdependence of the living marine resources and their physical and chemical environment in the North Atlantic and its adjacent seas, including the Baltic Sea. About 1 500 scientists are involved in ICES activities in the Member Countries, and more than 700 scientists annually attend meetings (*e.g.* working groups) at ICES Headquarters (Copenhagen, Denmark). ICES work encompasses the broad areas of fisheries, oceanography and environmental sciences including marine pollution, and ecosystem-based studies, and is organized and carried out by scientists from its Member Countries. The supervision of the Council's work programme resides mainly in various standing committees. On the scientific side, there are seven interdisciplinary science Committees (Baltic, Fisheries Technology, Living Resources, Mariculture, Marine Habitat, Oceanography, Resource Management) providing a wide coverage of the facets of marine science, three advisory committees (Advisory Committee on Fishery Management, Advisory Committee on the Marine Environment, and Advisory Committee on Ecosystems), and a Consultative Committee consisting of the Chairs of the science committees and the advisory committees, plus its Chair. The Consultative Committee oversees all aspects of the Council's scientific work. The primary means by which the actual work is planned, coordinated, conducted, appraised, and reported on for subsequent peer-review, are the large number of working, study, planning, and steering groups and workshops. These entities are established as needed to address the questions and terms of reference assigned to them. Each group has a parent committee to which it reports progress and from which it receives instructions for its work. ICES currently has about 100 working, study, planning, and steering groups and workshops forming the basis for its annual work programme. Subjects include such wide ranging fields as marine chemistry; sediments; physical oceanography; environmental impacts of mariculture; fish diseases, behaviour, and genetics; ecology of benthos, plankton including harmful algal blooms, fish, seabirds, and marine mammals; biological effects of contaminants; trend monitoring; marine data management and statistics; single- and multispecies fish-stock assessments; fishing technology; and surveys for fish eggs, larvae, juveniles, and adults. ICES provides its Member Countries as well as HELCOM, IBSFC and the European Commission with the best available scientific information and advice on environmental, fisheries and ecosystem-based management, which is politically neutral, for management and regulatory purposes. In 1998, IBSFC and ICES signed a Memorandum of Understanding (MoU) governing the basis for their collaboration. In 1999, a similar MoU was signed by HELCOM and ICES. A MoU has been in force between ICES and the European Commission since 1987. Further information about ICES is found at: <http://www.ices.dk/>

Periodic surveying and monitoring of the components of the environment and its living resources forms the basis for carrying out assessments of the changing status and trends of the ecosystem related to human pressures and natural variability. Thus, surveys, monitoring and assessments can facilitate the formulation of integrated management measures for the implicated human activities in order to maintain or achieve desired ecological quality objectives related to reducing levels of pollution, achieving more viable utilization of living resources within sustainable ecosystems, and conservation and protection of vulnerable species and habitats. In order to monitor the status of the environment and its living marine resources, a programme of measurements and information gathering is conducted in time and space. As national networks of collaborating laboratories and other institutions in many countries collect the data, it is necessary that data be collected according to agreed protocols involving their inter-comparison and quality assurance. On the basis of quality assured data, periodic assessments are then carried out—often involving peer-review and necessary consensus— in order to provide the best available scientific information and advice for the political decision-making process for management (*e.g.* regulatory) purposes. Thus it is vital that the underpinning process starting with surveys and monitoring provides both the appropriate quantity and quality of data so that those involved in the scientific and political processes can agree on the status and trends concerning the ecosystem and its components. The work necessary to conduct surveys and monitoring of the Baltic Sea region is the responsibility of the coastal countries, but these are coordinated through the auspices of ICES and HELCOM. The assessment of the status and trends in the environment, fisheries and the ecosystem components are generally conducted by peer-review (*e.g.* by ICES advisory committees supported by their working groups) on the basis of information and data submitted at the national level.

1.4.2 The precautionary principle, ecosystem approach and European Marine Strategy

The ***precautionary principle***[4]—and the way to implement it (the precautionary approach)—and the ***ecosystem approach*** are inherently incorporated into many internationally binding Conventions and agreements, such as the HELCOM and Gdansk Conventions, and many EC instruments including the ***European Marine Strategy***, EMS, '*towards a strategy to protect and conserve the marine environment*' (COM(2002) 539 final) which recognizes that diverse human activities pose major threats that impact the marine environment and its associated ecosystems (EC 2002a). The EMS should *inter alia* cover all the actions needed to ensure that all human activities with an impact upon the oceans and seas are managed so that marine biological diversity and critical habitats are conserved and human use of them is sustainable. It is agreed that the development of the EMS should be focused on the concept of an integrated ***ecosystem approach to management*** which is defined as: '*the comprehensive integrated* ***management of human activities*** *based on the* ***best available scientific knowledge about the ecosystem and its dynamics****, in order to identify and* ***take action*** *on influences which are critical to the* ***health of marine ecosystems****, thereby achieving* ***sustainable use of ecosystem goods and services and maintenance of ecosystem integrity***' (JMM 2003a).

1.4.3 The ecoregion and Large Marine Ecosystem concept

Marine ecoregions are regions of the world's oceans being identified to aid in conservation activities for marine ecosystems (ICES ACFM/ACE 2004). Thus, the identification of an ecoregion may take account of ***inter alia*** biogeographic and oceanographic features, with due regard to links between the marine and terrestrial environment, including patterns of land use and distribution and density of human populations, as well as to existing political, social, economic and management divisions. In essence, marine ecoregions are nested within a biogeographically based framework and encompass distinctive biological communities and over which characteristic ecological processes and productivity occur under the influence of distinguishing physical and chemical oceanographic regimes (*c.f.* Sherman 1994; Longhurst 1998; Hopkins 2004). The fluid nature of water and ocean currents, and the dispersal patterns of many plants and animals, results in the patterns of biodiversity being 'transboundary' and not conforming to national waters and national exclusive economic zones (EEZs). Thus, conservation at an ecoregional scale and other large-scale approaches are essential for the successful management of the marine environment including its biodiversity. Accordingly, ecoregional conservation provides a framework for applying the 'ecosystem approach' at a variety of scales.

The ***Large Marine Ecosystem*** (LME) concept for monitoring, assessment and management of international coastal waters was conceived in the 1980s, and has been developed and further refined as a complementary instrument for achieving an ecosystem approach to management (Sherman 1994; Sherman & Duda 1999; NOAA 2005). LMEs are regions of the ocean encompassing coastal areas from river basins and estuaries out to the seaward boundary of continental shelves, enclosed and semi-enclosed seas, and the outer margins of

[4] UNCED 1992 definition '*where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*'.

the major current systems. They are relatively large regions of the order of 200 000 km^2 or more, characterized by distinct bathymetry, hydrography, productivity, and trophically dependent populations of plankton, benthos, fish, seabirds and marine mammals. Within a total of about 64 LMEs currently identified, about 95% of the usable annual global biomass yield of exploitable fish and shellfish is produced. However, within their waters most of the global marine pollution, overexploitation of living resources, and coastal habitat degradation occurs. Information for monitoring, assessing, and managing LMEs is organized according to five interrelated modules focused on: 1) ecosystem productivity, related to carrying capacity; 2) fish and fisheries; 3) pollution and ecosystem health; 4) socioeconomic conditions; and 5) governance protocols. A major area of the operational application of LMEs is in international development cooperation aided by the Global Environment Facility (GEF). **The Baltic Sea Large Marine Ecosystem (BSLME) forms a clearly delineated ecoregion and is currently designated as LME No. 23**. The **GEF Baltic Sea Regional Project** (BSRP, implementation start March 2003) aims to introduce ecosystem-based assessments within the Baltic Sea LME for strengthening the management of Baltic Sea coastal and marine environments through regional cooperation and targeted, transboundary marine and watershed activities, with a view to reducing impacts from non-point sources of pollution and to increasing sustainable biological production (Thulin *et al.* 2005). The BSRP supports the HELCOM Joint Comprehensive Environment Action Programme (JCP) and provides linkages with country activities. It is consistent with GEF global environmental policy to contribute significantly to "reducing stress to [the] international waters environment" by integrating sound land and water resource management strategies through a more favourable political and regulatory climate and activities that promote sustainable development. The Project's long-term goal is for the three intergovernmental organizations — HELCOM, IBSFC, and ICES—to utilize project-developed management tools for sustainable ecosystem management, and to contribute to the improvements in the social and economic benefits of the ecosystem to the coastal fishing and farming communities in the recipient countries of the eastern Baltic Sea area.

2 BONUS-169: PROGRAMME AIMS AND WORKPACKAGES

BONUS-169 is a joint programme proposal under Article 169 of the Treaty, involving the eight EU Member States in collaboration with the Russian Federation that together form the contiguous Baltic Sea coastal countries, **aimed at creating a cooperative, well-integrated and focused transnational research programme for the Baltic Sea region, in order to support the sustainable development of the region through the provision of outputs facilitating implementation of ecosystem-based management**, including:

1) ***Better coordinating the region's nationally funded research by more closely promoting, planning, funding, implementing, and publicizing pan-Baltic research.***
2) ***Bridging the gap between science and users by ensuring that the research needs connected with sustainable development of the Baltic Sea better reflects the initiatives and outputs of the region's scientific community, while also better synthesizing and disseminating research outcomes for improved receptivity and utilization in policy and decision-making.***
3) ***Developing capacity to create prudent, long-term, holistic multidisciplinary solutions involving sustainable use of the sea, by:***
    a) ***understanding and quantifying the role of climate change and variability, and its implications for the dynamics of the region's ecosystems and associated impacts on human communities;***
    b) ***understanding the physical, chemical and biological functioning of marine ecosystems, and understanding and quantifying human impacts (e.g. pollution including eutrophication, unsustainable fisheries and aquaculture, and degradation of habitats and ecosystems) on the marine environment and its biodiversity and human well-being;***
    c) ***developing the scientific basis for sustainable use and protection of the marine environment and its associated biodiversity, recognizing the essential benefits arising from socioeconomic development while also realizing the responsibility to conserve, and where appropriate restore, ecosystem health and the production potential of natural capital.***
4) ***Educating and training new generations of young scientists and technicians to apply novel concepts and technologies for the above-mentioned purposes.***

To this effect, BONUS-169 is built up around eight workpackages (**Fig. 1**) that are further elaborated in the following sections.

2.1 Workpackage 1: Natural forcing and climate change

2.1.1 Potential BONUS-169 research and application issues

Workpackage 1 acts in a 'cross-cutting' capacity, being designed not only to provide essential information and outputs on the natural environmental variability and climate change of the region in its own right but also to provide essential inputs on environmental forcing functions that affect, and need to be integrated with, the 'pillar' workpackages 2-5.

WP1: NATURAL FORCING AND CLIMATE CHANGE

Investigating the regional effects of natural forcing and climate change, including studies of how changes in the atmosphere, the sea, and the land with the associated watersheds affect the climate of the Baltic Sea region, and the implications for ecosystems and human communities and their activities.

Key potential research and application issues are further described below:

a) Studying the generation, transport and modification of climate signals in the region, and the relative roles of the different coupling processes for climate.
b) Analyzing climate variability and change over several centuries and providing regional climate projections for the Baltic Sea basin for the 21st century.
c) Investigating the palaeoclimate record as a key to comprehending long-term processes in the region's climate system, including distinguishing between natural climate changes and human induced climate changes.
d) Reconstructing the geological past in the context of climate change with a view to predicting future coastal developments including changes in sea level and coastlines related to human settlements and sustainable development planning in the coastal zone. This involves *inter alia* understanding, via a combination of data analysis and modeling, the complex relationships involving land uplift and subsidence, sediment transport connected with geochemical processes, erosion and deposition, compaction, and climate change and their role as driving forces for relative sea level change.
e) Analyzing and predicting meteorological, hydrological and water exchange forcing factors (*e.g.* periodicity in the North Atlantic Oscillation Index), including the use of models, on water renewal events in the Baltic Sea.
f) Improving our general understanding of the energy, water and associated geochemical cycles affecting the Baltic Sea and its surrounding watershed.
g) Improving understanding and the capability to model geochemical cycles with a view to *inter alia* understanding ocean carbon sequestration (*e.g.* 'missing sink' phenomenon) and setting conditions for biological productivity modeling in the Baltic Sea region.
h) Developing and validating more accurate ocean - atmosphere models for predicting future climate status including periodic and abrupt/extreme changes, and assessing the role of human activities in such changes.
i) Developing and validating oceanographic models for highly stratified areas in basin gradients (*e.g.* salinity/density, oxygen) that accurately describe and predict the major inflow events of saline water.
j) In collaboration with WPs 2-5, developing coupled physical-chemical-biological models that *inter alia* explain and predict the distribution and transport in the Baltic Sea of pollutants including eutrophication, and pelagic biota such as phytoplankton (including harmful algal blooms), zooplankton, fish eggs and larvae, and alien (*i.e.* non-indigenous) organisms, and which bridge the gap between fish and ecosystem models.
k) Demonstrating how climatic forcing (in collaboration with other impacted WPs) affects the distribution, population dynamics and productivity of indigenous and non-indigenous (*e.g.* alien) biota in the Baltic Sea region including microbes together with pathogens and diseases, plankton, fish, benthos, waterbirds and marine mammals; and (in collaboration with WP6 and other implicated WPs) provide scenarios regarding implications for socio- and ecological economics.
l) Identifying major upwelling areas and front systems, including those which are of transient and recurring character, and (in collaboration with WP2, WP4 and WP6) relate the importance of these areas/systems for enhanced phytoplankton productivity and an associated high abundance of zooplankton, attracting foraging concentrations of fish, seabirds and marine mammals. In so doing, consider the possible

candidacy of such areas/systems as MPAs/BSPAs.

m) Developing capability for forecasting, hindcasting and back-tracking of the drift of oil (*e.g.* from maritime accidents) and floating objects, and relate trajectories to the risk of causing especially serious ecological impacts in certain areas.

n) Providing improved water-management tools, with an emphasis on more accurate forecasts of extreme events and long-term changes.

o) In the area of operational oceanography, working in conjunction with BOOS to: a) coordinate, improve and harmonize observation and information systems, b) increase the quality and harmonize user-orientated operational products, c) provided high quality data and long time-series required to advance the scientific understanding of the Baltic Sea, d) provide data and forecasts to protect the marine environment, conserve biodiversity, and monitor climate change and variability.

p) In collaboration with WP6, exploring the consequences of various climate variability and change scenarios on socioeconomics and the sustainability of 'ecological goods and services'.

q) In collaboration with WPs 6-8, strengthening interaction with decision-makers, with emphasis on climate change impact assessments and taking action to redress the root causes of human induced clmate change.

r) In collaboration with WP7, promoting education, building capacity and conducting outreach activities at the regional level.

2.1.2 Background

Policy and management

The 1992 UN Framework Convention on Climate Change (UNFCC) is concerned with ecosystem management and aims to reduce greenhouse emissions to allow ecosystems to adapt naturally to climate change. Parties are committed *inter alia* to promote sustainable management and to cooperate in the conservation of sinks and reservoirs of greenhouse gases such as the oceans and coastal and marine ecosystems. The 2005 Kyoto Protocol measures, approved by all of the Baltic Sea States, commit the Parties to cutting greenhouse gas emissions by eight % during 2008-2012 from 1990 levels.

Climate change, caused by the emission of global warming gases, is potentially the most significant threat to biodiversity, and to the sustainable use of biodiversity by humans, at both the global and regional scales (IPCC 2002; CBD 2003). However, most environmental assessments of regional seas, including the Baltic Sea region, have not given major attention to natural forcing and climate change effects (HELCOM 2003; Hopkins 2004). There is a general lack of understanding concerning the relationships between trends in climate and changes in physical oceanography, and how this influences patterns of water movement and the biological production of marine plants and animals.

Much greater focus needs to be applied to examining regional climate change scenarios and assessing the biological, landscape and habitat, and socioeconomic impacts of climate change at the regional scale. National and regional environmental awareness campaigns should be developed in order to help deliver reductions in emissions.

Status and developments regarding natural forcing and climate change

Periodical variability of the atmospheric and oceanic environments is closely coupled and profoundly affects climate at the regional and local scales. Such environmental variability is due to natural cycles as well as to changes that are human induced. In the case of human induced changes, the Intergovernmental Panel on Climate Change (IPCC) has emphasized that increases in emissions, such as greenhouse gases, are contributing substantially to global warming that places human systems as well as the natural environment and biodiversity under major stress (IPCC 2002).

The regionalization of climate variability and climate change is a major goal of research in shelf seas oceanography, meteorology and hydrology in regions such as the Baltic Sea. Our ability to understand, and to predict forcing events—due to natural and human induced causes—affecting weather, climate, and global change depends critically on our capability to measure and model all processes determining the water and energy cycles between and within the components of our climate system (*c.f.* BALTEX, the Baltic Sea

Experiment). However, the impacts of human induced climate change on marine ecosystems, including biodiversity and living resources, are of major concern and will have associated impacts on human communities (IPCC 2002; Frid *et al.* 2003).

Climatic variability on the European continental shelf is dominated by events over the North Atlantic, and in particular by the North Atlantic Oscillation (NAO) (Dickson *et al.* 1996). Decadal variations in the NAO cause changes in the circulation of the North Atlantic and its adjacent seas such as the Baltic Sea, and strongly influence ocean circulation, precipitation, temperature, wind patterns, and is a proxy for effects seen in both terrestrial and marine ecosystems (Ottersen *et al.* 2001; Drinkwater *et al.* 2002). The physical conditions in the Baltic Sea may respond to climate change through 1) direct air-sea interactions, 2) the magnitude of freshwater run-off, and 3) interactions with the ocean at the open boundary (Stigebrandt & Gustafsson 2003). Surface temperatures are determined by the dominance of either westerly winds with mild Atlantic air conditions (high NAO index) or easterly winds with cold continental air resulting in decreased temperatures and extensive ice cover (low NAO index) (Doscher & Meier 2004). River run-off reduces the salinity of surface waters in the Baltic (Graham 2004). Renewal of the deep water in the Baltic Sea basins by inflows of saline oxygen-rich water from the North Sea is limited by elevated freshwater run-off input, due to increased zonal atmospheric circulation (Matthäus & Schinke 1999). The period of high NAO index values after the 1980s caused an increase in average water temperatures (Fonselius & Valderrama 2003) and the dominance of westerly winds further increased the amount of freshwater run-off causing substantially reduced salinities (Hänninen *et al.* 2000). In turn, the delicate ecological balance of the coastal and offshore areas of the Baltic Sea is greatly influenced by the frequency and magnitude of saltwater intrusions causing flushing and increased oxygen levels in the deeper basins, as well as by the volume and quality of run-off connected with the effects of leaching and dispersal of nutrients and pollutants (Graham 1999; Köster *et al.* 2005).

Saltwater intrusions have become reduced from about 13 events per decade before 1976/77 to four events since then to the present (*c.f.* EC funded BASYS – Baltic Sea System Study). The period from the 1990s onwards has been among been the warmest recorded, and this combined with reduced intrusions of oxygen rich water into the Baltic Sea have caused increased frequencies of oxygen depletion at numerous localities, *e.g.* in 2002 (HELCOM 2002; Frid *et al.* 2003). These climate connected changes can detrimentally impact marine life and fisheries in the Baltic Sea (Köster *et al.* 2005), as well as reducing the sea's ability to remove greenhouse gases from the atmosphere.

Continued global warming will probably have serious consequences on marine biodiversity and living resources, which are already seriously stressed through over-exploitation, pollution and habitat degradation. The likely impacts of further climate change on boreal marine ecosystems, including those of the Baltic Sea, are substantial (Hessen 2001; Hänninen *et al.* 2000; Frid *et al.* 2003; Stigebrandt & Gustafsson 2003; Köster *et al.* 2005; Hopkins 2005). The potential effects may include : a) longer ice-free periods leading to increased areas of open water, resulting in intensified wind mixing, upwelling and winter convection, leading to increased availability of nutrients for phytoplankton production; b) changes in ocean temperatures and currents that can affect fish migration, behaviour and distributions, with impacts on the associated food webs; c) seals, associated with ice-filled environments, will be affected by loss of habitat or possibly alter their migrations and distributions, with possible consequences for their prey; d) increased precipitation, anticipated from global warming, will increase inputs of terrestrial material to coastal areas; e) rising sea levels and elevated temperature will accelerate coastal erosion, reducing light penetration in coastal waters, and alter coastal habitats; g) more storms, especially in autumn, will lead to greater mixing in the water column, greater supply of nutrients, enhanced sediment transport and more rapid coastal erosion, h) increase in UV-B radiation levels, due to reduction in the thickness of the ozone layer, causing damaging effects on biota and humans; and i) the wider establishment of more cosmopolitan alien species.

2.1.3 Major international collaboration activities of relevance to the workpackage

- The Baltic Sea Experiment (BALTEX) and Baltic Operational Oceanographic System (BOOS, under EuroGOOS). BALTEX, including its projected Phase II, aims *inter alia* to improve the capability to analyze the effects of potential climate variability and change, incorporating aspects from hydrology, oceanography and meteorology. On a more fundamental level, hydrological efforts are aimed at representing the water balance of the entire Baltic Sea Drainage Basin in a single model within the constraints of data and basin information currently available. This has application to many aspects of run-off dependent activities including water resources planning, water quality issues, improved flood forecasting, and operational input to oceanographic models. BOOS, a EuroGOOS regional project founded in 1999, is a collaboration between national government agencies of the nine coastal countries of the Baltic Sea with a view to providing information such as data modelling products and forecasts for the marine industry, the public and other end users.

- Under the auspices of ICES, the ICES Oceanography Committee and its subsidiary groups, *e.g.* ICES Working Group on Modelling of Physical/Biological Interactions (WGPBI), ICES Working Group on Marine Data Management (WGMDM), ICES – IOC Steering Group on GOOS (SGGOOS), ICES – GLOBEC Working Group on Cod and Climate Change (WGCCC), Steering Group for the ICES/GLOBEC North Atlantic Programme and Regional Office (SGNARO). There is also a joint ICES/BSRP Study Group on Baltic Ecosystem Model Issues (SGEM).
- EC funded research projects (FP5 and FP6) of relevance with Baltic links include: AICSEX – Arctic ice cover simulation experiment; FERRYBOX – From online oceanographic measurements to environmental information; FLOOD RELIEF – A real-time decision support system integrating hydrological, meteorological and radar technologies; HIPOCAS – Hindcast of dynamic processes of the ocean and coastal areas of Europe; IRIS – Ice ridging information for decision making in shipping operations; MERSEA – Development of a European system for operational monitoring and forecasting of the ocean physics, biogeochemistry, and ecosystems, on global and regional scales; METROL – Methane fluxes in ocean margin sediments: microbiological and geochemical control; MOTIF – Models and observations to test climate feedbacks; OROMA – Operational radar and optical mapping in monitoring hydrodynamic, morphodynamic and environmental parameters for coastal management; OCEANIDES – Harmonized monitoring, reporting and assessment of illegal maritime discharges; PAPA – Programme for a Baltic network to assess and upgrade and operational observing and forecasting system in the region; SEA-SEARCH – Pan European network for oceanographic and marine data and information management; SWARM – Autonomous underwater multi-probe system for coastal area/shallow water monitoring; GRAND – GOOS regional alliances networking development, ALARM – Assessing large-scale environmental risks with tested methods.

2.2 Workpackage 2: Eutrophication

2.2.1 Potential BONUS-169 research and application issues

WP 2: EUTROPHICATION

Investigating the inputs and origins, dispersion/transport and impacts on ecosystems and human communities of eutrophication in the Baltic Sea region, including evaluating the efficacy of management options to redress the root causes of eutrophication and making proposals for improvements.

Key potential research and application issues are further described below:

a) In conjunction with WPs 1 and 3, providing biological productivity estimates for the Baltic Sea, through bio-optical modelling (*e.g.* photosynthesis model driven by satellite ocean colour data), in order to apply this information for the assessment of eutrophication status and trends, and with a view to developing dynamic ecosystem (*e.g.* coupled physical-chemical-biological) models linking to higher trophic levels. This activity should *inter alia* include the assessment of satellite remote sensing data and numerical modeling results for revealing new information on phytoplankton dynamics.
b) Elaborating a strategic design for phytobenthos, water quality and productivity monitoring in the coastal zone and measures for coastal fish monitoring in support of the requirements of HELCOM and the EC WFD. In these activities, eutrophication-related ecological quality objectives/indicators concerning phytobenthos and coastal fish communities should be developed for use in monitoring and assessment purposes.
c) In collaboration with WP5, elucidating the role of nutrients and eutrophication in processes regulating/modifying the transport and bioavailability of contaminants.
d) In collaboration with WP6, developing and applying techniques and methodology, including the use of

ecological and socioeconomic indicators, for linking information on discharges and losses of nutrients from non-point source agricultural activities with eutrophication effects in recipient coastal aquatic environments in order to redress the root causes of eutrophication and to provide more effective implementation of management solutions.

e) Increasing understanding and awareness of the importance of benthic organisms and communities in moderating the effects of eutrophication including interactions involving the carbon cycle and pelagic-benthic coupling in determining the flow of energy and materials to demersal fish.
f) Classifying the eutrophication status of the Baltic Sea at appropriate geographic sub-levels, based on elaboration and application of appropriate methodologies, with reference to relevant ecological quality objectives/indicators, and taking into account the catchment area, coastal waters and open sea waters, in accord with the WFD aims.
g) In collaboration with WP1 and WP3, investigating the impact of climate change and variability on phytoplankton dynamics and phytoplankton-zooplankton-fish interactions.
h) Making advances in applying novel techniques for identification and enumeration of plankton species, including new and improved optical sensors, image acquisition and molecular analyses, and deployment platforms for plankton sampling.
i) Contributing to updating of the annual ICES Plankton Status Report with regard to the Baltic Sea region, including extending the time-series with new sites with regard to phytoplankton and zooplankton time-series.
j) Elaborating a Phytoplankton Checklist for the Baltic Sea region and compare if species from the list fit into the Integrated Taxonomic Information Structure (ITIS) for reporting phytoplankton data to ICES.
k) Summarizing the status and trends of phytoplankton and zooplankton communities (*e.g.* biomass, species and size composition, temporal and spatial distribution) for input to a periodic pan-Baltic regional assessment.
l) In collaboration with WP1, analyze the development of eutrophication-related events at the temporal (*e.g.* short- to long-term, seasonal) and spatial scale in the Baltic Sea region, using information gathered from marine biology, oceanography, meteorology and satellite remote sensing, and develop scenarios and predictive models regarding the risk of such events occurring in particular areas.
m) Elaborating and harmonizing monitoring methods and models for assessing or predicting anthropogenic or natural nutrient loading into inland, coastal and marine waters of the Baltic based on nutrient sources information or nutrient sources scenarios. Physical modeling and optical remote sensing should be seen as complementary tools in facilitating the assessment of eutrophication.
n) Developing an integrated set of ecological quality objectives/indicators for nutrients and eutrophication effects in the Baltic Sea, taking into account developments in appropriate forums (*e.g.* EEA, HELCOM, OSPAR), that are in accord with the aims of the WFD. The elaborated indicators should be considered as an integrated set to serve as a tool to, for example, establish whether measures for nutrient reduction at source are sufficient in order to achieve a healthy marine environment where eutrophication does not occur. The elaborated integrated set of indicators should *inter alia* consider targets concerning the levels of nutrients, phytoplankton (chlorophyll *a* and eutrophication indicator species), oxygen, and phyto- and zoo- benthos (affected by eutrophication).
o) Further developing, harmonizing and applying dose-response models linking nutrient loading to ecological impact in different water body types and categories. Important to the development of these models is the translation and integration of science into information and tools that are useful to managers, and reporting of results to the public.
p) Investigating the dynamics of toxin producing phytoplankton (including cyanobacteria) in the Baltic Sea and the transfer of phycotoxins and their metabolites to other biota, related to phytoplankton abundance and phytoplankton community structure with reference to harmful algal bloom (HAB) dynamics.
q) Collating national reports and updating the decadal mapping/monitoring of harmful algal events for the IOC/ICES harmful algal database (HAE-DAT). In this context, also a) developing and applying tools (*e.g.* GIS techniques) to facilitate the computerized production of decadal maps spanning the whole Baltic Sea region from submitted country reports, and b) proposing types of analyses that should be performed using the IOC-ICES HAE-DAT dataset.
r) In collaboration with WP6, developing methods, tools and approaches (*e.g.* decision-support systems, and qualitative and quantitative models including 3-D coupled physical-chemical-biological models) to calculate the socioeconomic and ecological cost-benefit of various nutrient load reduction strategies (*e.g.* proportional load reduction approach, cost effective approach) in the Baltic Sea region.

s) Defining and justifying achievable states in the rehabilitation of the eutrophic Baltic Sea ecosystem(s), forecasting the trajectory of rehabilitation, and proposing the most effective means to reduce nutrient inputs that are also in accord with ecosystem health considerations.
t) In collaboration with WP6, developing a human use/socioeconomic index that puts the degradation of water quality and loss of use into context for the public as well as quantifying these costs and losses on a national and trans-Baltic basis.
u) In collaboration with WP6, evaluating the eutrophication status in a demonstration project in a specific area (*e.g.* Gulf of Riga) for testing/validating the developed eutrophication assessment tools (*e.g.* indicators and EcoQOs), to examine the consequences of restoring good ecological status on biodiversity, fisheries and other human socioeconomic aspects (*e.g.* recreation and tourism). In so doing, substantial focus should be directed at applying the ecosystem approach to management, quantifying the socioeconomic impacts of eutrophication, and possible cost-effective mitigation measures.
v) In collaboration with WP7 and WP8, strengthening interaction with decision-makers, with emphasis on the need to combat eutrophication.
w) In collaboration with WP7, promoting education, building capacity and conducting outreach activities at the regional level.

2.2.2 Background

Policy and management

The immediate human-induced causes of eutrophication[5] are the aquatic load of nutrients and atmospheric deposition of nitrogen to inland water bodies and into the Baltic Sea (Nixon 1990; GIWA 2005). The main sectors responsible for eutrophication of the Baltic Sea are agriculture, urbanization, energy production and transport. Agriculture is responsible mainly for the diffuse inputs due to excess use of fertilizers and uncontrolled manure and slurry disposal. Urban areas are responsible for nutrient inputs from municipalities and industrial enterprises discharging untreated or partly treated waste water to the environment. Energy production and transport are responsible for high emission levels of nitrogen, having a significant influence on the deposition rate. The resulting eutrophication may result in serious and pervasive environmental and socioeconomic impacts, such as modification of ecosystems and ecotones, oxygen depletion, harmful algal blooms, loss of benthic biota, and loss of commercially valuable fish (GIWA 2005).

HELCOM has been working to implement the 50% reduction targets for nutrient emissions and discharges set by the 1988/1998 Ministerial Declarations. This is now gradually being taken over by a general objective to reach good ecological status. The implementation of HELCOM and other requirements in the Baltic Sea region have resulted in a significant reduction of nutrient loads from point sources, with the 50% reduction target having been achieved for phosphorus but the reduction of nitrogen is still substantially behind schedule for achieving the 50% target (HELCOM 2002; Selin & VanDeever 2004). Measures to reduce nutrients from agriculture, currently the major source of inputs due to excessive use of fertilizers, have fallen short of their aims. Improvements in the ecological status of the Baltic Sea are difficult to substantiate as a result of the nutrient load reduction policy, and the need for greater scientific input on formulation of management policy has been raised (Turner *et al.* 1999; Gren *et al.* 2000; Neumann *et al.* 2002).

The environmental problem of eutrophication is addressed in several EC policies and Directives (*e.g.* Urban Wastewater Treatment Directive, Nitrates Directive, Directive on Shellfish Growing Waters, WFD, and European Marine Strategy). The WFD requires, *inter alia,* the establishment of classification schemes to reflect the ecological status or potential of surface water bodies and coastal waters as measured by the condition of specific biological, hyrdomorphological and physico-chemical elements. The WFD sets the classification requirements, and associated methods, for coastal waters and is legally binding for EC States. Within the WFD, the coastal waters are first typified and then classified by the Community States into five ecological quality status classes (*i.e.* high, good, moderate, poor and bad) with the ultimate objective of

[5] Defined by the EC Urban Waste Water Directive (91/271/EEC) as '*enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce undesirable disturbance to the balance of organisms present in the water and to the quality of water concerned.*'

achieving good status for surface waters. A set of guidelines and methodology for classification of coastal waters is developing. In the intercalibration process, EC States will decide on interpretation of the environmental objectives.

Changes in nutrient levels and balance on geochemistry and plankton production

The input of nutrients, in the form of nitrogen (N) and phosphorous (P) compounds, to the Baltic Sea has increased by ca. 3-5 times compared with the 1940s levels, and the concentration of N and P in the sea has doubled and quadrupled, respectively, since about 1950 (Nehring 1984, 1987; Nehring *et al.* 1984; Larsson *et al.* 1985; Rosenberg *et al.* 1990; Wulff *et al.* 1990; Jansson & Dahlberg 1999). The long-term increased input of nutrients from anthropogenic causes has introduced substantial shifts in the ratio between available N and P, with the latter becoming more available and silica (Si) having become reduced.

