Oceanography Committee

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REPORT OF THE

WORKING GROUP ON SHELF SEAS OCEANOGRAPHY
Hamburg, Germany

15–17 March 1999

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

TABLE OF CONTENTS

1 WELCOME AND OPENING

The vice President of the BSH Prof. Rühl welcomed the group on the behalf of BSH. The chair Björn Sjöbeg could not attend the meeting, therefore Hans Dahlin opened the meeting and welcomed all the participants. Hans Dahlin was elected to be temporary Chair 15-16 March and Einar Svendsen 17 March. The list of participants is given in Appendix II.

2 APPOINTMENT OF RAPPORTEUR

Nils Kajrup was elected as rapporteur.

3 APPROVAL OF THE AGENDA

The agenda was approved. The agenda is at Appendix III and the terms of reference with their justification are at Appendix IV.

4 REPORTS ON NATIONAL ACTIVITIES OF SPECIFIC INTEREST TO WG MEMBERS

Phil Gillibrand reported on that in Scotland, oceanographic research is presently dominated by deep sea oceanography in the North-east Atlantic, and coastal oceanography in the fjordic sea lochs of the Scottish west coast. With regard to shelf seas oceanography, a series of research cruises measuring the distributions of physical, chemical and biological parameters in the Minch has recently been completed. The Minch is the sea area between the Scottish mainland and the Outer Hebrides, an archipelago lying to the west, and is one of the most scenic and unimpacted areas in the UK. The cruises have provided data on the seasonal patterns of water temperature, salinity, nutrients, chlorophyll, phytoplankton and zooplankton throughout the region. The physical parameters suggest that the deep intrusion of Atlantic water into the South Minch is a permanent feature, but that a similar intrusion into the North Minch is more transient. Data from current meters deployed in the area indicated cyclonic circulation patterns around these intrusions in both the North and South Minch. Previous drifter deployments in the South Minch also indicated the existence of a cyclonic circulation.

A three-dimensional, density-driven numerical model is currently being developed to confirm this circulation pattern and to investigate its variability. Once fully operational, the model will be used to estimate transport rates and transit times of contaminants along the Scottish west coast, and will provide data for oil spill and biological dispersion models.

Juan Brown reported on their participation in the GLOBEC. They also compiled a dataset on nutrients in the Irish Sea.

An introduction of the North Sea circulation experiment was given. In June/July 1996, a survey of the offshore region between the north-east coast of England and Dogger Bank was undertaken using towed and conventional CTD's and satellite tracked drifters. Strong bottom fronts bounded a pool of cold, dense bottom water isolated below the seasonal thermocline. These features extend continuously for 500 km along the 40 m contour, from the Firth of Forth to the eastern end of Dogger Bank. Geostrophic current estimates and drifter trajectories demonstrates the existence of persistent and narrow (10-15 km) cores of cyclonic near-surface flow (cold bottom water to the left) with velocities in excess of 0.1 m s^{-1}. The results are consistent with the seasonal baroclinic flow skirting the north east coast of England which provides a direct pathway for material and fish larvae from coastal regions to the northern Dogger Bank and central North Sea.

A similar project was performed in the south Irish Sea and the results from that experiment did not differ dynamically from North Sea experiment. A persistent and narrow geostrophic current was found along the coast of Cornwall with a weak recirculation southward along the Irish coast.

Jüri Elken presented a short overview of ongoing research. Estonian Marine Institute (EMI, URL: www.sea.ee) carries out basic research in physical, chemical and biological oceanography, marine ecosystem modelling and applied tasks like marine environmental monitoring and fish stock assessment. Estonian Meteorological and Hydrological Institute (EMHI) is running the network of coastal stations and performing surveillance on surface wave and ice conditions. Baltic Sea is the main geographic region of interest. Oceanographic research topics at EMI include hydrography and exchange processes of the basins, mesoscale eddies and fronts, strait and channel flow, deep water renewal, coastal zone dynamics, optical methods, modelling of circulation, ecosystem, waves and turbulence. After sale of RV LIVONIA, fieldwork is done on small vessels. Reconstruction of a 30-m fishery ship into a specialised research vessel is under way. EMI is involved in the EU projects BASYS, MITEC, DOMTOX. Recently data and results from the Gulf of Riga Project (Nordic-Baltic cooperation funded by NMR) have been compiled on the CD-ROM what is available from Bertil Håkansson (bertil.hakansson@smhi.se). These 3-year intensive data (monthly hydrography and nutrient mapping, strait process studies) can be used for skill assessment of models. Operational monitoring of algae dynamics is carried out jointly with FIMR onboard a ferry Tallinn-Helsinki (URL: http://www2.fimr.fi).

Gerd Becker reported that the Baltic Sea monitoring programme of the IOW is continued in close co-operation with the BSH. The components are: five seasonal cruises and the development and maintenance of a net of fixed stations. A mast station on the Darss sill, which is important to follow the water exchange processes of the Baltic and the Kattegatt, is in operation since several years. A buoy station in the Pomeranian Bight close to their mouth of the Odra River is important to follow the fate of the river discharges. In 1999, a third station will be deployed in the central Arkona Sea. The current research programmes concentrate the patterns of water exchange between the Baltic and the North Sea, water mass transformations through mesoscale circulation features and small scale mixing. New inside on the variability of the current patterns could be achieved with the help of towed CTD (Scanfish) and ADCP (mounted on a catamaran). The theoretical research and modelling is focused on the understanding and simulating the marine ecosystem of the Baltic. Coupled chemical biological models and circulation model provided new insides on the physical control of the phytoplankon development. Outside the Baltic field work and theoretical studies are carried out on the shelf of southwest Africa. In particular the Angola front was studied by a cruise in 1998, further work including the Angola Dome is ongoing.

Synthesis and new conception of North Sea Research (SYKON) is a new interdisciplinary North Sea research project initiated by the Centre for Marine and Climate Research in Hamburg (coord. J. Suendermann) and supported by the German Ministry for Education, Science, Research and Technology. The central objective is a comprehensive inventory and critical evaluation of our present knowledge of the North Sea system. The work includes a) the presentation of the current state of North Sea research, b) the assessment of research deficiencies and c) the identification of new challenges. The results will be published in two forms: one for scientists and one for interested laypersons and people concerned with marine research and environmental policy. The project has been approved for the period from May 1998 to August 2000. The work has been divided into the ten areas of expertise listed below:

1) Data: Inventory, Evaluation and Documentation
2) Hydrodynamic Parameters
3) Suspended Particulate Matter
4) Atmospheric Parameters
5) Mass Fluxes
6) Biological Models
7) Phytoplankton
8) Zooplankton
9) Higher Organisms
10) Benthos

Furthermore the shelf sea research activities of the centre of marine and climate research (ZMK) are mainly focused on modelling the circulation and the hydro- and thermodynamics. Most of the running projects are carried out with the HAMSOM (Hamburg Shelf Sea Model). This model is a coupled ice/ocean model, including a full thermodynamic module (Harms, 1994; Schrum and Backhaus, 1999). The model results are used to investigate environmental processes. For example, to investigate pollution pathways and sea ice drift, the model is applied to the Barents Sea/ Kara Sea region (national BMBF project). Furthermore, the model is used to study the influence of circulation and turbulence processes on *Calanus finmarchicus* (EU-TASC) and on fish recruitment (EU-STEREO) in the Greenland Sea, Iceland Sea, Norwegian Sea and the Northern North Sea. With a slightly different focus, the model is applied to the North Sea/ Baltic Sea region (KLINO, national BMBF project). The main purpose of this project is to model the seasonal, intra- and interannual variability of the circulation, the sea ice conditions and the hydrographic conditions in both shelf sea regions. The idea of the project is to develop a model system, which can be used to investigate the influence of climate variability on the shelf sea region. By using different observational data sets (e.g. Janssen *et. al.*, 1999; Becker and Pauly, 1996) for validation purposes, it will be investigated how large the error bars of the different modelled quantities have to be, and how strong trends in the model results are. The model development and the investigation of the model behaviour is carried out as a necessary ground work in modelling the influence of climate change on shelf sea regions. In this context, the model is furthermore coupled to a regional atmospheric model to investigate the influence of the regional coupling and to evaluate possible improvements in shelf sea modelling. Additionally the model is applied to the Black Sea (INCO-COPERNICUS, EU) and the Caspian Sea (NATO Grant) to investigate their seasonal and interannual variability of the hydrographic conditions (and the ice conditions of the Caspian) and to investigate the water and heat budgets in these regions.

The Federal Maritime and Hydrographic Agency (BSH, Hamburg and Rostock) concentrates its activities on monitoring of the environment. The monitoring cruises are supported by physical and chemical data from the MARNET, fixed station in the German Bight and the western Baltic. The quality of the high resolution automated nutrient analyses (CANVAS project) has increased during 1998. It is expected to get fully operational within the next year.
A towfish (Delphin) survey in the North Sea was carried out during the maximum summer stratification. For the first time, a fast response oxygen sensor was added to the towed CTD and high-resolution oxygen sections in the German Bight and the central North Sea obtained. The in-situ data will be compared with prognostic model data of the BSH

operational North Sea model to try to get information on the North Sea heat and salinity budget and the quality of model data. The weekly analysis of the North Sea SST has continued in its thirties year without any break. Additionally weekly Baltic Sea SST analysis has started, based on IR data (NOAA satellites).

He also reported on the project concerning Cyclones and the North Atlantic Climate System

The objective is to improve our understanding of the coupling between the high and the low frequency variability of the ocean/atmosphere/cryosphere system in order to expand the climate-predictability up to decadal time scales.

The climate is controlled by the interactions of atmosphere, ocean, cryosphere, biosphere and lithosphere. The interactions cover a spectral range from local weather to global changes on geological time scales. Climate predictability, including the discrimination between natural and anthropogenic causes of climate change, is a focus of present days climate research. Coupled models of the system, process-studies and long-term series of environmental parameters are major tools in this research. The prediction of decadal climate variability requires the inclusion of the deep thermocline circulation in the coupled modelling. Its driving critically depends on the thermohaline exchanges between ocean and atmosphere in high latitudes, with the Northern Atlantic being a centre for this interaction.

With a perspective of 10 years of funding oceanographers and meteorologists from the University of Hamburg, the Max-Planck-Institute for Meteorology in Hamburg, the Alfred-Wegener-Institute for Polar- and Marine Research in Bremerhaven and the GKSS-Research Center in Geesthacht have joint forces in modelling, observations and analysis on this topic. The study area covers the North Atlantic from the belt of westerlies into the Arctic, with experimental work initially focussing on the effects of mesoscale cyclones onto the ice flux through Fram Strait, the role of freshwater in the convection of the Greenland Sea and the export of intermediate and deep waters from the convective centres. Modelling ranges from conceptual models of storm track variability to the state of art coupled GCM's and high resolution regional modelling.