In connection with these changes, primary production in the Baltic Sea region has increased by about 50-100% since the beginning of the 20th century, sedimentation of organic matter from the pelagial has increased almost two fold since the late 1920s, and the content of organic matter (*e.g.* carbon, C) in the uppermost sediment layers has about doubled from the 1930s to the late 1980s resulting in increased biological oxygen demands for its breakdown (Elmgren 1989; Jonsson & Carmen 1994). There are also indications that the spatial and temporal coverage of novel, nuisance and harmful blooms (*e.g.* cyanobacteria, dinoflagellates) have increased, probably not only due to the increase in nutrient concentrations, but also to changes in the seasonal availability and relative proportions of nutrients, *e.g.* an imbalance in the Redfield ratio governing N:P in seawater, and subsequent changes in Si availability (Edler *et al.* 1996; Bianchi *et al.* 2000; Lagus *et al.* 2004). Increases in the retention of Si have increased globally in aquatic ecosystems due to regulation of rivers and enhanced deposition in sediments via eutrophication (Conley *et al.* 1993), mainly through the stimulation of primary production and its sedimentation by increased enrichment with N and P. Changes in Si retention with eutrophication and decreasing Si loads to the coastal ocean are especially prevalent in large enclosed marine systems, such as the Baltic Sea (Wulff & Rahm 1988; Rahm *et al.* 1996; Snoeijs 1998).

The growth of diatoms depends on the presence of dissolved Si whereas the growth of non-diatom phytoplankton does not (Kristiansen & Hoell 2002). When concentrations of dissolved Si become low, other types of algae (*e.g.* flagellates) not requiring Si can dominate the algal community composition and decrease the relative importance of diatoms. In addition, global increases in novel and harmful algal blooms have been linked to increases in N and P concentrations and changing Si:N and Si:P ratios (Smayda 1990; Pan *et al.* 1996). Thus, changes in the retention and inputs of Si may have major consequences for geochemical cycles and the structure of planktonic communities.

Classic theory considers diatoms as the preferred food of many grazers and organisms in the upper trophic levels, and diatoms thus form the basis for many of our productive fisheries (Ryther 1969). Since diatom abundance is partly dependent upon Si availability, any changes in the biogeochemical cycling of this element may have repercussions on the pelagic food web including fisheries (Harvey *et al.* 2003). Diatoms also sink efficiently (Smetacek 1985). The large-sized, fast growing planktonic diatoms are the major producers of sinking particulate material (Michaels & Silver 1988), thus fuelling benthic production and the production of demersal fish. Sinking diatoms bring N, P and C with them. Perturbation of the biogeochemical cycle of silicate and the reduction of diatoms in the planktonic community reduces sinking losses. The net effect is to leave excess N and phosphorus in surface waters while Si is depleted. Thus, the long-term increases in N and phosphorus and the long-term decreases in Si concentrations may be coupled to the formation of novel harmful algal blooms (Conley 2000; Boesch 2002). Furthermore, increased organic production and nutrient supply also stimulates microbial (*e.g.* bacteria and viruses) populations and processes, making the microbial loop a more prominent trophic pathway in pelagic and bottom environments (Boesch 2002).

Recently significant progress has been made in applying novel techniques, including modeling approaches, for examining the spatial distribution of phytoplankton biomass, incorporating selected indicators and species on an annual and seasonal basis over the whole Baltic Sea, using the comprehensive CHARM phytoplankton data base (Thamm *et al.* 2004). Such developments are potentially important for examining the distribution patterns of phytoplankton with respect to Baltic Sea typology required by the WFD.

Given the long-term increases in planktonic primary production in the Baltic Sea resulting from increased eutrophication, elevated herbivorous zooplankton production would also be expected intuitively, not least based also on the high current biomass and catch of planktivorous pelagic fish (*e.g.* herring and sprat) stocks (see WP3). Despite such reasoning, longer-term studies of Baltic Sea zooplankton have been equivocal in their ability to demonstrate correspondingly similar trends in species composition, abundance or biomass in a similar manner to that for primary production, although salinity and climate related changes are frequently evident (Elmgren 1989; Vuorinen & Ranta 1987; Viitasalo *et al.* 1990; Vuorinen *et al.* 1998; Möllmann *et al.* 2000; Kornilovs *et al.* 2001). Accordingly, zooplankton have not been successfully used as indicators of eutrophication in Baltic Sea monitoring programmes. In order to redress this perplexing challenge, greater efforts are required to develop a routine, coordinated and integrated zooplankton sampling programme at the pan-Baltic level, using modern sampling methodology combined with high-frequency acoustical techniques, and to couple these with ecosystem modeling studies.

As emphasized above, these eutrophication-related changes in the Baltic Sea environment may have fundamental effects on the structure and function of the food web. In this context, it is also pertinent to note that although the ultimate causes of the M74 syndrome decimating salmon recruitment are unknown, there is increasing evidence that the syndrome is linked to thiaminase activity of prey species (herring) in the Baltic Sea (ICES ACME 2004). The prevalence of M74 may be affected by a shift in phytoplankton species composition and related alterations in the lipid-rich food chain leading to fatty fish (*e.g.* herring and salmon) (Bengtsson *et al.* 1999; Hansson *et al.* 2001; ICES ACME 2004).

Eutrophication effects on benthic and fish communities and habitats, and human amenities and health

The increased consumption of oxygen due to eutrophication has made the Baltic Sea more sensitive to the long periods between inflows and more likely to produce H_2S. When inflow does occur, much of the oxygen is needed simply to oxidize the H_2S since the previous inflow (Jansson & Dahlberg 1999). One phenomenon that is associated with the wide extent of anoxic bottoms, exacerbated by eutrophication, is benthic developments on shallow and deep bottoms in the Baltic Proper. Over large areas of the Baltic Sea, particularly in the deeper depressions of the Baltic Proper, oxygen is entirely depleted and replaced by poisonous H_2S, and severe oxygen deficiency frequently may occur in late summer and autumn in other parts of the Baltic. In the Kattegat/Belt Seas, for example, a severe oxygen deficiency now frequently arises in late summer and autumn, causing major mortality of benthos as well as degradation of water quality and human amenities (Karlson *et al.* 2002). Eutrophication, in conjunction with infrequent intrusions of oxygenated water, has caused substantial changes in the benthic community structure and productivity that are essentially dissimilar in the shallower compared with the deeper areas of the Baltic Sea.

In waters above the halocline, with plentiful oxygen, there has been a 3-5 fold increase in the benthic biomass since the 1920s (Cederwall & Elmgren 1980; Perus & Bonsdorff 2004), due to an enhanced food supply supported by a substantial increase in primary production and sedimenting particulate organic material (POM). In the bottom fauna of the shallower regions of the Baltic Sea, bivalves have thrived while crustaceans have declined (Leppäkoski 1975; Plinski 1990). Long-term reduction in the light penetration has occurred in many places in the Baltic Sea due to the presence of high primary production and increasing turbidity (Messner & Oertzen 1991; Trzosinska 1992; Sandén & Håkansson 1996). The depth distribution of perennial macrophytes (*e.g.* bladderwrack) attached to the seabed has decreased, and short-lived filamentous, epiphytic or drifting algae have become increasingly prevalent (Kautsky *et al.* 1986; Wachenfeldt *et al.* 1986; Vogt & Schramm 1991; Eriksson *et al.* 1998; Berger *et al.* 2004; Martin & Torn 2004). These are connected with a higher input of nutrients since the 1940s. Blue mussels and green and brown filamentous algae have replaced the bladderwrack in many places, covering some shallow soft bottoms and changing the nutrient flux at the sediment-water interface by decreasing the oxygen content (Bonsdorff *et al.* 1997). The increased incidence of filamentous green algae tends to smother macroalgae and seagrasses, with major ecological consequences, and 'slimy' green algae reduce amenities for tourism and recreation purposes (Leppäkoski & Mihnea 1996).

In the deeper depressions, such as in the Baltic Proper, increased planktonic sedimentation and reduced oxygen availability has changed the species composition of the bottom fauna, with some biota having been virtually eliminated due to hypoxia and anoxia. Before about 1950, large long-lived filter-feeding bivalves (*e.g. Macoma balthica, Arctica islandica, Astarte spp.*) were common in such areas but have been replaced by sediment eating polychaete worms that are more tolerant to hypoxia. There has also been a shift from predominantly K-selected benthic species towards r-selected opportunistic species (Leppäkoski & Mihnea 1996). This has *inter alia* resulted in a decrease in the decomposition of organic material as well as an impoverished diet for bottom-feeding fish (Jansson & Dahlberg 1999). There are 70 000 to 100 000 km^2 of periodically dead bottoms in the Baltic Proper that are essentially devoid of bottom fauna (Leppäkoski & Mihnea 1996).

The impacts of eutrophication on fish stocks and communities can be viewed as both beneficial and detrimental: moderate levels of excess nutrients may be beneficial in oligotrophic systems, but increased enrichment may result in harmful effects. In the Baltic Sea, as in the Great Lakes of North America, a decrease in bottom-feeding fish and flourishing pelagic fish assemblages have been observed in semi-enclosed areas subjected to intense eutrophication. Caddy (2000) has drawn attention to the impacts of fishing on nutrient enriched ecosystems and provided a schematic presentation of transitional stages of development reflecting the synergistic impact of increasing fishing intensity and nutrient run-off on marine food webs, and bottom oxygen depletion, leading *inter alia* to a decline in mean trophic level as measured by the ratio of the landed weight of small pelagic fish (*e.g.* herring and sprat) versus demersal (*e.g.* cod) fish. Such changes in fishing regimes, under highly eutrophic conditions, have had detrimental socioeconomic consequences (GIWA 2005). Furthermore, many hard bottom areas previously covered by brown macroalgae (*e.g.* bladderwrack) in shallower waters, representing preferred spawning habitats by Baltic herring and several other commercial and non-commercial fish species, have been degraded by eutrophication, contaminants and increased sedimentation of detritus, leading *inter alia* to transitions to enlarged areas of soft-bottom covered by filamentous algal mats that are unsuitable for successful spawning (Bonsdorff *et al.* 1997; Jansson & Dahlberg 1999).

Some fish species of freshwater origin have increased substantially in eutrophied coastal waters of the Baltic Sea, with catch levels and the proportion of species connected with eutrophication being negatively correlated with water visibility (Bonsdorff & Blomqvist 1992; Sandström 1994). These increases verify the model developed in European freshwaters, predicting that fish production will increase during the first stages of eutrophication. For example, the abundance of cyprinid fishes (*e.g.* roach, bream and silver bream) has more than doubled since the mid-1960s at numerous localities (Neuman & Sandström 1996; Ådjers *et al.* 1995). In these shallower coastal waters, larger, more economically valuable fish (*e.g.* pike-perch) have declined in both relative and absolute terms under the effects of eutrophication.

For over a century, human induced organic input (*e.g.* from biomass enhancement via eutrophication and discarded by-catch and offal) and physical impacts (*e.g.* mortality and bottom disturbance from towed demersal fishing gears and sand and gravel extraction) have increased and favoured opportunistic species with 'r-selected' life history characteristics and eliminated vulnerable species with 'K-selected' life histories (Svelle *et al.* 1997; Newell *et al.* 1998; Nilsen *et al.* 2002). The resulting changes in the benthic fauna and flora in the shallower more eutrophic and heavily bottom-trawled areas have tended to favour shifts in the composition of the fauna selecting towards i*nter alia* non-fragile fast growing and mobile scavengers, predators, and sediment or suspension feeders such as polychaetes, amphipods, and starfish rather than slow-growing and longer lived sessile organisms such as many of the larger, sessile and frequently fragile filter-feeding bivalve species. Thus, the impacts of the above-mentioned anthropogenic activities have combined to result in the elevated biomass, productivity and changed structure of the demersal and benthic communities (Pearson & Rosenberg 1978; Hall 1999; Kaiser & de Groot 1999; Karlson *et al.* 2002; Nilsen *et al.* 2002).

Although the dumping of sewage sludge is prohibited in the EC, treated and untreated sewage continues to be discharged from land-based sources into the marine environment throughout the coastal areas (HELCOM 2003; GIWA 2005). Bacteria and viruses associated with sewage and agricultural run-off can affect water quality (*e.g.* bathing water) and can accumulate in filter-feeding shellfish (*e.g.* bivalves such as mussels). Bacteria and organic matter (*e.g.* sewage and agricultural run-off) pose serious threats regarding polluting bathing water at many coastal beaches. The use of new or improved treatment plants for waste water and sewage is contributing to substantial improvement of bathing water quality. Bathing waters at designated beaches in the region must now conform to the standards set by the EC Bathing Water Directive (76/160/EEC) with regard to hygiene, based on monitoring of biological and physico-chemical parameters.

However, a lack of harmonized methodology for evaluation purposes makes it very hard to compare States. The EC Directives for shellfish water quality (79/923/EEC) and shellfish hygiene (91/492/EEC) set permissible limits for bacteria (*Escherichia coli*) levels in water and shellfish, respectively. The States must establish appropriate monitoring programmes and classify shellfish growing waters according to the extent that shellfish samples from an area are contaminated by *E. coli* bacteria. Although important for the protection of public health, the standards for the microbial quality of bathing water and shellfish as established by these Directives are not able to protect all persons against the full range of human pathogens to which they may be exposed through bathing or eating shellfish.

2.2.3 Major ongoing international collaboration activities of relevance to the workpackage

- Under the auspices of ICES, scientific issues connected with eutrophication are addressed in the following expert groups: Working Group on Phytoplankton Ecology (WGPE); ICES/IOC Working Group on Harmful Algal Blooms (WGHABD); Working Group on Zooplankton Ecology (WGZE); Working Group on Modelling of Physical and Biological Interactions (WGPBI); Benthos Ecology Working Group (BEWG); Study Group to Review Ecological Quality Objectives for Eutrophication (SGEUT); ICES-IOC-SCOR Study Group on GEOHAB Implementation in the Baltic (SGGIB); ICES/HELCOM Steering Group on Quality Assurance of Biological Measurements in the Baltic Sea (SGQAB). There is also a joint ICES/BSRP Study Group on Baltic Sea Productivity Issues (SGPROD).
- The BSRP Productivity Coordination Centre (CC PROD in Riga, Latvia), as well as its subsidiary Lead Laboratory (LL) on Phytobenthos Monitoring/SOOP (Ships of Opportunity, connected with further development of the alg@line phytoplankton monitoring initiative) and LL on Ichthyoplankton and Zooplankton are actively engaged in developing networks of coastal and offshore monitoring stations/transects involving water quality, phytobenthos, and coastal fish and plankton productivity (phytoplankton, zooplankton and ichthyoplankton) monitoring related to ICES and HELCOM needs. Activities have also included holding several workshops: ECOPATH/ECOSYM modeling tools for comparative assessment of Baltic coastal ecosystems; strategic design of phytobenthos, water quality and productivity monitoring in the coastal zone.
- EC funded research projects (FP5 and FP6) of relevance with Baltic links include: ALGINET – Microalgae as cell factories for chemical and biochemical products; CHARM – Characterization of the Baltic Sea ecosystem: Dynamics and function of coastal types; COSA – Coastal sands as biocatalytic filters; DANLIM – Detection and analysis of nutrient limitation: Impacts of loading on coastal plankton communities across a hierarchy of temporal and physiological-systematic scales; ELME – European lifestyles and marine ecosystems; FATE – Transfer and fate of harmful algal bloom (HAB) toxins in European marine waters; FERRYBOX – From online oceanographic measurements to environmental information; HABES – Harmful algal bloom expert system; HABILE – Harmful algae blooms initiation and prediction in large marine ecosystems; SIBER – Silicate and Baltic Sea ecosystem response; SIGNAL – Significance of anthropogenic nitrogen for central Baltic Sea nitrogen-cycling; REBECCA – Relationships between ecological and chemical status of surface waters;
- Research projects, recently funded by the Nordic Council of Ministers, of relevance with Baltic links include: Cost effective reduction of the nutrient load to the Baltic Sea sub-basin – combining economics and ecology; DEFINE – Defining reference conditions for coastal areas in the Baltic Sea for the Water Framework Directive; DONKEY – Dissolved organic nitrogen as a key nutrient for marine plankton; EQUAL – Estuarine quality classes for Water Framework Directive indicators; RETRO – Reference conditions and typologies for aquatic vegetation and macrozoobenthos in the Skagerrak and Kattegat;

2.3 Workpackage 3: Sustainability of living resources

2.3.1 Potential BONUS-169 research and application issues

WP3 focuses primarily on the theme of ***Sustainable Fisheries and Aquaculture in Sustainable Ecosystems***, and the relationship between these human activities and the ecosystem.

WP3: SUSTAINABILITY OF LIVING RESOURCES

Investigating the *sustainability of fisheries and aquaculture in Baltic Sea ecosystems*, including developing and applying scientific methodology, analyses, models and actions/measures furthering the rational exploitation of the utilized living marine resources and aimed also at understanding and limiting the ecosystem effects of fishing and aquaculture activities. In this context it is important also to develop a market and information system for consumers of seafood products that arise from sustainable practices in healthy ecosystems.

Key potential research and application issues are further described below:

a) Developing, coordinating and implementing sampling designs and joint surveys to extend the quality and coverage of *inter alia* a) the Baltic trawl - hydroacoustics surveys (*e.g.* BITS, BIAS), and b) joint hydroacoustics and productivity surveys, to better integrate information on the distribution of fish, plankton (phytoplankton and zooplankton) and macrobenthos, and extend such surveys on a pan-Baltic scale (*e.g.* the north and coastal areas) using, where appropriate, chartered vessels. These activities should also facilitate national data submission to DATRAS (Database Trawl Survey), FishFrame (Fisheries and Stock Assessment Data Framework), BAD2 (Baltic Acoustic Survey Database) and COBRA databases.
b) Improving the reliability of a) age determination (*e.g.* from analysis of otoliths and scales, as well as size-based techniques) and growth analysis, and b) stomach sampling and feeding analyses, of Baltic Sea offshore and coastal fish stocks using transnational intercalibration and training exercises (*e.g.* workshops) with nationally collected data inputs. These should contribute *inter alia* to improving the capacity to provide data necessary for both single species and multispecies analysis purposes.
c) Further developing and applying (in collaboration with WP 4) reference points (limit, precautionary and target) and management plans for all assessed commercial fish stocks in the Baltic Sea, and especially in the case of stocks outside safe biological limits (SBLs) elaborate harvest rules and recovery plans, and demonstrate how these measures may be extended to non-assessed and non-target fish as well as other by-catch biota including benthos, waterbirds and marine mammals.
d) Implementing into national regulations the multi-annual management plans agreed by the IBSFC for Baltic cod and salmon.
e) Improving international coordination, quality assurance (‘credibility’) and integration of fisheries statistics collected from commercial fishing vessels working in offshore and near-shore areas including use of log-books, landings statistics and biological data from landings, with a view to facilitating stock assessment work as well as inputs to the FAO Coordinating Working Party on Fishery Statistics (CWP) and the EC’s EUROSTAT.
f) Improving techniques and their application, in collaboration with other WPs (*e.g.* WP1, WP2) for providing early estimates of recruitment of fish stocks, taking into account *inter alia* density dependence, predation/cannibalism, spawning stock biomass and environmental variability (*e.g.* climate, eutrophication).
g) Developing and applying multispecies fish stock models and, in conjunction with other WPs (*e.g.* 1, 2, and 4), bridging the gap between these and ecosystem models (*e.g.* coupled physical-chemical-biological models, ECOPATH) with linkages to both lower and higher trophic levels.
h) Developing and applying data collection strategies and research programmes to assess the impact of particular fisheries and their deployed gear on non-target (*e.g.* zoobenthos and phytobenthos, fish, waterbirds, and marine mammals) and associated or dependent species and their environment using underwater technology and observer programmes (*i.e.* data collected by independent observers monitoring fishing aboard vessels at sea), and adopting plans which are necessary to ensure the conservation of such species and to protect habitats of special concern. In the case of waterbirds and marine mammals, this should be conducted in conjunction with WP4.
i) Establishing, in collaboration with other WPs (*e.g.* WP1, WP4), methodology and approaches for integrating information on genetic and phenotypic variation into oceanographic and ecological knowledge and modeling of fish stock assessments and the ecosystem impacts of fisheries. In this connection, it is notable that historical collections of commercial and other species are of great value in assessing loss of genetic diversity (*e.g.* effective and census population sizes) due to fishing and other anthropogenic effects.
j) Proposing, in collaboration with other WPs (*e.g.* WP4, WP6), candidate areas for incorporation into the

networks of marine protected areas/Baltic Sea protected areas of significant size, with clearly defined management goals (*e.g.* purpose, use and access rules), including undisturbed areas having 'no-take/no-trawl' zones to enhance the protection of juvenile fish, spawning areas and vulnerable benthic species and habitats. In this context it is important to devise and implement effective habitat classification and mapping programmes for constructing spatially orientated inventories, coupled with restoration schemes to enhance the recovery of substantially degraded environments (*e.g.* seabed).

k) Further developing, in collaboration with other WPs (*e.g.* WP1, WP2, WP5), information and knowledge concerning the impacts of water exchange periodicity (*e.g.* flushing and stagnation) on water quality parameters, including the distribution and levels of contaminants and eutrophication, of importance to fish stocks and communities as well as other living resources.

l) Reconstructing, in collaboration with other WPs (*e.g.* WP4, WP6), catch and effort data from historical sources (*e.g.* records of taxes and tithes, sales of fish, lists of food provisions, reports of privileged fisheries, historical sediment records in anoxic regions of the sea for the presence of fish scales of different species) with a view to assembling reliable long-term (multidecadal) time series of fish and marine mammal abundances in order to explore relationships with human induced activities (*e.g.* fishing and hunting, pollution, eutrophication, global warming) and naturally caused environmental (*e.g.* ocean climate) variations.

m) Extending age- or size-structured virtual population analyses (VPA) for Baltic fish stocks backwards in time (*c.f.* Pope & Macer 1996 for the North Sea, Nilssen *et al.* 1994 for the Barents Sea). For Baltic fish stocks, the approach provides an alternative means to estimate stock biomasses (*c.f.* Thurow 1997) and provides support for results obtained with catch data. Some catch-at-age information is already available for the pre-VPA period (Thurow 1997) and additional data is anticipated to be available in archives of fishery research institutes. Compilation of such information is relatively easy, compared with researching data archaeology archives, and should enable some VPAs to be extended backwards several decades.

n) Developing qualitative and quantitative scenarios (in conjunction with WPs 1, 2, 4 and 6) regarding the potential developments in recruitment and biomass of cod, herring and sprat, including interactions with marine mammals, in the Baltic sea region in the 21st century taking into account the predicted regional effects of global climate change/variability, current and alternative policies regarding nutrient load regulation, and possible strategies for sustainable fisheries.

o) Developing improved technical measures for fishery management including selectivity and technological devices that minimize by-catches of non-target as well as undersized target species. Other measures include making proposals regarding fishing gear substitution and modification that can be used in alternative and more rational fishing strategies, as well as fishing methods that have a reduced physical impact on the seabed and habitats. Taking into account the behaviour of biota during fishing and capture, is important when deciding on appropriate fishing regulations for better management of fisheries.

p) Investigating, in collaboration with WP4, use of the 'slope of the size spectra', connected with the average length and average size of an individual fish, in monitoring the effects of fishing mortality on fish populations and fish communities in coastal and offshore areas.

q) Reviewing, prioritizing, selecting and further developing, in collaboration with other WPs, a suite of DPSIR (Driving forces - Pressures-State- Impacts – Responses) indicators connected with monitoring sustainable fisheries and aquaculture involving ecological quality and socioeconomic reference points (*c.f.* FAO 1999). For fisheries, these should *inter alia* include consideration of: fishing effort and gear deployed by specific fleets relating to geographic areas/sub-areas/localities; ratio between stock yield and SSB; number of licensed commercial fishers reflecting the status (*e.g.* biomass) of the targeted stock; contribution of fishing to national and regional economy; management of fishing effort (total time fished, number/size of fishing vessels, gear type and their selectivity); by-catch on an area and fishery (*e.g.* gear deployed) basis; ratio of pelagic : demersal fish landings; ratio between scientific advice and degree of management implementation; area fished by bottom trawls (*e.g.* total fished area or proportion of total bottom area; degree of repeated trawling); frequency and persistence of bottom trawl tracks (*e.g.* use of scanning sonar and ROV investigations); average trophic level of the catch (mainly for community but also for species as a measure of 'fishing down the food chain'); national performance measures to minimize accidental catch of target and non-target species; incidence of MPAs and no-take zones.

r) Developing and applying analytical techniques and models that explore the environmental and ecosystem impacts of aquaculture and elaboration of mitigatory measures, including *inter alia*: use of toxic and persistent chemicals (e.g. antibiotics and pesticides) leading to resistant microbes; production of nutrients and deposition of organic material leading to eutrophication-related effects; combating the loss of 'escapees' in the form of cultivated organisms that may impair gene pools, transfer parasites and diseases, and compete for food and habitats in the wild); control of aquaculture stock movements with a view to limiting the spread of parasites and diseases including potential introductions and transfers of invasive alien species; and improving environmental impact assessments related to granting of aquaculture licences and subsequent environmental monitoring regimes to assess and limit impacts.

s) Developing ecolabelling, organic production and other certification schemes, in collaboration with other WPs (*e.g.* WP4, WP5 and WP6), to promote sustainable practices for capture fisheries and aquaculture in the Baltic Sea region, offering a market- and information-based system for consumers of products that are healthy, safe, and of good quality, as well as promoting high animal health and welfare standards and maintenance of a healthy environment.

t) Evaluating and further developing risk assessment methods regarding food safety issues connected with products from capture fisheries and aquaculture. These products may be associated with certain food safety issues, *e.g.* the risk of contamination of products by chemical and biological agents. Food safety issues associated with such products will differ from region to region and from habitat to habitat and will vary according to the method of production, management practices and environmental conditions. Foodborne parasitic infections and foodborne disease associated with pathogenic bacteria, residues of agrochemicals, veterinary drugs and heavy metal contamination are potential hazards of aquaculture products. The origins of such food safety concerns range from inappropriate practices, environmental pollution and cultural habits of food preparation and consumption. Thus, with the important contribution of these products to food sustainability and to regional and international trade, proper assessment and regulation of any food safety concerns are becoming increasingly important. Research must provide the scientific basis for protocols and standards, and especially legislation. The geographical and cultural divergence of capture fisheries and aquaculture in the Baltic Sea region means that the task of incorporating national and regional information to this European dimension will be challenging.

u) In collaboration with WP7 and WP8, strengthening interaction with decision-makers, with emphasis on the need to ensure the sustainability of living resources.

v) In collaboration with WP7, promoting education, building capacity and conducting outreach activities at the regional level.

2.3.2 Background

Policy and management

Fisheries affect the marine ecosystems and the fish stocks are affected by the ecosystems. Fisheries management must, according to recent international agreements and codes, consider the effect of fisheries on the marine ecosystem (*e.g.* FAO 1995; UN 1995; IMM97; Hopkins 1999; EC 2002a; Nilsen *et al.* 2002; NSC 2002; JMM 2003a). Fish are important components in the marine ecosystem due to their frequently high biomass and role in food chains as predators on zooplankton, benthos and other fish, as well as in turn providing food for higher trophic levels including seabirds, marine mammals and mankind (Nilsen *et al.* 2002). Thus, their management and exploitation, both as target and non-target (*e.g.* by-catch) species in fisheries, are of major ecological concern and must be seen in an ecosystem perspective.

The Baltic Sea region is a major contributor to the world's marine fish production, with harvests of fish from demersal (*e.g.* cod and flatfish) and pelagic stocks (clupeids such as herring and sprat, and salmon) currently amounting to about 800 000 tonnes annually (Anon. 1994; Degnbol & Symons 2000; FAO 2000; ICES ACFM/ACE 2004). Fisheries are among the major industries contributing to food security and socioeconomics in the Baltic coastal countries (Palmer 2005). The first-hand value of the catches is currently estimated at about EUR 500 million per year. Although the biomass of the catch is high, the economic value of the catch for human consumption has decreased as the composition of the catch has changed towards relatively low value pelagic species rather than demersal species (Caddy 2000).

The impacts of fisheries in the Baltic Sea region are ranked amongst those of major importance and concern (HELCOM 2003; GIWA 2005). The majority of assessed commercial fish stocks in the region are overexploited due to unsustainable fishing effort and practices including perverse subsidies and economic reform failures, irrational fishery management, and the associated ecosystem impacts of fishing have become increasingly apparent (HELCOM 2003; ICES ACFM/ACE 2004; GIWA 2005).

The Baltic Agenda 21 Goal for Sustainable Fisheries states that '*a sustainable fishery is achieved when a high probability of fish stocks being able to replenish themselves over a long period of time within a sound ecosystem is assured, while offering stable economic and social conditions for all those involved in the fishing activity*'. Thus, the goal for achieving sustainable development in Baltic Sea fisheries forms the means for achieving economically and socially sustainable, environmentally safe and responsible fisheries by a) maintaining biologically viable fish stocks, the marine and aquatic environment, and associated biodiversity; b) within these limits establishing maximum fishing possibilities and appropriate selective fishing techniques for harvesting stocks; and c) distributing the direct and indirect benefits of open sea and coastal fishery resources between local communities in an equitable manner (Baltic 21 2000).

For the EU Baltic Sea countries, management of fisheries and aquaculture is regulated within Community waters under the EC Common Fisheries Policy (CFP), and within Russian waters by national policy and legislation. Additionally, IBSFC aims at promoting conservation and optimal utilization of fish stocks in the Gdansk Convention area. Fisheries information and advice, including on ecosystem related issues, is provided to all these parties by ICES.

Article 2 of the Framework Regulation concerning the CFP states that '*the Community shall apply the precautionary approach in taking measures designed to protect and conserve aquatic resources, to provide for their sustainable exploitation and to minimize the impact of fishing activities on marine ecosystems. It shall aim at a progressive implementation of an ecosystem-based approach to fisheries management*'. Within an integrated management approach there are three main objectives related to conservation and the development of environmentally-friendly fishing: 1) to reduce fishing effort to sustainable levels and keep it there; 2) to optimize catches of target species and minimize unwanted catches; and 3) to minimize the impact of fishing on habitats (EC 2004).

Status and trends of fish stocks including fisheries and environmental variability

There is a total of about 100 fish species living in the Baltic Sea region, and due to the brackish water of the environment the fish are a mixture of marine, brackish and freshwater species (Voipio 1981; Anon. 1994; Jansson & Dahlberg 1999). The commercially exploited species in the Baltic fisheries are mainly marine fish, *i.e.* cod (*Gadus morhua*), clupeids (sprat: *Sprattus sprattus*; herring: *Clupea harengus*) and flatfish (flounder: *Platichthys flesus*; plaice: *Pleuronectes platessa*; turbot: *Psetta maxima*; brill: *Scophthalmus rhombus*; dab: *Limanda limanda*). Other important target species are the Atlantic salmon (*Salmo salar*), and sea trout (*Salmo trutta*), pike-perch (*Stizostedion lucioperca*), whitefish (*Coregonus lavaretus*), vendace (*Coregonus albula*), vimba bream (*Vimba vimba*), eel (*Anguilla anguilla*), eel pout (*Zoarces viviparous*), bream (*Abramis brama*), roach (*Rutilus rutilus*), smelt (*Osmerus eperlanus eperlanus*) and three spined stickleback (*Gasterosteus aculeatus*), perch (*Perca fluviatilis*) and pike (*Esox lucius*). Cod, herring, and sprat, on average, constitute over 90 % of the total annual commercial catch. The number of marine species is highest in areas near the Danish Straits and diminishes eastwards and northwards, while the number of fresh water species increases when salinity decreases. Marine species such as herring, sprat and cod dominate in open waters, while both marine and freshwater species inhabit coastal areas. Of great importance to the fishery are the coastal areas, which serve as spawning, nursery and feeding areas for several species of fish.

Although some historically reconstructed records are available, fisheries landings data in the Baltic Sea have been systematically registered since the 1920s whereas the stock dynamics of most commercially important species are available since only the 1960s or 1970s (Sparholt 1994; Thurow 1997; MacKenzie *et al.* 2002). The total annual catch of the open sea fish stocks in the Baltic Sea has increased 10-fold during the past 50 years. Until the 1930s, catches remained at about 120 000 tonnes, then increased to about 500 000 tonnes by the late 1950s, and after a steep rise in the mid-1960s almost reached a million tonnes by the end of the 1970s and has remained about 800 000 tonnes since then (Thurow 1989; Jansson & Dahlberg 1999; MacKenzie *et al.* 2002; ICES ACFM/ACE 2004).

Both the eastern Baltic and western Baltic stocks of cod—which are close to their minimum historically recorded biomasses—and herring are classified as overfished, while sprat are currently fished within safe biological limits according to ICES assessments (ICES ACFM/ACE 2004). For the flatfishes (*i.e.* flounder, plaice and dab), the state of the stocks is unknown and there is an absence of management plans agreed by IBSFC. For cod, although management plans have recently been adopted by IBSFC, the fishing mortality is unsustainable and ICES has consistently advised either negligible or no catch. For salmon, a management plan has been adopted by IBSFC, but for salmon in the Main Basin and Gulf of Bothnia the fishing mortality exceeds that for the maximum sustainable yield, while for salmon in the Gulf of Finland the wild stocks are in a precarious state and spawning biomass and fishing mortality in relation to precautionary reference points is unknown. For herring, no management plans have been adopted by IBSFC, whereas a management plan is in place for sprat. The landings of sprat for industrial purposes have increased markedly during the last decade. Herring and sprat are used mainly for human consumption when landed in the eastern Baltic countries, but landings are used for production of fishmeal and oil in the countries on the west coast. The exploitation rate of pelagic stocks in the Baltic Sea has increased since the mid-1990s, a situation facilitated by the natural mortality of Baltic herring and sprat being currently low due to the reduced abundance of cod, their main predator. However, a fourfold increase in sprat catches occurred between 1991 and 1997 and the development of this fishery, and consequently the rate of natural mortality, needs careful monitoring (ICES ACFM/ACE 2004). It should be noted that the production of cod, herring and sprat is influenced by both climate conditions and species interactions, such as competition and predation (Köster *et al.* 2003). Warm temperatures improve herring and sprat recruitment (Ojaveer 1995; MacKenzie 2002), while major inflows of well-oxygenated saline water are crucial for successful egg survival and the formation of strong year-classes of cod (MacKenzie *et al.* 2000; Köster *et al.* 2005).

The substantial increase in the Baltic fish catch, particularly of clupeids but also of cod, during the 1900s has received the attention of numerous authors (*e.g.* Elmgren 1989; Nehring *et al.* 1989; Hansson & Rudstam 1990; Hammer *et al.* 1993, Rudstam *et al.* 1994; Nielsen & Richardson 1996; Thurow 1997; MacKenzie *et al.* 2002), and is due to a combination of the following factors: a) increased eutrophication providing the basis for overall enhanced energy available in the food chain from lower to upper levels, as well as improved recruitment conditions for juvenile fish in coastal nursery areas; b) increased fishing pressure resulting from fleet expansions coupled with improvements of fishing gear and techniques; and c) a shift in fish communities towards more productive r-strategists rather than K-strategists connected with the effects of intensive fishing selectively changing the size spectra of the fish community in favour of smaller fish rather than larger fish at both the inter- and intra- specific levels. Thus, the relative number of larger piscivorous cod has decreased compared with smaller cod, thereby reducing the predation pressure from cod on small pelagic fish such as herring and sprat; and d) decreased predation by substantially reduced stocks of seals.

There is concern that the spawning stocks of fish, in losing the buffering demographic presence of older age-groups as a result of intensive fishing mortality, have increased their susceptibility to the combined effects of high fishing mortality and climate variability (Daan 1994; Cardinale & Arrhenius 2000). Accordingly, it is important to devise new fishing strategies limiting the catch of the spawning stock (*c.f.* Jakobsson & Stefánsson 1998). In this context, the future for the eastern Baltic cod stock in particular appears bleak based on predictions regarding the combined effects of climate warming continuing to reduce the frequency and magnitude of oxygenated saline water intrusions into the Baltic Sea that are essential for egg development and production of good cod year-classes, the trend for excessively high fishing mortality, and high predation mortality exerted on eggs and juvenile stages of cod by abundant herring and sprat (MacKenzie *et al.* 2002).

There are also major concerns over the presence of high levels of persistent organic pollutants (POPs) in some Baltic fish, including dioxins in fatty fish such as herring and salmon and PCBs in cod (ICES ACME 2001). These pollutants are transferred in food chains to top predators (*e.g.* predatory fish, marine mammals and waterbirds) and pose serious threats to ecosystem health including human health and food security (MacKenzie *et al.* 2004) (see also WP5). The removal of fish biomass by fishing has quantifiable impacts on the overall flux of nutrients (Hjerne & Hansson 2002) and persistent organic pollutants (MacKenzie *et al.* 2004). Levels of these substances removed annually by fishing account for 1-7% of the total loading.

Ecosystem effects of fishing and mitigation measures

The fundamental effects of intensive fishing on ecosystems, and their living resources, have been comprehensively documented (Hall 1999; ICES ACME 2000; Nilsen *et al.* 2002; Ojaveer 2002; Huse *et al.* 2003; Frid *et al.* 2003), and mainly affect the marine ecosystem through:

1) Removal of biomass as food—changing the food base for other biota.
2) Removal of biomass of predators—removing predators and thus reducing predation pressure in the system.
3) Removal of target species leading to changed abundance and population structure of these populations.
4) Removal of non-target species.
5) Discarding unwanted catches—creating a food source that would otherwise not be available at that time and place.
6) Mechanical effects inflicted by the fishing gear on the bottom environment, which result in changes in the seabed and benthos communities.
7) These more direct impacts on the ecosystem will result in more general changes in the structure, function and integrity of ecosystems including as a result of changes in the size composition of individuals in populations and communities, trophic structure and biodiversity.

Point 3 above has historically been the main focus of fisheries management, but the change in target populations is a concern not only in relation to the immediate resource base for fisheries, but also in relation to changes in the species composition and structure of the ecosystem. The new ecosystem-based fisheries management must also focus on this point and the other points in order to create sustainable fisheries in sustainable ecosystems. In all the above points, intensive and selective fishing mortality can affect the gene pools of both target and non-target species, with potentially serious consequences (ICES WGAGFM 2004).

Numerous reviews (Jennings & Kaiser 1998; Watling & Norse 1998; Hall 1999; ICES ACME 2000; Nilsen *et al.* 2002; Ojaveer 2002; Huse *et al.* 2003; Thrush & Dayton 2002) of the impacts of bottom trawling have recognized the following basic and ubiquitous effects prevalent in continental shelf seas that have experienced unrelenting and intense fishing effort: a) <u>Effects on habitats</u> causing removal of major physical features, reduction of structural biota, reduction in habitat complexity, changes in sea floor structure; b) <u>Effects on species</u> causing reduction in geographic range, decrease in species with low turn-over rates, changes in relative abundance of species, fragile species more affected, surface-living species more affected than burrowing species, sub-lethal effects on individuals, increase in species with high turn-over rates, increase in scavenger populations. In the Baltic Sea region, intensive and widespread bottom trawling, including expansions into new areas and the endurance of trawl tracks on the seabed, raise major concerns (Krost *et al.* 1990; Lundälv & Jonsson 2000; Andersson & Jonsson 2003; Hopkins 2003).

Substantial attention has been focused on the impacts of fishing on nutrient enriched ecosystems, such as the Baltic Sea, reflecting the combined impact of increasing fishing intensity and nutrient run-off on marine food webs, and bottom oxygen depletion, leading *inter alia* to a relative decrease in the landings of demersal fish (*e.g.* cod) compared with pelagic species (*e.g.* herring and sprat), and associated declines in mean trophic level of the fishery and the economic yield per unit biomass of the fishery (Bagge 2000; Caddy 2000). Thus, the joint effects of increased eutrophication and increased fishing pressure have resulted in a change in the structure of the fish community and the fisheries regime that has been pursued. Baltic Sea cod appears to be close to its limits of ecological tolerance, as reflected in the increase in pelagic/demersal catch ratio from about 2 in 1976 to over 10 in 1993 (Caddy 2000). Besides these effects, bottom trawling can remobilize substantial amounts of bottom sediments, including associated nutrients and contaminants, smothering some filter-feeders, and adding to the pollution load and biological oxygen demand (Caddy 2000).

By-catch[6] including discards[7]constitutes one of the major ecosystem effects of fishing of potentially even greater harm than the direct harvest of target species (ICES WGECO 1998). Most of the studies attempting to improve methods for quantifying by-catches and discards have been designed to improve fish stock assessments and fisheries management. Thus, these studies tend to focus on commercially exploited fish species and there is a pressing need to improve the knowledge on all species that are caught, including non-target species. The quantity and quality of data on discards also needs to be improved in order to make a proper evaluation of the ecosystem effects of fishing possible and to increase the reliability of current single and multispecies assessments and the models that are applied. Despite the historical and current deficiency of

[6] The part of the catch that is made up of marine organisms that are not the primary target of the fishing effort. This may include – depending on the fishing gear used – both unwanted commercial species as well as non-target (i.e. non-commercial species of fish, benthos, seabirds and marine mammals)
[7] The part of the catch that is returned to the sea as a result of legal, economic or personal reasons

dedicated programmes that measure and report on the amount of by-catch and discards (ICES ACE 2003), it is clear that by-catch and discarding are extensive in the Baltic Sea for both commercial fish species and incidentally caught non-target species (*e.g.* non-commercial fish, benthos, waterbirds and marine mammals) (Ojaveer 2002; Koschinski 2002; Österblom 2002; Österblom *et al.* 2002; Tschernij & Suuronen 2002; Valdermarsen 2003).

As fisheries operate within a complex array of species interactions, ecosystem-based approaches to science and fisheries management are increasingly being promoted. However, the application of multispecies modeling techniques (*e.g.* MSVPA and MSFOR) currently plays a limited role in providing scientific advice for fisheries management, being primarily used in the Baltic Sea for determining predation mortality exerted by larger fish (*e.g.* cod) on smaller fish (*e.g.* herring and sprat) (ICES ACFM/ACE 2004). Modelling studies involving trophic interactions with other potential top predators (*e.g.* marine mammals and waterbirds) and lower levels of the food chain (*e.g.* zooplankton and benthos) in an ecosystem context should include a wider range of perspectives, tools, and disciplines. One of the grand challenges is to bridge the gap between single species and multispecies fish stock assessment models on the one hand, and environmental and ecosystem models on the other hand (Walters *et al.* 1997; Giske *et al.* 1998; Neumann 2000; Harvey *et al.* 2003; Fennel & Neumann 2004).

ICES has reiterated that substantial reductions (*e.g.* 30-50%) in fishing mortalities need to be applied for stocks outside safe biological limits (*i.e.* overexploited) (ICES ACME 2000; ICES ACFM/ACE 2004). The yield from many target fish stocks would be significantly higher with a lower fishing mortality and different exploitation pattern, and reductions will also substantially reduce the associated ecosystem impacts of fisheries. However, many of the management measures available (*e.g.* TACs in accord with scientific advice, increased mesh sizes, fleet capacity reductions, application of the precautionary principle) have not been successfully implemented as seen from the continued declining status of many of the stocks (ICES ACFM/ACE 2004). The provision of timely and dependable (*e.g.* without misreporting) data regarding catches and other fisheries statistics is a significant problem in the Baltic Sea, and results *inter alia* in substantial problems for fish stock assessments that are dependent on them (Maguire 2001; ICES ACFM/ACME 2004).

Several changes—including full integration and implementation of the precautionary and ecosystem approaches, incorporating biodiversity and environmental objectives, into the principles, objectives and operational framework of fisheries research and management—will contribute to significantly reduce the ecosystem effects of fishing (FAO 1995; IMM 1997; ICES ACME 2000; JMM 2003a). Important measures include implementing: a) major reductions in the excessive fishing effort (*i.e.* fleet capacity) that forms the major obstacle to environmental integration; b) gear substitution and modification, including fishing methods that have a reduced physical impact on the seabed and habitats coupled with limiting the fishing effort of bottom trawling fleets and preventing expansion of areas impacted by bottom trawls, and application of selectivity devices that minimize by-catches of non-target as well as undersized target species; c) 'harvest rules' governing exploitation, and recovery plans with target points for the restoration of depleted populations; d) for the fished stocks, building diverse communities with larger numbers of bigger and older individuals and hence larger spawning stocks, especially for larger species; e) limits on by- or incidental catches of target and non-target species, especially for vulnerable species listed in environmental legislative instruments; f) closed areas for fishing (*e.g.* spatial and real time closures), including marine protected areas, to enhance the protection of juvenile fish and vulnerable species or habitats; g) habitat restoration schemes; i) national plans of action underpinning the FAO International Plans of Action; j) the ability to detect and measure ecosystem impacts; k) interactions with groups working on conservation of the marine ecosystem; l) control and enforcement of regulations at sea and at landing of catch; m) governance changes, including a wider societal representation in decision-making forums for fisheries management; n) ecolabelling schemes offering a market- and information-based tool to promote sustainable fisheries practices.

Fisheries science, data collection and advice

An important responsibility of ICES is the coordination of fisheries-related scientific research. This comprises providing information, through surveys and monitoring, on the abundance and composition of fish stocks, including developing appropriate methods to estimate fish-stock abundance, collecting statistics on fish catches, fishing effort, relevant biological data on the various life stages of fish, recruitment to fish stocks, and multispecies interactions and their effects on individual fish stocks. The fisheries management advice is provided by ICES Advisory Committee on Fishery Management (ACFM) based on estimating the current size and structure of the assessed stocks and the level of exploitation on it, relating these to historical trends, analyzing the cause of any changes that have occurred and making forecasts of future changes and catch possibilities, providing advice on the expected impact of various fisheries management measures (*e.g.* technical measures and closed areas), and making recommendations on management actions required. ICES Advisory Committee on Ecosystems (ACE) provides scientific information and advice on the status and outlook for marine ecosystems and on the exploitation of living marine resources in an ecosystem context. ACE provides a focus for advice that integrates consideration of the marine environment and fisheries in an ecosystem context, such as the ecosystem effects of fishing.

In preparing advice on the status of fish stocks and their management, ICES uses all relevant information provided by the nationally nominated scientific experts. All data and information are collected by ICES Member Countries. ICES may coordinate the data collection and review its quality assurance, but is as such not involved in carrying out surveys and sampling.

The fundamental problem for fisheries management is to achieve an appropriate balance between fishing effort and the available fish resources. At present, managers apply a system of catch quotas and total allowable catches (TACs) as the main instrument used to control fishing mortality rates, as well as other measures such as restricting the number of fishing vessels, their fishing capacity, time spent fishing and area of operation at sea. A control and enforcement system monitors fishing compliance activities at sea as well as the catches on landing. TACs have not been effective in reducing fishing mortality on demersal stocks and have been only partly effective on pelagic stocks, even in those cases where TACs have been set according to the biological advice. Supplementary effort reduction measures have been either lacking or insufficient to prevent stocks from falling outside safe biological limits. Many of the management measures employed have been unsuccessful as evidenced by the precarious status of numerous stocks, the present control system is seriously flawed with uncertainty and misreporting of catches and landings, and the sub-optimum quality of nationally conducted stock surveys and their related databases have caused serious problems for the reliability of fish stock assessments (ICES ACFM/ACE 2004).

For the implementation of long-term management plans in accordance with the precautionary approach for commercially harvested stocks, precautionary limit and target reference points are required, and indicators for sustainable development of marine capture fisheries should be identified and implemented (FAO 1995; FAO 1999; Nilssen *et al.* 2002). However, for numerous Baltic stocks (*e.g.* several stocks of herring and salmon, sea trout and all flatfishes) precautionary reference points have not yet been defined, and the development of sustainable fisheries indicators is in its infancy. According to the EC's Biodiversity Action Plan for Fisheries and in line with the precautionary principle, rules for exploitation of such stocks need to be established, which should take into account the history of exploitation, yield and the likely biological outcomes of exploitation. Although progress has been made in developing precautionary reference points for some fish stocks, fisheries management and the fishing industry have so far resisted the implementation of target points for stock recovery purposes.

In determining conservation population limits and targets for recovery purposes, recent data (Hauser *et al*. 2002; Turner *et al*. 2002; Hutchinson *et al*. 2003) indicate that the 'effective population' size of marine fishes, especially those characterized by high fecundity and high larval mortality, is typically $10^2 – 10^6$ orders of magnitude smaller than census population sizes. Such discrepancies have profound implications for estimating both quantitative change in population size relative to recruitment and harvesting, but also for qualitative change, in terms of the nature and speed of genetic change in marine populations. A low ratio of effective population size to census size suggests greater vulnerability to changes in genetic diversity, patterns of genetic differentiation and responses to environmental change (*e.g.* selection pressures). The relationship between successful spawners and subsequent recruits is critically important to stock assessment models. Genetic estimates of effective population size may assist in the formulation of more accurate, independent measures of these parameters.

Sustainable aquaculture and environmental interactions

Over about the last 25 years, aquaculture has become an important industry for coastal communities around the Baltic Sea, although the production level (ca. 69 000 tonnes in 1996) for human consumption, based mainly on rainbow trout and carp, is still small compared with other European regional seas (Varadi *et al.* 2001; IBSFC 2005). Aquaculture production for enhancement, stocking and put-and-take fisheries is also important, mainly using salmon smolts, cyprinids, pike, pike perch, whitefish and eel. The industry is highly motivated to increasing production from both intensive (*e.g.* in enclosures) as well as extensive (*e.g.* sea ranching) forms of mariculture. The potential to do so is considerable, both from the currently cultured species and from extending the range of species farmed to include cod, flatfish, and several shellfish species. Demand for mariculture has increased as the stocks and fisheries catches of wild marine species have declined (Watson & Pauly 2001).

The environmental impacts of mariculture are diverse and represent substantial threats to the ecosystem (Hutchinson 1997; Wildish & Héral 2001; GESAMP 2001). Mariculture produces substantial amounts of nutrients and deposition of organic material (overfeeding/food wastage, faeces) in the vicinity, particularly where there is poor flushing of the surrounding waters. This can lead to local eutrophication including changes in the biomass and composition of benthic communities. Escaped cultivated fish ('escapees') represent substantial threats (*e.g.* impairing gene pools, transferring parasites and diseases, competing for food and habitats) to wild fish populations, many of which currently are at historically low levels. Sea lice control is a major problem in commercial salmon cultivation and represents a serious threat to wild salmon and sea trout. There is often a high prevalence of pathogens and diseases in farmed fish compared with wild stocks. Inadequate control of mariculture stock movements facilitates spread of internal and external parasites and diseases including introductions and transfers of invasive alien species. The sustainability of feed supplies, particularly from capture fisheries, has also received major attention (Watson & Pauly 2001). Other impacts include the use of toxic and persistent chemicals, *e.g.* pesticides, antibiotics leading to resistant bacteria, impregnation of nets with copper. The national regulatory authorities are progressively tackling the impacts, most notably significantly reducing the use of chemicals and antibiotics. Environmental impact assessments are frequently required before mariculture licences are granted, followed by environmental monitoring to assess and limit impacts. Several environmentally positive initiatives are becoming more common, including a) situating marine fish cultivation in recirculating systems; b) for land-based operations, depuration treatment of wastes is now being increasingly applied with reservoirs where phytoplankton blooms occur that allow associated production of bivalve molluscs; c) combining culture of filter-feeding molluscs (*e.g.* mussels) with fish to reduce eutrophication effects; d) applying fallowing strategies in fish cage farming to break disease cycles and to allow a period of recovery of the benthic environment; e) applying minimum distances between mariculture installations, to minimize the effects on the water column, on the benthos, and to reduce parasites and diseases spreading.

The 1995 FAO Code of Conduct for Responsible Fisheries addresses the main issues of Aquaculture Development in Article 9, which was followed up by the publication of the 1997 FAO Technical Guidelines on Aquaculture Development drawing attention to various aspects of good practice in the industry. The European Commission (EC 2002b) has highlighted specific objectives and measures towards sustainability development of European Aquaculture, principally focusing on the ambitions of: a) creating long-term secure employment, in particular in fishing dependent areas; b) assuring the availability to consumers of products that are healthy, safe, and of good quality, as well as promoting high animal health and welfare standards; and c) ensuring an environmentally sound industry. The document sets out those elements of the strategy that should be taken forward at European Commission level and those that should be taken forward at Member State level. Elements of the strategy currently being taken forward at Commission level include harmonization of standards for organic production, rules concerning introductions, transfers and containment of aquatic organisms in aquaculture, updating and revising the legislation in relation to animal health and re-focusing of priorities for public aid through the Financial Instrument for Fisheries Guidance (FIFG). Currently there are no internationally binding organic aquaculture regulations. Council Regulation (2092/91/EEC) establishes a framework of Community rules on production, ecolabelling and inspection for organic farming. In the interests of producers and consumers, the Commission wishes to create specific common definitions and norms for organic aquaculture, and include norms for organic aquaculture in the Regulation.

Sustainable development of mariculture requires that the environmental impact of the industry be limited as far as possible. The environmental impacts of mariculture are recognized (see above), but there has been a lack of international cooperation at the regional level to ensure that equivalent and effective measures are put in place proactively to redress the root causes. Although various national measures have been established to attempt to redress the environmental impacts of mariculture, these are highly variable from country to country and not effectively coordinated on a regional basis. Furthermore, the issue of the environmental impacts of mariculture has not yet received the full focus of intergovernmental conferences in the Baltic Sea region as has fisheries and pollution. Connected with this, there is also a general scarcity of official information flowing into appropriate international bodies concerning levels of aquaculture production and best environmental practices. At present, there appears to be a lack of either a clear mandate and/or a will by regulatory intergovernmental bodies in the region to place the issue of environmental impacts of mariculture on the high-level agenda. The impacts of this sector, as with other human activities, need to be addressed in an integrated and comprehensive manner within the new WFD.

HELCOM Recommendation (18/3), concerning measures aimed at the reduction of discharges from marine fish farming was adopted in 1997. This Recommendation does not apply to natural fish cultured for re-stocking purposes. Through this recommendation phosphorus and N discharges from marine fish farms are expected to be reduced. The quality of best environmental practice and best available technology in the field of aquaculture, which is below common standards compared with other food industry sections, needs tot be improved. All possible effects and environmental changes including direct and indirect ecological impacts arising from aquaculture should be considered before licenses for new production sites are granted. In the Community, fish farming can be included in national plans such as water protection plans. Larger scale fish farming needs a special permit/licence from an independent institution. Locally reared and adopted brood stocks and juveniles should be preferred, rather than foreign imports, in order to limit risks of spreading pathogens, diseases and invasive alien species. In coastal areas, furunculosis is the most serious disease threat. The production in the farms could be secured by the use of prophylactic measures or, in acute outbreaks, with proper medical treatment. Substantial concerns have been expressed about the potential to spread diseases to wild fish migrating through rearing areas (*e.g.* salmon and sea trout). As already determined in the IBSFC Salmon Action Plan 1997-2010, the genetic integrity of wild salmon stocks should be protected from the influence of cultivated fish.

2.3.3 Major ongoing international collaboration activities of relevance to the workpackage

- For the Baltic Sea, scientific information and advice related to fisheries, environmental and ecosystem issues is provided by ICES ACFM, ACME and ACE in response to requests from Member Countries, HELCOM, IBSFC and the EC. Among the ICES groups involved are: Baltic Fisheries Assessment Working Group (WGFAS); Baltic International Fish Survey Working Group (WGBIFS); Baltic Salmon and Trout Assessment Working Group (WGBAST); Working Group on Fisheries Acoustics Science and Technology (WGFAST); Working Group on the Application of Genetics in Fisheries and Aquaculture (WGAGFM); ICES/GLOBEC Working Group on Cod and Climate Change (WGCCC); Working Group on Ecosystem Effects of Fishing Activities (WGECO); ICES/EIFAC Working Group on Eels (WGEEL); Working Group on Fish Ecology (WGFE); Working Group on Marine Fish Culture (WGMFC); Working Group on the Environmental Interactions of Mariculture (WGEIM); Working Group on Marine Shellfish Culture (WGMASC); Benthos Ecology Working Group (BEWG); Working Group on Seabird Ecology (WGSE); Working Group on Marine Mammal Ecology (WGMME); Stock Identification Working Group (SIMWG); Study Group on Multispecies Assessment in the Baltic (SGMAB); Study Group on Target Strength Estimation in the Baltic Sea (SGTSEB); Study Group on Ageing Issues in Baltic Cod (SGABC); Study Group on the Biology and Life History of Crabs (SGCRAB); Study Group on Acoustic Seabed Classification (SGASC); Study Group on Survey Trawl Standardization (SGSTS); Study Group on Regional Scale Ecology of Small Pelagic Fish (SGRESP).
- The BSRP Coordination Centre on Fish and Fisheries, together with relevant subsidiary bodies (*e.g.* Lead Laboratory on Joint ICES Surveys, Lead Laboratory on Age determination and Stomach Analysis) plays an active role in fish and fisheries issues particularly with reference to capacity building in the BSRP beneficiary countries (*i.e.* Estonia, Latvia, Lithuania, Poland and Russia.). A supporting function is also provided by the ICES/BSRP Study Group on Baltic Fish and Fisheries Issues (SGBSSI). Other relevant ICES/BSRP actors include the Study Group on Baltic Ecosystem Health Issues (SGEH) with its Sub-Group on Effects of Fishing Activities, the Study Group on Baltic Ecosystem Model Issues

(SGBEM), and the Coordination Centre on GIS/Data Coordination connected with spatial data collection and database matters.

- EC funded research projects (FP5 and FP6) of relevance with Baltic links include: BECAUSE - Critical interactions between species and their implications for a precautionary fisheries management in a variable environment - a modelling approach; CODYSSEY – Cod spatial dynamics and vertical movements in European waters and implication for fisheries management; COST IMPACT – Costing the impact of demersal fishing on marine ecosystem processes and biodiversity; DATRAS – Development of a central database for European trawl survey data; EAEF – Economic assessment of European fisheries; EUMAR – European marine genetic biodiversity; ELME – European lifestyles and marine ecosystems; EUR-OCEANS – European network of excellence for ocean ecosystems analysis; HERGEN- Conservation of diversity in an exploited species: Spatio-temporal variation in the genetics of herring (*Clupea harengus*) in the North Sea and adjacent areas; INDECO – Development of indicators of environmental performance of the Common Fisheries Policy; PANDA – Permanent advisory network on diseases in aquaculture.

2.4 Workpackage 4: Biodiversity

2.4.1 Potential BONUS-169 research and application issues

Workpackage 4 focuses mainly, but not exclusively, on aspects of biodiversity regarding priorities of substantial nature conservation and environmental protection interests with respect to the work of HELCOM.

WP4: BIODIVERSITY

Applying and further developing methodology, including analytical techniques and models, to describe and quantify the biodiversity of the Baltic Sea region—incorporating the molecular and genetic levels as well as those of species, communities, habitats and ecosystems—with a view to understanding the role of biodiversity in a range of environments spanning from a baseline in relatively pristine ones to those that are more human impacted. This should include determining the effects of naturally and human induced changes on biodiversity, on the goods and services provided by coastal and offshore ecosystems, and providing scientifically-based concepts and tools for monitoring and assessing biodiversity and the associated environment, and applying ecosystem-based actions and measures for conserving and, where appropriate, restoring biodiversity.

Key potential research and application issues are further described below:

Fish surveys and monitoring regarding human and naturally caused environmental effects

a) Developing the scientific basis for the implementation of an integrated programme for coastal fish monitoring, with supporting meta-database, including engagement of fishers in the monitoring activities, as well as elaborating a strategy for conducting assessments of changing status and trends of coastal fish communities related to natural environmental variability including climate change, and the effects of human activities (*e.g.* fishing, eutrophication, pollution, and loss of habitat).
b) Identification and development of indicators for coastal fish populations and communities including, for example, i) species diversity and composition, ii) species abundance, iii) nursery function, iv) trophic integrity, v) community degradation, vi) biological health, vii) fish health, viii) biotic integrity, and ix) fish recruitment, taking into account migratory and resident fish components.
c) In conjunction with WP 3, investigation of the use of the 'slope of the size spectra', connected with the average length and average size of an individual fish, in monitoring the effects of fishing mortality on fish populations and fish communities in coastal and offshore areas.
d) Further developing, with appropriate justification, of a List of Threatened and Declining Fish Species in the Baltic Sea region and elaboration of a system of concerted actions and measures regarding restoration and recovery plans for the affected species and their associated habitats.
e) Further elaboration and implementation of the Salmon Action Plan, including restoration activities in appropriate rivers, at the national level, in accord with scientific advice provided by ICES to HELCOM and IBSFC.

Marine mammals

a) Elaboration and application of state-of-the-art techniques and methodology to estimate marine mammal abundances including stock structure, census (methodologies, techniques, and biases), population growth rates and trends, ageing techniques, mortality, consumption models, and habitat requirements.
b) In collaboration with WP5, providing an up-to-date synthesis of marine mammal habitat requirements with respect to the health status of marine mammals, particularly in relation to exposure to contaminants.
c) In collaboration with WP5, elaboration and implementation of a programme of research on cause-and-effect relationships between contaminants and population-level effects in seals.
d) In collaboration with WPs 3 and 5, developing a population simulation model framework whereby the population-level effects of human-induced impacts on marine mammals may be assessed.
e) In collaboration with WPs 3 and 5, developing proposals for appropriate Ecological Quality Objective (EcoQO) indices for Baltic Sea marine mammal populations, including preparation of provisional estimates for the current levels, reference levels, and target levels for the EcoQO indices, taking into account progress in other geographical regions (*e.g.* North Sea).
f) Development, in collaboration with WP3, of a comprehensive database on marine mammal diet composition in the Baltic Sea that can be used to evaluate two-way trophic interactions between marine mammals and fisheries.
g) Developing and applying, in collaboration with WP3, a programme to determine the impact of fisheries by-catch on seals and harbour porpoise including observer programmes (*i.e.* data collected by independent observers monitoring fishing aboard vessels at sea).
h) In collaboration with WP3, further developing and applying appropriate methods and schemes for reducing incidental damage and mortality of marine mammals in fisheries, *e.g.* steps for mitigation of seal damage by improved fishing technology and by alternative fishing methods.
i) Developing and implementing national actions and measures to implement the ASCOBANS Recovery Plan for Harbour Porpoises in the Baltic Sea (Jastarnia Plan).

Waterbirds

a) Developing and applying proposals for indicators/EcoQOs for monitoring waterbird species and populations in the Baltic Sea region, taking into account developments in other regions including, but not restricted to, the proportion of oiled birds among those found dead or dying on beaches, mercury concentrations in waterbird eggs and feathers, organochlorine concentrations in seabird eggs, plastic particles in stomachs of seabirds, seabird population trends as an index of seabird community health.
b) Make progress towards implementing a trans-Baltic Waterbird Monitoring Programme as required by the HELCOM Monitoring and Assessment Strategy.
c) Investigating the size, distribution, and status and trends of waterbird populations in the Baltic Sea and relating these to natural environmental variability including climate change, and the impacts of human activities (*e.g.* fishing, eutrophication, pollution and other forms of habitat disturbance).
d) Studying waterbirds in relation to marine wind farms and elaborating national collaborative studies for the Baltic Sea.
e) Developing state-of-the-art techniques and methodology to estimate waterbird abundances including population structure, census (methodologies, techniques, and biases), population growth rates and trends, ageing techniques, mortality, consumption models, and habitat requirements.
f) Examining, in collaboration with WP1, relationships between seabirds and oceanographic features (*e.g.* upwelling and frontal systems), considering also the effects of climate change.
g) Investigating, in collaboration with WP3, the prey consumption of selected waterbirds in the Baltic Sea region, and determination of the multispecies interactions involving waterbirds and fisheries with a view to bridging the gap between fisheries and ecosystem modeling.

Combatting alien organisms

a) Developing pure and applied programmes of research (*e.g.* life histories and biology, taxonomy, ecology, multispecies interactions, ecosystem functioning and effects, surveys/monitoring/assessment, control and combating, evaluation of legislation) on IAS issues. This knowledge is fundamental for improving the capacity to predict risks and spreading, as well as for devising optimal measures for regulating, controlling and eradicating IAS. In so doing, it is essential to foster closer collaboration between the natural, technological and social sciences.

b) Developing applied research to improve the design and performance of mapping, monitoring and assessment systems for IAS.

c) Conducting risk assessments for the main shipping pathways responsible for transporting IAS to national 'hot spots' (*e.g.* ports and shipyards), and establishing appropriate monitoring and control schemes.

d) Developing and applying techniques and methodologies, including models, for environmental impact assessments and risk analysis concerning IAS.

e) Devising the scientific basis for a periodic mapping, monitoring and assessment system for IAS in the Baltic Sea region that is cost effective, responsive and able to be integrated into existing national and international programmes (*e.g.* biodiversity, fisheries, and environment). Regular, efficient and comprehensible procedures should be developed for assessing the data provided by the monitoring programmes in order to determine the changing status and trends (*e.g.* time series) of IAS, with timely dissemination of results including establishing effective early warning and rapid response systems for new unwanted introductions, and subsequent combating and eradication measures.

f) Establishing 1) national catalogues of experts, covering a wide range of specialties and disciplines, on IAS, and 2) national databases, as part of a monitoring and assessment system, with an inventory of known and expected IAS linking with a network of regional and global databases. The databases should a) be harmonized with common CBD-approved formats and standards, and b) should function as an online reference system open for use by workers and managers in the environmental and living aquatic (*e.g.* fisheries and aquaculture) resources sectors, the shipping and maritime operations sectors, monitoring institutions, researchers, students, and other stakeholders in the public and private sectors. Such databases will provide inventories of the IAS that are present in the respective countries, with a compilation of species accounts of the most invasive species. These species accounts should, wherever possible, include species taxonomy and identification features, area of origin, vector of introduction, distribution history in the region and specific area, abiotic environmental and habitat preferences, life cycle information, risks concerning ecological and economic impacts, best practices for eradication and control, and bibliographies of the relevant literature. GIS supported distribution maps of IAS should be produced, facilitating the monitoring and assessment of the status and trends of introductions and further spread of IAS in the region. These measures, as a whole, are expected to provide an important contribution towards developing a regional early warning system on the introductions and transfers of IAS.

g) In connection with the above, elaborating and applying an internet-based network, with website portal, giving open access to updated knowledge on IAS issues, for strengthening cross-sectoral awareness and concerted action for monitoring, assessment, management/regulation of IAS. The portal should be constructed to a) form a hub linking the national databases and regional information resources in the Nordic/Baltic region, and b) further connect the network with the websites of other regional and global activities and networks related to invasive alien species. The portal should provide access to the searchable regional database of experts, a bibliographic database, links to the existing lists and inventories of IAS, and provide other services. Services listed in the recommendations of the Joint Convention on Biological Diversity/Global Invasive Species Programme Informal Meeting on Formats, Protocols and Standards for Improved Exchange of Biodiversity-related Information CBD Report UNEP/CBD/COP/6/INF/18. The portal should function as both an input and output mechanism for online Internet users from all branches of society to access information and data from the Baltic situated national databases and cooperating international associates.

h) Quantifying and predicting the role of different maritime activities in the introduction and spread of IAS, and proposing appropriate control measures.

i) With regard to the 2004 IMO Ballast Water Convention, a) reporting on and further developing effective cleaning technologies for ballast water management, b) proposing recommended localities for ballast water exchange in accord with the Convention; c) speedily developing the required Guidelines for the Convention and work for the early ratification of the Convention; d) developing harmonized tools for regional and local municipalities—including port/harbour authorities—to apply measures for implementing the Convention.

j) Compiling, evaluating and applying control and eradication measures for IAS.

k) Developing and publishing cohesive national policies on IAS, with supporting strategy and goals for implementation of such policies including reviewing and proposing improvements to the national laws and litigation on IAS.

l) Elaborating and implementing effective management and regulatory measures (*e.g.* combatting, controlling and eradication) essential for restricting the risk of establishment and spread by IAS. The success of these measures depends *inter alia* on better awareness and understanding amongst a wide group of stakeholders in society as to how the goals of numerous international agreements and instruments may be applied at regional, national and local scales through appropriate policies, litigation and operational practices.
m) In collaboration with WPs 6 and 7, identifying the actors (*e.g.* industry/trade groups, regulatory authorities, educational establishments) requiring information on the risks of IAS, including finding the best media for delivering such information.
n) In collaboration with WPs 6 and 7, establishing greater participation and cooperation involving the navy, coastguard, port and harbour authorities, shipping companies, and aquaculture industry (in addition to scientific institutions) to improve monitoring of IAS.
o) Identification, with justification, of a single national authority (*e.g.* Ministry or specialized agency) to be appointed as having overall responsibility for coordination of management/regulation of IAS.
p) Utilization of the potential of the coastguard to play a major role in controlling/enforcing ballast water exchange regulations, *e.g.* use of approved sea areas for exchange, inspecting Ballast Water Record Books, *etc*.
q) In collaboration with WP6, ensuring that coastal zone management plans proactively take account of IAS issues.