This project starts in 1998 and will be funded by the Deutsche Forschungsgemeinschaft as Sonderforschungsbereich 1626. The co-ordinator is:

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Einar Svendsen and Didrik Danielsen reported that the tendency to increased salinity and temperature in 1997 continued in 1998 on the North Sea plateau and in the Norwegian Trench due to increased inflow of Atlantic water. This was in accordance with observations by German colleagues that the temperature in the eastern and south-eastern North Sea in February was among the highest recorded during the last 100 years, and the winter and spring about 1.5°C above the mean in the surface layer. The 1998 summer was in contrast to the year before, however, rather cold and cloudy. There appears to be a very close positive correlation between calculated inflow of Atlantic water to the North Sea in the winter and the catch of Horse Mackerel in the autumn.

In 1998 the modelled Atlantic inflow from the north was of normal size, in contrast to the inflow through the English Channel during the first half of the year which was rather large. This inflow lead to an un-normal large north-easterly transport in the southern North Sea along the west coast of Jutland in April.

There was an unusually large inflow of Atlantic water to the Skagerrak in the autumn with Atlantic water up the surface on the Danish coast which is very unusual (see Appendix V). This inflow caused a renewal of bottom water to many of the Norwegian Skagerrak fjords, which prior to this event had a long stagnation period. As autumn is an unusual time for renewal of bottom water (it happens normally in the winter/spring period), the temperature in the inflowing water was quite high.

In the late winter and spring large amount of nitrate in the Jutland coastal water was recorded along the Danish Skagerrak coast, and in April also along the Danish west coast. On the southern Danish west coast (near Esbjerg) up to about 60 µmol/l. This anthropogenic input has its origin in river runoff in the southern North Sea. In April and first part of May this nutrient-rich water masses caused a harmful algae bloom in the area. It caused both mortality of Atlantic salmon in pens on the southern Norwegian coast, and mortality of wild fish in the Skagerrak and along the western coast of Denmark. The algae *Chatonella* aff. *Verruculosa* had never been reported before in these waters and it was the first time worldwide it has been found to cause fish mortality. This large amount of dead biological material from this bloom was possible the reason to the very low oxygen concentrations recorded on the Danish coast in June, less than 4 ml/l, which is unusually low at that time of the year. Normally the lowest oxygen values appear in this region in late summer/early autumn.

Denis Lefaivre reported on that in the Department of Fisheries and Oceans (DFO) government laboratories, an emphasis on studies linking physical and biological oceanography continued to grow, with salmon being the primary focus on the West Coast and cod being the focus on the East Coast. Studies looking at the paths of contaminants in the environment and the effects of climate change also gained in prominence. In academic institutes, significant efforts continued on national and international multidisciplinary programs such as global climate change, large-scale ocean circulation, sea-ice interactions, etc. The " bloom " in numerical circulation models (both coastal and basin-scale), coupled atmosphere-ocean models, ice models and remote sensing studies also continued. In general, large, fully integrated, multidisciplinary teams and studies became more prolific.

The classifications were chosen to be the Coastal Atlantic, Coastal Pacific, Arctic Ocean, Labrador Sea, Pacific Ocean, St. Lawrence River and Gulf, Turbulence and Mixing, and Ocean Circulation Modelling. Extensive information on the research carried out at Canadian universities and government laboratories is now generally available through Internet Homepages.

Coastal Atlantic Studies

Research programmes involved participation in international and national programs like GLOBEC (Global Ocean Ecosystem Dynamics), interdepartmental government activities like PERD (Panel for Energy Research and Development), and collaborative projects with universities, industry and provincial governments.

Advances in continental shelf physics included: the description of the predominant influence of the subpolar Labrador Current system on the NW Atlantic shelf (e.g. Loder *et. al.* 1998); the description and understanding of interannual hydrographic variability on the NW Atlantic shelf (e.g. Drinkwater 1996; Umoh *et. al.* 1995); the numerical modelling of seasonal circulation (e.g. Han *et. al.* 1997; Tang *et. al.* 1996), particularly its predominant baroclinic component (e.g. Hannah *et. al.* 1996); the description and modelling of current variability on the Newfoundland and Scotian Shelves (e.g. deTracey *et. al.* 1996; Greenberg *et. al.* 1997; Petrie and Buckley 1996); the description of turbulent mixing on Georges Bank (e.g. Horne *et. al.* 1996; Yoshida and Oakey 1996); the numerical modelling of benthic boundary layer dispersion (Hannah *et. al.* 1998); methodologies for data assimilation in ocean circulation models (Xu 1998); and improved descriptions of shelf tides from altimetry data (Han *et. al.* 1996). Field programs (P. Smith and collaborators) were carried out into seasonal circulation variability in the Laurentian Channel and Cabot Strait region, interannual circulation variability in the Northeast Channel and Georges Bank region, and near-surface drift on the Scotian Shelf. Hydrographic sampling of the Halifax and other cross-shelf sections on the Scotian Shelf was increased in 1997 and 1998, as part of GLOBEC (A. Herman and collaborators) and an Atlantic Zonal Monitoring program.

During this period, studies of circulation and dispersion in coastal embayments have increased, in support of aquaculture, water quality evaluations and engineering developments. Emphases have included current measurements and circulation modelling in Passamaquoddy Bay, New Brunswick (F. Page, D. Greenberg), and field studies in the Bras d'Or Lakes and Country Harbour, Nova Scotia (G. Bugden, B. Petrie).

Efforts to better document the interannual to interdecadal variability of physical properties in shelf waters off Eastern Canada led to several publications (e.g. Colbourne *et. al.* 1997, Drinkwater 1996, Gilbert and Pettigrew 1997, Prinsenberg *et. al.* 1997). The monitoring program over the Canadian eastern shelf waters has also been reviewed in detail and significant adjustments are taking place to improve our capacity to understand and detect climate changes.

Thompson and colleagues at Dalhousie University have focussed their research on the development of an assimilating operational model for the Scotian Shelf (Thompson and Sheng, 1997; Griffin and Thompson, 1996; Dowd and Thompson, 1997; Sheng and Thompson, 1996). Although this model is presently forced by winds and coastal sea-levels, preliminary tests with another model capable of simulating the complete three-dimensional circulation have been carried out.

Both Tony Bowen and Alex Hay of Dalhousie have participated in near-shore dynamic experiments at Queensland Beach N.S., Duck, North Carolina (Hay and Bowen, 1998), and at the wave research flume at the National Research Council in Ottawa . Their research encompasses edge wave trapping (Bryan and Bowen, 1996), shoaling and breaking waves (Doering and Bowen, 1995), and sediment transport (Sheng and Hay, 1995).

Coastal Pacific Studies

Numerous modelling studies were carried out between 1995 and 1998 along the Pacific coast of Canada. Barotropic tides were simulated for the inner waters of Juan de Fuca Strait and the southern Strait of Georgia (Foreman *et. al.*, 1995) and western continental margin of Vancouver Island (Foreman and Thomson, 1997) while both barotropic and baroclinic tides were represented for the northern coastal waters (Cummins and Oey, 1997). Generation mechanisms for the Vancouver Island Coastal Current were investigated (Pal and Holloway, 1996; Masson and Cummins, 1999) and background buoyancy currents were simulated diagnostically for Dixon Entrance (Ballantyne *et al*, 1996) and the western continental margin of Vancouver Island (Foreman and Thomson, 1997). Drifter observations were used to determine surface currents (Crawford *et. al.*, 1998a,b) along the north coast of British Columbia and compared with model results, and TOPEX/POSEIDON altimetery was combined with coastal tide gauge data to calculate seasonal surface elevations and flows (Foreman *et. al.* 1998).

Labrador Sea

As a Canadian contribution to WOCE (World Ocean Climate Experiment) and CLIVAR, a field and modelling program for the Labrador Sea investigated the importance of heat and freshwater fluxes of the pack ice and coastal shelf water along the Canadian east coast on the oceanographic properties of the Labrador Sea and the North Atlantic. Instrumentation (ice beacons, moorings and Helicopter-borne sensors) were used to quantify the areal pack ice fluxes flowing south along the Canadian east coast determined from remotely-sensed data (RADARSAT imagery). Cross-shelf heat and freshwater fluxes determine from observation and simulated by coupled ice-ocean models were found to be important to the oceanographic properties of the Labrador Sea (vertical mixing). Ice-ocean models developed and calibrated against observations were used for both real-time short-term ice ocean forecasts and for long-term predictions of ice and ocean climate changes due to global warming.

St. Lawrence River and Gulf

Ice–ocean instrumentation are being developed to quantify the ice signatures seen in remotely-sensed imagery for the improvement of the safety and efficiency of the marine transportation and offshore developments of the Gulf of St. Lawrence. Ice beacon and helicopter-sensors are being designed and tested to deliver real-time data set to the Canadian Coast Guard and the Canadian Ice Service which in turn provided ice breaking service and ice information the marine industry. All ice data is being used to better our understanding of the ocean-ice-atmospheric interaction processes of the Gulf for the uses in both ice forecasting and research in the variability of ocean parameters and their affects on fish and mammal stocks.

Numerous models have been developed for hindcasts in all or parts of the St. Lawrence River and Gulf (Gan *et. al.*, 1995) However, following the steps taken in operational meteorology for some years, models are also being used routinely to forecast currents (Saucier *et. al.*, 1999), water levels, waves, or sea ice, such fields being needed for various applications: surface current charts for navigation, search and rescue planning, or oil spill trajectory modelling (Lefaivre *et. al.*, 1997; Guerrier *et. al.* 1997), water levels for under-keel clearance in shallow channels, storm surges for coastal flooding, and sea-ice for navigation. Canadian laboratories are now continuously updated with near real-time observations for the weather, sea-ice, water levels, sea-surface temperature and salinity, and other remote sensing observations. Such real-time observations still lack for currents but should become available in the next few years.

Hans Dahlin reported that the revision of the Swedish part of the BMP has started. There are ongoing discussions with Denmark about a common buoy system in the Kattegatt. Also, one tries to achieve bi- or trilateral agreements with other countries around the Baltic about common stations and exchange of data for validation of models.

Sweden has recently adopted a new environmental monitoring programme that will commence 2000. The new features in the programme is that focus is on the coastal zone, and that spatial variability is to prefer before timely. To maintain the sampling frequency for some stations agreements with other countries on exchange of data will be established.