Conservation of habitats, and protection of vulnerable and declining species including genetic diversity

a) Further developing the HELCOM Lists of Threatened and Declining Species and Habitats in the Baltic Sea region, taking into account progress in applying and further developing the EC Habitats and Wild Birds Directives and their associated instruments, and elaborating a system of concerted actions and measures, at the international and national levels, for restoration and recovery purposes, including further development of the Baltic Sea Protective Areas (BSPAs) outlining dedicated management plans concerning their use and access conditions regarding human activities.
b) Developing and applying tools and methods for rapid, cost-effective and reliable classification, mapping and monitoring of coastal and marine habitats and their associated biota, taking into account the progress of international habitat classification and mapping programmes (*e.g.* EC Interreg MESH - Development of a framework for Mapping European Seabed Habitats, EEA, HELCOM, ICES, OSPAR), and evaluating international habitat mapping methodologies with a view to developing a best practice approach applicable to the Baltic Sea.
c) Developing and applying analytical, empirical and modelling tools, including species accumulation curves and use of genetic/molecular based methods (*e.g.* barcoding in the Census of Marine Life initiative), for establishing species and community inventories, and for estimating species richness in coastal and offshore ecosystems/habitats with a view to identifying loss of biodiversity and setting conservation priorities at the special and temporal scales.
d) Presenting and reviewing National Status Reports on habitat mapping activity according to the standard format used by the ICES Working Group on Marine Habitat Mapping.
e) Developing a benthic/pelagic habitat map for the Baltic Sea region, using national and international data sources for compilation into a GIS, including relating such habitats to their associated biodiversity.
f) Developing guidelines for habitat mapping incorporating a working definition of the terms habitat and marine landscape/seascape for the purposes of habitat mapping, including reviewing developments of protocols and standards for habitat mapping, *e.g.* connected with the EC Interreg MESH - Development of a framework for Mapping European Seabed Habitats project and other relevant initiatives.
g) Advancing intercalibration and quality control of habitat mapping techniques, and constructing a habitat mapping decision-tree that can be applied to various management issues, identifying base requirements and evaluate the incremental values of habitat mapping techniques.
h) Developing metadata standards for habitat mapping.
i) Assessing and further developing the application of and needs for habitat maps in a management context, including case studies to illustrate particular applications.
j) Developing a virtual Network of Taxonomic Experts in the Baltic Sea region with a view to furthering the application of taxonomy in assessment and conservation of biodiversity.
k) Developing a virtual Network of Genetic Experts in the Baltic Sea region with a view to furthering the application of genetics in assessment and conservation of biodiversity.

General aspects regarding outreach, education and capacity building connected with biodiversity

a) In collaboration with WP7 and WP8, strengthening interaction with decision-makers, with emphasis on the need to conserve, and where appropriate restore, biodiversity.
b) In collaboration with WP7, promoting education, building capacity and conducting outreach activities at the regional level.

2.4.2 Background

Policy and management

The definition of biodiversity has broadened over the last few decades, and in the Convention on Biological Diversity the term means "*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*" (CBD 1992). Thus, biological diversity is now understood to include the levels of species and their genes, as well as ecosystems. This broad definition will be used hereafter in this document, and has implications for plans to conserve and manage biological diversity—as information on biological diversity on a gene or ecosystem level is generally limited—placing the focus of most biodiversity action plans on the species and habitats levels.

The marine biodiversity of the Baltic Sea region encompasses a wide range of taxonomic and ecological groups, including microorganisms (*e.g.* bacteria, viruses), plankton, benthos, fish, birds, and marine mammals. These biota are linked through food webs that, together with their environment, comprise the various ecosystems of the region. Due to the inherent characteristics of the Baltic Sea marine environment and the unsustainable nature of various human activities, the biodiversity of the region is low and substantially threatened (HELCOM 2003).

For the Baltic Sea area, HELCOM is the primary international organization concerned with coastal and offshore environmental management and protection of biodiversity, as mandated in the HELCOM 1974/1994 Convention (**Table 1**). HELCOM (*e.g.* HoD Meeting 16/2004) has emphasized the importance of nature protection and biodiversity, with special focus on the implementation of the network of Baltic Sea Protected Areas (BSPAs), threatened and/or declining species in the Baltic Sea Area and progress in developing ICZM. In particular the following issues have been highlighted:

- *Specific measures taken in the Baltic on activities impacting on the plant and animal species* - developing a system of coastal and marine Baltic Sea Protected Areas BSPAs) and on implementation of integrated marine and coastal management of human activities in the Baltic Sea Area and HELCOM recommendations related to endangered species: HELCOM Recommendation 9/1 on Protection of seals; HELCOM Recommendation 17/2 on protection of harbour porpoise (*Phocoena phocoena*); HELCOM Recommendation 19/2 on protection and improvement of the wild salmon (*Salmo salar*) populations.
- *Status of plant and animal species* - the HELCOM List of threatened and/or declining plant and animal species in the Baltic Sea Area.
- *Status of the BSPAs* - implementation of existing BSPAs, evaluation of the ecological coherence of the network of BSPAs.
- *Conceptual framework for the assessment of the status of the marine environment* - ecological quality objectives and associated initial indicators for nature protection and biodiversity as well as indicators for management efficiency.
- *Identification of the need for additional measures* - possible proposals for development of the BSPA network (increase in ecological coherence) and conceptual framework for the management plans for BSPAs (outcome of the HELCOM Project on Baltic Sea Protected Areas).

The following sub-sections provide further background and justification of relevance to BONUS-169.

Fish communities

Compared to the information and data available for the commercially important target fish species (*c.f.* WP4), there is a paucity of data on non-target and non-assessed fish species and communities, both in offshore and coastal waters. An important role has been outlined for HELCOM in mitigating the environmental impacts of fisheries by coordinating the monitoring of coastal, non-commercial and non-target fish species, as well as in assessing their status and the impact of fisheries on them. This would allow HELCOM *inter alia* to: a) produce inventories, especially of Baltic Sea non-commercial fish species, thus contributing to the further development of a Red List of threatened species in the Baltic Sea area, b) identify gaps in the network of BSPAs and propose measures to be taken to enhance the protection of species and habitats in the Baltic Sea area, and c) identify potential action plans aimed at recovering species threatened by fisheries. The management of fisheries in BSPAs is also forming an important topic for HELCOM in providing environmental nature conservation advice in a future Baltic Regional Advisory Council (RAC), under the updated EC CFP.

It should be noted that matters related to commercial fisheries, including single and multispecies fish stock assessments and associated methodological development (*e.g.* techniques including models, and establishment of databases), are considered under WP3. Furthermore, the primary responsibility regarding work on the ecosystem effects of fisheries is also assigned to WP3, but close collaboration on this issue involving WP4 is essential.

Coastal fish surveys and monitoring regarding human and naturally caused environmental effects

Fish community data collected in the 20th century have highlighted a decrease in the abundance of larger fish resulting in a shift in both relative and absolute abundance towards smaller-sized fish as well as fish species (Nilsen *et al.* 2002; Christensen *et al.* 2003). This applies to both target (*i.e.* commercial) fish and non-target fish, and are mainly due to selective and increasing fishing pressure on larger species of fish and the size groups within species that are caught. Changes in fishing mortality have been shown to result in a long-term change in the slope of the size spectrum of the fish community (Rice & Gislason 1996; Piet 2001). The decrease in the relative abundance of the larger fish is more pronounced in heavily fished areas than in other areas (Pope *et al.* 1988; Gislason & Rice 1998). The average weight and average maximum length of fish have been proposed as the two most suitable metrics of fish community structure (Nilsen *et al.* 2002). Overfishing of the higher trophic level stocks (*e.g.* larger piscivorous fish like cod) has resulted in 'fishing down the food web' whereby fishing effort has been increasingly directed at lower trophic levels (*e.g.* smaller planktivores and benthos feeders), resulting in a disturbance of the structure and functioning of the food web (Pauly *et al.* 1998). The impacts of such changes may have major consequences, particularly when combined with the effects of eutrophication, on both human socioeconomics and ecological economics (*e.g.* ecological 'goods and services') (see also WP2, WP3 and WP6). Management measures should aim at building diverse fish communities with larger numbers of bigger and older individuals and hence larger spawning stocks, particularly of larger species (Nilsen *et al.* 2002).

In the offshore areas of the Baltic Sea, scientific information and advice on the status of the commercial fish stocks, including levels of fishing mortality and fishing effort, is provided by ICES to Member Countries, the IBSFC and the EC. However, as yet, there has been a lack of progress made for both the open sea and coastal areas of the Baltic to establish a pilot project on the relationship between the fish size spectrum for the fish community and changes in fishing mortality along similar lines to that conducted for the North Sea (ICES SGEH 2005).

In coastal areas of the Baltic Sea, collaboration is developing between HELCOM and BSRP with a view to elaborating and implementing coastal fish monitoring and assessments (HELCOM 2004a; BSRP/HELCOM 2005). Within this perspective, it is highly desirable to develop an array of appropriate indicators to measure the status and trends in coastal fish stocks and communities, including the effects of fishing (*e.g.* parameters connected with the fish size spectrum). These coastal fish communities provide important economic, cultural, social and recreational values. They are also a main component of the Baltic Sea ecosystem that is well known and of concern to the general public. Coastal fish communities are a sensitive indicator of the ecological status of the ecosystem, which is affected by changes in environmental conditions caused by multiple anthropogenic pressures (*e.g.* fishing, eutrophication, pollution and habitat degradation).

The main objective of the Baltic Sea coastal fish monitoring is to provide reliable data on long-term changes and regional diversity of commercial and non-commercial coastal fish communities for assessing ecological status of the Baltic Sea including biodiversity aspects. The HELCOM coastal fish monitoring and assessment programme coordinates several national monitoring programmes to produce sub-regional and Baltic-wide topical assessments, which will provide a regional component for the pan-European assessment products. The HELCOM coastal fish monitoring and assessment programme is in line with the requirements of the EC WFD and will include species and habitats listed by the Habitats Directive, thereby supporting monitoring of Natura 2000 areas. Increased attention to the ecosystem approach calls for additional information on the Baltic Sea fish community. Coastal fish monitoring in the Baltic Sea will therefore provide substantial added value to the stock assessment of commercial species performed within the framework of ICES.

Wild Baltic salmon

The Baltic salmon is a geographically isolated group of Atlantic salmon (*Salmo salar* L.) that is genetically distinct from salmon in the North Atlantic, and exhibit marked population structuring with genetically distinct populations in different rivers (Karlsson & Karlström 1994; WWF 2001). Most salmon migrate to the Baltic Main Basin and feed there for up to four years before returning to the rivers to spawn. In the Baltic Sea area, naturally reproducing salmon stocks are found in 31 rivers draining into the: Gulf of Bothnia (12), Baltic Proper (8), Gulf of Riga (5), Gulf of Finland (6). At the beginning of the 20th century, such stocks were present in more than 100 rivers. Since many of these rivers have been dammed, spawning and nursery areas have disappeared. Only about 10-20 % of the current production capacity in Baltic rivers is at present utilized, so there is a major potential for restoration/recovery plans to be established and implemented. Of the historical salmon bearing rivers of the Baltic, only 5.25% are considered as 'healthy', and the remainder are either 'extinct' (71%), 'critical' (11%), 'endangered' (3%), 'vulnerable' (4.25%) or of 'unknown status' (5.25%) (WWF 2001). Wild Atlantic salmon stocks, including those in the Baltic Sea, are at their lowest recorded level with declining recruitment lasting for about 20 years (O'Maoléidigh 2002; HELCOM 2003).

The major threats to wild salmon are: a) overfishing; b) hydropower dams and other man-made constructions hindering migrations; c) river engineering schemes causing habitat fragmentation and loss; d) numerous forms of toxic and eutrophication caused pollution that degrade salmon habitats and affect mortality and behaviour; e) salmon aquaculture, including ineptly organized stock enhancement schemes, constitutes a major threat to wild salmon stocks by eroding natural gene pools and transferring pathogens and diseases (WWF 2001).

The fishing pattern of salmon has changed substantially during this century. In the 1920s and 1930, the total annual catch levels were about 1 500 tonnes, with salmon caught in rivers, river mouths and offshore. Before about 1940, only about 33% of the fishery took place offshore. Afterwards, the offshore fishery expanded, due to development of both boats and fishing gear to reach 80-90% of the total catch in the late 1980s, before falling in the late 1990s and remaining at about 70%. Besides the change in fishing pattern, total catch increased to about 5 000 tonnes in the 1980s. After the adoption by IBSFC of a TAC for salmon in the main basin of the Baltic Sea and the Gulf of Bothnia, the catch levels have decreased substantially to about 1 500 tonnes in 2003, but the fishing mortality of salmon in the Baltic remains very high so that few salmon manage to return to the rivers as adults for spawning. The Baltic salmon is exploited by an offshore fishery (*e.g.* drift nets and long lines), a coastal fishery (*e.g.* trap nets and a non-commercial fishery with ordinary nets) and in rivers where seine nets and sport fishing are the most common methods. The recruitment to the total Baltic salmon stock now consists of 80-85% compensatory reared salmon, released in the smolt stage. The present wild populations are threatened by a harvest pattern based on the status of reared populations but simultaneously overexploiting the wild salmon.

The establishment of the IBSFC in 1974 potentially provided the basis for internationally more effective management using the advice provided by ICES ACFM. The TAC level adopted is now based on the need of the wild salmon populations. Besides the measures adopted by IBSFC, to protect the wild populations, additional national regulations aiming to direct the fishery to harvest reared populations should be implemented. However, ICES management advice connected with wild Baltic salmon has not always been universally adopted and implemented. ICES has also included new operational objectives including a) safeguarding the genetic status of all Baltic stocks, taking into account genetic variability, and b) safeguarding, with high probability, each wild salmon stock.

In 1997, HELCOM and the IBSFC launched the Salmon Action Plan 1997 - 2010 to prevent the extinction of the wild Baltic salmon populations, to increase the natural production of wild Baltic salmon to a level of 50% of the estimated potential in each salmon river by 2010, and to re-establish wild populations in potential salmon rivers. As part of the plan, the IBSFC has listed rivers with naturally reproducing salmon populations whose stocks should no longer be artificially supplemented after 2005. So far, progress with the Salmon Action Plan has resulted in the increase of the average smolt production in wild salmon rivers in some few rivers in the Gulf of Bothnia, and requires to be successfully extended to aid the weak and threatened populations in about 25 other Baltic salmon rivers. In addition to management problems there are concerns about the environment of the Baltic, particularly in relation to the long-term effects of pollutants (*e.g.* dioxins) and the M74 syndrome. It is important to solve the long-term eutrophication and pollution problems in the Baltic that adversely affect the salmon stocks and their habitats.

Marine mammals

Prior to about 1940 hunting was the major source of mortality for marine mammals of the Baltic Sea. More recently, mortality is due to 'incidental take' (*i.e.* by-catch) in fisheries and by pollution that may compromise immune systems, *e.g.* resulting in increased incidence of phocine distemper virus. By-catches in fisheries usually result in serious injury or mortality to the marine mammals and may result in damaged fishing gear and reduced fishing time and catch. Marine mammals are particularly vulnerable to the long-term toxicity of man-made chemicals in the marine environment, due to their place at the top of the marine food web and due to the accumulation of some pollutants in fat deposits.

The three species of seal found in the Baltic, the grey seal (*Halichoerus grypus*), the harbour seal (*Phoca vitulina*) and the Baltic ringed seal (*Phoca hispida botnica*), live mainly in the archipelagos (Walday & Krogland 2002). The maximum number of grey seals counted in the Baltic in recent years is about 6 000 individuals and the population is slowly increasing but is considered as small in number compared with conditions prior to the mid-1940s (HELCOM 2002). The harbour seal accounts for only a few hundred animals in the southern Baltic and the situation is considered alarming. The ringed seal numbers about 3 000 animals in the Gulf of Bothnia, but only a few hundred in the Gulf of Finland and Gulf of Riga where the populations are still particularly vulnerable (HELCOM 2001).

The human colonization of the coastal waters of the Baltic was closely related to the substantial socioeconomic benefits of seal hunting and the salmon fishery (Palmer 2005). However, at the end of the 19^{th} century, seals began to lose their economic importance as cheaper alternatives to Baltic seal oil became available. Seals were increasingly seen as competitors with fisheries, and bounty systems were instigated periodically from 1889 to 1975 to reduce seal abundance. In the 1920s professional seal hunters complained of smaller catches despite advances in weapons, during the 1930s traditional haul-out sites were abandoned and the low number of active seal hunters was connected with problems in finding seals, and by the 1970s substantially reduced seal stocks were confirmed (Söderberg 1974; Helle 1980a). A disease complex involving reduced pregnancy rates was apparent in grey seals (Bergman 1999), and high incidence of occlusions in the uterine horns was documented in ringed seals (Helle 1979, 1980b). The presence of persistent organic pollutants (*e.g.* PCBs and DDT) in seal tissues has been identified as a causative factor for this disease situation (Jensen *et al.* 1969; Blomkvist *et al.* 1993; Bergman 1999), resulting from bioaccumulation of POPs in the lipid-rich food chain (Roots & Aps 1993; MacKenzie *et al.* 2004).

The Baltic grey seal population decreased from about 80 000-100 000 in the early 1900s down to about 4 000 in the late 1970s, while the Baltic ringed seal population decreased during the same period from about 190 000 - 220 000 down to about 5 000 (Harding & Härkönen 1999). In the mid-1960s, the growth of the remaining populations was inhibited over a period of about 25 years by sterility caused by organochlorines. The decrease in seal numbers was a consequence of excessive hunting, but the present low numbers are due to reduced fertility rates after 1965 (Harding & Härkönen 1999). Since about 1980, surveys have indicated recovering stocks of grey seals and ringed seals (HELCOM 2003). After prohibition of seal hunting in the Baltic in 1988, the incidence of interactions with passive fisheries gears has occurred and increased by-catches of grey seals has been registered (ICES ACME 2000). In the case of the ringed seal, climate warming represents a major threat to their winter sea-ice habitat (Meier *et al.* 2004).

The harbour porpoise (*Phocoena phocoena*) population is the only cetacean regularly recorded in the Baltic Sea, and is probably genetically specific and reproduces exclusively within this area although they may emigrate through the Danish Straits in autumn before returning again in spring (Møhl-Hansen 1954; Schulze 1996; HELCOM 2002; Walday & Kroglund 2002). The current status of the population is considered to be critical and not sustainable (Berggren *et al.* 2002), and is estimated at less than about 1 000 porpoises in the Baltic Sea (ICES ACE 2003). The EC Habitats Directive (92/43/EEC) requires the designation of special conservation areas for harbour porpoise (*c.f.* Annexes II and IV).

Otters (*Lutra lutra*) used to be common in the archipelagos but numbers have fallen dramatically during the past few decades, probably due to PCB pollution (Walday & Kroglund 2002). Otter recovery projects in adjacent countries are, however, beginning to succeed and may result in an increase in the Baltic population.

Threats and measures to reduce by-catch

In recent years, ICES has reviewed requirements for scientifically sound programmes for collection and handling of data on by-catches, including a review of methods for monitoring cetacean by-catch. ICES Member Countries have been urged to monitor their fisheries to identify gear types, areas and seasons where marine mammal by-catches occur in order that robust estimates of abundance and information on the distribution (stock identity) of affected species need to be obtained in addition to estimates of total by-catch.

The EC Council Regulation No. 1239/98 of 8 June 1998 banned the utilization of drift nets from 1 January 2002 in order to conserve small cetaceans and other non-target species. Driftnets in the Baltic will be progressively phased out by 1 January 2008 when their use will be completely prohibited.

ICES has recommended that, in order to reduce by-catches below the agreed target of 1.7%, mitigation measures should be established giving particular priority to sea areas where by-catches of harbour porpoise are a serious problem. Fishing effort reductions will not only reduce the opportunities for by-catch of small cetaceans but also will reduce the overall ecosystem impacts. Furthermore, scientific tests indicate that acoustic 'pingers', as warning devices, appear to be effective in reducing the by-catch of porpoises in gillnets by up to 90% (Nilsen *et al.* 2002). The deployment of these devices will be made mandatory for gillnet fisheries from June 2005 for the North Sea and the Baltic Sea. However, vessels $\leq$ 12 metres will be exempted.

Seal-safe eel traps (fyke nets and pond nets) are being devised, and methods are being developed for scaring seals away from fishing operations, including mechanical means of protecting fishing gear and alternative fishing methods. Financial inducements can enable fishers to purchase seal-safe fishing gear, *e.g.* replacement of old salmon traps.

International conservation of marine mammals

Management and conservation measures have been proposed and/or are being implemented to reduce marine mammal by-catches on both global (*e.g.* UN Resolution 44/225 § 4a that called upon Member States to impose a moratorium on high seas drift nets by 30 June 1992) and regional levels (*e.g.* ASCOBANS).

Research on small cetaceans is conducted throughout the ASCOBANS area, but the need for synoptic surveys and increased data collection on seasonal and spatial distribution, as well as long-term monitoring of population trends, has been emphasized. ASCOBANS is compiling information on threats affecting small cetaceans, and promotes the establishment of protected areas for harbour porpoises. ASCOBANS is also concerned about the most important threat facing small cetaceans, *viz.* incidental take or by-catch, including measures for by-catch reduction in the Agreement area. In 2000, ASCOBANS adopted a resolution that that competent authorities should take precautionary measures to ensure that the total anthropogenic removal of small cetaceans in the Agreement area and its adjacent waters be reduced as soon as possible to below 1.7 % annually of the best available abundance estimate. Furthermore, as a precautionary objective, an annual by-catch of less than 1 % of the best available population estimate has been set.

The ASCOBANS Recovery Plan for Harbour Porpoises in the Baltic Sea (Jastarnia Plan), adopted by ASCOBANS Parties in 2003 and supported by HELCOM, represents an important milestone for conserving the only cetacean species native to the Baltic. HELCOM Recommendation 17/2 and the EC's Natura 2000 provide the legislative instruments to designate protection measures for small cetaceans. A joint HELCOM/ASCOBANS reporting format and reporting periodicity for HELCOM Recommendation 17/2 has been adopted. There is, however, no joint monitoring programme for harbour porpoises in the Baltic Sea and up-to-date statistics on the species are either lacking or very poor.

At the 2002 Fifth International Conference on the Protection of the North Sea, Ministers agreed to reduce the by-catch of harbour porpoises below 1.7% of the best population estimate. The Ministers also agreed on a precautionary objective to reduce by-catches of marine mammals to less than 1% of the best available population estimate, and urged the competent authorities to develop specific limits for the relevant species. As yet, a similar initiative has not been adopted throughout the Baltic Sea.

Waterbirds

Seabirds, shorebirds and coastal wetland birds (referred to hereafter as 'waterbirds') play important roles in coastal and offshore ecosystems due to their abundance and position as predators at or near the top of food chains (Reid 1997; Nilsen *et al.* 2002). Many waterbirds eat benthic animals and plants, and feed on fish both live and as discards and offal from fisheries, and some consume zooplankton. These birds are liable to ingest and further accumulate contaminants already present in their prey, and to experiencing the biological effects of pollution (Nilsen *et al.* 2002).

A brief introduction to Baltic waterbirds is provided by Walday & Kroglund (2002). Almost 10 million birds from roughly 30 species use the Baltic as an overwintering area (Durinck *et al.* 1994). The winter seabird fauna is numerically dominated by the benthivorous species, especially sea-ducks (*e.g.* eider and long-tailed duck (*Clangula hyemalis*)) that comprise about 80% of the total number of birds. More than 30 species of waterbirds breed along the coasts of the Baltic Sea, among them the common eider (*Somateria mollissima*), tufted duck (*Aythya fuligula*), red-breasted merganser (*Mergus serrator*), redshank (*Tringa totanus*), sandpiper (*Actitis hypoleucos*), herring gull (*Larus argentatus*), arctic tern (*Sterna paradisaea*) and common terns (*Sterna hirundo*), razorbill (*Alca torda*), black guillemot (*Cepphus grylle*), common guillemot (*Uria aalga*) and cormorant (*Phalacrocorax carbo sinensis*). Among birds of prey, there is small number of the Baltic population of the white-tailed eagle (*Haliaeetus albicilla*) that is recovering from the effects of DDT, PCB and other organochlorines on recruitment in the 1960s and 1970s.

Human caused factors that affect waterbirds include: a) *positive factors* such as increases in food supply due to reduction in large fish competitors, dumping of offal and discards from fishing, and the reduction of hunting and egg gathering, and b) *negative factors* such as introduced predators, overfishing of small pelagic fish (*e.g.* herring and sprat), oil pollution, disturbance in general, and other pollutants including hazardous substances and litter at sea (Nilsen *et al.* 2002). In terms of trophic ecology, the removal of large piscivorous fish by fisheries has enhanced the stocks of some small pelagic fish and probably contributed to an increase in some seabird populations. However, stock declines of small pelagic fish (*e.g.* sprat and herring) – from fisheries and/or natural causes – can detrimentally affect seabird breeding success (Tasker *et al.* 2000). Discards and offal, as major by-products of fisheries, have probably supported population increases in several seabirds that can scavenge (*e.g.* larger gulls) (Furness & Tasker 1999; Nilsen *et al.* 2002; Garthe & Scherpe 2003). Long-lines and most types of fishing nets can drown seabirds, but gill- and other static nets form the greatest risk to seabird populations (Nilsen *et al.* 2002) (see also under WP3). Although seabirds prey on smaller sizes of fish, the impact of this is less than from predatory fish such as cod (Furness & Tasker 1999). More recently, concerns have been raised over the potential effects of windfarms on waterbirds in the Baltic Sea region (Garthe & Huppop 2004).

The incidental seabird catch in commercial longline fisheries has caused substantial concern, regarding both the mortality effects on the impacted seabirds and the detrimental effect on fishing productivity and profitability. Accordingly, FAO adopted in 1999 the International Plan of Action for the Reduction of Incidental Catch of Seabirds in Longline Fisheries (IPOA-SEABIRDS). Measures that can significantly reduce by-catches include bird-scaring devices towed from the fishing vessel during longline shooting, and setting of the lines through a protective tube into deeper water (Dunn & Steele 2001).

Monitoring and assessments of aquatic birds in the Baltic Sea area have traditionally been carried out in a fragmented and essentially uncoordinated manner by a number of national governmental institutions, non-governmental institutions (*e.g.* BirdLife International network, Ornis Consult, BMB), and reported on by the ICES Seabird Ecology Working Group (WGSE). With the insertion of Article 15 '*Nature Conservation and Biodiversity*', in the 1992 Helsinki Convention, the status of waterbirds has been given increasing emphasis in the HELCOM Periodic Assessments. Based on agreement regarding the necessity for a common waterbird monitoring strategy in the Baltic Sea, HELCOM HABITAT has reviewed and adopted in 2004 the results of a pilot project that included ongoing monitoring conducted by the majority of coastal countries, which can be used as the basis for a joint programme, including presentations of recent trends (HELCOM 2004b). In this context, it is notable that the open sea areas remain mainly unmonitored. The proposed HELCOM Baltic Waterbird Monitoring Programme will be composed of three key elements: a) monitoring of overwintering waterbirds, b) monitoring of breeding waterbirds, and c) monitoring of oil pollution related to beached-bird surveys. The desirability of taking steps for early implementation of the proposed HELCOM Waterbird Monitoring Programme, as an integral part of COMBINE, has been emphasized.

It is anticipated that waterbird monitoring data collected throughout the Baltic area will constitute a new and important source of information on the state of the marine environment in relation to eutrophication, hazardous substances, shipping and maritime activities, overfishing and habitat degradation (HELCOM 2004b). Connected with this, is the pressing need to develop EcoQOs for Baltic waterbirds to complement similar ongoing activities coordinated by OSPAR in the North Sea. ICES WGSE and WGECO have substantial experience in developing EcoQOs for seabirds in the North Sea that can be used as a starting point for development of waterbird-related ecological quality indicators for the Baltic.

Alien organisms

Since the early 1800s about 103 alien species (also called non-indigenous, exotic, invasive *etc*.) have been recorded in the Baltic Sea area, of which more than 50 have been registered in the 20th century and are colonizing new areas at a rapid rate (Leppäkoski *et al.* 2002a). In the brackish conditions, horizontal and vertical gradients provide the IAS of different origin an extended range of hospitable conditions as documented by the Baltic Sea Alien Species Database <http://www.ku.lt/nemo/mainnemo.htm>. The percentage of introduced species relative to the total number of indigenous species is surprisingly high in the Baltic Sea area, and most of the species have donor sources from other parts of Europe (71%), while Asia (12%) and North America (9%) account for the second and third most common areas of origin (Weidema 2000; Leppäkoski *et al.* 2002b).

The introduction and transfers of invasive alien species (IAS) between continents, regions and countries—irrespective of whether the causes of such movements are intentional or accidental—can have far-reaching and often harmful impacts on the recipient aquatic and terrestrial ecosystems. Alien species *inter alia* reduce biodiversity, alter ecosystem processes, act as vectors for new parasites and diseases, and cause socioeconomic consequences for humans (Jansson 1994; Weidema 2000; Mack *et al*. 2000; Mooney *et al*. 2000; Leppäkoski *et al*. 2002a). Accordingly, the issue of IAS has been identified as one of the primary and growing environmental concerns affecting the conservation of biodiversity, including impacts on ecosystems, habitats and their associated species (CBD 1992; Sandlund *et al*. 1999; McNeely *et al.* 2001; Hopkins 2005). Global trade and commerce, as well as the human agricultural and industrial enterprises, drive the process of biological invasions (Williamson 1996; Lovel 1997; Weidema 2000). The many vectors that facilitate the introductions and spreading of IAS include transport via shipping-related ballast water discharge and hull fouling, horticulture, the aquarium trade, tourism and recreational activities, and removal of natural barriers (*e.g.* construction of man-made canals). Having been introduced to an area, natural transfer processes (*e.g.* dispersion by water currents and wind) may supplement the further spread of IAS.

A series of key international agreements and other instruments (*e.g.* UNCLOS 1982; CBD 1992; ICES ACME 2003; IMO 2004) have played a seminal role in fostering the requirement to prevent, reduce and control the introduction and transfers of alien species. However, despite the good intentions of these international instruments to contain the movements of alien species, they are largely ineffective in dealing with the problem as emphasized by the exponentially increasing establishment of alien species at the regional and global levels, including the North-East Atlantic area and its adjacent seas such as the Baltic Sea (Gollasch & Leppäkoski 1999; Weidema 2000; Hopkins 2001; Leppäkoski *et al*. 2002a, b). The spread of aliens is predicted to increase, due mainly to expanding trade and traffic routes as well as climate warming (Hopkins 2001). Shipping (*e.g.* via ballast water discharge, hull fouling) and aquaculture (*e.g.* via import of alien species, and non-intended spread of escapees and 'stowaways') currently are the vectors responsible for about 90% and 10%, respectively, of the introductions of marine alien species in the North-East Atlantic and adjacent seas (Minchin & Gollasch 2002). In order to redress this situation, a number of steps *inter alia* highlight *the role of international and regional cooperation* for creating common information and coordination systems, in order to increase access to knowledge and build capacity, harmonize and standardize work programmes and procedures (*e.g.* developing databases for collecting and accessing data and information, and establishing systems for monitoring and risk assessment), avoiding unnecessary duplication and thereby increasing efficiency and sharing costs (Weidema 2000; CBD 2002; Hopkins 2005).