Hans Dahlin also mentioned the ongoing projects BALTEX and the new MARE. He also shortly introduced the expert system BalticHOME, which is under development. He also reported on the present state of SeaNet and the SeaNet data interface.

Pekka Allenius reported on that the Finnish Institute of Marine Research (FIMR) has been very active in recent years in developing a new monitoring strategy for the Baltic Sea. The idea is to monitor the fluctuations in the Baltic Sea ecosystem in real time using many different approaches. In addition to traditional research vessels, high-frequency automatic instruments on ships of opportunity, remote sensing, automatic buoy stations, sampling in coastal waters and numerical models are used. This is implemented in the operational Alg@line project, a joint effort of research institutions and shipping companies, co-ordinated by the FIMR. Shipping companies Silja Line and Transfennica are essential partners that have supported the project in many ways.

Automatic instruments are installed onboard five regularly operating ships on routes between Finland and Germany, between Finland and Estonia and between Finland and Sweden (the ferry lines are Helsinki - Travemünde, Helsinki - Stockholm, Helsinki - Tallinn and Kokkola - Travemünde. This activity can also be considered to be a part of the Baltic

Operational Oceanographic System, BOOS, and it is intended to be a demonstration case for EuroGOOS, but also to be the platform for continued operational co-operation in the Baltic.

The instrumentation onboard the ships of opportunity consists of a flow through sampling system. The system includes a fluorometer, a thermo-salinograph, a GPS-navigator, a water sampler, a GSM mobile phone and a PC. The continuous plankton recorder, a method to collect zooplankton, is in operational use on a ferry between Finland and Germany. The sampling is continuous forming a series of surface observation along the ship route with very high spatial resolution.

The ship route from Helsinki to Travemünde takes 36 hours and the ship is in the harbour about 12 hours. Thus, the route is covered twice a week. The route from Helsinki to Stockholm takes about 14 hours and the ship stays in the harbour about 9 hours so that the route is cover each night. The route between Helsinki and Tallinn takes only 3.5 hours. The data collected within the Alg@Line project is processed to information that is publicly available in the World Wide Web (http://meri.fimr.fi) in four languages (Finnish, Swedish, English and Estonian). The pages are produced in co-operation with Finnish Institute of Marine Research, Estonian Marine Institute (EMI), Uusimaa Regional Environment Centre, City of Helsinki Environment Centre, Southeast Finland Regional Environment Centre and Finnish Environment Institute. Alg@Line monitors phytoplankton and related parameters in the Baltic Sea and reports are published at least weekly during March-September. The web pages give lots of background information including phytoplankton image gallery etc. The pages also contain annual assessments on the state of the marine environment. Coupled 3D hydrodynamic-ecosystem model, FinEst, is under continuous development as a co-operation between EMI and FIMR. The aim is to develop from it an operational ecosystem model version as a part of the Alg@Line system.

5 REVIEW THE OUTCOME OF THE THEME SESSION ON SKILL ASSESSMENT OF ENVIRONMENTAL MODELLING

Einar Svendsen reported on the theme session. The report from the session is in Appendix VI.

The WG recommended that a framework for validation should be created and that ICES should support further development of this field. In addition, one agreed on that an integrated approach is needed. The discussion of the WG dealt with issues concerning validation techniques, data sets for validation and the reliability of the validation. Some questions where raised during the discussion concerning the main problems:

- Will there ever be sufficient data sets for validation of models?
- How good advises can we give to ICES based on environmental models?

Clearly, the data sets are crucial for the validation, both in quantity and in quality. There are some data sets available today on sea surface temperature and sea level, but more compiled and quality controlled data must be available for validation of environmental models. Especially ecological models lack good data sets for validation.

Concerning validation techniques one agreed on that the cost-function and the SMAC, discussed during the theme session, are not sufficient. The validation technique must be suitable for the aims of the model, and one pointed out that a framework could be one opportunity to deal with this issue.

The discussion will continue within the WG and the issue should be lifted up on a wider basis outside ICES (GOOS?). The outcome from the SYKON-project can also contribute in this topic.

6 NORTH SEA DRIFTER EXPERIMENT

This experiment was not funded and there are no plans to go on further at this point.

7 SYNTHESIS OF AVAILABLE TIME SERIES RELATED TO THE SKAGERRAK

Harry Dooley could not attend the meeting, but Didrik Danielsen presented time series from the Torungen-Hirtshals transect.

An overall conclusion of the available time series on this transect is that it is too short to determine trends with a sufficient statistically power. The purpose with time series therefore is mainly to identify extreme events and for validation of models. The figures of the time series are presented in Appendix VII.

Two stagnation periods in density are clearly identified, one beginning in the late 80s and ending in early 90s and one during 1992-1993. Also, in the 90s there is a tendency of a stagnation period although not as clear as the previous ones. Although the stagnation periods are more common and intensive in the 90s than in the 70s, there are no trends. Due to the stagnation, there were higher concentrations of nutrients, PO_4-P and NO_3-N, during the 90s than during the 80s when they were normal. In addition, due to the stagnation, low oxygen concentrations were recorded during the 90s. A well correlation between the nutrient concentration and the oxygen concentration was found.

Inflows of Atlantic water were recorded 1992, 1993 and 1995-1996 at 300 m. It seems that the inflows of Atlantic water has become more usual on recent years compared to during the 70s, although no trend is detectable.

8 REPORT FROM THE FOURTH BACKWARD FACING WORKSHOP

Einar Svendsen, Corinna Schrum and Joachim Dippner shortly presented this issue for the WG. The main conclusions from the workshop are in appendix VIII.

9 EVALUATION OF THE EFFECTIVENESS IN ENVIRONMENTAL MONITORING PROGRAMMES

Hartmut Heinrich (BSH) presented the objectives, the strategy and background theories for the German monitoring programme (OSPAR). The German programme is mainly based on three theories:

- monitoring during the season of (almost) complete mixing and low biological productivity
- sampling along concentration gradients
- normalisation of the nutrients to a certain salinity for trend detection.

These assumptions are not fully true in the German Bight. Therefor the monitoring leads to a biased description of the nutrient situation and the temporal trends. To overcome the problems with undersampling, in future the major backbone of the German nutrient monitoring programme will be the use of an automated buoy system, developed within the German CANVAS - programme. At the moment two stations - still in the evaluation phase - are moored in the German Bight (UVS "ELBE"; UVS "DEUTSCHE BUCHT"). It is planned to deploy at least one additional buoy in the outer German Bight. These time series will be supplemented with a number of limited spatial distributed stations.

The WG member discussed the problem of the rather high effort to keep this kind automated stations working in rough sea conditions. The WG members also pointed to the problem of undersampling in all other North Sea regions as well as the missing international co-ordination of national monitoring programmes. The detection of the end member concentrations for the calculation of salinity normalised nutrient concentrations was found to be difficult, because the source regions, the transport route and the transit time are not known exactly. To overcome this problem the application of the different operational North Sea models was proposed.

10 CURRENT AND FUTURE USE OF REMOTE SENSING IN SHELF SEA STUDIES

Roland Doerffer, GKSS, was invited to present this issue.

Available optical remote sensing are Ocean colour instruments (suspended matter distribution) and SeaWIFS (chlorophyll). The latter is still functioning while the first one ceased 1986. The main problem with these techniques is that there are no operational methods to separate substances (e.g. chlorophyll, suspended matter, yellow substances).

New remote sensing systems are to be launched, MODIS (TERRA) this year, LANDSAT-7 this year and ENVISAT.

For validation of remote sensing products CZCS inverse modelling is used. In the future neural network will be used.

An application of remote sensing is to calculate primary production. Available remote sensing products are SST and chlorophyll (not working in turbid areas).

From this brief introduction the WG agreed on that remote sensing is a "brick in the wall", beside monitoring and models.

11 COMMENTS ON THE ICES WORKSHOP ON GOOS

Hans Dahlin introduced this issue in an informative way. GOOS (Global Ocean Observing System) consists of five modules

- Climate
- Health of the sea
- Coastal
- Living resources

- Services

The EuroGOOS is the European part of GOOS.
The GOOS work is ratified by each government through the Rio-declaration.

Given the five modules it is clear that there are natural connections between ICES and GOOS. Thus, one should try to find co-operations between GOOS and ICES.

12 SENSITIVITY STUDIES OF OPEN BOUNDARY CONDITIONS ON MODEL PERFORMANCE

A presentation of this study was given by Thomas Pohlmann and Hermann Lenhart.

Existing North Sea models always have to face the problem, that not enough open boundary data are available. This is especially true if the model is intended to simulate realistic periods in a prognostic mode for salinity and temperature. In general due to lacking boundary data at open boundaries, climatological means are prescribed. Obviously, these data do not include phenomena like a North Atlantic salinity anomaly, which produce strong deviations from the climatological mean at the outer edge of the North Sea.

One suggestion to circumvent this problem is based on the assumption that the major Atlantic water masses enter the North Sea either through the Fair Isle Passage, east of the Shetlands or through the Dover Strait. This would imply that only three operational stations are needed to provide all the North Sea modellers with adequate boundary conditions. As in general, the vertical stratification in all the three inflow regions is very weak probably only surface data would be sufficient.

The aim of this study was to demonstrate the actual importance of these correct boundary data for the whole North Sea domain. In a first approach this has been done by using the Hamburg North Sea Model, which has provéd its reliability in a large number of different applications.

This model study was carried out as an example for the year 1982. Altogether 5 simulations have been performed in order to illustrate the influence of the open boundary conditions on the interior of the North Sea domain. These five runs only differ with respect to the salinity data, which are prescribed at the open boundaries. Along the entire section of every individual boundary a constant value was added, i.e. +1 psu or -1 psu. All the other model settings are unchanged and taken in the standard configuration.

For this study it can be observed that the salinity values at the northern entrance are more relevant for most parts of the North Sea compared to the values in the English Channel. The result of the change of the northern boundary conditions reaches the central North Sea at end of July. At the end of December the difference has reached about 0.5 psu, which is 50% of the prescribed change. In the German Bight the impact of Channel water dominates. At the end of 1982 the effect is nearly 0.1 psu, which is 10% of the prescribed change in the English Channel.

In this preliminary study it was not possible to conclusively discriminate between the pure advective/diffusive influences of the salinity change at open boundaries and barotropically induced effects. Since the latter influence the circulation in the entire North Sea, this question needs further more specific investigations.

After the presentation Einar Svendsen mentioned that they had made similar scenario runs with NORWECOM that produced less pronounced results. In the following discussion this reduced effect in NORWECOM runs was related to the positions where the boundary conditions are prescribed for NORWECOM, which are far more away from the North Sea entrance than for the HAMSOM study. In general there was a feeling that, since at the open boundaries the barotropic pressure gradients and therefore also the barotropic currents are still inconsistent with the prescribed salinity values, these HAMSOM runs can only be accounted for as preliminary studies. The further discussion opened the question of validation data, so that a comparison between hydrodynamical model and measurements could provide an impression of the deviations caused in the model by the use of climatological boundary conditions. Here Phil Gillibrand mentioned that from his lab, current meter recordings might be available for such a direct comparison and he would like to look into the possibility of making them available. Finally, Hans Dahlin suggested to add this sensitivity study to the general topic of modelling (subtopic boundary conditions), but he also underlines that the topic should be further investigated.

13 THE EFFECTS ON THE COASTAL ZONE OF REGULATING FRESHWATER RUN-OFF

This item was not discussed due to the absence of Francois-Jacques Saucier who was main responsible.

Holger Schinke and Wolfgang Matthäus has published a work dealing with impacts of regulated river runoffs on the Baltic Sea (*On the causes of major Baltic inflows – an analysis of long time series*, Continental Shelf Research, 1998, **18**, 76-97). An excerpt from that paper is given in Appendix IX.

14 ESTIMATES OF TRANSIT TIMES ALONG THE SCOTTISH WEST COAST AND AROUND THE NORTH SEA

Juan Brown presented the results on the study of distribution of Technetium-99 in UK coastal waters.

The concentrations of ^{99}Tc, discharged to the northeast Irish Sea from the nuclear processing plant at Sellafield, have been measured in UK coastal waters. Temporal and spatial distributions of this radionuclide in surface seawater are provided prior to and post the authorised discharge of elevated quantities of ^{99}Tc, arising from the operation of the Enhanced Actinide Removal Plant (EARP).

Preceding the commissioning of EARP, concentrations of ^{99}Tc in a large proportion of the Irish Sea were reasonably uniform (1-4 mBq l^{-1}). Increased levels from most recent discharges were observed along the Cumbrian and southern Scottish coastline. However, ^{99}Tc concentrations decreased rapidly away from the coastline and were dispersed in a parallel direction to the shore, consistent with residual surface currents. Following elevated discharge periods, a significant pulse of ^{99}Tc was rapidly transported northwards parallel to the shore. Post-EARP surveys indicate that the most rapid migration of ^{99}Tc from the outfall to the North Channel was less than 3 months and the mean transit time is estimated to be in the order of 6 months. Comparisons of UK coastal surveys, prior to and post EARP, suggest that ^{99}Tc had migrated to the northern North Sea within some 9 months following initial elevated discharge.

15 ICES STRATEGIC PLAN – POSSIBLE CONTRIBUTION FROM WGSSO

Hans Dahlin introduced the strategic plan and the comments given by Harald Loeng. The WG agreed on adjustments of the objectives with their justification as follow:

O1: Describe, understand and quantify the variability and state of the marine environment in terms of its biological, physical and chemical components.	Ongoing knowledge of the environmental and ecosystem conditions in the ICES area is of fundamental importance to accomplishing the ICES mission. This objective will document relevant environmental and ecosystem conditions by monitoring important environmental and ecosystem parameters through time, and by studying the outcome from hindcast models. This information will be used both in achieving an increased understanding of ecosystem processes and for initiating, evaluating and applying models predicting ecosystem conditions. The capability to quantify the effect of natural environmental variability on the physical conditions within the ocean will require an understanding of how variability in the driving forces influences critical physical processes within the ocean. This objective seeks to develop a process based understanding between variability in climate and other driving forces with important marine physical processes.
O3: To understand and quantify the impacts of climatic variability on the dynamics of marine ecosystem.	The capability to forecast the effect of natural environmental variability on ecosystem conditions will require an understanding of how climatic variability influences key ecosystem processes. The understanding will be the basis for developing management tools.
O4: To understand and quantify the impact of human activities on marine ecosystem, in relation to natural variability.	We need to evaluate the effect of human activities in perspective of the natural variability in the environment.
O6: To promote the implementation and further development of tools for the incorporation of environmental information into fisheries and ecosystem management.	Incorporating the impact of environmental variations into population assessment and management strategies represents one of the key elements in improving the understanding of long term sustainability.

The WG suggests that ICES plays an active role in GOOS, especially on marine monitoring and process understanding related to living resources in the north Atlantic and adjacent seas. For assessment and management purposes, the turnover of oceanographic knowledge and information then need to be "operational" in a sense relevant for the living resources.

In this perspective and in relation to the new strategic plan/objectives for ICES suggested by the Oceanography Committee and being supported by the WG, the following activities are suggested:

1. Collate and update some of the key oceanographic time series, and produce integrated information (maps?) of prime parameters. Make this information available in a form and frequency useful for assessment of the environment and the living resources.
2. Continue the support to the annual Ocean Climate Status Summary being produced by WGOH.
3. Assess the current level of information of key processes and time series needed for following work:
4. Demonstrate, update and search for new relations between environmental parameters/processes and recruitment, growth and migration of the fish stocks.
5. Promote the results of the ongoing activities on circulation and ecosystem modelling and quality assurance of such models.

Einar Svendsen claimed that the are problems with the first activity regarding what to provide, however, the WG agreed on at that it is important. One way to see what to provide is to set up a web site where users can provide their information they think is useful. The responsibility of such a web site should be on ICES. The Bulletin Board on the North Sea gadoid outburst is an example of such a web site, that is managed by ICES, where users can exchange information in a simple way.

Regarding the fifth activity, the WG saw a need of compiling and collating data sets for validation. Those data sets must be listed in a way so that is clear for what purposes each data set is intended for. With those data sets available, the WG should encourage inclusion of error estimates in the model results.

16 PLACE, DATE AND TOPIC FOR THE NEXT MEETING

The WG members agreed on having a joint meeting with WGHABD in Barcelona, 20-25 March 2000. Terms of reference with justifications for the next meeting are in Appendix I.

17 CLOSING OF THE MEETING

The meeting ended Wednesday 17 March 1999 at 13.00 hours.

Appendix I. Recommendations and justifications

The Working Group on Shelf Seas Oceanography (Chair: Björn Sjöberg) will meet in Barcelona, Spain, from 20 to 25 March 2000 to

1. Assess the relevance and the effectiveness of monitoring programmes especial in relation to statistical aspects, such as statistical power, statistical significance and statistical independence.
2. Discuss and develop generally principles and, if possible, guidelines for initialisation, validation and assessment of numerical models especially in relation to,
- - numerical models sensitivity to perturbed boundary conditions
- - numerical models need for adequate and relevant data for validation.
3. Finalise the compilation, and assess the value of, available time series from the Skagerrak.
4. In co-operation with WGHABD, assess current knowledge on the importance of physics in relation to harmful algal blooms as well as possible implications of modelling input on pelagic biological monitoring programmes.
5. Review current developments in operational oceanography, especially regional GOOS projects.
6. Compare model parameterisations for growth rates, nutrient uptake rates, nutrient limitation, predation rates, remineralization rates and the physics of the turbulent fluxes and stresses (joint with WGHABD)

Justification

1. It is important to evaluate individual monitoring programmes in determine possible trends against natural variability. A number of programmes have been discussed during previous WGSSO meetings. Now we will try to compile some general remarks and recommendations.
2. Management is increasingly using results from numerical models as tools for decision making. So far, there is a great lack of evaluation and quality assurance of model results. This is especially true for coupled physical-chemical-biological models. Since coupled models are of prime importance for ICES work in the near future there is a need to create a framework for validation.
3. A first overview of long time series from Skagerrak has been collated to provide a useful set of data to investigate ecosystem variability in the region. These different time series must be brought together to form a coherent dataset.
4. Recent developments and status of physical models for coastal circulation will be reviewed as to understand the inherent accuracy, resolution, assumptions and parameterisations etc. in relation to biological parameterisations. This is necessary to appropriately couple physics and population dynamics to provide meaningful calculations of population development.
5. Operational oceanography is becoming increasingly important as a tool for getting appropriate data available in time but also as a platform for an integrated approach involving observations, remote sensing as well as models.
6. In order to compare model parameterisations for growth rates, nutrient uptake rates, nutrient limitation, predation rates, demineralisation rates and the physics of the turbulent fluxes and stresses, it was felt necessary that a joint session of the WGHABD and WGSSO be held. On the basis of case examples such as the Baltic, the Gulf of Maine, the estuary of Saint Laurence, the Bay of Biscay, etc., it should be possible to compare and discuss implications of the different biological processes formulations.

   Recent developments and the status of physical models for coastal circulation will be reviewed to understand the inherent accuracy, resolution, assumptions and parameterisations, etc. This understanding and interaction is necessary to appropriately incorporate the details of the population dynamics (bloom initiation, growth, and mortality...) to provide meaningful calculations of the population development.

   During this joint meeting, physicists could also provide advises to some biologists regarding design of oceanographic investigations.

APPENDIX II. List of participants

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Gerd Wegner BFA	wegner.ish@bfa-fisch.de	+	+