Conservation of habitats, and protection of vulnerable and declining species and genetic diversity

Habitat classification and mapping, and establishment of marine protected areas

Protection of habitats is vital for protecting the species that are dependent on the habitats for their viability. Degradation, fragmentation, and eventual loss of habitat caused by the impacts from human activities represent serious threats to marine biodiversity (GESAMP 1997). These habitats have specific faunal and floral communities associated with them, and have been threatened over the past century by human activities and changes in climate (Frid *et al.* 2003). The protection of vulnerable and declining species and habitats is a rapidly growing need with regard to the conservation of biodiversity. Understanding genetic structure facilitates the identification of stocks and the magnitude of genetic flow and exchange. Use of different genetic/molecular markers permits differences in individual and stock variability to be aged in evolutionary terms, thereby allowing for evaluation of evolutionary factors in determining precautionary limits for levels of degradation of stocks, communities and habitats.

There are many unique ecosystems and biotopes around the Baltic Sea which serve as vital breeding grounds, nurseries, shelters and food sources for many aquatic and terrestrial species (HELCOM 1996a, 1996b, 2002, 2003). Despite the low number of typical marine species, the Baltic Sea still hosts a unique variety of plants, animals and microorganisms, specially adapted to the brackish-water environment. However, the overall assessment of threats to the marine and coastal biotope complexes and biotopes of the Baltic Sea, the Belt Sea and the Kattegat gives cause for concern: over 80% of all biotopes of the survey area are rated as endangered, 15% being classified as 'heavily endangered'.

In April 2004, the UN's International Maritime Organization (IMO) designated in principle the whole Baltic Sea, except for the Russian territorial waters, as a Particularly Sensitive Sea Area (PSSA). A PSSA is an area that needs special protection through actions of the IMO because of its significance based on recognized ecological, socioeconomic, or scientific reasons, and which may be vulnerable to harmful impacts from international maritime activities. PSSA status comes into force after June 2005 when associated protective measures (APM´s), *i.e.* binding regulatory measures improving maritime safety, are added to the PSSA.

As protection requires knowledge of which habitats are present and their locations, collaboration occurs between HELCOM, OSPAR, ICES and the EEA to classify and map habitats by developing and applying the EUNIS (European Nature Information System) classification. The collaborative work comprises: a) habitat classification: developing a classification system, for all marine habitats/biotopes, and b) habitat mapping: preparing maps of the coastal and offshore areas, showing the spatial distribution and extent of habitats according to a consistent classification system, to meet the needs in the assessment and protection of habitats. Furthermore, it is vital to clearly relate these habitats to the full array of species and communities that are inherently associated with them.

Article 15 of the HELCOM Convention requires parties to conserve natural habitats and biodiversity, and to protect ecological processes. Accordingly, HELCOM is actively working to conserve and protect the ecosystems and the biological diversity of the Baltic Sea area, and to restore, where practicable, coastal and marine areas which have been adversely affected by human activities. In order to facilitate this, it has been agreed to establish a network of Baltic Sea Protected Areas (BSPAs). The selection and establishment of BSPAs is related to the assessment of species and habitats in need of protection, habitat classification and identification of biogeographic regions, and to developing the ecosystem approach including setting ecological quality objectives.

In 1994, 62 BSPAs were designated under HELCOM Recommendation 15/5. Although preference was given to areas already under some form of protection, very few of the designated areas have as yet been finally incorporated in the BSPA network yet. There still remains the additional task to incorporate 24 offshore areas identified by experts in 1998 into the network. Furthermore, the development of management plans for such areas, determining conservation and protection measures, have not made sufficient progress.

HELCOM HABITAT has emphasized the need to compile national lists of the most threatened species, as well as species in urgent need of protection (*e.g.* rare species) with the aim of contributing to such a list of threatened marine species by October 2005. The need has been emphasized for further development of the HELCOM Red List of Biotopes (*c.f.* Nordheim & Boedeker 1998), taking into account several existing national and international lists of threatened species and threatened biotopes/habitats by harmonizing the classification system (*e.g.* connected with EUNIS), particularly in a pan-European context, is also highlighted. The HELCOM Contracting Parties have been requested to compile national lists of the most threatened species as well as species in urgent need of protection (*e.g.* rare species) for those parts of the marine environment of the Baltic Sea area which fall under their jurisdiction (inner waters, territorial waters and EEZ). To achieve this goal, either Red Lists (national or international such as IUCN lists) can be used or expert opinions can be commissioned, *e.g.* to carry out national expert workshops. EU Member States should consider the respective Annexes of the Habitats and Birds Directives. Possibilities should also be considered—in cooperation with ICES, OSPAR, EEA and the Nordic Council of Ministers—for further developing the list of threatened biotopes/habitats using the EUNIS classification system particularly in a pan-European harmonization context.

In order to foster implementation of the network of BSPAs, HELCOM HABITAT has proposed the establishment of a special HELCOM project with the purpose to evaluate, by 2006, whether the BSPAs are sufficient to constitute a ecologically coherent network jointly with the OSPAR corresponding network of marine protected areas, and take steps to identify and fill any identified gaps, to ensure that by 2010 there is an ecologically coherent network of well-managed marine protected areas for the maritime areas of both HELCOM and OSPAR.

The EC Habitats and Wild Birds Directives, supported by the Natura 2000 initiative, form the cornerstone of the Community's biodiversity conservation strategy and are anticipated to play a major role in achieving the Community's objective of halting biodiversity loss by 2010 (Boedeker & Nordheim 2002). These and other measures, such as the WFD and the European Marine Strategy, are of paramount importance. However, despite the important commitments under the Directives, their application to the coastal and offshore marine environment in the form of Natura 2000 needs to be substantially accelerated. The European Commission has emphasized that the Habitats and Wild Birds Directives apply to the whole EEZ of the Member States, and not just in territorial waters. However, implementation of these Directives outside the 12-mile limits is still held back by legal problems in some States, although many States are applying the Directives to all waters and are proposing Natura 2000 sites in the offshore zone.

In order to harmonize the approaches and the implementation processes for marine protected areas (MPAs) in the Baltic Sea and the Northeast Atlantic, HELCOM and OSPAR have jointly developed a detailed work programme on MPAs, including a concrete timetable for implementation by 2010. This programme was adopted and endorsed by the region's Environment Ministers at the 2003 joint meeting of both Commissions in Bremen, Germany (JMM 2003b). HELCOM (HELCOM HABITAT 2/2001) has requested ICES to include the whole Baltic Sea area in its work on a marine habitat classification and mapping system. The EUNIS system should be taken into consideration as well as other ongoing projects in the region such as the EC CHARM project (Characterization of the Baltic Sea Ecosystem Dynamics and Function of Coastal Types), which is connected with the WFD. There is, however, a need to coordinate and to harmonize the methods used for habitat/biotope mapping in the different Baltic coastal countries.

Assessing species richness: analysis of species accumulation data and genetic diversity

Signatories to the CBD are obliged to assess the species richness within their national jurisdiction. A major part of the necessary assessments involves estimating how many species of a given taxon, or all taxa, occur in different habitats. Thus, estimates of species richness are needed, for example, for setting conservation priorities. However, in analyzing species richness patterns in natural communities, it is only rarely possible to conduct a complete census of organisms in a particular area and so sampling is the only option (Krebs 1989). This is the situation with most marine data sets involving plankton, benthos and fish communities. Initially, many species are found as larger areas are sampled and a plot of accumulated number of species against area sampled rises steeply at first and then more slowly as increasingly rare species are added. The species – accumulation curve may approach an asymptote for data sets of species that be identified easily, but in other habitats one cannot anticipate counting all species and thus asymptotes are uncommon thereby limiting information content on rare species. So, quantifying species richness, particularly in the marine environment, has inherent difficulties but the focus in marine research has recently begun to address such challenges (Rumohr *et al.* 2001; Ugland *et al.* 2003; Ugland & Gray 2004; Ugland *et al.* 2005). It has become clear that 1) a proper assessment requires substantial taxonomic expertise, especially for marine habitats that have a high phyletic diversity, and 2) most species accumulation curves do not reach an asymptote (Ugland & Gray 2004). The problem with species identification can be eased by using a variety of experts, and practicing quality control in sampling and sorting. In practice, the deficiency of taxonomic experts for the many marine habitats is primarily an educational and economic problem whereby recruitment of young scientists is not counteracting the loss of retiring, older scientists. The lack of an asymptote in the species – accumulation curve presents a major scientific predicament, such that all estimates have to depend on extrapolative techniques. Because all marine benthic surveys, for example, have covered only a small fraction of the total area of the seabed, it is reasonable to guesstimate that eventually we are likely to find about double the number of species known (May 1992; Ugland *et al.* 2003). Traditionally used analytical expressions provide large underestimates of species richness, which is a serious problem in relation to the conservation of biodiversity. Accordingly, it is paramount that major attention is given to developing analytical species – accumulation curves that are a) applicable to a wide variety of data, b) provide sound estimates of the species richness of larger areas, and c) play an important role in unraveling the structure of natural, as opposed to anthropogenically impacted, biological communities.

Most aquatic species occur in poorly known taxonomic groups such that most of these species are not yet known to science (Greer & Harvey 2004). It is symptomatic that—while focusing on biota having larger body size that makes them more amenable to taxonomic and ecological studies, as well as being those that are most threatened by human induced pressures due to their life history characteristics—relatively little attention currently is devoted to increasing biodiversity related knowledge about smaller eukaryotes and microbes (e.g. bacteria and virus). For example, less than 5% of marine bacteria are known according to estimates using molecular biological techniques, and so many new biochemical pathways remain to be discovered as well establishing the role of these organisms in biogeochemical cycles and in providing ecological goods and services (Munn 2004).

As noted with reference to the definition of biodiversity, knowledge about biodiversity at the genetic level is very limited, and accordingly places substantial constraints our ability to apply meaningful measures to conserve genetic diversity. Genetic biodiversity is the sum of genetic information contained in the genes of individual plants, animals and microorganisms, including acting as an immense storehouse of evolutionary traits and characteristics, which can enable organisms to withstand and adaptively respond, within reasonable limits, to a varying environment including human induced pressures such as climate change. Each species consists of numerous individuals exhibiting a range of genetic variability, *i.e.* with very few exceptions virtually no two individuals of the same species are genetically identical. Accordingly, with regard to conservation outcomes, populations of declining and endangered species are loosing their genetic diversity such that even if such populations increase again there is a great likelihood that future generations become more genetically uniform than their ancestors. Thus, a low ratio of ‘effective’ population size to ‘census’ population size increases vulnerability to changes in genetic diversity associated with human induced pressures such as overexploitation, pollution, climate change and habitat degradation (Hartl 2000). Thus, it is important to map and understand the importance of genetic resources in coastal and offshore regions, and the processes associated with the maintenance of genetic variation in natural and captive (e.g. cultured) populations including threats from genetically modified organisms (GMOs). Such fundamental and applied knowledge is of use to many stakeholders including nature conservation, fisheries conservation and aquaculture practitioners. Besides application of more traditional analytical techniques in the field of genetics, major progress is being made in the field of molecular genetic approaches including utilization of gene probe and DNA 'barcoding' techniques as illustrated by, for example, the Census of Marine Life project's <http://www.coml.org/> contribution to the international Barcode of Life - an international initiative to promote a process enabling the rapid and inexpensive identification of the estimated 10 million species of eucaryote life on Earth (e.g. Bucklin *et al.* 2003; Hebert *et al.* 2003). As a uniform method, DNA barcoding has broad scientific applications, including great potential utility in conservation biology as well as surveying and monitoring biodiversity, together with discrimination and identification of species, discovery of new and cryptic species, reconstruction of evolutionary relationships among species and higher taxa.

2.4.3 Major ongoing international collaboration activities of relevance to the workpackage

Fish communities

- The ICES Baltic Salmon and Trout Assessment Working Group (WGBAST) is central in developing information and advice provided by ICES ACFM to both HELCOM and IBSFC concerning monitoring and assessing the status of the Baltic salmon stocks as well as fisheries management and nature conservation issues, including the formulation of actions and measures connected with the Salmon Action Plan. Other relevant ICES groups include: Baltic Fisheries Assessment Working Group (WGBFAS); Working Group on the Application of Genetics in Fisheries and Aquaculture (WGAGFM).
- HELCOM COMBINE monitoring programme, supported by HELCOM/BSRP Coastal Fish Monitoring Workshops, held in 2004 and 2005, to develop a strategy for coastal fish monitoring and assessments in the Baltic Sea and the BSRP Fish and Fisheries Coordination Centre (Riga, Latvia) with its subsidiary Lead Laboratory on Coastal Activities (Tallinn, Estonia). Monitoring is coordinated by the Coordination Organ for Baltic Reference Areas (COBRA). The ICES/BSRP Study Group on Baltic Fish and Fisheries Issues (SGBFFI) and the ICES/BSRP Study Group on Baltic Ecosystem Health Issues (SGEH) are closely associated with the monitoring and assessment of coastal fish stocks and communities, and the development of indicators/ecological quality objectives and are also closely collaborating with HELCOM.
- The BSRP Coordination Centre for Fish and Fisheries (Riga, Latvia), as well as its subsidiary Lead Laboratory on Coastal Activities (Tallinn, Estonia) and Lead Laboratory on Salmon Restoration (Riga, Latvia) is actively engaged in research and management related issues connected with coastal fish communities, and with implementing, and appropriately adapting at the national level, recommendations arising from the Salmon Action Plans.
- EC funded research projects (FP5 and FP6) of relevance with Baltic links include: BECAUSE - Critical interactions between species and their implications for a precautionary fisheries management in a variable environment - a modelling approach; COST IMPACT – Costing the impact of demersal fishing on marine ecosystem processes and biodiversity; ELME – European lifestyles and marine ecosystems; EUMAR – European marine genetic biodiversity; MARBENA – Creating a long-term infrastructure for marine biodiversity in the European Economic area and the Newly Associated States; MARBEF – marine biodiversity and ecosystem functioning – EU network of excellence.

Marine mammals

- In ICES, the Working Group on Marine Mammal Ecology (WGMME) plays a central role in preparing scientific information and advice on marine mammals (*e.g.* health including the affects of pollutants, and population dynamics, trophic relationships, and habitat requirements) that is provided by ICES Advisory Committee on Ecosystems requested by Member Countries, HELCOM and the European Commission. The Working Group on Ecosystem Effects of Fishing Activities (WGECO) *inter alia* provides information on the effects of fishing on marine mammals.
- The History of Marine Animal Populations (HMAP) forms part of the global research programme Census of Marine Life. HMAP's long-term aim is to improve our historical understanding of ecosystem change and our ecological understanding of man's role in changing marine ecosystems. The Baltic — North-Norwegian Sea is one of seven ecosystems selected for investigation.

- EC funded research projects (FP5 and FP6) of relevance with Baltic links include: BECAUSE - Critical interactions between species and their implications for a precautionary fisheries management in a variable environment - a modelling approach; ELME – European lifestyles and marine Ecosystems.

Waterbirds

- In ICES, the Working Group on Seabird Ecology (WGSE) plays a central role in preparing scientific information and advice on waterbirds and shorebirds (*e.g.* health including the affects of pollutants, and population dynamics, trophic relationships, and habitat requirements) that is provided by ICES Advisory Committee on Ecosystems to requests by Member Countries, HELCOM and the European Commission. The Working Group on Ecosystem Effects of Fishing Activities (WGECO) *inter alia* provides information on the effects of fishing on seabirds.
- The ICES/BSRP Study Group on Baltic Ecosystem Health Issues (SGEH) has been instrumental in promoting the establishment of a Baltic Waterbird Monitoring Programme that is in accord with HELCOM's requirements, especially in the BSRP beneficiary countries (*i.e.* Estonia, Latvia, Lithuania, Poland and Russia).
- EC funded research projects (FP5 and FP6) of relevance with Baltic links include: BECAUSE – Critical interactions between species and their implications for a precautionary fisheries management in a variable environment – A modelling approach; ELME – European lifestyles and marine ecosystems.

Alien organisms

- ICES provides scientific information and advice to HELCOM pertaining to monitoring, assessment and management of non-indigenous organisms in the Baltic Sea region. The specialist groups involved in this process include ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO) and the Joint ICES/IMO/IOC Study Group on Ballast Water and Other Ship Vectors (SGBOSV). Information on the status and trends of such organisms is also provided, via HELCOM and ICES, to the European Environment Agency (EEA).
- Other important IAS-related bodies and initiatives include the BMB Working Group on Non-Indigenous Estuarine and Marine Organisms (WGNEMO), Baltic Sea Alien Species Database, Nordic – Baltic Network on Invasive Species (NOBANIS), Nordic - Baltic Invasive Species Information Management Working Group (WGISIM), ERNAIS - Regional Biological Invasions Centre (RBIC) Information System, European Research Network on Aquatic Invasive Species (ERNAIS) of the International Association of Theoretical and Applied Limnology (SIL) and the SIL Working Group on Aquatic Invasive Species (WGAIS), the IMO Ballast Water Working Group (BWWG) and GEF/UNDP/IMO Global Ballast Water Management (GloBallast) Programme.
- The BSRP Coordination Centre for Ecosystem Health (Gdynia, Poland), as well as its subsidiary Lead Laboratory on Alien Species (Klaipeda, Lithiuania) is actively engaged in research and management related issues connected with introductions and transfers of non-indigenous species in the Baltic Sea region.
- Ongoing EC funded research projects (FP5 and FP6) of relevance with Baltic links include: , ALARM - Assessing large-scale environmental risks for biodiversity with tested methods; ALIENS – Algal introductions to European shores; DAISIE – Delivering alien invasive species inventories for Europe.

Conservation of habitats, and protection of vulnerable and declining species and genetic diversity

- Under HELCOM work is continuing on the development of Red Lists of threatened and declining species, including fish species, as well as the further elaboration of Baltic Sea Protective Areas (BSPAs) as part of the collaboration with OSPAR to establish a coherent and cohesive network of marine protected areas (MPAs).
- Under ICES, the work is conducted mainly by the Marine Habitat Committee and its subsidiary groups (*e.g.* Working Group on Marine Habitat Mapping (WGMHM), Working Group on Integrated Coastal Zone Management (WGINC), Study Group on Information Needs for Coastal Zone Management (SGINC), Study Group on Acoustic Seabed Classification (SGASC), Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT), Benthos Ecology Working Group (BEWG)).

- ICES/BSRP Study Group on Baltic Ecosystem Health Issues has a Sub-Group on Biodiversity Loss whose work includes the development of habitat classification and mapping techniques, identification of potential marine protected areas (MPAs) as well as the elaboration of indicators that may be used in association with these issues.
- Ongoing EC funded research projects of relevance with Baltic links include: BIOCASE – Biodiversity collection access service for Europe; BIOCOMBE – Impact of biodiversity changes in coastal marine benthic ecosystems; CHARM - Characterization of the Baltic Sea ecosystem dynamics and function of coastal types; COST IMPACT – Costing the impact of demersal fishing on marine ecosystem processes and biodiversity; ELME – European lifestyles and marine ecosystems; EUMAR – European marine genetic biodiversity; INDECO – Development of indicators of environmental performance of the Common Fisheries Policy; MARBEF – Marine biodiversity and ecosystem functioning EU network of excellence; MARBENA – Creating a long-term infrastructure for marine biodiversity research in the European Economic Area and the Newly Associated States; MGE – Marine genomics Europe;

2.5 Workpackage 5: Pollution and ecosystem health

2.5.1 Potential BONUS-169 research and application issues

WP5: POLLUTION AND ECOSYSTEM HEALTH

Conducting investigations to elucidate the inputs and origins, dispersion/transport, and fate of pollutants (e.g. heavy metals, persistent organic pollutants and artificial radionuclides) in the ecosystem and the effects on human communities in the Baltic Sea region, including evaluating the efficacy of management options to redress the root causes of pollution and making proposals for improvements.

Key potential research and application issues are further described below:

a) Developing the scientific basis for research and monitoring programmes involving pollutants, including elaboration of indicators to identify changing status and trends. This includes evaluating the impacts of pollutants on coastal and offshore ecosystems as well as on human communities, incorporating the development of analytical techniques and models for assessing the levels of pollutants in water, sediments and biota, as well as identifying ecological quality indicators regarding pollution including the integrated measurement of pollutants and their biological effects. Attention should also be given to validating methodologies for exploring the use of biomarkers/bioassays in ecological risk assessments.
b) In collaboration with WP2, examining the role of sedimentation and pelagic – benthic coupling processes, including resuspension and biological and geochemical processes, in determining the concentration, persistence and toxicity of harmful and hazardous substances in the marine ecosystem.
c) Developing and applying indicators for the biological effects of contaminants, including harmful and hazardous substances such as artificial radionuclides, in the Baltic Sea region, ranging over different levels of biological organization, and validate the use of biomarkers/bioassays/toxicity identification and evaluation procedures (TIEs) in specific demonstration projects at a range of localities for the routine/periodic assessment of contamination and for the improvement of national and international monitoring programmes. Attention should also be given to validating methodologies for exploring the use of biomarkers/bioassays/TIEs in ecological risk assessments. The outcomes should *inter alia* include developing a network of research(ers) working with these techniques in the Baltic Sea coastal countries.
d) Developing and applying monitoring strategies in relation to compliance checking of good quality status for application to different types of water covered by the WFD. Aspects for consideration are *inter alia*: Monitoring strategies including frequency and location of monitoring; Trend monitoring; Discharge monitoring; Areas of impact; Contaminant background concentrations; Matrices recommended for monitoring; Analytical protocols including sampling/sample treatment, laboratory methods and alternative methods; quality assurance; Data to be reported.
e) In collaboration with other relevant WPs, developing a comprehensive approach to elaborating the concept of 'ecosystem health' with respect to eutrophication, hazardous substances, fisheries, and loss of biodiversity and habitats, in the Baltic Sea region, taking into account the need to implement the

ecosystem approach to management including via the WFD, and using a variety of complementary measures to conserve and, where necessary restore, the structure, function and integrity of coastal and marine ecosystems.

f) Investigating the short-term to long-term impacts of oil spills on marine and coastal environments and their associated biota and, in collaboration with WP6, assessing the human socioeconomic impacts.
g) In collaboration with WP6, compiling and analyzing information on shipping accidents in the Baltic, including the types of ships involved and the location of accidents, and consequences involving pollution for the marine environment including human socioeconomic costs.
h) Developing models for investigating the dispersion of radionuclides in the Baltic Sea, including investigations of radionuclides in water, sediment and biota.
i) With regard to the EC AMPs (Analysis and Monitoring of Priority Substances) activities and Priority Substances listed under the WFD, planning and executing workshops to conduct a series of development and intercalibration exercises to ascertain variability in accuracy and precision of analytical techniques concerning occurrence in the sampling matrix (water, sediments and biota).
j) In collaboration with WP3 and WP6, ascertaining the effects of environmental contamination (*i.e.* harmful and hazardous substances) on the development of fisheries and marine aquaculture.
k) In collaboration with WP6, investigating and quantifying the ecological and socioeconomic impacts of litter/waste in order to adequately consider the effects and necessary measures to conserve species and habitats. Major sources of litter/waste need to be monitored and controlled through effective enforcement measures. Comprehensive programmes and measures should be established not only to reduce ecological impacts but also to counter the socioeconomic costs of the problem. There has been a failure to establish effective awareness programmes and measures to reduce the ecological impact and counter the socioeconomic costs of the litter/waste problem.
l) In collaboration with WPs 6 and 7, investigating the distribution and environmental threats posed by dumped munitions and chemical warfare agents, including: Identification and mapping of locations of dumped munitions and chemical warfare agents; investigating the ecological and ecotoxicological effects of chemical warfare agents; determining the presence of chemical warfare agents in the various marine compartments and in particular the presence of the more persistent and poorly soluble chemical warfare agents in sediments and biota; and the elaboration of national guidelines on how fishers and authorities should deal with chemical munitions; and compilation of information on the state of corrosion of munitions varying from intact to completely corroded.
m) Investigating contaminant concentrations in coastal and offshore marine fish and other aquatic food products and, in collaboration with WP6, estimating the intake of contaminants and nutritional factors associated with the consumption of fish and other aquatic food products by humans and their health implications in the Baltic Sea region.
n) In collaboration with WP6, developing scientific principles for the control and management of pollution sources, including examining the socioeconomic and ecological cost – benefit of various options regarding regulatory actions and measures.
o) In collaboration with WP6, building the scientific basis and criteria relating to legal instruments and other measures for the prevention, control or abatement of environmental degradation associated with marine pollution.
p) In collaboration with WP7 and WP8, synthesizing and preparing information and advice for diverse user groups, policy-makers and managers about the biological effects of contamination on living marine resources and human health.
q) In collaboration with WP7, promoting education, building capacity and conducting outreach activities at the regional level.

2.5.2 Background

Many pollution sources within the Baltic Sea drainage basin, as well as advective processes transporting pollution into the region from outside, may harm the marine environment detrimentally affect human health and livelihoods (HELCOM 2002; AMAP 1997, 2002).

Marine pollution is defined as '*Introduction of man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazard to human health, hindrance to marine activities including fishing, impairment of quality for use of* *seawater, and reduction of amenities'* (GESAMP 1987). The GESAMP definition has been used in all internationally agreed legal instruments for the prevention and control of marine pollution.

The definition has two important qualities in a) being clearly identified as a human activity, and b) being harmful and hazardous, and scientists can identify the various pollutants found in water, sediments and biota in the marine environment, measure their quantities and determine their sources in terms of the root causes of pollution, provide estimates of their potential danger for the health of both marine life and humans, and determine actions and measures that can be applied by management (*e.g.* regulation and compliance) to redress the root causes of the implicated human activities.

Although eutrophication is included in the GESAMP definition of pollution provided above, this issue will be dealt with under WP2, while all the other aspects of pollution will be dealt with under WP5.

Policy and management

Many Conventions, agreements and other instruments address the policy and management aspects of coastal and marine pollution. These are too numerous to refer to in their entirety here, but attention will be drawn to selected instruments in the context of the Baltic Sea region.

The International Convention for the Prevention of Pollution from Ships (MARPOL/73/78) and the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1972 London Dumping Convention), for example, are the key global international agreements addressing pollution from marine-based sources. MARPOL limits operational discharges of oil, noxious liquids, and ship generated garbage including litter. The London Dumping Convention prohibits the disposal (*i.e.* dumping) of wastes at sea, with the exception of dredged material, waste from fish processing, and inert material of natural origin. Potentially polluting wrecks should be cleaned-up or removed, particularly where they hamper or endanger other legitimate uses of the sea. In this context, IMO is working to finalize the development of an International Convention on Wreck Removal aiming at its adoption by the end of 2005.

At the regional scale in the Baltic Sea, HELCOM *inter alia* applies a range of actions and measures to prevent pollution from land-based, atmospheric and sea-based sources. Carefully coordinated international cooperation on reducing pollution is vital, and has been the focus of attention of HELCOM's Baltic Sea Joint Action Plan (JCP) that forms the international environmental management framework for the long-term restoration of the ecological balance of the Baltic Sea (Selin & VanDeever 2004). The JCP objective is to facilitate the implementation of pollution reduction measures at the most polluted sites in the Baltic Sea catchment area. Implementation of the JCP has resulted in the cleaning up of about 50 of the 132 serious pollution areas, so-called 'hot spots', identified around the Baltic Sea since 1992. Focus has been on investments made to reduce pollution from a variety of sources, including the serious pollution 'hot spots' designated by HELCOM, and on drafting management plans for sensitive coastal lagoons and wetlands.

In cooperation with IMO, HELCOM has brought to global recognition the sensitivity of the Baltic Sea, and thus obtained for the Baltic Sea designation as a PSSA (see section 2.4.2) and as a Special Area Status under MARPOL Annexes I, II and V, on oil, noxious substances and garbage respectively. Consequently, there are more stringent requirements than in other sea areas and in some cases even prohibitions on the discharges of these substances. As of 19 May 2006 the Baltic Sea became a 'SOx emission control area', under Annex VI of MARPOL 73/78. Since the late 1990s, HELCOM has been working to implement a comprehensive set of measures to reduce pollution by ship generated waste (known as the Baltic Strategy for Port Reception Facilities for Ship Generated Wastes and Associated Issues). Regarding litter, the importance of mounting clean-up campaigns, public information activities and educational projects are emphasized.

One of the main efforts concerning preventing pollution has been directed at hazardous substances, particularly at substances that are persistent, liable to bioaccumulate and toxic (PBTs) or which have harmful properties giving rise to an equivalent level of concern (*e.g.* endocrine disruptors and substances that can damage immune systems) (Nilsen *et al.* 2002). In this context, chemicals that are both very persistent and very bioaccumulative (VPVB) have also been addressed, since they have a tendency to accumulate in the aquatic food chain and because, once discharged, they are practically impossible to remove from the environment. Some of the persistent organic pollutants (POPs) are subject to long-range transport. Mixtures of such substances are also of concern, even at low concentrations due to their harmful, sometimes synergistic, effects on biota and threats to human health.

Long-term objectives are increasingly being adopted to progressively reduce discharges, emissions and losses of pollutants, including hazardous substances, towards an ultimate aim of concentrations of pollutants in the marine environment near background values for naturally occurring substances and close to zero for man-made synthetic substances (EC 2002b; JMM 2003a). The cessation of discharges, emissions and losses of hazardous substances within about one generation (ca. 25 years) has become an internationally agreed political goal. HELCOM has taken up the one generation target, and aims to phase out the discharges, emissions and losses of selected substances by 2020. In addition to aiming at very ambitious limitations of discharges, emissions and losses, it changes the focus from a static target—related to percentage reductions of a fixed list of hazardous substances—to a more dynamic target. This new target allows the Community to tackle by prioritization the control of those substances that at any time are viewed to be of the highest concern.

In 2000, a concept similar to the one generation target was integrated into the WFD. The Directive introduces the concept of a combined approach, whereby the reduction—and for some substances cessation—of discharges, emissions and losses of hazardous substances is achieved through mutually reinforcing combination of i) setting environmental quality objectives, and ii) adopting control measures on emissions and products. The one generation cessation target concept specifically addresses a group of chemicals designated as 'priority hazardous substances'. The WFD requires the cessation or phase-out of discharges, emissions and losses of these substances within 20 years of the adoption of the relevant measures. A list of priority substance, including the 'priority hazardous substances', has been adopted, together with a time schedule for the development of cost effective and proportionate control measures for these substances as well as a system for updating the list. The adoption of the one generation target for the 'priority hazardous substances' identified under the WFD underlines that the resulting measures taken under the Directive will be legally binding for all EC States.

The new EC Chemicals Policy – REACH (Registration, Evaluation, Authorization and Restrictions of Chemicals) (COM(2001) 88) aims to achieve that, within one generation (2020), chemicals are only produced and used in ways that do not lead to a significant detrimental impact on human health and the environment, in line with the WFD and with commitments that EC States and the Community have undertaken in international forums. A common regime is envisaged for the registration, evaluation, and authorization of new and existing substances and foresees a shift in the burden of data generation and evaluation from regulators to producer and user industries. The EC has developed prioritization mechanisms for selecting those substances of greatest concern to the marine and aquatic environments, and has produced a Priority List containing about 30 chemicals for which measures are being developed to meet the aims of the WFD. PBT-substances are also addressed under various EC priority lists on dangerous substances and pesticides.

Although there is evidence of decreasing levels of input of many of the traditional hazardous substances, major attention is drawn to the fact that a large number of relatively novel man-made compounds, for which the ecological effects are largely unknown, are still being discharged into and detected in the Baltic Sea region (Selin & VanDeer 2004). For a large number of hazardous substances, there are still shortcomings both with respect to actual reductions, as well as for the quantification of the emissions and discharges. The quantification of reductions has been carried out on a different basis among States, which limits the scope for comparisons between States with different categorization numbers (Nilssen *et al.* 2002). Accordingly, there is a pressing need for further development and implementation of new procedures (*c.f.* HARP-HAZ Prototype for the North Sea) for quantification and country-based reporting on hazardous substances in order to increase transparency and thus comparability on performance regarding meeting reduction targets. Such procedures should involve the source-orientated approach (SOA) and the load orientated approach (LOA). The SOA is based on the quantification of discharges and emissions from identified sources. The LOA quantifies the loads entering the marine environment via rivers, estuaries and direct discharges. In both cases procedures should be put in place to increase the transparency of how data has been collected and results calculated, in accord with the 1998 Aarhus Convention that has been ratified by the EC, in order to enable a comparable assessment of achievements and the pinpointing of the remaining most significant sources of hazardous substances entering the Baltic Sea.

Pollution and impacts on ecosystems including human health

A large list of toxic substances and dumped material threatens the Baltic Sea environment (AMAP 1997, 2002; HELCOM 2002, 2003). These include heavy metals, POPs, oil pollution, artificial radionuclides, and dumping of munitions and litter, and contaminants released by dredging activities. It has been increasingly evident that the region is a sink for many toxic pollutants, such as heavy metals and POPs that originate from industrial and agricultural activities in the region as well as from outside into the region. The transport vectors include wind-driven air masses, rivers and water currents and ice-drift. Long-range airborne transport of pollutants, with subsequent releases in rain and snow over the region, deposit pollutants on land, in melt water in rivers and in the surface highly productive layers of the sea. Once in the region, toxic pollutants may be biomagnified upwards in the food chain, particularly in lipid-rich food webs (AMAP 2002). Pollutants are also transported to and from the region and released through the food web by migratory populations, such as aquatic birds.