III. Agenda for the Working Group on Shelf Oceanography meeting at BSH, Hamburg, Germany 15-17 March 1999

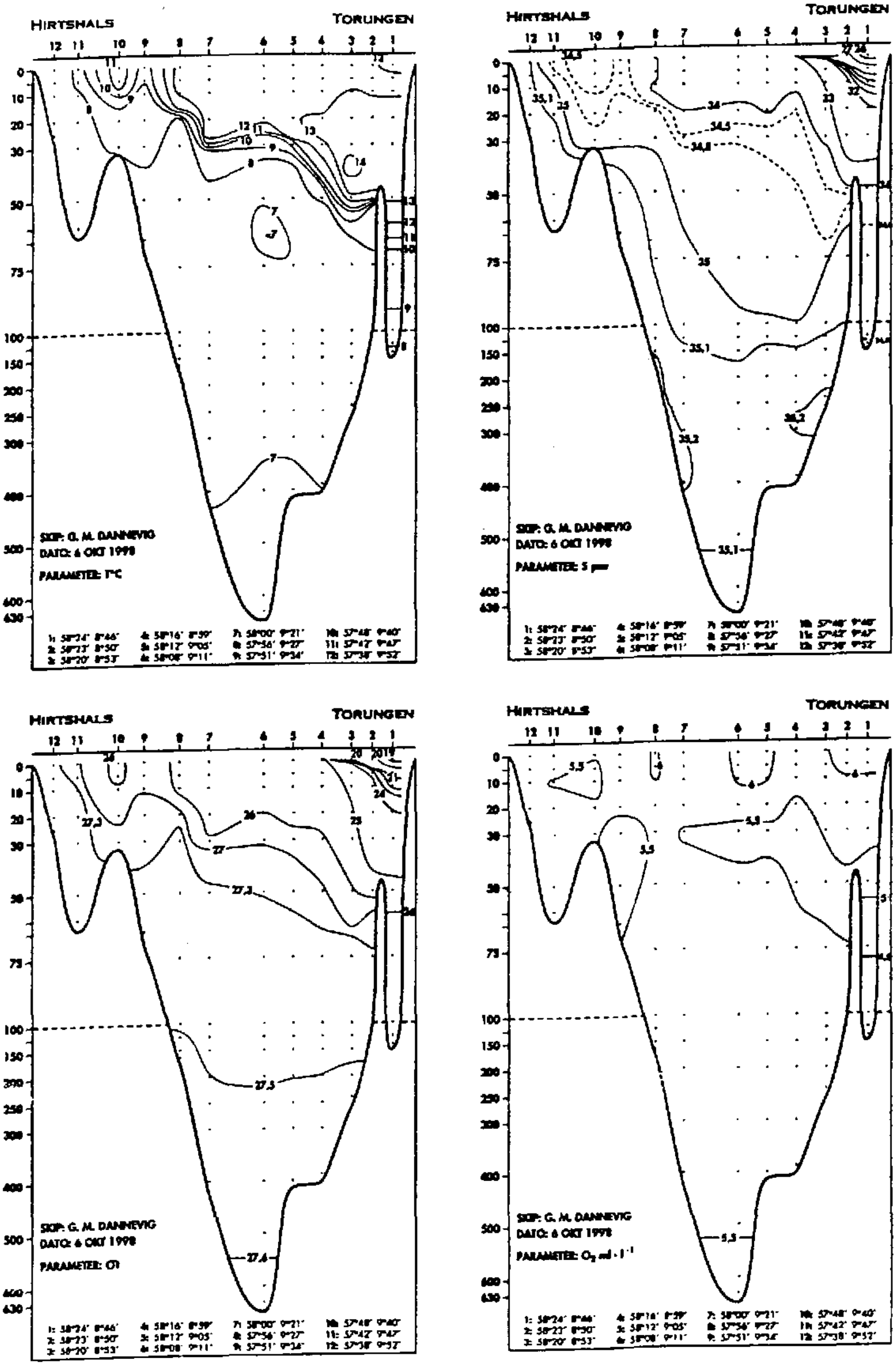
i) Welcome and opening
ii) Appointment of rapporteur
iii) Approval of agenda
iv) Report on national activities of specific interest to WG members
   a) Review the outcome of the theme session on skill assessment of environmental modelling
   b) North Sea drifter experiment
   c) Synthesis of available time series related to the Skagerrak.
   d) Report from the Fourth Backward facing Workshop
   e) Evaluation of effectiveness in environmental monitoring programmes
   f) Current and future use of remote sensing in shelf sea studies
   g) Comments on ICES Workshop on GOOS
   h) Sensitivity studies of open boundary conditions on model performance
   i) The effects on the coastal zone of regulating freshwater runoff
   j) Estimates of transit times along the Scottish west coast and the North Sea
   k) ICES Strategic plan – possible contribution from WGSSO
v) Place, date and topic for the next meeting
vi) Closing of the meeting

APPNEDIX IV. Terms of Reference and their justifications

a) Commence the synthesis of available time series related to the Skagerrak ecosystem variability
b) Prepare input to the Fourth Backward Facing Workshop
c) Summarise and review the outcome of the theme session on skill assessment of environmental modelling
d) Continue the evaluation of the effectiveness in environmental monitoring programmes (with focus on the North Sea) in determining trends against the background of natural space and time fluctuations, and the possible support from models
e) Review the current and future applications of remote sensing in shelf sea studies
f) Review the progress of the North Sea drifter experiment and agree protocol for evaluating model performance
g) Examine the effects on the coastal zone of regulating freshwater runoff (with focus on the Baltic Sea) and the effects on long term shifts in runoff patterns
h) Improve estimates of transit times along the Scottish west coast and around the North Sea
i) Extend the sensitivity studies of open boundary conditions on model performance
j) Propose tactics, activities and products in support of the Oceanography Committee' five-year plan objectives

Justifications:

a) The previous meeting (CM1998/C:2) prepared a list of parameters related to the Skagerrak which could be compiled to provide a meaningful and useful data set to investigate ecosystem variability in the region. These data must now be brought together to form a coherent set in a regular format that could be made widely available.
b) The Fourth Backward Facing Workshop takes place during 1999. In order to investigate past anomalies in the North Sea during the 1960s and 1970s, long time series of relevant parameters covering the period in question are required. A list of suitable available parameters has been drawn up and must be collated into a coherent data set in preparation for the workshop.
c) A Theme Session at the ICES Annual Science Conference 1998 was "Skill Assessment of Environmental Modelling". The meeting should summarise the methods of skill assessment that were described at the conference, review the statistical accuracy and reliability of the methods, and examine the applicability of the methods to various models.
d) During a discussion on the Baltic Monitoring Programme at the WG in 1997, some clear criticisms were raised especially with respect to undersampling, weak objectives and general status. Changes in strategy are underway, but before firm conclusions on the general functioning of monitoring programmes, the WG wants at least to review monitoring in the North Sea. Some ongoing monitoring programmes have problems with funding and some are heavily criticised. Therefore, it is important to evaluate the effectiveness of individual environmental monitoring programmes in determining possible trends against natural variability. Since Bundensamt für Seeschiffart und Hydrographie is responsible for the production of MURSYS environmental status report for the North Sea and the Baltic, Dr. G. Becker will present the monitoring behind this to see what general conclusions can be drawn.
   In the discussion of this matter in ACME 1998, ACME additionally advise that materials on this topic contained in the WGSAEM report (CM 1998/E:8) should be considered.
e) The basic marine research tools today are observations from ships and fixed (or drifting) platforms/buoys, remote sensing from satellites (and aircraft), numerical modelling and laboratory/mesocosm experiments. The WG therefore feels the need to be updated on the current and future application of remote sensing in shelf areas and will invite an expert in the field to present the topic.
f) At the previous meeting (CM 1998/C:2), it was agreed to conduct a drifter experiment in the southern North Sea (subject to funding being forthcoming). The experiment was planned to commence in February, so during present meeting it should be underway. The meeting should assess the progress of the experiment to date and modify or confirm future plans as required. In addition, the meeting should discuss and agree on a protocol for evaluating the performance of the numerical models, which will attempt to simulate the field results.
g) Freshwater runoff plays a vital role in the dynamics of the coastal zone. The regulation of freshwater discharge for hydroelectric schemes is increasing and the impact of such schemes on coastal zone dynamics and ecosystems is presently unknown. On longer time scales, climate change may lead to shifts in runoff patterns with similarly unknown effects on coastal waters.
h) Estimates of transit times from the Irish Sea into the North Sea are still based on tracer experiments and modelling studies (simulated under climatological mean conditions) conducted in the late seventies and early eighties. Recent pulsed discharges into the Irish Sea have been traced round the shelf seas far as the Norwegian coast and should allow for improved estimates of transit times to an around the North Sea. Recent current meter deployment on the Scottish west coast shelf may confirm estimates of transport rates.
i) Open boundary conditions are a crucial point for numerical models, especially those seeking to simulate nature. Since the North Atlantic exhibits strong variability on different scales, a study on how these variabilities influence the shelf seas and to what extent these variabilities have to be included in the boundary conditions is necessary. A preliminary study has been conducted, but it is proposed to extend the study to increase realism of the changes to the boundary conditions i.e., to balance the barotropic and baroclinic forces at the boundary.



Isolines of temperature, salinity, density and oxygen

APPENDIX VI. Report from the Theme Session on Skill Assessment of Environmental Modelling

Convener: Mr E. Svendsen (Norway) and Mr B. Sjöberg (Sweden)
Rapportuer: Mr. B Sjöberg (Sweden)

Background

Numerical models can be, and are, used for simulations of nature. The need for improved quantified knowledge (within reasonable costs) of the marine environment has strengthened the need for complex numerical simulations. How does one, in an objective way, assess the performance of and results from, a coupled environmental model? The answer to this question becomes increasingly important since model results are being used increasingly by management at many levels of decision making.
A number of comparisons between model results and field measurements exist with the aim to evaluate the current ability of numerical models to reproduce nature and their effectiveness in support of monitoring programmes. Numerical models can, among other things, be used for estimating typical scales and magnitudes of natural environmental variability, crucial information within any monitoring programme. However, there is still a great lack of objective quantified validation. Although some models show promising results, there is still a long way to go towards proper stepwise QA/QC of models. This is especially true for coupled physical-biological-chemical models.

Opening

The session was opened by Dr. Einar Svendsen

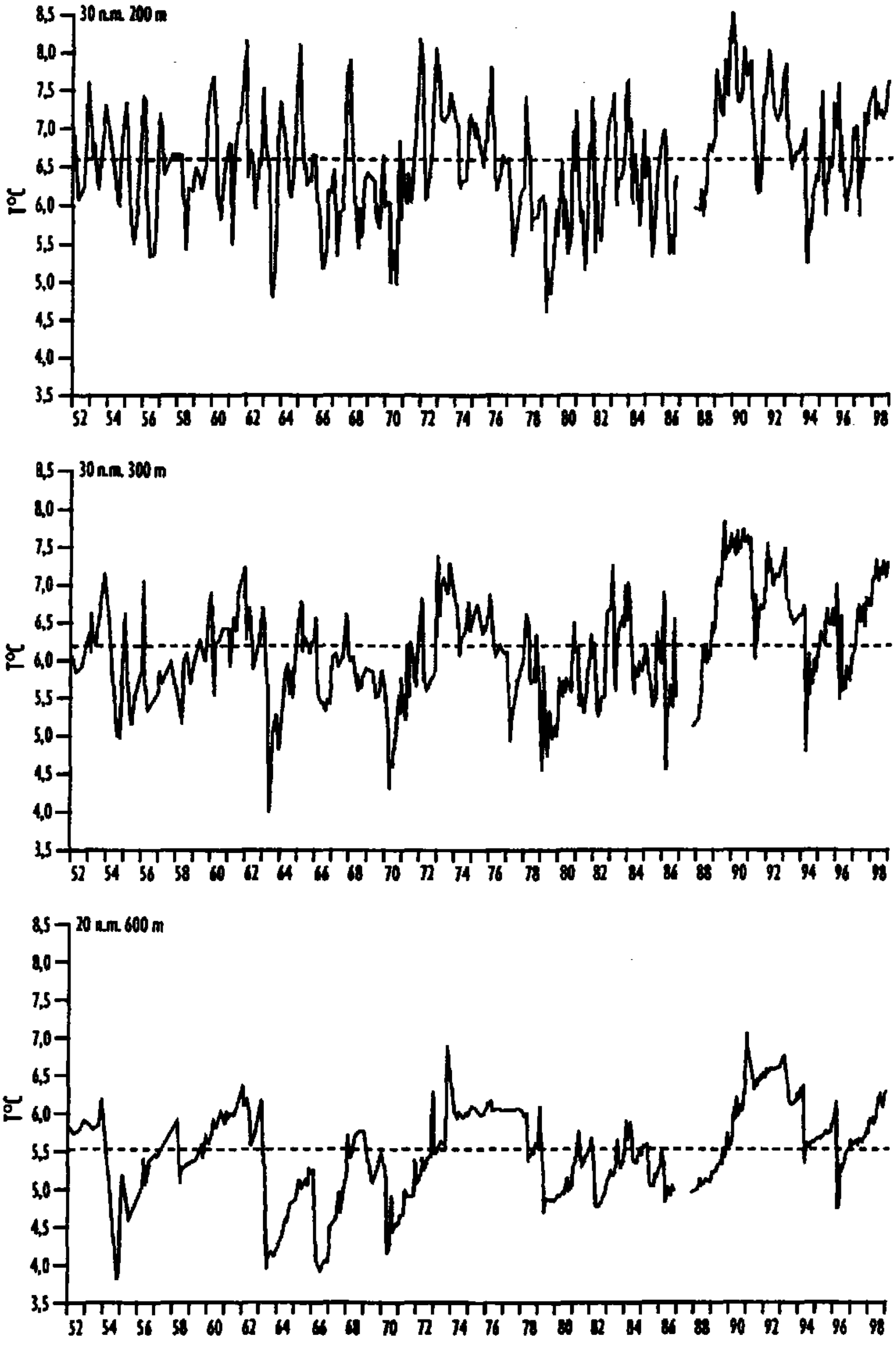
Presentations

Eight papers were presented. Six addressed validation-assessment procedures of specific models of different complexity whereas two papers discussed a conceptual framework for validation, generic as well as functional, and its implications on modelling.

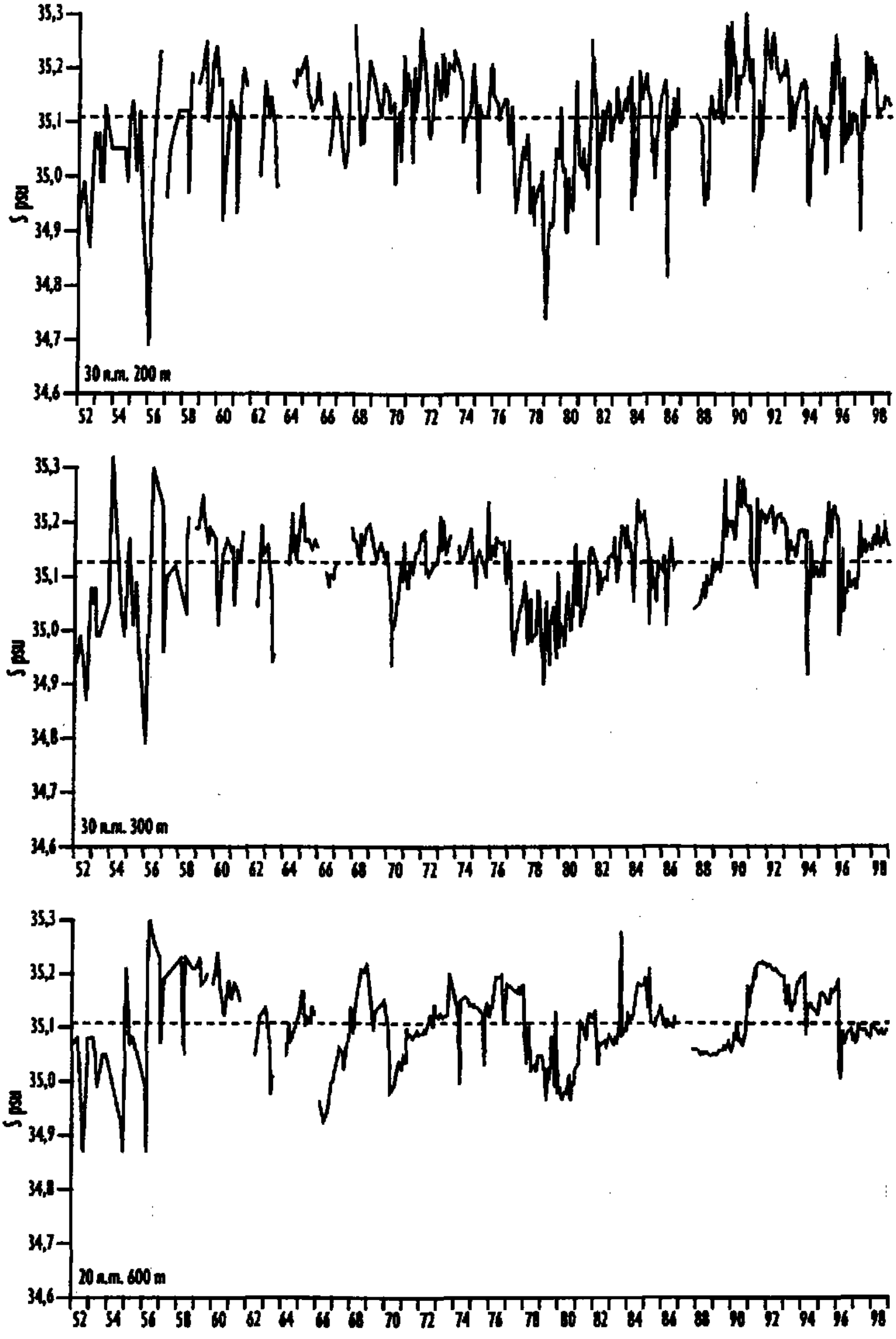
Conclusions

Unfortunately there was not enough time for discussion, but the conveners note the following conclusions:

1. In addition to more qualitative statements of model behaviour, two relatively new measures of integrated model performance were presented; the Cost Function and the SMAC (Simulation Model, Acceptability Criterion) method.
2. There are insufficient data available for adequate data for validation.
3. These methods needs further testing on a variety of areas, parameters and processes.
4. More attention should be paid towards testing models on their ability to reproduce ecosystem variability as opposed to mean conditions.
5. More works is needed to create a framework for validation.
6. Coupled ecosystem models are of prime importance for ICES work. ICES should actively support further development.