Heavy metals

Heavy metals (*e.g.* arsenic, cadmium, chromium, copper, lead, mercury, zinc) are naturally occurring and do not degrade, so man-made pollution involving these metals above background levels in the environment can cause serious harmful effects to marine biota and, following transfer and accumulation via the food chain, may even constitute a problem for human health (AMAP 1997, 2002; HELCOM 2002, 2003). In contrast to organic pollutants, metals accumulate in protein tissues and bone rather than fat (AMAP 1997). Salinity is a factor that affects the toxicity of heavy metals to marine and estuarine biota associated with the increasing accumulation of heavy metals with respect to decreasing salinity (McLusky *et al.* 1986). Mercury and cadmium have no known biological function but can bioaccumulate and be toxic in small quantities. Lead is also toxic. The anthropogenic loads of cadmium, lead, and mercury to the Baltic Proper are 5-7 times higher than the natural loads, and the copper and zinc loads are twice as high as the natural loads (Lithner *et al.* 1990). Recently formed sediments from the Baltic Proper can contain 10 times more cadmium and mercury than the deeper layers, 3-5 times more lead and zinc, and about 2 times more copper. Studies of sediments from the Baltic Sea Proper show metal concentrations rising during the 1950s and reaching a peak in the 1960s and 1970s. Although concentrations of many metals have decreased since the 1980s, they are still significantly higher than in the 1940s (Jansson & Dahlberg 1999). However, sediment concentrations are dependent on the amount of organic matter sedimenting to the bottom and are linked to the eutrophication process. Thus, there are concerns that apparent reductions in heavy metals in sediments in the 1980s may be masked by eutrophication signals.

Dissolved copper can affect trophic levels such as phytoplankton, while cadmium, mercury, and lead can be toxic at levels that are only moderately above background levels. Filter-feeders and sediment feeders (*e.g.* shellfish), and predators are at risk due to bioaccumulation (OSPAR 2000; AMAP 2002). Concentrations of cadmium, lead, mercury, copper and zinc are high, and may exceed environmental quality standards (*e.g.* EACs[8]) in the sediments and/or water of several Baltic Sea 'hot spots', that are generally close to current or past inputs as shown by the JCP. Such concentrations cause concern for biological effects on plants and animals. Several heavy metals travel long distances in the atmosphere causing transboundary pollution in other areas. Although inputs of metals to the Baltic Sea have generally decreased, levels in the marine environment remain high and cause serious concern both at the regional and local scales.

Persistent organic pollutants

A range of POPs is found in the Baltic Sea marine environment and represent substantial threats to biodiversity and humans who utilize living marine resources (Roots 1995; AMAP 1997, 2002; HELCOM 1996a, 2002). Despite the phasing out of many traditional hazardous substances in Europe and North America over the last two decades, a large number of additional POPs are being registered. The large number

[8] Ecological Assessment Criteria: concentrations of specific substances in the marine environment below which no harm to the environment or biota is expected. EACs refer primarily to acute toxicity, and their derivation does not include bioavailability under field conditions, the degree of bioaccumulation, carcinogenity, genotoxicity, and hormone balance disturbances (*e.g.* endocrine disruption).

of chemicals classified as POPs (*e.g.* PCBs, dioxins, PAHs, brominated flame retardants, TBT and several other organometallic compounds, certain pesticides and their breakdown products such as DDT and DDE, pharmaceuticals and industrial chemicals) are characterized by being lipophilic, tend to have low degradation rates and are persistent and toxic, and so are prone to accumulate in living tissue, becoming concentrated as they pass up the food chain by predators consuming contaminated prey (AMAP 2002). Elevated levels of POPs have been found in the tissues of numerous biota in the region, especially birds, fish and marine mammals, with concentrations being higher than in similar biota in the North Sea and North Atlantic (Jensen *et al.* 1969; Helander *et al.* 1982; Blomqvist *et al.* 1992; Roots & Aps 1993; HELCOM 1996a, 2002; Larsson *et al.* 1996). Even at very low concentrations, POPs can result in harmful biological effects including affecting the liver, disturbing neurobehaviour, impairing reproductive processes (*e.g.* disrupting sex hormones, causing malformations of reproductive organs, reducing breeding success) and immune systems, and acting as cancer promoters (AMAP 1997, 2002). POPs can also accumulate in organic-rich sediments potentially creating submerged pools of contaminants that may be released by benthic bioturbation or human disturbance (*e.g.* dredging, trawling). Many POPs are classed as xenobiotics, *i.e.* unknown to the environment before their production by humans.

Large-scale production of PCBs started in the 1930s but intensified during the 1960s and the beginning of the 1970s. The use of DDT started after 1945 and culminated in the Baltic Sea area during the 1960s and 1970s. These POPs and their congeners and metabolites continue to be a diffuse source of pollution despite a ban on their production, use and marketing in the Baltic Sea region and elsewhere in Europe. Although concentrations are now about one magnitude lower than they were 20 years ago, the levels of POPs in the Baltic Sea ecosystems are still several times greater than in the open North Sea and North Atlantic (HELCOM 1996a, 2002). Reduced levels in body tissues and increased breeding success has been registered in a number of Baltic Sea animals, including grey seals, guillemots, and white tailed sea eagles, such that regulatory actions and measures to redress the root causes of the problems have contributed towards substantially restoring many populations of these species. However, there are no grounds for complacency as the levels of POPs are still very high in seals, being significantly higher than the levels permitted in fish for human consumption (see below for further details).

Great attention recently has been focused on a range of natural and man-made substances (*e.g.* TBT and several other organometallic compounds, PCBs, dioxins, and certain pesticides, pharmaceuticals and industrial chemicals) that can impair the reproductive process (*e.g.* through interfering with hormonal systems and causing 'imposex'[9] in snails and whelks) in aquatic organisms. These so-called 'endocrine disrupters' can have effects at very low ambient concentrations that are substantially less than those that are mutagenic and acutely toxic. Imposex disturbances have been registered in estuarine and coastal areas of the Baltic Sea that have the greatest concentrations of shipping-related activities and the highest levels of TBT in sediments and biota.

The DDT pollution problem, and to a lesser extent that from PCBs, has been tackled through legislation and governance. Furthermore, since the implementation of the HELCOM 1988 Ministerial Declaration, the load of hazardous substances to the Baltic Sea has diminished by 20-50%. Unfortunately, a large number of chemicals, either known to be hazardous or for which the intrinsic effects are largely unknown, are still entering the Baltic marine environment. Additional POPs, identified for action by the EC, are not yet included in long-term monitoring programmes. These substances include brominated flame retardants, chlorinated paraffin's, synthetic musks, additional known endocrine disrupters, and dioxins that are not manufactured but are produced as combustion by-products, or during the production of certain chlorinated chemicals and pulp bleaching.

Oil and petroleum hydrocarbons

Reviews regarding the environmental impacts of oil and petroleum hydrocarbons in the region are provided by AMAP (1997, 2002), HELCOM (1996a, 2003), and Patin (1999).

Petroleum-derived hydrocarbons in the Baltic Sea environment stem from different sources, and are composed of numerous single substances that give rise to different problems. Exploration and exploitation of

[9] Imposex is the development of the sexual characteristics of the other sex.

oil in and around the Baltic Sea is becoming an increasing concern, especially oil spills from ships caused by accidents. Where such spills occur, they can cause severe damage, especially in the form of mass stranding and mortality of oiled seabirds. Over 7 000 sailings involving the transport of oil occur each year in the Baltic Sea. A risk assessment has indicated that the number of accidents will probably increase, as the oil transported by sea is likely to rise by about three-fold in the coming decade compared with the mid-1990s. Oil pollution is expected to increase, due *inter alia* to increasing trade in oil in the Baltic Sea countries, increasing fleets, old vessels, inferior control, unqualified crews, and general difficulties in implementing international treaties. The biologically most harmful substance group within the petroleum-derived hydrocarbons is the polycyclic aromatic hydrocarbons (PAHs). They occur in minute amounts within fossil oils, and are mainly anthropogenic products of many combustion processes with oil-products or coal, but can be synthesized by microorganisms. Their concentrations in the Baltic Sea are about three times those in the North Sea, and atmospheric deposition is the main source of these compounds.

During the last decade shipping has steadily increased around the Baltic Sea, reflecting intensifying international collaboration, trade and economic prosperity. About 2 000 sizeable ships are normally at sea at any time in the Baltic, including large oil tankers, ships carrying dangerous and potentially polluting cargoes, and many large passenger ferries. Oil transportation has doubled in the past six years and it is expected to increase to up to 160 million tonnes by 2010 as a result of the building of new oil harbours in Primorsk and in Vysotsk (Russia). The Baltic Sea has some of the busiest shipping routes in the world. Due to a number of prominent shipping accidents, the IMO in 2004 declared the Baltic Sea, with the exception of Russian waters, as a particularly sensitive sea area (PSSA) needing special protection because of its ecological importance and sensitivity to threats from shipping. PSSA status is meant to avoid or reduce accidents, intentional pollution and damage to habitats. Because PSSAs are marked on sea charts, the crews of ships are expected to be particularly careful. Upon request by the countries concerned, the IMO can also decide on special measures, *e.g.* restricted areas, traffic separation areas, coastal traffic and deep water areas, special rules for waste disposal, compulsory pilotage, mandatory reporting or ship traffic management.

Artificial radionuclides

Reviews of artificial radionuclides in the region are provided by HELCOM (1995a, 1996a, 2002) and AMAP (1997, 2002). HELCOM MONAS is supported by a special project on Monitoring of Radioactivity in the Baltic Sea Area, MORS.

The levels of artificial radionuclides in the region are now generally decreasing, although there are still major concerns. The principal artificial radionuclides in the Baltic Sea environment are ^{137}Cs and ^{90}Sr. Their occurrence is mainly based on four sources that have contributed very differently to their total input. Until 1991, about 4 850-5 750 TBq ^{137}Cs and 720 TBq ^{90}Sr entered the Baltic Sea, *i.e.* 1) up to 80% of the ^{90}Sr fallout of the Chernobyl accident of 1986, 2) up to 19% for ^{137}Cs and 83% for ^{90}Sr from the global fallout due to atmospheric nuclear weapons testing during the 1960s, 3) about 5% each for ^{137}Cs and ^{90}Sr from discharges of the reprocessing plants at Sellafield (Windscale/Irish Sea, UK) and La Hague (Channel, France), that partly are transferred to the Baltic Sea with salt-water inflows, and 4) only about 0.01% for ^{137}Cs and about 0.04% for ^{90}Sr from nuclear installations within the drainage area of the Baltic Sea. Since, at present, the contribution to humans from marine radionuclear contamination adds about 1% of the total exposure to radioisotopes, this source is not considered as a matter of major immediate concern for the general public in the Baltic Sea region. Nevertheless, there is significant concern about the risk due to increasing age and uncertain safety standards of the Soviet nuclear reactors in the area, *e.g.* in Russia and Lithuania.

Hydrodynamics and sedimentation are of major importance in determining transport pathways and the fate of radioactive material released to and transported within the marine environment. Particle – water exchange is one of the most important geochemical factors affecting the transport of radionuclides. In water, radionuclides are partitioned between the dissolved and particulate phases. Partitioning depends on the radionuclide's chemical form, the physical–chemical properties of the chemical/elemental analogues, and environmental characteristics. Biological uptake and associated dose assessments for human exposure generally depend on the levels of dissolved radionuclides in water, but filter feeders (*e.g.* bivalve mollusks) may accumulate radionuclides from particles. For benthic infauna and epifauna, which are closely associated with marine sediments, concentrations of radioactivity in sediments have a major influence on the extent of uptake. Radioecological vulnerability is affected by factors such as water exchange rates; water column residence times for radionuclides; sediment and sedimentation properties, including bioturbation and resuspension; freshwater inflow and salinity; oxygenation of the water column and sediments; and ice conditions. In terms of economics, highly productive areas for fisheries and aquaculture are at risk from loss of market both from realized contamination and from rumours of contamination.

International radiological protection has historically focused on the protection of humans with the view that if humans are adequately protected then other living organisms are also likely to be sufficiently protected. In addition to the current system of radiological protection that is entirely based on human health protection, AMAP (2002) has promoted the need for the rapid development of a system for the protection of the environment and its living resources from the effects of radiation. This has been motivated by increasing focus lately on protection of the marine environment from possible detrimental effects of ionizing radiation, with questions arising as to whether the principle of protecting humans is sufficient for protection of the environment. Currently the impacts of radionuclides on marine wildlife have not been assessed, and there are no internationally accepted radiological criteria for the protection of marine flora and fauna. Greater emphasis should be devoted to assessing biological and ecological effects in the marine environment arising from existing and foreseen discharges of radioactive substances. It is important to develop environmental quality criteria for the protection of the marine environment, including fauna and flora, from adverse effects of radioactive substances. In this context, it is pertinent to note that the International Commission on Radiological Protection (ICRP) is considering a need for guidelines and criteria to focus on the environment, and is in the process of reviewing its position on environmental protection.

Concern has been expressed about potential accidents during the transport of radioactive material by sea, and the need to protect environment and human health, as well as socioeconomic implications. The 2001 General Conference of the International Atomic Energy Agency (IAEA) has called for further efforts to examine and improve measures and international regulations relevant to the international maritime transport of radioactive materials. The importance has also been stressed of having effective liability and indemnification mechanisms in place.

Dumping and dredging

Sewage sludge

The dumping of sewage sludge in the sea increases the fallout of organic material and associated contaminants to the bottom. In already nutrient rich coastal waters, sewage sludge contributes towards eutrophication and thereby affects water quality and changes the pelagic and benthic community structure and productivity. Sludge from coastal sewage treatment plants are frequently spread on agricultural land (*c.f.* EC Directive 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture) and deposited in landfill sites, but with the cessation of the sea disposal-option an increased use of incineration is probable. Although the dumping of sewage sludge at sea is effectively being stopped through EC legislation, the impacts of sewage, manure, and nutrients flowing into the sea from mariculture and from land-based sources remain serious. These are *inter alia* described under WP2 and WP3.

Sewage sludge arising from waste-water treatment tends to concentrate heavy metals and poorly biodegradable trace organic compounds as well as potentially pathogenic organisms (viruses, bacteria, *etc*.) present in waste waters. Sludge is, however, rich in nutrients such as N and P and contains valuable organic matter that is useful as fertilizer or organic soil improver when soils are depleted or subject to erosion. The progressive implementation of the EC Urban Waste Water Treatment Directive 91/271/EEC in all Member States is increasing the quantities of sewage sludge requiring disposal. From an annual production of some 5.5 million tonnes of dry matter in 1992, the Community is heading towards nearly 9 million tonnes by the end of 2005. This increase is mainly due to the practical implementation of the Directive as well as the constant rise in the number of households connected to sewers and the increase in the level of treatment, up to tertiary treatment with removal of nutrients in some Member States.

Dredged material

Marine substrate (*e.g.* sand and aggregate) extraction and dredging activities are becoming more frequent in the coastal zone of the Baltic Sea, (ICES ACME 2001, 2004). Dredging is a localized problem in the region, with most dredged material arising from clearing navigation channels for ports/harbours and from coastal construction and engineering projects. Uses of dredged material include beach nourishment, land reclamation and marshland preservation. The impacts of dredging in the marine environment are reviewed by Newell *et al.* (1998). Dredging causes physical disturbance and affects the redistribution and form of contamination. Disturbance increases suspended matter, affecting primary production and restricting the growth of filter feeding organisms, causes burial of the benthos and changes in the substrate, with potential changes in benthic communities. Contaminants can be resuspended and remobilized from sediments and pass into the food web. Most harbour dredgings are contaminated by metals and organic substances. Dredged spoil contaminated above specific limits should be deposited in specially built (*e.g.* capped) dumps. Dredging may accelerate coastal erosion and change the morphology of natural channels, causing more widespread habitat changes. The benefits of dredging include the removal of contaminated sediments and their relocation to safe, contained areas, and the possible improvement of water quality made by the restoration of water depth and flow. Maintenance dredging is predicted to increase due to more storm-induced climate change events that shift bottom sediments and reduce shipping channels. More use of larger ships with greater draught will increase dredging in and approaching ports.

HELCOM Dredged Material Guidelines were produced in 1994 and ICES Guidelines for the Management of Marine Sediment Extraction were produced in 2003. In general dumping of dredged material is managed by licenses and controls on contaminant levels but not on loads (Newell *et al.* 1998). There is imprecise information on the actual amounts of contaminants transferred by dredging and the effects of dispersed fine material on benthic habitats. There is also a need to monitor contaminant residues in sediments and biota outside the disposal areas.

Litter and garbage

Marine litter arises from land-based and marine sources, and is found in large quantities on seabeds, in the water, and on the shores (Hall 2000). It is a serious problem not only in the Baltic Sea region but also worldwide. The main marine sources of litter are shipping, fishing and mariculture operations. Land-based sources are mainly from garbage sites on or close to shorelines, sewage-derived debris, and items discarded by recreation on beaches and the coastline generally. About 80% or more of this material consists of non-degradable plastic and mainly results from waste from fishing and commercial shipping, and recreation and tourism. The problem is likely to increase as tourism and urban development in the coastal zone increase.

Despite the above-mentioned MARPOL-related measures, no obvious improvement has occurred concerning reducing the amounts of marine litter and their associated ecological and socioeconomic impacts. The socioeconomic impacts of litter, most of which is non-degradable plastic, are substantial and include the unsightly aesthetic fouling effects, the substantial costs of clearance, and impacts on the fishing and tourism industries. The ecological impacts involve injury, smothering, entangling, drowning and obstruction of the digestive system of several biota, notably aquatic birds and marine mammals. Litter also spreads toxic substances, and floating and drifting litter can act as a vector transporting alien species to new areas by ocean currents. The ecological and socioeconomic impacts of litter and waste need to be further quantified in order to adequately consider the effects and necessary measures to conserve species and habitats. Local sources of litter and waste need to be monitored and controlled through effective enforcement measures. Accordingly, comprehensive programmes and measures should be established not only to reduce ecological impacts but also to counter the socioeconomic costs of the problem. There has been a failure to establish effective awareness programmes and measures to reduce the ecological impact and counter the socioeconomic costs of the litter problem (Hall 2000).

In 2005, HELCOM was invited by UNEP to participate in a Global Environment Facility (GEF) Medium Sized Project on Marine Litter, which provides HELCOM with financial resources to initiate a study to assess the magnitude of marine litter in the Baltic Sea Area and, if so needed, to develop a strategy to address the management of marine litter.

Munitions and military activities

During the First and Second World Wars, substantial numbers of ships were sunk in the region, the wrecks of which litter the seabed with debris, and contain various pollutants including potentially hazardous material

(HELCOM 1994, 1995b; Glasby 1997). Additionally, Large amounts of chemical weapons were produced and stockpiled in the Second World War, comprising several agents that include mustard, nerve and tear gases, and the lung irritant phosgene. During 1945-1948, both chemical munitions and conventional ammunition were sunk in the Baltic Sea area, such as east of Bornholm and southeast of Gotland. There are also reports of other smaller dumpings in the latter 1940s. Surveys of some of the dumpsites have shown a range of chemical munitions from completely corroded shells free of warfare agents, to intact munitions. Because of the precarious state of many of these munitions and uncertainties in making reliable predictions about their future progressive state, it has been decided not to salvage them and to leave them in place on the seabed.

HELCOM reported on chemical weapons dumped in the Baltic Sea through formation of an Ad Hoc Working Group on Dumped Chemical Munitions (HELCOM CHEMU). HELCOM CHEMU (HELCOM 1994, 1995) concluded that about 40 000 tonnes of chemical munitions, containing up to about 13 000 tonnes of chemical warfare agents, were dumped in the Baltic Sea region. Some munitions may have been short-dumped or may have drifted outside the dumpsite at the time of dumping. Munitions may also be relocated by fishing activities but are unlikely to be relocated by natural processes. It was not possible to estimate the extent of corrosion of munitions casings, and very little is known regarding the chemical behaviour of chemical warfare agents in the marine environment. Concerning the marine environment and the risk to the seafood consumer, it was concluded that, based on the knowledge at the time, widespread risk to the environment or to the consumer is negligible. However, it was recognized that fishing vessel crews, operating in and close to dumpsites, could be in danger of chemical munitions and chemical warfare agents. As a result of the CHEMU findings, HELCOM Contracting Parties report on relevant national information on dumped chemical munitions. CHEMU identified the following topics for further investigations and development connected with HELCOM: identification and mapping of the locations of dumped munitions; investigation of the ecological and ecotoxicological effects of chemical warfare agents containing arsenic compounds and mustard gas; determination of the presence of chemical warfare agents in the various marine compartments and in particular the presence of the more persistent and poorly soluble chemical warfare agents in sediments and biota; the elaboration of national guidelines for fishers on how to deal with chemical munitions, based on HELCOM Guidelines; Contracting Parties should agree the financial aspects of denomination of fishing vessels, noting that some Contracting Parties considered prohibiting bottom trawling within dumpsites to be a useful risk management strategy; the preparation of guidelines on how authorities should deal with incidents where chemical munitions are caught by fishers; compilation of information on the state of corrosion of munitions varying from intact to completely corroded.

The military activity of the Russian part of the Baltic Sea region is today clearly the most significant in environmental terms, and is *inter alia* connected with the naval bases and ship repair facilities in Kaliningrad. Following the end of the Cold War, Russian and EC military activities in the region are undergoing substantial downsizing. Military activities connected with fisheries protection and surveillance operations produce insignificant environmental impacts.

Integrated chemical and biological effects measurements: safeguarding nature and humans

It has often been claimed that toxic substances, and particularly POPs, are best monitored by analysis of top consumers, assuming that biomagnification is enhanced at each step in the food chain. However, biomagnification does not occur under all situations (Larsson *et al.* 2000), and so it is necessary to be precautionary about possible toxic effects lower down the food chain (Gray 2002). Some pollutants may occur at even higher concentrations in zooplankton or benthic invertebrates than in the fish that feed on them, and invertebrates may be more sensitive than higher organisms, due to having smaller body size, different physiology and biochemistry, *etc*.

Monitoring of the state of the seas has traditionally been based on measurements of concentrations of harmful substances in seawater, sediments, and biota. However, with the already enormous and continuously increasing number of potentially toxic substances present in and released into seas this approach alone is no longer considered meaningful, cost-effective, or even possible. So, the classical paradigm of assessing pollution by measuring a long and ever growing list of pollutants is currently challenged by the integrative approach combining chemical and biological methods, such as ecological indicators, molecular and cytological markers and toxicological bioassays. Specifically, ICES ACME advocated in 2002 that '*it is* *important that each method [of monitoring] is not used alone and that a strategy using integrated chemical and biological effects measurements is developed*'.

When developing indicators of ecosystem health appropriate for incorporation in a monitoring and assessment programme for the Baltic Sea, the health status of the marine biota in the ecosystem should be considered. Because the health status of an organism represents an integrative response to environmental factors affecting its well-being, including responses to human induced pressures such as pollution, ecosystem health indicators should also include dimensions reflecting the linkage between environmental quality and human health, and accordingly the role of humans as an inherent part of the ecosystems.

In order to assess the biological effects of the various harmful substances an integrated chemical-biological monitoring approach is needed. During the past decade such programmes have been in progress in other sea areas, in Europe mainly in the North Atlantic (*e.g.* by OSPAR) and the Mediterranean (*e.g.* MEDPOL), and in the USA (*e.g.* NOAA National Status and Trend Program). In the Baltic Sea region, the first steps have been made towards a biological effects marker approach (*e.g.* in the EC BEEP – Biological Effects of Environmental Pollution on Marine and Coastal Ecosystems project). However, further actions are needed that (1) lead to the validation of suitable methods, (2) support a Baltic Sea network of institutions aiming at the use of biological effects methods, and ultimately (3) lead to the implementation of selected biological effects methods in national and international (e.g. HELCOM) monitoring programmes.

The examination of biological responses of organisms to contaminant exposure has many advantages in comparison with traditional chemical analyses (McCarthy & Shugart 1990; Stentiford *et al.* 2003; Lehtonen & Schiedek in press). Molecular, cellular, biochemical and physiological effects of environmental contaminants are rapidly manifested, and the observation of relevant disturbances may be used to quickly focus detailed analytical chemistry on presumed problem areas. The choice of biomarkers applied can be adapted according to the regional pollution situations, for example, in the case of known pollution (*e.g.* point sources) contaminant-specific biomarkers can be included. Numerous chemicals and their metabolities are potent geotoxins, cause pathological lesions and reproductive disorders that may detrimentally affect individuals, populations and communities. Thus, biomarkers indicating the effects of chemicals serve as early warning signals with respect to application of the precautionary principle. The EC WFD has emphasized the importance of biological parameters as indicators of ecological quality, such that further development of the integrated chemical and biological effects approach has a potentially important role to play in implementing the WFD.

The development of pollution indices (PI) offers a promising approach in its potential application to the Baltic Sea (ICES SGEH 2005; ICES EHW 2005). For example, such an index might consist of five elements, each consisting of separate indicators, investigating as follows: 1) concentrations of selected contaminants; 2) a battery of biomarkers of exposure and effects; 3) histopathology; 4) external fish diseases; and 5) reproductive disorders. The elements involved in the proposed PI represent the different levels of detection of pollution and its effects in the marine environment. The calculation procedure for the PI (including the weighting of the different elements according to their importance/severity in the final result) is a matter for investigation. One possibility to test and validate the method would be to use parts of the existing BEEP Baltic Sea database (ICES SGEH 2005; ICES EHW 2005).

Effects of pollution on seafood quality and human health

Consumers are becoming increasingly aware of the quality of seafood products and of the more stringent regulations being introduced to ensure quality with respect to human health concerns. Discharge into the environment and accumulation in the food web of pollutants represent genuine threats to the health of aquatic biota and to the quality of seafood consumed by humans, and in turn regarding risks to human health. The problems of contamination of coastal and offshore environments and, consequently, of aquatic products by pathogenic bacteria and viruses contained in water contaminated with sewage, and in uncontrolled run-off from urban and agricultural areas, are manifest in the Baltic Sea region. Eutrophication from the same sources also encourages harmful algal blooms that may contaminate fish and shellfish, whether wild or cultured. Oil spillage may result in seafood products becoming tainted and unmarketable.

In the Baltic Sea, concentrations of lead and POPs in Baltic Sea fish (*e.g.* cod, herring and perch) generally have shown significant decreasing trends since about the end of the 1970s. However, despite obvious progress in the reduction of discharges, emissions and losses of such pollutants to the environment, their concentrations in sea water, sediments and similar fish are still substantially higher in many areas of the Baltic Sea compared to most areas of the North Sea and North Atlantic (Svensson *et al.* 1995; HELCOM 1996a, 2002). Fatty fish such as salmon and herring contain high levels of DDT, PCB, and their congeners and metabolites, and persons (*e.g.* in fishing communities) having a high consumption of these fish display a substantial increase in the levels of these agents in their blood (Skerfving 1995; Larsson *et al.* 1996; Kiviranta *et al.* 2003). Additionally, the use of Baltic cod-liver oil has been restricted in some countries due to substantial levels of PCBs (Falandysz *et al.* 1994). As these POPs are excreted into human milk, there has also been great concern about the exposure to breast-fed infants (Skerfving 1995). Furthermore, there have been some indications that human immunological effects, low infant birth-weights and greater risk of breast cancer may be associated with a frequent intake of POPs-polluted fatty fish from the Baltic Sea (Skerfving 1995).

Fish is an important food source for marine mammals and humans, being a major source of protein, essential minerals (*e.g.* selenium) and n-3 polyunsaturated fatty acids. Baltic fishers have exhibited low mortality from coronary heart disease, which appears to be associated with the positive aspects of fish intake (Skerfving 1995). Thus, it is a calamity that recommended consumption restrictions, based on contamination concerns, apply to Baltic fish in many countries. However, the restrictions on the use of DDT and PCB seem to have been effective, as during the last several decades concentrations of DDT and its metabolite DDE have decreased dramatically in the blood of Baltic fishers (Skerfving 1995). Unfortunately, there are undoubtedly many other chemical pollutants still to be detected, once the analytical techniques are available. Thus, it is essential that analytical chemists and environmental toxicologists continue to identify and assess the toxicity of pollutants in fish.

The ecosystem health concept

One of the overall aims of marine protection policies is to promote sustainable use of ecosystem goods and services and to conserve ecosystems by implementing an ecosystem-based approach to the integrated management of human activities that cause pressures on the various components of ecosystems. The need to maintain and, where necessary, restore the ***'health of marine ecosystems'*** is a central feature of the ecosystem approach (JMM 2003), building in turn on application of the precautionary principle, as highlighted in the European Marine Strategy (EC 2002). In order to monitor and assess changes in the status and trends of marine ecosystems and their components, and avoid problems related to 'shifting baselines', a coherent system for conserving the health of the ecosystem needs to be established, including: a) establishing the vision; b) setting the strategic goals; c) setting the operation ecological quality objectives (EcoQOs); d) developing performance indicators with respect to assessing the 'health' status of the ecosystem (*e.g.* as categorized in the WFD), including determining target, precautionary, and limit reference points that should not be transgressed; and e) establishing a 'cause-and-effect' relationship, based on a causal chain analysis, between those human activities causing serious impacts on ecosystem components, so that management/regulatory measures aimed at redressing the root causes of the pressures will result in a substantial decrease in the detrimental ecosystem effects. Connected with these activities, a major thrust is being devoted to promoting spatial management measures, including ICZM, the development of Baltic Sea Protected Areas incorporating management guidelines and the compilation of lists of habitats and species in particular need of protection. The EcoQOs and associated indicators will be used to describe and lay out the borders within which a healthy and sustainable Baltic marine ecosystem should lie, and will guide implementation of the future HELCOM Baltic Action Plan. Major activity by HELCOM regarding managing human-induced pressures is being applied in the areas of eutrophication, hazardous substances, fisheries, and loss of biodiversity and habitats.

To realize the goals of actively conserving and restoring the health of marine ecosystems, major research will be needed for supporting scientific information and advice, monitoring and assessment tasks and the science-based formulation of appropriate management measures.

2.5.3 Major ongoing international collaboration activities of relevance to the workpackage

- In ICES, scientific issues connected with pollution and ecosystem health are addressed in ACME and ACE by the following expert groups: Working Group on Biological Effects of Contaminants (WGBEC), Working Group on Marine Sediments in Relation to Pollution (WGMS); Marine Chemistry Working Group (MCWG), ICES/HELCOM Study Group on Quality Assurance of Chemical Measurements in the Baltic Sea (SGQAC); Working Group on Statistical Aspects of Environmental Monitoring (WGSAEM); Working Group on Pathology and Diseases of Marine Organisms (WGPDMO); Working Group on the Effects of Extraction of Marine Sediments on the Marine Ecosystem (WGEXT);
- There is also a joint ICES/BSRP Study Group on Baltic Ecosystem Health Issues (SGEH) that *inter alia* is focused on reviewing, prioritizing, and eventually selecting a suite of ecosystem health indicators relating to human induced pressures connected with the effects of hazardous substances (in addition to effects of eutrophication, impacts of fisheries, and loss of biodiversity) involving ecological quality reference points (*e.g.* targets, limits, and precautionary levels that should not be transgressed), development and application of a biological effects monitoring programme including fish diseases/pathology monitoring, and evaluation of the applicability to the Baltic Sea of the Coastal Condition Indicators and Reference Points of US Coastal Water developed by the US Environmental Protection Agency (EPA).
- The BSRP Coordination Centre on Pollution and Ecosystem Health, together with relevant subsidiary bodies (*e.g.* Lead Laboratory on Histopathology and Fish Diseases, Kaliningrad, Russia) plays an active role in pollution and ecosystem health issues particularly with reference to capacity building in the BSRP beneficiary countries (*i.e.* Estonia, Latvia, Lithuania, Poland and Russia).
- EC funded research projects (FP5 and FP6) of relevance with Baltic links include: BEEP – Biological effects of environmental pollution in marine coastal ecosystems; CHARM – Characterization of the Baltic Sea Ecosystem: Dynamics and functional ecosystem types; COSA – Coastal sands as biocatalytical filters; ELME – European lifestyles and marine ecosystems; GENIPOL – Genomic tools for pollution assessment; OCEANIDES – Harmonized monitoring, reporting and assessment of illegal marine oil discharges; REBECCA – Relationships between ecological and chemical status of surface waters.
- Research projects, recently funded by the Nordic Council of Ministers, of relevance with Baltic links include: CAPNE – A comparative assessment of persistent organic pollutants and their metabolites with emphasis on non-traditional contaminants in the West-Nordic and the Baltic Proper environments; Assessment and classification of the chemical conditions of contaminants in the Baltic Sea and Kattegat; Description and dissemination of short and long-term ecological effects of oil spill in the Baltic Sea, Kattegat, Skagerakk, and the North Atlantic.

2.6 Workpackage 6: Socio- and ecological economics

2.6.1 Potential BONUS-169 research and application issues

Workpackage 6 acts in a ‘cross-cutting’ capacity, being designed not only to provide essential information and outputs on socio- and ecological economics in its own right but also to provide the essential inputs on these issues that need to be integrated with, the ‘pillar’ Workpackages 2-5.