Temperature


35,3
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S psu
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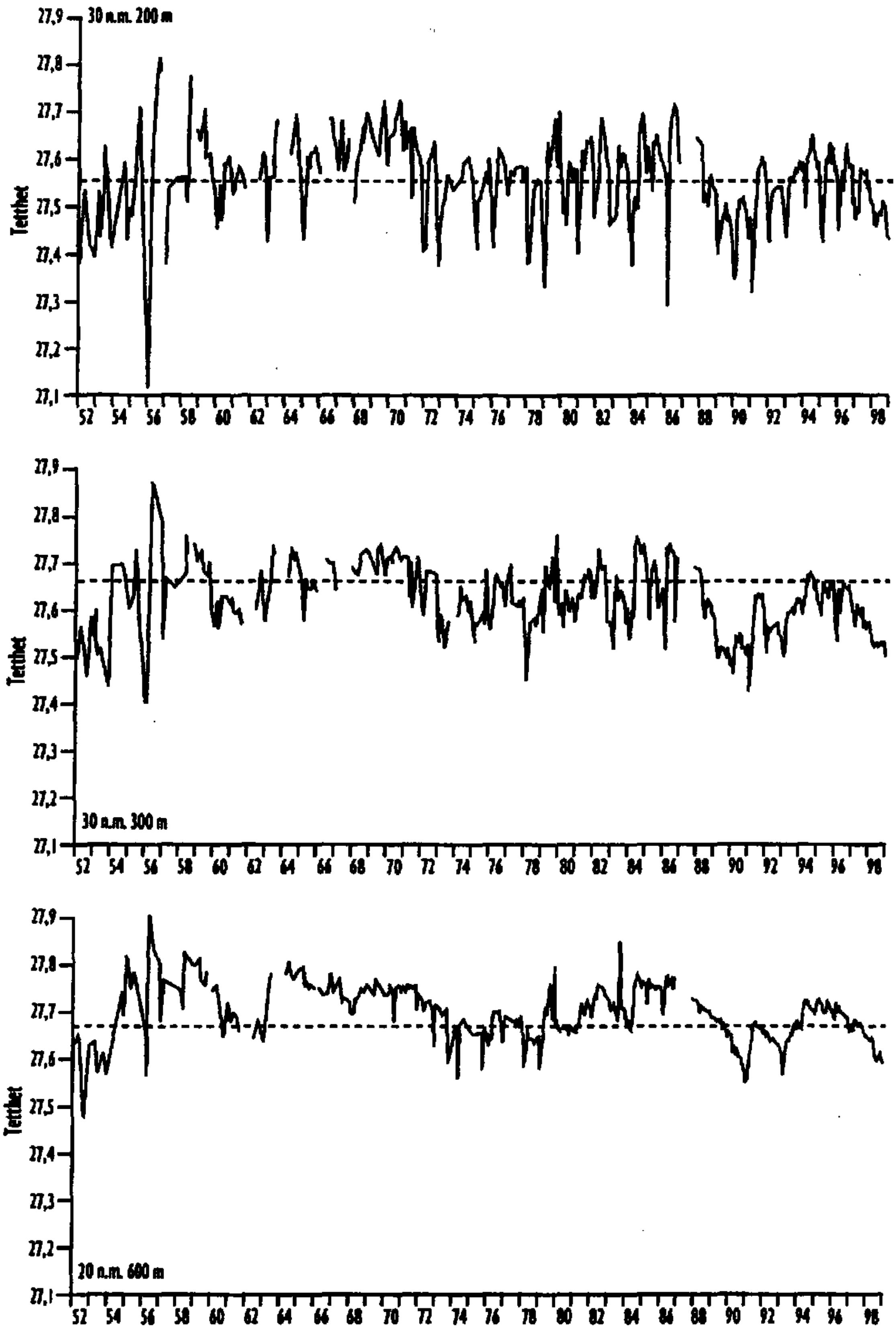
Salinity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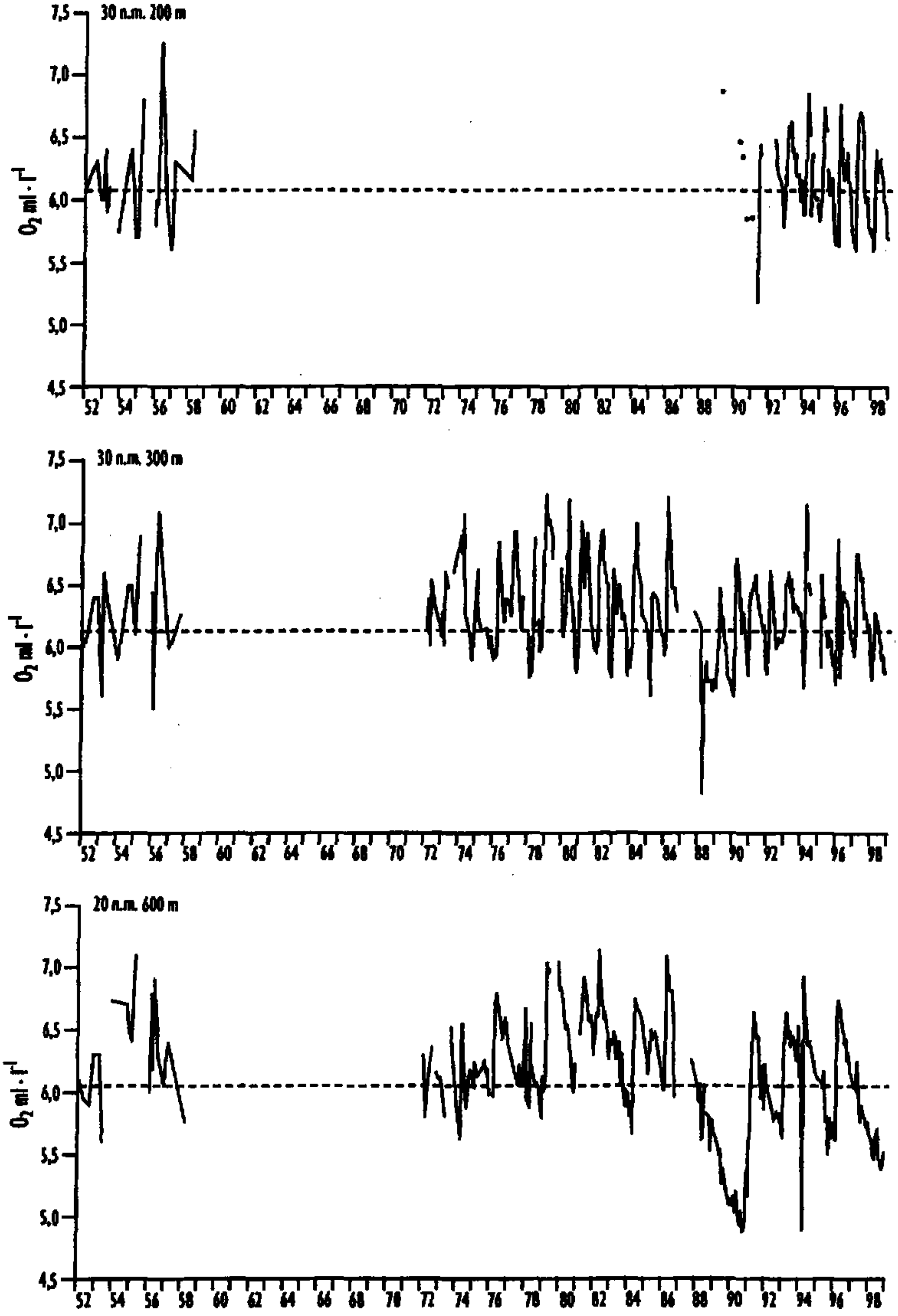
Sigma-t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O2 ml · l-1
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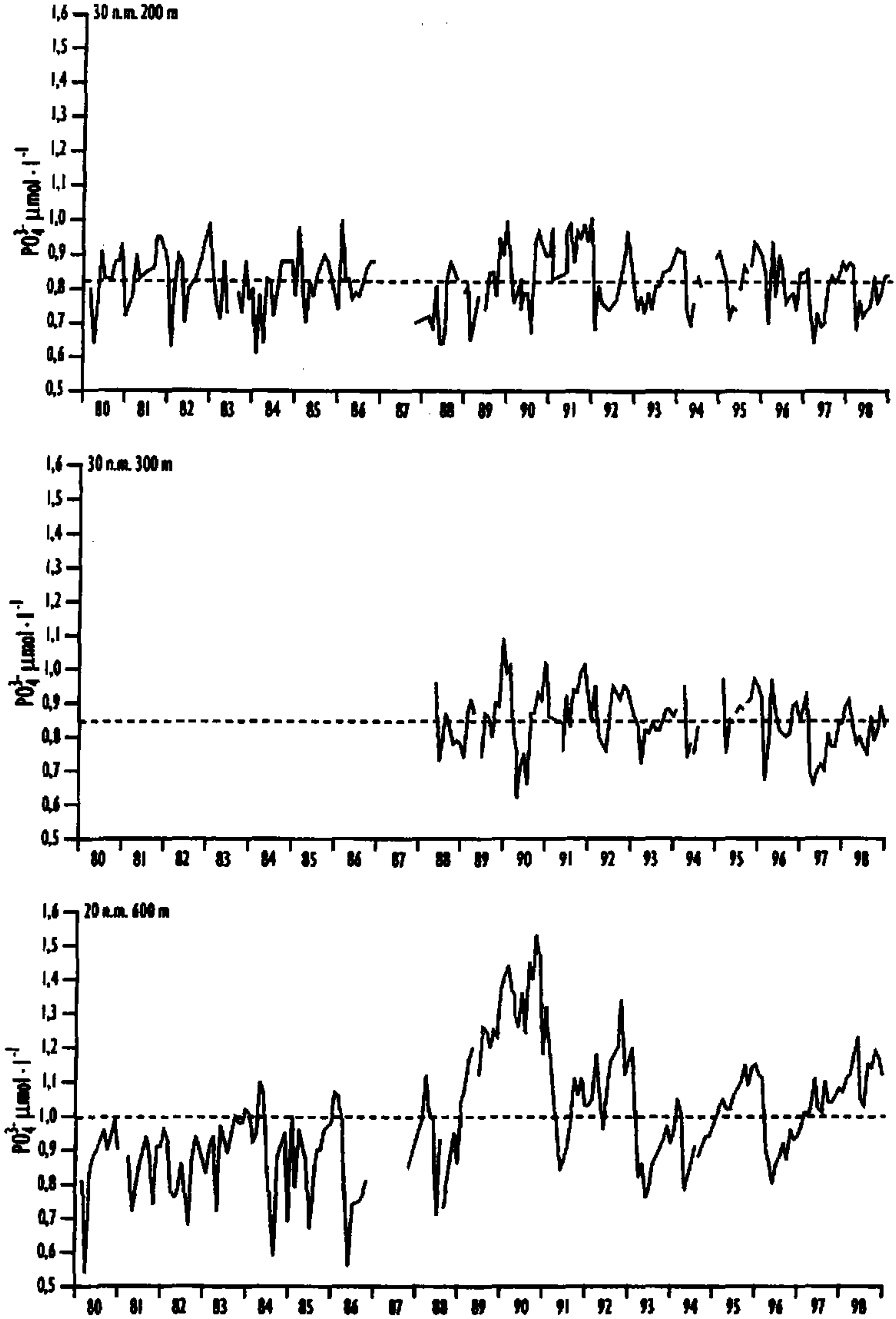
Oxygen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PO_4^{3-} µmol · l⁻¹
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0,9
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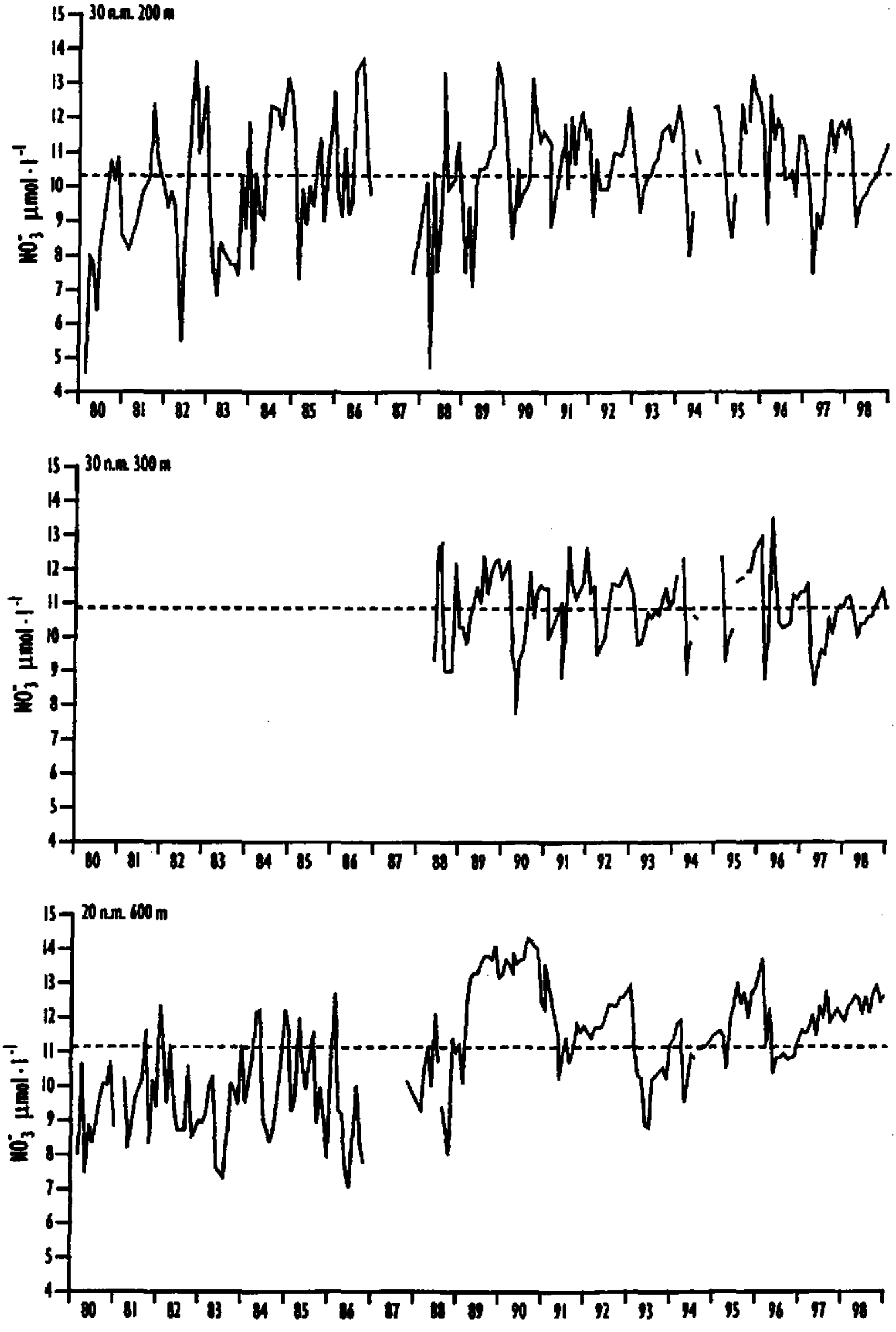
Phosphate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NO3- µmol · l-1
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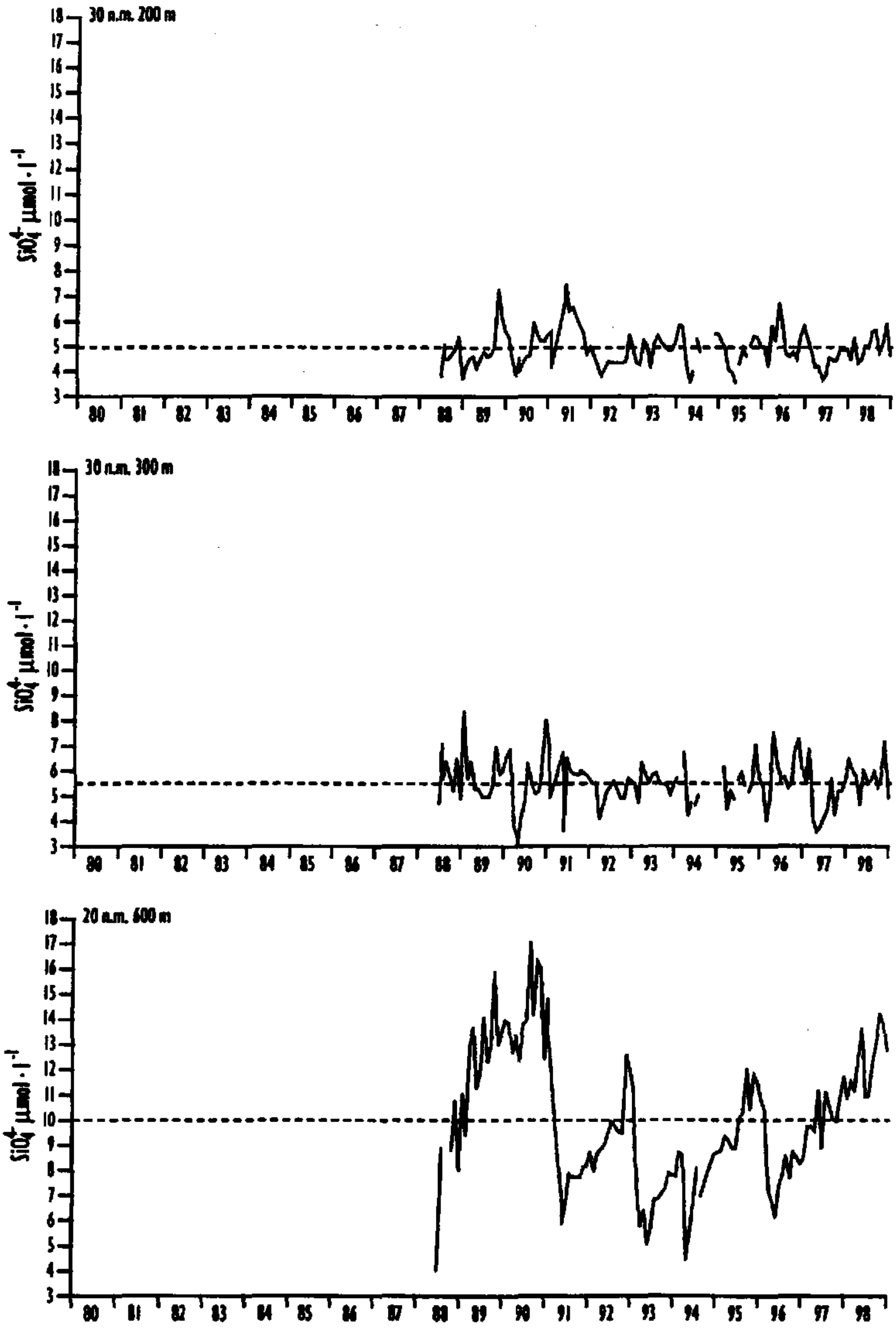
Nitrate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SiO_4^{4-} µmol · l^{-1}
80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98