WP6: SOCIO- AND ECOLOGICAL ECONOMICS
Developing an integrative approach in the field of socio- and ecological economics by analyzing and improving (e.g. through cost – benefit considerations) environmental decision-making scenarios and their implications for both the environment and human socioeconomy, by *inter alia*: the elaboration and selection of interlinked environmental and socioeconomic indicators related to measuring the performance of sustainable development; environmental valuation (e.g. natural capital arising from ecological goods and services) and ‘green’ accounting; improvement of environmental policies through fostering the use of economic, regulatory, and institutional instruments for enhancing environmental management; improvement of governance systems leading to better cross-sectoral representation and consensus regarding the integration of environmental issues into decision-making processes regarding

coastal zone management, rational utilization of commercially important living resources, and nature conservation; and not least, the elaboration and provision of educational, capacity-building and outreach activities for emphasizing the dependence of human socioeconomic sustainability on ecological sustainability.

Key potential research and application issues are further described below:

a) In collaboration with other relevant WPs, conducting, with the help of qualitative and quantitative modeling techniques where applicable, socioeconomic root cause/casual chain analyses (including when appropriate use of qualitative and quantitative models) concerning human drivers of environmental/ecological impacts in the Baltic Sea, and identifying cost-effective management actions and measures to redress the root causes.
b) In collaboration with other relevant WPs, conceptualizing and developing studies, projects, and analysis in the field of environmental scenarios, and developing/further elaborating novel methodologies and approaches to environmental scenarios. Such measures should contribute to the implementation of a strategic approach to scenarios and future studies.
c) In collaboration with other relevant WPs, investigating and evaluating management options for sustainable use of marine resources including ecological goods and services produced by the Baltic Sea and taking into account the conflicts of interest among user groups.
d) In collaboration with other relevant WPs, conducting economic analyses of water use, at the basin scale, for the Baltic Sea region as required by the EC WFD.
e) In collaboration with other relevant WPs, establishing a network of experts in socioeconomics who are conversant with environmental and fisheries issues. In the fisheries area, the European Association of Fisheries Economists (EAFE) has been highlighted as a valuable network of excellence to consider collaborative activities of mutual benefit. However, it should be noted that the newly acceded EU States in the Baltic currently have no single scientist or institution that is a member of EAFE.
f) In collaboration with WP3, developing various scenarios for future development in the fishing industry and the fish-processing industry of the Baltic Sea countries, and calculating the implications of these scenarios on the national economies of the region.
g) In collaboration with WP 3, analyzing the development of the fishing sector of the new EU Member States (*i.e.* Estonia, Latvia, Lithuania, Poland) during the post-Soviet period, taking into account *inter alia* the structure of the fishing sector in the national legislation, employment in the fishing sector during the post-Soviet period, catch statistics, property rights in fishing, and the structure of national databases.
h) In collaboration with WP3, evaluating and further developing bioeconomic models for the fisheries of the Baltic Sea region.
i) In collaboration with WP3, conducting a needs assessment regarding fisheries economics data in the Baltic Sea. In this process, open access of databases should be promoted for international quality assurance and compatibility purposes as well as for supporting international collaboration.
j) Investigating the cost structure, capacity, profitability, and value of the catch from Baltic Sea fleets, and the costs of fisheries management.
k) In collaboration with WP 3 and 4, analyzing the value and wider socioeconomic implications of recreational fisheries in the Baltic Sea region.
l) In collaboration with WPs 2-5, developing socioeconomic indicators regarding a) effects of eutrophication, b) effects of hazardous substances, c) impacts of fisheries, and d) biodiversity loss, concerning ‘direct’ and ‘indirect’ effects related to ecological ‘goods and services’.
m) In collaboration with other relevant WPs, developing GIS-based maps for the Baltic Sea region showing the spatial distribution and abundance of living marine resources/biodiversity (both species and habitats) and the distribution and abundance of human populations (*e.g.* municipalities, industries, ports/harbours) and their activities/impacts (*e.g.* eutrophication, fisheries/fishing effort, pollution, sand and gravel extraction, *etc*.) with a view to linking socio- and ecological economics.
n) In collaboration with WP3, examining the likely socioeconomic cost-benefit of dispensing with common property rights (‘tragedy of the commons’) in the exploitation and management of living marine resources, including evaluating promising alternative options.
o) In collaboration with other WPs, further developing appropriate environmental policies for the Baltic Sea region through fostering the use of economic, regulatory, and institutional instruments for enhancing environmental management.
p) In collaboration with other WPs, outlining ways to improve governance systems leading to better cross-

sectoral representation and consensus regarding the integration of environmental issues into decision-making processes for coastal zone management, utilization of commercially important living resources, and nature conservation.

q) In collaboration with WPs 3 and 4, examining possible ways to increase the understanding of stakeholders in the food sector of their action on nature and biodiversity by contributing to the integration of nature and biological diversity into food sector policies and programmes.

r) In collaboration with other relevant WPs, developing demonstration projects for the application of ICZM in particular sub-areas of the Baltic Sea, with a view to achieving sustainable development as well as limiting conflicts among multiple users of coastal and marine environments.

s) In collaboration with WP7 and WP8, strengthening interaction with the wider public and decision-makers, and outlining and further developing schemes for educational, capacity-building and outreach activities for emphasizing the dependence of human socioeconomic sustainability on ecological sustainability.

2.6.2 Background

Policy and management

The ecosystem approach is embedded in the concept of sustainable development, which requires that the needs of future generations are not compromised by the actions of people today. Thus, emphasis is placed on maintaining the health of the ecosystem alongside appropriate human use of the marine environment, for the benefit of current and future generations (UN 1987). Application of the ecosystem approach is based on a long-term perspective, and highlights the dependence of human economic and social sustainability on ecological sustainability (JMM 2003a).

'Agenda 21 for the Baltic Sea Region – Baltic 21' is an international, long-term process started by the Prime Ministers of the 11 Member States of the Council of Baltic Sea States (CBSS – the nine Baltic Sea Coastal States and Iceland and Norway) in 1996. Baltic 21 has the objective of attaining sustainable development in the Baltic Sea Region. The Baltic 21 members include the CBSS Member States, the European Commission, intergovernmental organizations, international networks of sub-regional and local authorities, international financial institutions and various other non-governmental organizations.

The CBSS countries differ widely as far as economic, social and environmental preconditions are concerned, but they agree on the long-term goals they wish to attain for the region as a whole. The emphasis is on regional cooperation, and the work is focused on seven economic sectors (*i.e.* agriculture, energy, fisheries, forests, industry, tourism and transport) as well as on spatial planning and education. The Baltic 21 Action Programme addresses the three dimensions of sustainable development, *viz.* the environmental, social and the economic aspects, and includes goals and indicators. It features 30 different actions, both sectoral and cross-sectoral, which are mostly of pilot and demonstration character and address the transition to sustainable development in the Baltic Sea Region. Criteria for sustainability include *inter alia* the consideration of social equality, environmental protection and corresponding socioeconomic aspects such as economic development, education schemes, democracy and governance.

The Mission of Baltic 21 is to pursue sustainable development in the Baltic Sea Region by regional multi-stakeholder cooperation. Accordingly, Baltic 21 provides a regional network to implement the globally agreed Agenda 21 and World Summit on Sustainable Development activities, while focusing on the regional context of sustainable development. During the 5th Baltic Sea States Summit in June 2004 in Estonia, while taking note of the Baltic 21 Five-Year Report, the Heads of Government underlined the importance of integrating the principles of sustainable development into policy making by all relevant stakeholders and expressed their interest in the Baltic 21-proposed concept of making the Baltic Sea region an Eco-Region for Sustainable Development covering the economic, ecological and social spheres. Further information regarding Baltic 21 is found at: <http://www.baltic21.org/>.

Article 5 of the WFD requires Member States to carry out an economic analysis of water use at a basin scale. This is to help decision-makers and the public make more rational judgments about the allocation of resources and the costs/benefits of activities that impinge on the aquatic environment *e.g.* the cost of pesticide removal, value of wetland amenity, *etc*. Economic analysis will also inform decision-makers about the applicability of derogations. Article 9 requires Member States to fully recover the costs of *'Water Services'* (*e.g.* supply of water and disposal of effluent) including the costs of environmental and resource impacts.

Socioeconomic importance of the Baltic Sea region

The Baltic Sea region has a long history of multiple usage by people from many nations (Jansson & Velner 1995). There is a need to safeguard the marine ecosystem and to achieve sustainability in respect of human use. Knowledge of the main human pressures and understanding their impact is essential for the development and implementation of effective measures to achieve sustainable use.

Many human activities occur in the Baltic Sea region:

- *Recreation and tourism* in coastal areas and adjacent land is an important social and economic activity with intense development pressure;
- *fishing* and *mariculture* mainly directed at fish and shellfish;
- *coastal engineering* includes the damming of rivers, but also beach nourishment, diking and land reclamation;
- *power generation* by wave energy and windmills ('wind-farms') are currently limited to relatively few locations but are anticipated to increase substantially in numbers;
- *mineral extraction* (*e.g.* sand and gravel, calcium carbonate shell aggregates) takes place in nearshore areas;
- *dumping* of waste or other matter is prohibited (*e.g.* by HELCOM, MARPOL, and various EC Directives) except *dredged material* (for maintenance dredging, and laying of cables and pipelines), waste from fish processing, and inert material of natural origin. *Litter* generated by fishing vessels and commercial shipping, and tourism and recreational activities causes substantial problems;
- *shipping* is prominent in the area, with some of Europe's largest ports being situated on the coasts in bays and estuaries;
- *oil and gas* exploration and exploitation has become a major economic activity in the region, particularly in the eastern areas;
- *coastal industries* of various kinds are located along the coasts and estuaries of the region, often requiring large amounts of water for cooling and washing purposes;
- *military use* of the sea, including coastguard and fishery protection/compliance patrols, and naval exercises.

Approximately 90 million people live within the catchment area of the Baltic Sea and put great pressure on the region (Sweitzer *et al.* 1996; Palmer 2005). The number of people in coastal areas varies substantially on a seasonal basis due to tourism and leisure activities.

The environment of the Baltic Sea region provides socioeconomic benefits based on biodiversity, and renewable and non-renewable resources (Gren *et al.* 2000). Recreation and tourism also provide high socioeconomic value, with tourism being placed amongst the most highly valued global industries. The sea and its interactions with the land and the atmosphere have a valuable role in maintaining climate stability and moderating climate change. Few of these aspects have been properly quantified. Governments are resorting to new priorities, whereby economic growth has to be replaced by sustainable development as an overriding goal to a) support a healthy economic development, b) achieve general welfare, c) protect the environment and d) safeguard its living resources.

The future development of coastal zones requires careful spatial planning and control, and the many different—and potentially conflicting—uses coordinated in line with the principle of sustainability. Towards this end, ICZM seeks, over the long-term, to balance the respective benefits from *inter alia*: economic development and human uses of the coastal zone; protecting, preserving and restoring coastal zones; minimizing loss of human life and property; public access to and enjoyment of the coastal zone; all within the limits set by natural dynamics and carrying capacity (EC 2000).

Intrinsic value of nature: ecological goods and services

Healthy ecosystems perform a diverse array of essential functions that provide both goods and services to humanity, in which '***goods***' refers to items given monetary value in the market place and '***services***' from ecosystems are valued but rarely bought and sold (Lubchenco 1994; Edwards-Jones *et al.* 2000; Nilsen *et al.* 2002). For example, ecosystem goods are food (*e.g.* from fisheries and aquaculture), medicinal materials, raw materials and wild genes, while ecosystem services include maintaining the hydrological cycle and composition of the atmosphere, regulating climate; storing and recycling essential nutrients; absorbing and detoxifying pollutants; sustaining food webs and habitats; generating and maintaining sediments and reefs; providing sites for tourism, recreation and research. The sustainability concept depends on two aspects: sustainability of use (sustainable use) and sustainability of ecological resources and their associated ecosystem. These aspects are tightly connected as sustainable use of ecological resources can only be achieved if these resources themselves are sustainable. Thus, the ecosystem approach to management involves, *inter alia*, a paradigm shift from managing commodities towards sustaining the production potential for both ecosystem goods and services (*i.e.* 'natural capital') (Costanza *et al.* 1997). Ecological economists have valued global marine industries (*i.e.* producing goods/commodities) at about USD one trillion, but that of marine ecosystem services is about USD 21 trillion or equivalent to 60% of the world's ecosystem services (Costanza *et al.* 1997). By comparison, marine industries account for only about 4% of the global GDP. Thus, the life support system of the globe is connected with the oceans.

It is essential to comprehensively develop capacity to create prudent, long-term, integrated and holistic multidisciplinary solutions involving sustainable use of the sea while also resolving the interests of a wide range of industries and other relevant stakeholders. For example, the following human activities benefit from as well as potentially impact the sustainability of the marine environment and its living marine resources in coastal and offshore areas: Oil and gas exploration and production; power generation including wind-farms; dredging and dumping of wastes and litter; mineral and aggregate extraction; fisheries and mariculture; coastal engineering and land reclamation; human settlements and coastal industries; and recreation and tourism.

Knowledge of the human pressures and understanding of their impact on the structure and function of the ecosystem and its resources is essential for the development and implementation of effective measures to achieve sustainable use. Accordingly, it is essential to devise and implement locally relevant, area-based management of marine ecosystems by using indicators for setting targets (goals) and limits (outside which we should not transgress) for environmental or ecological quality, and applying the precautionary principle and the ecosystem approach to management. It is essential to manage human activities at the appropriate spatial scale and identify what activity/use is appropriate for parts or the whole of the area, *i.e.* who is allowed or not allowed access to it and under what conditions. Thus, one must establish management policies and rules for particular marine areas, defining their specific purpose and use, for example, through the application of ICZM.

Many so-called MPAs are multiple use conservation areas that permit both consumptive and non-consumptive activities (*e.g.* responsible fishing, diving, boating and swimming). They include national marine sanctuaries, research reserves, national parks and wildlife refuges with marine components, and underwater parks. Multiple use MPAs function both to protect ecosystems and, at times, to support sustainable fisheries and mariculture while allowing access for recreation and tourism. MPAs have a key role to play in ocean and seabed cultivation schemes that promote the restoration of environmental quality and the production potential for both ecosystem goods and services. In order to function optimally, such areas need to have clear management plans and associated rules outlining *inter alia* their purpose, access and usage.

2.6.3 Major ongoing international collaboration activities of relevance to the workpackage

- Under the auspices of ICES, scientific issues connected with socio- and ecological economics are addressed in the following expert groups: Working Group on Fishery Systems (WGFS); Working Group on Integrated Coastal Zone Management (WGICZM); Study Group on Information Needs for Coastal Zone Management (SGINC);

- There is also a joint ICES/BSRP Study Group on Baltic Ecosystem Health Issues (SGEH) that has recently begun to consider issues connected with socio- and ecological economics in its work.
- The recently established BSRP Socioeconomy Coordination Centre (Tallinn, Estonia) has *inter alia* focused on establishing a network in socioeconomics related to environmental and fisheries issues. In this connection, a mapping exercise is being conducted of socioeconomically-related Study/Working Groups in ICES with a view to coopting established experts and also to train developing experts from the BSRP beneficiary countries. Other BSRP connected initiatives of relevance include holding the 2005 ICES BSRP/HELCOM/UNEP Regional Sea Workshop on Baltic Sea Ecosystem Health where *inter alia* obligatory terms of reference were set for four sub-groups (Effects of eutrophication; Effects of Hazardous substances; Impacts of Fisheries; Biodiversity loss) working under the ICES BSRP Study Group on Ecosystem Health to develop socioeconomic indicators in the area of direct and indirect effects related to ecological goods and services.
- EC funded research projects (FP5 and FP6) of relevance with Baltic links include: COST IMPACT – Costing the Impact of Demersal Fishing on Marine Ecosystem Processes and Biodiversity; EAEF – Economic Assessment of European Fisheries.
- Research projects, recently funded by the Nordic Council of Ministers, of relevance with Baltic links include: Cost effective reduction of the nutrient load to the Baltic Sea sub-basin – combining economics and ecology.

2.7 Workpackage 7: Synthesis and dissemination

Workpackage 7 acts in a 'cross-cutting' capacity, being designed not only to provide essential information and outputs concerning synthesis and dissemination in its own right but also to provide essential inputs on this topic that affect, and need to be integrated with, the 'pillar' Workpackages 2-5.

2.7.1 Potential BONUS-169 research and application issues

The candidate tasks/activities of relevance for inclusion under WP 7 have their origin to a large extent, although not exclusively, under the respective science-driven WPs. When the full range of potential individual issues (*i.e.* bullet points) under the six science based WPs (*i.e.* 1-6) have been fully elaborated, vetted and approved, a definitive list of candidate issues applicable to the focus of WP6 should be highlighted in an appropriate matrix under this sub-section.

WP7: SYNTHESIS AND DISSEMINATION

A major role of the programme is the synthesis and dissemination of sound and objective scientific information and knowledge, in a timely manner, to a wider public regarding the importance of healthy marine ecosystems and their relation to humanity, as a basis for education and understanding underpinning appropriately informed public opinion, policies and political will for their implementation. This requires focus at all appropriate levels within the programme, as well as interactions between the programme and numerous potential stakeholders using all available media, arrangement of dedicated meetings (e.g. workshops and conferences) and other opportunities. Cooperative education and capacity building schemes, aimed at young scientists and technicians, should figure prominently in the programme.

Key potential research and application issues are further described below:

General matters:

a) Conducting a mapping exercise to identify the stakeholders/users (*e.g.* shipping, aquaculture, fisheries, offshore oil and gas, ports/harbour, customs and border control, tourism and recreation, secondary and tertiary education and environmental sectors) for information dissemination on the issues addressed by the programme, and determining the most effective ways (*e.g.* media) for such dissemination.
b) Establishing lines of communication with national and international media outlets that are interested in scientific information on marine ecosystems and human activities depending on, and affecting, them.
c) Developing tools and approaches for synthesizing and analyzing information on multiple marine

ecological disturbances in the region, including quantification of financial costs to human society from losses of resources, recreational opportunities, and in remedial actions.

d) Producing a range of products (*e.g.* reports and articles, chapters in books, peer-reviewed papers in scientific journals, brochures, newsletters, web-pages) regarding synthesis and dissemination of key issues being tackled by the programme in paper and electronic media, as well as arranging workshops, study/groups, and conferences that promote wider networking to enhance synthesis and information dissemination.

e) Developing a relational bibliography, using an appropriate database, for all the documents and presentations emanating from BONUS-169 and make this widely available via the programme's website portal.

f) Preparing documentation of important scientific accomplishments by the programme tailored for non-scientists.

g) Maximizing the use of electronic media to distribute the programme's scientifically-based products, including electronic publications and the programme's website as a source of 'living documents' that are updated as soon as new information is produced. In this context, also developing a pilot project examining the possibility to provide continuous and real-time assessments of the changing state of the Baltic marine environment and its associated ecosystems, the natural and human induced causes of these changes, and the consequences for human socioeconomics.

h) Preparing a list of subject matter experts from within the programme community to serve as media contacts on important issues.

i) Producing popularized scientific presentations aimed at specific stakeholders (*e.g.* TV, radio, magazines, newspapers, internet), and improving the education and understanding of journalists, regarding important issues addressed by the programme.

j) From knowledge provided within each of the programme's core science WPs (*i.e.* WPs 1-6), identifying potential national and international workshops and training courses, *etc*., that can be conducted to disseminate information on important issues and features such as threats, risks and impacts, management/regulation, combating and control practices, for specific stakeholders.

k) Promoting active national participation from the programme in governmental and non-governmental organizations (NGOs) that further the timely exchange of information and knowledge on major scientific issues of relevance to management and regulation. For example, in the case of alien invasive species, such activities include *inter alia* those connected with the: CBD's Conference of the Parties (COP), its Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) and its Clearing House Mechanism (CHM); European Environment Agency (EEA); European Inland Fisheries Advisory Commission (EIFAC); European Research Network on Aquatic Invasive Species (ERNAIS); Global Invasive Species Programme (GISP) and its Information Management Working Group (IMWG); ICES Working Group on Introductions and Transfers of Marine Organisms (WGITMO); Joint ICES/IMO/IOC Study Group on Ballast Water and Other Ship Vectors; IMO's Marine Environment Protection Committee (MEPC) and its subsidiary Ballast Water Working Group (BWWG); Nordic – Baltic Network on Invasive Species (NOBANIS); Nordic - Baltic Invasive Species Information Management Working Group (WGISIM); HELCOM's HABITAT, MONAS, MARITIME; IUCN Invasive Species Specialist Group (ISSG); Regional Biological Invasions Center (RBIC); World Organization for Animal Health (OIE); and Databases such as the FAO Database on Introductions of Aquatic Species (DIAS), GISP's Global Invasive Species Database (GISD).

l) Facilitating the education and training of young scientists and technicians through building intellectual, technological and information integration skills in a large multidisciplinary forum. This should include developing a BONUS-169 Training Plan with a view to enhancing the capacity of young scientists and technicians connected with the programme.

m) Developing, as a potential pilot project for eventual implementation, a formalized pan-Baltic education and training strategy involving research and teaching institutions in the coastal countries with a view to providing a commonly accepted system of electives, credits and inter-comparable gradings for undergraduate and post-graduate students connected with natural and social sciences focusing on the Baltic Sea region.

n) Supporting the potential establishment, with appropriate justification, of a system of Centres and Networks of Excellence that will further the overall aims of BONUS-169.

o) In collaboration with WPs 1-6 and WP8, strengthening interaction with decision-makers, with emphasis on demonstrating the dependence of human socioeconomic development on ecological sustainability, and application of the ecosystem approach, including combating the causes of human induced climate change, eutrophication, pollution, unsustainable fisheries and aquaculture, and biodiversity loss.

p) In collaboration with WP7, promoting education, building capacity and conducting outreach activities at the regional level.

2.7.2 Background

Internal and external interactions

In BONUS-169, which is a multifaceted programme involving many scientific disciplines and potential stakeholders, the extensive synthesis and dissemination of results and information is of paramount importance. Thus, synthesis and dissemination outputs—regarding information emanating from the programme as well as from synthesizing information and data originating prior to the programme—must be far-reaching, relevant, responsive, sound and credible with respect to marine ecosystems and their relation to humanity. Ultimately, the greatest contribution made by sound scientific information and knowledge may be the influence it has on public opinion. Thus, BONUS-169 should play a major role in making objective scientific information and knowledge—which is easily assimilated—promptly accessible to a wider public, as a basis for education and understanding underpinning public opinion and policy-making.

Synthesis and dissemination of information arising within BONUS-169 must take place at all appropriate levels, and a proactive approach must be put in place in the form of structures and mechanisms to ensure that integration, synthesis and dissemination occurs across diverse scientific disciplines and management-related issues. There are two main levels that need to be considered: a) internal interactions within the programme itself, and b) interactions between the programme and outside, and *vice versa*.

Awareness of the need for synthesis and dissemination within BONUS-169 must be highlighted from the grass roots upwards and from the leadership downwards. For this purpose, a **Liaison Committee** (LC) should be established for ***inter alia*** identifying topics/issues for closer scientific integration and overseeing the conduct of the associated work, as well as developing robust strategies for promoting synthesis and dissemination, *i.e.* planning, directing, ensuring follow-up and generally overseeing the synthesis and dissemination process. An important goal is to provide timely information to the funders, users and other stakeholders, the wider scientific society and the public, including policy makers, about the aims, scope and results of the programme.

One of the main objectives of the programme is to publish the majority of scientific documents in peer-reviewed journals, thereby raising the quality of the product and assisting in training young scientists to engage in this publication process. However, there is a very important requirement for information and results from the programme to be distributed in a timely and effective fashion not only in English but also as national language products aimed at home-based user institutions and groups throughout the Baltic Sea countries. Information dissipation should maximize use of the existing communication media of the users and stakeholders.

The importance of political commitment, complemented by broad-based public support, needs to be recognized as a critical element for achieving success in protection and restoration of the Baltic Sea environment over the long-term. Thus, it is essential that the programme is able to highlight itself in order to gain political appreciation of its objectives and achievements. In this connection, public understanding and awareness of the scientific and management issues concerning the Baltic Sea environment remains essential for achieving and maintaining the political will necessary to carry out necessary action at the regional and national levels.

The dissemination of information and results is a vital aspect of any programme that has a wide stakeholder base. Effective information dissemination in BONUS-169 requires the development of a concerted Action Plan as part of an 'outreach' strategy aimed at achieving maximum contact and understanding amongst the various groups of stakeholders. Depending on the identified needs and the targeted recipients and collaborators, the products emerging from the programme will, for example, include:

- For the general public: nationally, brochures, posters, newspaper articles, and TV and radio presentations;
- For users: national web-page with aims, scope, results and general information (*e.g.* aimed at managers and workers in the appropriate maritime related sectors). Links to other relevant web-sites concerning references to management related documents (*e.g.* guidelines, protocols, codes of practice);
- Scientific society and international organizations: English web-page with aims, scope, results and general information. Participation in international working groups/workshops, and symposia /conferences. Published reports, chapters in books, and scientific papers in international peer-reviewed journals, links to other publications and relevant websites.

BONUS-169 will develop its own website and portal, linking it to a network of websites at the national, regional and global levels.

Within and between various WPs, it will be necessary to establish a number of specific ***Ad Hoc* Groups** (*e.g.* study/working/expert groups) **and workshops** to facilitate exchange and integration of views and arrive at robust conclusions, based on consensus, involving the diversity of individuals, institutions, and disciplines. Such activities should be constituted on the basis of a wide multinational representation. These should be given terms of reference that are periodically updated, to ensure that timely results are produced, targets are met and continuous progress is made. These activities will end up with reports for further critique and dissemination within the programme as a whole. This will be the responsibility of the specific WP Coordinators and their supporting networks (*e.g.* Project/Task Leaders), overseen by the Executive Management Committee (EMC, see WP8). Additionally, personnel at the task level will be expected to participate in the activities of relevant international scientific working groups and workshops (*e.g.* EEA, ICES, HELCOM), for information and exchange purposes. It may also be possible to establish joint groups and workshops with international organizations.

The programme should arrange an **Annual BONUS-169 Forum** (ABF) (ca. 3-4 days duration), functioning as a conference to bring the scientists, managers/regulators and other stakeholders together to strengthen collegiality and personal relationships, build confidence, present and discuss results, provide critique and feedback regarding progress, and to conduct necessary planning for the coming year.

BONUS-169, as a regional seas initiative, depends not only on close interaction with marine science and policy matters in the Baltic Sea region but also with other regional seas initiatives and also relevant initiatives at the wider international scale. For BONUS-169, close collaboration is essential at the appropriate scales concerning knowledge in the form of gathering and disseminating information including best practice. Numerous activities and institutions act as regional and global forums associated with science, advice and policy aspects of relevance to BONUS-169. Some of which have established database facilities (*e.g.* in exchange of information on IAS, *etc*). These and other relevant forums will be used for the exchange of information, data and knowledge from the programme, and for the rapid reporting of results of relevance for operational purposes in advisory and management contexts. Accordingly, BONUS-169 will seek to formally (*e.g.* through memoranda of cooperation or similar instruments) establish close collaboration and coordination with a wide range of activities and organizations. It should be noted that the Baltic Sea States associated with BONUS-169, together with their institutions and personnel, are already actively involved at the regional and global levels with the majority of relevant activities and organizations.

Relevant international organizations, at both the regional and global levels, need to be notified and periodically updated about developments and outputs from BONUS-169 and *vice versa*. In this context, particularly influential organizations, including their subsidiary bodies (*e.g.* committees, expert technical working groups), are (in alphabetical order): BMB, CBD, EC (Directorates General for Science, Environment and Fisheries), EEA, FAO (Fisheries Dept., including IAS matters), GEF, HELCOM, ICES, IMO, and NCM, In due course, an appropriate representational and promotional system for BONUS-169 should be considered, which may *inter alia* make use of the existing representatives of the various Baltic Sea States in these organizations, *e.g.* specified persons/countries may be nominated to act in an observer capacity on behalf of BONUS-169 in the relevant meetings of given organizations.

The role of users and other stakeholders in quality assurance and relevance

A range of stakeholders (see WP 8) should be consulted in the overall synthesis and dissemination process. These should be identified at the relevance level of each of the eight WPs by using an appropriate mapping-exercise. Their role is *inter alia* to ensure that the scientific approach used and the results generated are based on a real understanding of the stakeholder's working situation and operative needs concerning science, management, regulatory and policy fields. As these stakeholders have diverse viewpoints and practical experience, their input and critique is essential to facilitate the knowledge integration process, to promote wider dialogue and common understanding, cooperation and confidence building, information exchange, capacity building and relevant 'outreach activities'. They will also play an important role in evaluating the advantages and disadvantages of the possible outcomes of the project for their constituents and work areas. The stakeholders should have access to all information and reports arising from the programme's scientific production, and should be invited to attend all major project meetings (*e.g.* Annual BONUS-169 Forum). The stakeholders should be requested to identify means (*e.g.* financial and 'in kind' contributions) by which they can support the aims of the project regarding information dissemination and outreach activities.

Synthesizing information for analyzing marine ecological disturbances

The Baltic Sea region has been subjected to outbreaks of harmful algal blooms, fish kills, marine mammal and waterbird mortalities, anoxia, food web dysfunction, invasive species, marine disease epidemics, beach closures, human illness, and compromised seafood quality. These are the more apparent of the multiple marine ecological disturbances (MMEDs) affecting the region. Because these marine disturbances are not easily isolated in space, monitored in real time, or constrained through the actions of a single jurisdiction, a whole ecosystem approach is needed to monitor, assess, and mitigate the stressors on the ecosystem from MMEDs. The impact of MMEDs on the Baltic Sea region carries enormous, but as yet not fully quantified, financial costs from losses of resources, recreational opportunities, and in remedial actions. Recognition that the health of the Baltic is degraded has motivated decades of costly data collection. However, these data are highly sectorized and fragmented spatially and temporally. Results of studies pertinent to MMED assessment and mitigation remain scattered among thousands of peer-reviewed scientific articles, a network of government and academic researchers, reports, journals, semi-public (*e.g.* grey literature) depositories, existing data-sets and, for recent and current events, mass-media sources including the Internet. The key to recovering the loss of useful information within the Baltic region is to mine the results of already completed studies and to create or reconstruct critical time-series of events and observations in an electronically based system suitable for near-real time tracking of changes in ecosystem health. The methodology for introducing the HEED (Health, Ecological and Economic Dimensions of Global Change program, <http://www.heedmd.org/>), monitoring and assessment system for use in the Baltic Sea region has been transferred and integrated into a Baltic/MMED system for testing and evaluation, and implementation by Baltic Sea coastal countries (Sherman 2001). Existing components, including the Baltic Map Server (MAPBSR) and pertinent GIS Internet development by HELCOM, will be utilized along with GRID-Warsaw, GRID-Arendal, and the GIS layering capability developed during BALTEX for bathymetry, hydrography, sea surface temperature, salinity, oxygen, nutrients, and ocean colour. Tracking the status and trends of MMED events will facilitate a better understanding of the local and region-wide causes and impacts of such environmental change. This information can be used in assessing the resulting costs in terms of human and ecological health (*e.g.* socioeconomics and ecological economics). It can provide the background for development of policies for preserving ecosystem integrity, and reducing vulnerability to disturbance.

Education and capacity building

Education, training and capacity building are paramount to the overall aims of BONUS-169.

BONUS-169 should facilitate the education and training of young scientists at the M.Sc., Ph.D. and Post Doctoral levels through building skills in combining and integrating results in a large multidisciplinary forum. For these young scientists, the programme will provide access to sampling and data-handling opportunities both at sea and in the laboratory. The component projects including young qualified scientists and students are a core resource. Communal programme activities (*e.g.* workshops and study/working groups) will provide a great opportunity for junior personnel to experience work entailing associated design and analysis, and discuss and learn from senior colleagues, both from the region as well as international acclaimed experts ('peers') from outside the region.

Human capacity building should also take place through formal training funded by the programme. To this end, a BONUS-169 Training Plan should be developed that *inter alia* provides information on the current training capacity of the collaborating Baltic coastal countries, especially those in economic transition, and which is needs-driven. Education, training and capacity building must in due course contribute to the robustness, cost-effectiveness and sustainability of the ecosystem-based management systems being put in place for the long-term. The justification lies in the optimal and sustainable utilization and conservation of the living marine resources of the Baltic Sea area in the associated healthy ecosystems, and provides two main goals to achieve this, *i.e.* a) improved knowledge, and b) increased capacity. Cross-cutting issues are manifest in the basic aspects of relevance, quality and sociopolitical balance (*i.e.* fair and equitable country-driven) that forms an important inherent goal of the programme. Some of the capacity and training issues will be evaluated by suitable mechanisms, especially regarding quality in relation to production of knowledge and science in the domain of the standard peer review process. The peer review process acts when diverse project related reports and publications are presented and critiqued in a wider international forum formed by the programme itself and supplemented by the invitation of international experts ('peers') from outside the Baltic Sea region to participate in technical study groups/workshops is another mechanism for receiving advice and peer review.

The capacity building component of the BONUS-169 should be addressed through a number of task-orientated framework activities relevant to the science and technology component of the programme. These activities, which include training, the development of databases and communication networks, the optimization and sharing of facilities including research vessel time, the development of system and population models, and technology acquisition and transfer *per se*, will be tackled as collective objectives for: 1) building human capacity in the region, particularly in areas of greatest need and disadvantage; 2) developing, enhancing and maintaining the national and regional infrastructure and cooperation that is needed to support marine science and technology in the region for the purpose of conducting timely and effective surveys, monitoring and assessment obligations connected ecosystem-based management; and 3) making the region's coastal countries, and thereby the region as a whole, more autonomous in marine science and technology, so that the ecosystem-based management of the Baltic Sea can be conducted nationally and internationally on a sustainable basis for the benefit of local human communities.

The most important means of capacity building in BONUS-169 lies in opportunities for 'hands on' training which takes place through participation in key activities including projects, travel and exchange schemes, study/working groups, workshops and participation in other relevant forums. These activities provide young scientists and junior personnel a direct insight into the basic skills of science including project planning and logistics, sampling design, sample processing, data analysis, writing reports and publications and presenting results at conferences. Participation in discussions concerning task planning and interactions with the stakeholders of scientific outputs form excellent means to get an understanding of the relationship between science and the management of human activities connected with exploitation of natural resources and the protection of the marine environment and maintenance of ecosystem health. Participation in study groups and workshops provide an unsurpassed opportunity for junior personnel to experience the work with associated design and analysis, and discuss and learn from senior colleagues, from the region as well as from experts from outside the Baltic Sea region. In addition to formal training for researchers, general technical training (*e.g.* for laboratory and sea-going technicians) represents a priority training area. Training and intercalibration activities in the fields of oceanography/meteorology and environmental sciences, fisheries biology, gear technology and electronic instrumentation represent potentially important areas of focus.

The Baltic Sea region has several reputable institutions involved in maritime-related education and training. As is normal elsewhere in the world, the graduates being produced are primarily products of a sector-orientated approach to education whereby the major disciplines that are followed are either primarily academically orientated (*e.g.* marine biology) or are mainly focused on a single core-industry sector (*e.g.* fisheries). As a result, the responsible institutions tend to be highly focused, rather fragmented and loosely aligned regarding their collaboration. As many of today's challenges are increasingly of a multidisciplinary and inter-sectoral nature, there is also a need to produce professionals who have a wider cross-sectoral awareness and understanding of the main national and international aspects of marine industries, policy, best practices, and management and regulation including litigation, while also recognizing the importance of marine biodiversity and ecosystem conservation as essential elements of sustainable development. Accordingly, the question arises as to how this type of complementary broad-based training and education can be brought about in a cost effective way? There are several options, including developing a Centre of Excellence (CoE), *e.g.* faculty, in one locality encompassing the necessary disciplines or developing a cooperative but disaggregated modular organization spread over several institutions in one or more localities but having a central Secretariat. For both these options, appropriate inter-institutional collaboration schemes and the possible benefits of forming a 'chapeau' association to strengthen their role and common interests in the future need to be examined. Additionally, an appropriate system of course electives, credits and inter-comparable grading needs to be designed for undergraduate and post-graduate students wishing to eventually specialize for particular purposes (*c.f.* EC Erasmus/Socrates). In achieving success in developing such an organizational system, it is essential that close interactions are established with the stakeholders and users.

Technical and infrastructural support, including both sharing and new procurement, is necessary to improve the capacity of institutions in Baltic Sea coastal countries to gather, analyze and report information and data of relevance to the goals of BONUS-169 (see WP 8). In this respect, funding may be used to level the R&D capacity in disadvantaged institutions/countries and simultaneously to support, where appropriate, the establishment of science networks and thematic CoEs at the regional or sub-regional levels.

Centres and networks of excellence

CoEs should play a major role in the programme's synthesis and dissemination process. Some already established CoEs situated in the Baltic coastal countries can be utilized or further built upon, while the need for potential new CoEs may be identified and established with respect to the needs of BONUS-169.

A CoE is a structure where research and technological development (RTD) is performed of world standard, in terms of measurable scientific production (including training) and/or technological innovation. Key features of a CoE include: a 'critical mass' of high level scientists and/or technology developers; a well-identified structure (mostly based on existing structures) having its own research agenda; capable of integrating connected fields and to associate complementary skills; capable of maintaining a high rate of exchange of qualified human resources; a dynamic role in the surrounding innovation system (adding value to knowledge); high levels of international visibility and scientific and/or industrial connectivity; a reasonable stability of funding and operating conditions over time (the basis for investing in people and building partnerships); sources of finance which are not dependent over time on public funding. The CoE should contribute to the longer term building of capacity in key scientific areas, including enhancing teaching capability at undergraduate and graduate levels, as well as being instrumental in the provision of scholarships.

Marine data management and policy

Data collection and databanking and optimal use of data will form a vital part of BONUS-169 during the lifetime of the programme and for posterity. BONUS-169 provides a major opportunity to further develop and integrate data collection and databases on a pan-Baltic scale.

Regarding the collection, use and availability of scientific data, it is essential that BONUS-169 should establish a **Marine Data Management Committee** to *inter alia* determine at an early stage the programme's Data Policy to be followed for data submission, access and exchange, and oversee the policy's implementation throughout the programme. Examples of international marine data management policies include:

- UN Intergovernmental Oceanographic Commission's IODE: <http://ioc.unesco.org/iode>; and
- EU MAST <http://www.sea-search.net/guidelines-practices/guidel02.htm>.

Currently, ICES performs databanking and datahandling services for international organizations concerning the Baltic Sea (e.g. HELCOM) as well as other European regional seas. Further information is provided at <http://www.ices.dk/datacentre/data_intro.asp>.

2.7.3 Major ongoing international collaboration activities of relevance to the workpackage

- International synthesis and dissemination activities, including the promotion of environmental and sustainable development education, regarding the Baltic Sea region occur to various degrees in HELCOM, ICES, NCM, Council of Baltic Sea States, Baltic Agenda 21, through numerous NGOs (*e.g.* CCB, WWF), and numerous multifaceted websites addressing various issues.

2.8 Workpackage 8: Management and infrastructure

Workpackage 8 acts in a 'cross-cutting' capacity, being designed not only to provide essential information and outputs concerning management and infrastructure in its own right but also to provide essential inputs on this topic that affect, and need to be integrated with, the other Workpackages.

2.8.1 Potential BONUS-169 management and infrastructure issues

WP8: MANAGEMENT AND INFRASTRUCTURE

Timely, effective and cohesive management at all levels of the programme, involving internal as well as external affairs, is vital for the success of BONUS-169. This should be achieved by implementation of a devolved yet communally accountable governance model involving the establishment of appropriate leadership structures and mechanisms, including the allocation of unambiguous roles and responsibilities—as defined by clearly formulated protocols and procedures—at the levels of key institutional bodies and personnel. BONUS-169 aspirations, in the context of Article 169 of the Treaty, require comprehensive access to and mobilization of shared infrastructures and facilities in a cost-effective manner, in order to secure both the quantity and quality of scientific outputs at the pan-Baltic level.

Key potential research and application issues are further described below:

a) Establishment of a range of appropriate institutional bodies, including: Programme Steering Committee, Scientific Advisory Panel, Finance Committee, Liaison Committee, Infrastructure Deployment Committee, Marine Data Management Committee (see WP7), Executive Management Committee, and Secretariat.
b) Nominating/Appointing key personnel, together with their alternates, including a Programme Manager, the membership of the above-mentioned bodies, Coordinators for the various Workpackages, and Leaders for the Work Tasks and Principle Investigators heading up the subsidiary project activities.
c) Producing an organogram showing the roles and relationships, positions and reporting pathways of all the major programme structures, in order to contribute to the smooth running of the programme. This should be supported by elaborating clearly formulated Rules of Procedure, Terms of Reference, Post Descriptions, and annually based Workplans outlining use of human, financial and infrastructure resources with milestones (*e.g.* deadlines) and anticipated deliverables.
d) Ensuring that the programme is complementary to and supportive of relevant national and international initiatives, helping to meet the objectives of these initiatives as well as its own, Memoranda of Cooperation should be developed defining the collaboration and working relationships involved (*e.g.* agreements for sharing of infrastructure and information/data, representation at relevant meetings), and the value added by the implementation of such cooperation.
e) Developing a full inventory of the major types of infrastructures available to BONUS-169 in the Baltic, identified by country, capability/performance of the infrastructure entity and extent to which such infrastructure entities can be deployed in the programme to the benefit of other countries and under what circumstances. For new, major infrastructures purchased via Community finances, these may be viewed as common property unless legitimate reasons to do otherwise are provided.
f) Overseeing the planning and arrangement of an Annual BONUS Forum functioning as a conference to bring the scientists, managers/regulators and other stakeholders together to strengthen collegiality and personal relationships, build confidence, present and discuss results, provide critique and feedback regarding progress, and to conduct necessary planning for the coming year.

g) Overseeing interactions with decision-makers, with emphasis on demonstrating the dependence of human socioeconomic development on ecological sustainability, and application of the ecosystem approach including combating the causes of human induced climate change, eutrophication, pollution, unsustainable fisheries and aquaculture, and biodiversity loss.
h) Overseeing the synthesis and integration of knowledge, the promotion of education, building capacity and conducting outreach activities at the regional level.

2.8.2 Dedicated management: Administrative structures and mechanisms

The European Commission anticipates that for Framework RTD projects one '*must put in place very robust management structures that are adequate for the size and complexity of the envisaged project*'. For this purpose, active monitoring and adaptive management are necessary at several levels. The accent on monitoring is placed on achieving progress in the form of outputs/deliverables according to agreed milestones. Accordingly, BONUS-169 must be able to respond to and administer the multiplicity of facets encompassed by such a major programme acting as a high-profile regional seas demonstration venture, involving: many countries, and numerous scientific disciplines and management issues; a very substantial budget; and, not least, of exceptionally high political importance regarding manifestation of Article 169. Accordingly, it is essential that appropriate structures and mechanisms are established 'for good order', which are mandated to address proactively the characteristic administrative and organizational areas that are of a repetitious nature. Thus, it is desirable to implement a devolved, representative and communally accountable governance model involving the establishment of appropriate leadership structures and mechanisms, including unambiguous roles and responsibilities of key institutional bodies and personnel. Ideally, this should link the management 'core' to the national (i.e. country-driven) and international stakeholders.

Management includes the management of each individual WP, and the overall management of the programme including high-level relations with funders, users and other key stakeholders, and external affairs at the wider international scale. A key feature of the workpackage also requires the identification and mobilization of important facets of **scientific infrastructure** (*e.g.* research vessels and ship-time, laboratory facilities, information and databases, libraries and bibliographies, *etc*.), in addition to 'open funding', that are central to the concepts inherent in application of Article 169.

The partners have defined the steering of a joint research programme as a task undertaken by a **Programme Steering Committee** (PSC) which has a mandate for managing the overall strategy of the programme. Thus, the PSC is the programme's superior body. For the partners, it is essential that the steering of the programme is anchored at national level, and that all partners are represented on the PSC. The national representatives comprising the PSC will be appointed by the empowered national authorities. The PSC tasks will *inter alia* include deciding on organizing and launching the common call for research proposals, appointing scientific experts to conduct the evaluations, and appointing the programme's management (see below). The PSC will also be responsible for deciding on the common criteria for evaluation and reporting, including the type and frequency of reporting. The PSC plays an important role in the evaluation process as it will provide a final ranking of the proposals after the evaluation panel has provided its rating. The PSC also provides recommendations for funding to the funding organizations.

The PSC should also develop a consultative process to encourage appropriate representation and participation of additional institutions from the public, private sectors (including non-governmental organizations) and international organizations, including initiating a survey to identify a wide range of potential **stakeholders** (*e.g.* users, interested parties, and potential additional funders) that support the aims of BONUS-169. These stakeholders may include a wide range of private and public organizations from the environmental, shipping/maritime, aquaculture, fisheries, health, agriculture/forestry, travel and transport, tourism and recreation, and trade and commerce sectors, as well as municipalities or local communities.

A **Scientific Advisory Panel** (SAP), consisting of experts of high international scientific standing covering together the areas of the programme as a whole should be appointed to support the PSC. It is anticipated that the composition of the SAP and the **Evaluation Panel(s)** (*i.e.* ranking the submitted project proposals) will exhibit some degree of overlap. However, the composition of the Evaluation Panel(s) must be sufficiently extensive to cover in a credible manner almost all aspects of the natural and social sciences.

A **Programme Manager** (PM) should be appointed by the PSC in a full-time position. The incumbent should be the Coordinator of WP 8 and should *inter alia*: through the auspices of the Programme Management Committee (see below) coordinate and monitor the activities described in the programme's Workplan, and ensure timeliness and quality of outputs; prepare progress reports and annual programme reports, and oversee the preparation of all substantive and operational reports required; prepare terms of reference for any engaged consultants, contractors and technical personnel; manage the overall budget and chair the Programme Management Committee (see below); and not least report to the PSC in person on progress *inter alia* to ensure sustained funding for the programme.

An **Executive Management Committee** (EMC), empowered to act on behalf of the Steering Committee, should be established to advise and support the Programme Manager conduct the daily management of the project and to provide a cohesive management of the whole programme. Besides the Programme Manager, the EMC should be composed of the Coordinators of the Workpackages. The PSC should work by holding monthly meetings and by electronic (*e.g.* phone and video) conferencing means. The mandate and duties of the EMC are to implement decisions made by the PSC, facilitate communications between the Workpackages, organize and coordinate the overall internal flow of results and deliverables in the programme, liaise with collaborating national and international activities and institutions to ensure maximum synergy, oversee the education and development of the new generation of scientists, and otherwise support the PSC. The EMC should plan and arrange an **Annual BONUS-169 Forum** (ABF) (ca. 3-4 days duration), subject to prior approval of the plans by the PSC (further details under WP7). *Ad hoc* technical groups and meetings may be convened to support the EMC as required.

A **Finance Committee** (FC) appointed by the PSC, should be established to periodically review the Budget and balance between income and expenditure of the programme as a whole, including ensuring the highest standards of financial propriety are followed as expected by the funding agencies. The FC should be supported by qualified independent Auditors who should annually check the programme funds for the purpose of preparing a Balance Sheet, including inspecting the funds. The FC will submit annual Budgets/Forecast Budgets, and the Audited Accounts for the approval of the PSC.

It is paramount that an **organogram** is produced at an early stage showing the roles and relationships, positions and reporting pathways of all the major structures involved in the programme, in order to contribute to the smooth running of the programme. This should be supplemented with the production of written **Rules of Procedure, Terms of Reference and Post Descriptions** encompassing all structures and key personnel positions/responsibilities in the programme.

To ensure that development of BONUS-169 is complementary to and supportive of relevant national and international initiatives, helping to meet the objectives of these initiatives as well as its own, **Memoranda of Cooperation** (see also WP 7) may be developed defining the collaboration and working relationships involved (*e.g.* agreements for sharing of infrastructure and information/data, representation at relevant meetings), and the value added by the implementation of such cooperation.

The **Coordinators of the Workpackages** (WPs 1-8) will have responsibility for achieving the specific WP goals. They will be supported by the **Leaders of the Work Tasks** forming their WPs and by the **Principle Investigators** heading up the various subsidiary project activities. Subject to merit, these should be appropriately representative at the national level.

The magnitude of the BONUS-169 programme requires the establishment of a **Secretariat**. In addition to mediating between the component partners and projects, the responsibilities of the Secretariat should encompass liaising between the programme entities (Steering Committee, EMC, *etc.*) and ensuring the flow of information between these entities, the study/working groups and the principal investigators including leaders of the WPs and subsidiary tasks and projects. A major part of the Secretariat's work is concerned with budgeting and financial affairs related to the programme funds, including overseeing yearly accounting of the expenditures from funds provided by the various funding agencies, being in charge of programme documentation, such as records of bursaries, project lists, and a general follow-up of project documents arising from meetings, workshops or other project-related group activities. Other functions of the Secretariat include: standardizing and integrating research and training proposals from the regional scientific and academic community into an annual Workplan that provides the rationale for the programme's research and training activities for each fiscal year; liaising between scientists and funding institutions regarding the drawing up of joint proposals for the Workplan; facilitating, and occasionally initiating, programme meetings, workshops, symposia, joint research cruises, and training activities; advertising and otherwise promote the programme regionally and abroad; maintaining links between the programme and affiliated international marine science programmes; and communicating the programme's activities to participants and other interested parties through the media and a regular newsletter; and producing an annual report on the programme's activities and achievements.

2.8.3 Infrastructure and facilities

Because the demands for resources, infrastructure and facilities are considerable, marine research is by its nature highly collaborative, and interdisciplinary mobilization of infrastructure and facilities are essential for effective research in disciplines spanning from fisheries, environmental, and oceanographic and meteorological sciences. Optimal access to infrastructures and facilities, and their further development, will be essential for securing both the quality and quantity of scientific outputs at the national and pan-Baltic level. BONUS-169 aspirations, not least in the context of Article 169 of the Treaty, will require comprehensive access to and mobilization of infrastructures in the most cost effective manner. This implies, in the Baltic regional context, internationally using and sharing existing infrastructures in a complementary and efficient manner in space and time, as well as conducting a gaps analysis involving the current inventory of infrastructure to identify deficiencies due to limited accessibility, advanced age and/or inadequate performance.

The need for a European Strategy on Marine Research Infrastructure has been emphasized recently by the European Strategy Forum for Marine Infrastructure (ESFRI 2003). The material conditions required for European scientists to advance marine science to its full capacity, according to ESFRI, can be summarized in four strategic visions for the coming decade:

- European research vessels and associated marine equipment will constitute a coherent, flexible facility that can effectively respond to a wide array of research needs in European and international waters.
- European waters will be supplied by a network of buoys, profilers and sea bottom observation systems that will provide coherent data for monitoring the state of the environment, for modelling the ocean system, for tracing climate changes, for early warning of hazardous events (*e.g.* harmful algal blooms, storms), for search and rescue, and for operational forecasting.
- Samples, data analysis and other information retrieved by European marine scientists will benefit from the networks of well equipped marine centres, which provide on-line access to data, calibration and quality control procedures.
- European marine research will be supported by an integrated and interactive information system provided by new information technologies.

Review of the diversity, operation, management and coordination of Europe's marine research infrastructures as well as future requirements and investments, revealed the need for: a) better coordination and management of diverse marine research infrastructures; b) long-term coherent planning of marine research infrastructure requirements and investments; c) mechanisms to facilitate access to existing marine research infrastructures; d) interactive web-based information systems to provide access to information on marine research infrastructures. Priority areas that need to be addressed include: i) research vessels and other mobile infrastructures (*e.g.* submersibles); ii) marine monitoring and observing systems; iii) new emerging technologies/infrastructures; and iv) marine data centres and databases. The coordination of existing marine research infrastructures and planning of future infrastructures would be most efficiently planned and executed in the context of a European Marine/Ocean Research Policy, which does not, at the moment, exist. The 2002 European Science Foundation Marine Board Position Paper 'Integrating Marine Science in Europe' is a potential framework for a European Marine/Ocean Research Policy.

One of the goals of BONUS is to identify the preconditions and means for a common use of the regional research infrastructure similar to the barter-based Ocean Facilities Exchange Group (OFEG) for deep ocean research. Pooling of resources would improve *inter alia* the research vessel availability for institutions and marine scientists around the Baltic Sea, but there is insufficient research vessel capability for appropriate sub-regional coverage regarding deployment of equipment required for oceanographic, environmental and fisheries sciences. Thus, there is a need for an improved regional distribution of research vessels in the region, as well as a new sizable multipurpose vessel owned and operated by the Community.

Effective communal utilization of infrastructures should be managed via an Infrastructure Deployment Committee (IDC), requiring a planning timetable, incorporating bookings, for coordination of activities extending forwards over a period of several years, especially in the case of core capital entities. BONUS-169 should provide a full inventory of the major types of infrastructures available in the Baltic, identified by country, capability/performance of the infrastructure entity and extent to which such infrastructure entities can be deployed in the programme to the benefit of other countries and under what circumstances. For new, major infrastructures purchased via Community finances, these should be viewed as common property unless legitimate reasons are provided to do otherwise (*e.g.* capacity building needs in certain countries). Planning bodies must be established with appropriate national representation, relatable to the tasks of diverse WPs, and their efficacy monitored. Other challenges include: developing a system that assures equivalent values when exchanging facilities; solving legal and administrative issues regarding transboundary mobility of research vessels and scientists; collaborating institutions will have to establish mechanisms providing internal financial flexibility to handle exchange of marine facilities in return for reciprocal access to facilities.

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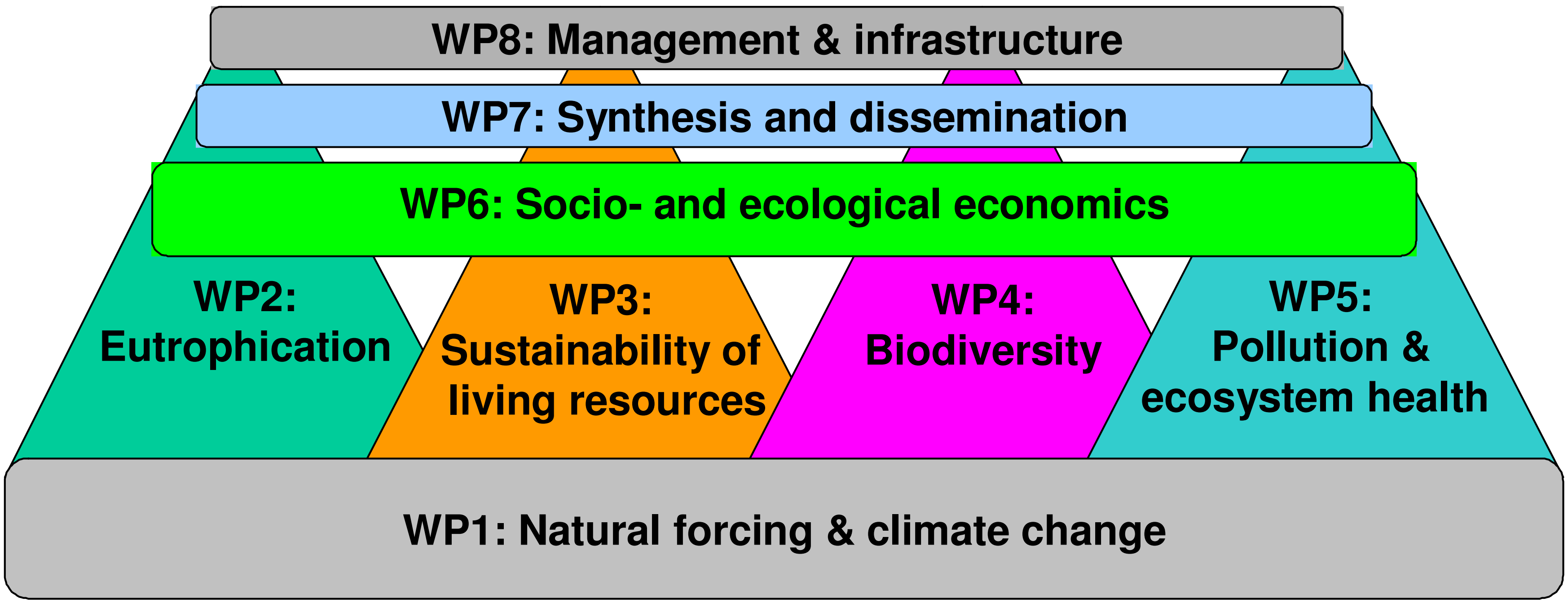
5 FIGURES, TABLES & ANNEXES

5.1 Figure 1: Overview of BONUS-169 structure showing the component workpackages (WP1 – WP8)

WPs 2-5 are pillars, and WPs 1 and 6-8 are cross-cutting. WPs 1-6 form the core science workpackages.



5.2 Table 1. Some international conventions, agreements and codes of conduct/guidelines concerning the environment and biodiversity, including conservation of fishery resources, of the Baltic Sea region. The list is illustrative rather than definitive.

Year	Instrument
1964	Convention for the International Council for the Exploration of the Sea (ICES), which was established in 1902, applying to the North Atlantic and its adjacent seas, including the Baltic Sea, aims to a) promote and encourage research and investigations for the study of the marine environment and its living marine resources, b) draw up programmes for this purpose and organize supporting research and investigations, c) publish or otherwise disseminate the results of research and investigations. Since the 1970s, a major task for ICES has involved the provision of scientific information and advice to intergovernmental regulatory commissions (*e.g.* HELCOM and IBSFC in the Baltic Sea), the European Commission, and the governments of ICES Member Countries, for purposes of fisheries conservation and the protection of the marine environment and its associated biodiversity and ecosystems.
1971	Ramsar Convention on Wetlands of International Importance, especially as Waterfowl Habitat.
1972	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention, formerly the London Dumping Convention). Prohibits dumping at sea, and bans disposal of radioactive waste at sea.
1973	MARPOL 73/78 – IMO Convention on Marine Pollution from Ships. Limits operational discharges of oil, noxious liquids, and ship generated garbage including litter.
1973	Convention on Fishing and Conservation of Living Resources in the Baltic Sea and Belts (Gdansk Convention), established the International Baltic Sea Fishery Commission (IBSFC) with the objectives of promoting close cooperation among its Contracting Parties in order to preserve and increase the living resources of the Baltic Sea and Belts and obtain the optimum yield, and to coordinate the management of the living resources of the Convention area by collecting, aggregating, analyzing and disseminating statistical data, including catch, fishing effort, and other information. All of the Convention area applies to waters under national jurisdiction.
1973	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) aims to ensure that international trade in specimens of wild animals and plants does not threaten their survival.
1974/92	The Convention for the Protection of the Marine Environment of the Baltic Sea Area, established the Helsinki Commission (Baltic Marine Environment Protection Commission, HELCOM) with the main objectives of protecting the marine environment of the Baltic Sea area from all sources of pollution, and to restore and safeguard the ecological balance of the Baltic Sea area. The 1992 Convention places greater focus on nature conservation and the protection of biological diversity including conserving natural habitats and protecting ecological processes to ensure sustainable use of natural resources.
1979	Bonn Convention on the Conservation of Migratory Species of Wild Animals, including 1991 ASCOBANS to protect and conserve small cetaceans in Baltic Sea and North Sea
1979	Bern Convention for Conservation of European Wildlife (fauna and flora) and Natural Habitats, giving particular emphasis to endangered or vulnerable species including those that are migratory species.
1982	UN Convention on the Law of the Sea (UNCLOS) identifying rights and responsibilities of States regarding resource management and protection of the marine environment.
1992	Convention on Biological Diversity (CBD) promoting the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources.
1992	UN Framework Convention on Climate Change (UNFCC) sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of heat-trapping 'greenhouse' gases (*e.g.* carbon dioxide, methane and chlorofluorocarbons). The Kyoto Protocol, an international and legally binding agreement to reduce worldwide the emissions of greenhouse gases, entered into force on 16 February 2005.
1995	FAO Code of Conduct on Responsible Fisheries providing guidelines and principles that promotes responsible fishing and fisheries activities, taking into account relevant biological, technological, economic, social, environmental and commercial aspects.
1995	UN Convention on Straddling Fish Stocks and Highly Migratory Fish Stocks, seeks to lay down a comprehensive regime for the conservation and management of such stocks.
1998	UN Economic Commission for Europe (UNECE) Aarhus Convention ensuring access to information, public participation in decision-making and access to justice in environmental matters.
2004	International Maritime Organization (IMO) International Convention for the Control and Management of Ships' Ballast Water and Sediments.

5.3 Table 2. Some European Community instruments applicable to the protection of the environment and biodiversity, including fishery resources, of the Baltic Sea region. The list is illustrative rather than definitive.

Year	Instrument
1976	Directive on Bathing Water (76/160/EEC) sets cleanliness standards for bathing water.
1976	Directive on Dangerous Substances (76/464/EEC) aims to reduce or eliminate pollution from chemicals.
1979	Directive on the Conservation of Wild Birds (79/409/EEC) establishes special conservation measures to protect habitats of rare or vulnerable species including migrants.
1979	Directive on Shellfish Growing Waters (79/923/EEC) aims to protect and, where necessary, improve the quality of waters where shellfish grow and to contribute to the high quality of directly edible shellfish products.
1983	Common Fisheries Policy (CFP), applying to fisheries and aquaculture, aims to ensure exploitation of living aquatic resources that provides sustainable economic, environmental and social conditions. Reforms of the CFP have *inter alia* aimed at greater integration of environmental and biodiversity concerns into fisheries policy.
1985/97	Environmental Impact Directive (85/337/EEC superseded by 97/11/EC) requires developer to provide information to competent authority about likely significant environmental effects.
1991	Directive on Aquaculture Animals and Products (91/67/EEC) aims to increase productivity, introduce health rules, and limit the spread of infections and contagious diseases.
1991	Urban Waste Water Treatment Directive (91/271/EEC) addresses the major point sources, namely the municipal waste water discharges, and sets minimum standards for the collection, treatment, and disposal of waste water dependent on the size of the discharge.
1991	Nitrates Directive (91/676/EEC) concerning the protection of surface and ground waters from pollution caused by the application and storage of inorganic fertilizers and manure from diffuse agricultural sources (farmland).
1992	EC Directive on the Conservation of Natural Habitats and Wild Fauna and Flora (92/43/EEC) designates and implements conservation measures for Special Areas of Conservation
1997	Amsterdam Treaty, strengthens previous environmentally orientated declarations, sets environmental policy objectives by explicitly stating, as Community tasks, 'a high level of protection and improvement of the quality of the environment'.
2000	Water Framework Directive (2000/60/EC) (WFD), promotes the integrated management of all water-related operations in fresh and marine waters, including coastal waters. The WFD aims to apply the ecosystem approach, and enhance conservation and where necessary recovery and restoration of ecosystems and their habitats, by establishing measures to terminate or phase out discharges, emissions and losses of pollutants including nutrients, with the ultimate aim of achieving concentrations in the marine environment near background values for naturally occurring substances and close to zero for man-made synthetic substances. The WFD *inter alia* requires classification of the quality status of coastal marine waters. By 2013, several of the components of EC water legislation will be streamlined and subsumed within the WFD.
2002	European Marine Strategy (EMS), 'towards a strategy to protect and conserve the marine environment' (COM(2002) 539 final) recognizes that diverse human activities pose major threats that impact the marine environment and its associated ecosystems. The EMS should *inter alia* cover all the actions needed to ensure that all human activities with an impact upon the oceans and seas are managed so that marine biological diversity and critical habitats are conserved and human use of them is sustainable. It is agreed that the development of the EMS should be focused on the concept of an integrated ecosystem approach to management.

5.4 Annex 1. Explanation of acronyms used in the document.

Acronyms only mentioned together with their full explanatory text are not provided. This includes the ICES Study/Working Groups.

Acronym	Explanation
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
BIAS	Baltic International Acoustic Surveys
BITS	Baltic International Trawl Surveys & Database
BMB	Baltic Marine Biologists
BSAP	Baltic Sea Action Plan of HELCOM
BSLME	Baltic Sea Large Marine Ecosystem
BSPA	Baltic Sea Protected Area
BSRP	Baltic Sea Regional Project
CBD	Convention on Biological Diversity
CCB	Coalition Clean Baltic
CFP	EC Common Fisheries Policy
CHARM	EC funded project 'Characterization of the Baltic Sea Ecosystem Dynamics and Function of Coastal Types'
COBRA	Coordination Organ for Baltic Reference Areas
COMBINE	Marine Monitoring Programme of HELCOM that quantifies the impacts of nutrients and hazardous substances in the marine environment, also examining trends in the various compartments of the marine environment (water, biota, sediment) and assessing physical forcing.
COP	Conference of the Parties of CBD
CoE	Centre of Excellence
EC	European Commission/European Community
EcoQOs	Ecological Quality Objectives
EEA	European Environment Agency
EIFAC	European Inland Fisheries Advisory Commission of FAO.
EMC	Executive Management Committee
ERA-NET	In the FP6 programme 'Integrating and Strengthening the European Research Area', the European Research Area Network (ERA-NET) scheme—supporting the coordination and cooperation of national and regional research programmes—aims at the national programme-makers and managers. These persons are, in most countries, either working in the Ministries or working in national funding agencies that implement programmes on behalf of their governments.
ERNAIS	European Research Network on Aquatic Invasive Species
EU	European Union
EUR	Monetary Unit of the European Union
FAO	Food & Agriculture Organization (UN)
FC	Finance Committee
FP6	Sixth Framework Programme for Research and Technological Development (EC funded)
FP7	Seventh Framework Programme for Research and Technological Development (EC funded)
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information System
GIWA	Global International Waters Assessment of UNEP
HABITAT	Protection and Biodiversity Group of HELCOM
HELCOM	Helsinki Commission — Baltic Marine Environment Protection Commission
IAS	Invasive Aquatic Species
IBSFC	International Baltic Sea Fishery Commission
ICES	International Council for the Exploration of the Sea
ICZM	Integrated Coastal Zone Management
IMO	International Maritime Organization (UN)
IOC	Intergovernmental Oceanographic Commission (UN Educational, Scientific and Cultural Organization)
JCP	Joint Comprehensive Environmental Action Plan of HELCOM
LME	Large Marine Ecosystem
LC	Liaison Committee
MARPOL	MARPOL Convention on Marine Pollution from Ships

MONAS	Monitoring & Assessment Group of HELCOM
MPA	Marine Protected Area
MSFOR	Multispecies Forecasting Model
MSVPA	Multispecies Virtual Population Analysis
NCM	Nordic Council of Ministers
NGO	Non-Governmental Organization
OSPAR	OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic
PBT	Persistent, liable to bioaccumulate and toxic
PSC	Programme Steering Committee
ROV	Remotely Operated Vehicle
SAP	Scientific Advisory Panel
SSB	Spawning Stock Biomass
TAC	Total Allowable Catch
UN	United Nations
UNEP	Environment Programme (UN)
USD	United States Dollar
VPA	Virtual Population Analysis
WFD	EC Water Framework Directive
WP	Workpackage
WWF	World Wide Fund for Nature