Silicate

APPENDIX VIII. Main conclusions from the Fourth Backward facing Workshop

1. The gadoid outburst.
   1.1. There is no doubt that something happened to the gadoid fish stocks in the North Sea during the 1960's, but it is difficult to generalise as to the nature of the event.
   1.2. The catch of all gadoids was certainly very much greater in the 1960's than previously or since, but individual species showed different responses. There was no synchronous increase in recruitment across all species, although each species exhibited one or more high year classes in this decade.
   1.3. The workshop was unable to identify any process linking individual species recruitments to environmental factors during the 1960's, but there does appear to be some global correlation between what happened to the fish stocks, the North Atlantic Oscillation, and sea temperatures.
   1.4. The workshop could find no evidence to support the case for any interaction between the fate of pelagic fish stocks during the 1950's to 1970's and the behaviour of gadoid stocks.
   1.5. There is no sense in which the fisheries themselves could have stimulated the increase in yield from the gadoid stocks in the 1960's since the few exceptional year classes which supported the 'outburst' originated from relatively low spawning stock sizes. However, the fishery was certainly responsible for the dissipation of the outburst in the 1970's and 80's.
2. The environment in the 1960's and since.
   2.1. The 1960's decade can be clearly distinguished as being different from subsequent decades in terms of a variety of physical oceanographic characteristics which all appear to be linked to the North Atlantic Oscillation.
   2.2. Aspects, which were clearly different, included Atlantic inflow to the North Sea, sea temperatures, freshwater runoff and wind speed and direction.
   2.3. There is some evidence that the changes in physical conditions has been responsible for changes in the timing and magnitude of primary production in the North Sea, and it would be surprising if this did not have a significant effect on the ecosystem at large.
   2.4. There have been changes in the composition and abundance of zooplankton in the North Sea since the 1960's, some of which correlate with NAO signals. However, understanding of the processes responsible still eludes us in the vast majority of cases.
3. Understanding of the ecosystem.
   3.1. There is no comprehensive understanding of how the North Sea ecosystem functions, and it is clear that at the holistic level it cannot be explained in terms of a few parameters.
   3.2. Similarly there is no clear understanding of the relative importance of processes affecting the survivorship of fish early life stages leading up to recruitment, although data analysed during the workshop gave strong indications that the late pelagic and settlement phase may be the most influential for North Sea haddock.
   3.3. Even the most basic information on the ecology of North Sea gadoids is sadly lacking at present. For example, there is no North Sea wide, detailed information on the locations of spawning for cod or haddock, and no systematic surveys of the distribution and abundance of eggs and larvae.
   3.4. Nevertheless, the existence of holistic correlations between, for example, recruitment variability in cod and NAO signals, indicate that there is a tangible relationship between climate and fisheries in the North Sea, even if the causal processes presently elude us.

The annual runoff distribution has changed due to river regulation during present century (Ehlin and Zachrisson, 1974; Hupfer *et. al.*, 1983; Bergström and Carlsson, 1994; Carlsson and Sanner, 1994). Carlsson and Sanner (1994) quantified the impact of river regulation on runoff to the Gulf of Bothnia. They found that runoff increased due to hydroelectric energy production from October to April and decreased due to impoundment between May and September. From January to March, regulation even increased river runoff by about 70%. They also found very large differences between May and July. The additional monthly runoff to Gulf of Bothnia was calculated to be about 2-6 km^3 between November and April. This corresponds to a theoretical sea level increase of 2-6 cm per month. Although most water exchange processes in the Gulf of Bothnia are caused by meteorological forcing, Carlsson and Sanner pointed out that the changed annual cycle in runoff has an impact on salinity conditions (cf. also Launiainen and Vihma, 1990; Samuelsson, 1996).

Changes similar to those affecting the Gulf of Bothnia apply to the Baltic as a whole. Obviously, any increase in water supply to the Baltic causes greater outflow through the Danish Straits and reduces the inflow of saline water (cf. Gustafsson, 1998). The effects of regulation on runoff can be demonstrated by comparing mean annual cycles. The period 1921/1960 is hardly affected by regulation, while the period 1961/1990 must be regarded as clearly influenced (cf. also Carlsson and Sanner, 1994). Distinct differences can be seen between these two periods (Table 10). During 1961/1990, lower runoff was recorded from June to September and higher runoff between November and May (cf. also Hupfer *et. al.*, 1983). The greatest difference was about 13 km^3 in June. From January to April, the difference of 6 km^3 between these two periods is just as high as the mean differences in runoff ΞR between seasons without and with MBI (cf. Table 6). No comparable differences between two periods were found in the other meteorological or oceanographic variables considered.

Apart from the values for April and May, differences in the annual variation show good agreement with values Carlsson and Sanner (1994) calculated as man-made differences between simulated natural and recorded regulated runoff to the Gulf of Bothnia. This leads to the assumption that regulation of rivers in Sweden and Finland is important for the water exchange between the North Sea and the Baltic.

Variations in river runoff seem to play a more important role for salt transport into the Baltic than hitherto supposed, and especially for the occurrence or absence of major inflows. Mean runoff is not affected by river regulation in September and October, but gives rise to unfavourable conditions for the occurrence of MBI between November and April. Therefore, runoff redistribution must be considered a possible cause for the absence of MBI.

Table 10

Mean annual variation of differences in river runoff between 1961/1990 and 1921/1960 (Significance levels: 1 dot: 95%, 2 dots: 99%, 3 dots: 99.9%, 4 dots: 99.99%)

	Difference (km^3) (1961/90)-(1921/60)	Significance level
January	+ 5.7	●●●
February	+ 5.7	●●●●
March	+ 5.9	●●
April	+ 7.2	●●
May	+ 1.2	
June	– 12.9	●●●●
July	– 8.3	●●●●
August	– 3.2	
September	– 0.9	
October	+ 0.1	
November	+ 2.1	
December	+ 3.4	
Year	+ 6.0	