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REPORT OF THE

ICES/GLOBEC COD AND CLIMATE "AGGREGATION WORKSHOP"

Charlottenlund, 22-24 August 1994

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*General Secretary
ICES
Palægade 2-4
DK-1261 Copenhagen K
DENMARK

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1 SUMMARY

Following the recommendations of the ICES/GLOBEC Cod and Climate Change Working Group outlined in Lowestoft 1993 (resolution 2:5:3:) the Cod and Climate Change "AGGREGATION" Workshop was held in Charlottenlund, Denmark from 22-24 August, 1994. The co-chairmen Dr B. MacKenzie (Denmark) and Dr M. St. John (Denmark) were directed to consider during this workshop whether and how intermediate-scale physical oceanographic processes (metres to kilometres and days to weeks as defined by Haury *et al.*, 1978) govern cod stock fluctuations. This report summarizing the discussions during the meeting was prepared by the co-chairmen and four rapporteurs (Drs Brad deYoung, Pierre Pepin, Ian Perry, Svein Sundby).

2 OBJECTIVES AND FRAMEWORK

The 1993 ICES/GLOBEC Cod and Climate Change Working Group in Lowestoft recognized the importance of physical processes in producing, aggregating and dispersing food organisms required by various stages of cod throughout its geographic range. In particular, the working group noted that there is a gap in our knowledge of how processes which take place at intermediate scales (spatial scales metres to kilometres, temporal scales of days to weeks) affect cod biology. During this meeting a number of processes and phenomena were identified on these scales. These included $h/(U)^3$ tidal mixing, shelf break fronts, eddies and rings, (e.g., Taylor columns, Von Karmen Vortex fields, topographically trapped eddies). These features were proposed for discussion in the AGGREGATION Workshop, as possible mechanisms affecting the distributions and feeding activities of cod populations both directly and indirectly, and it was suggested that different sizes of cod were affected in different ways by these phenomena.

In order to examine the interaction of these physical processes with cod biology a number of terms of reference were identified for focusing discussion on individual features. These were identified in the report of the working group on Cod and Climate C.M. 1993/G:3 and are as follows:

a) physical mechanisms resulting in enhanced nutrient flux;

b) the effects of physical processes on food webs and hence on transfer efficiencies to all stages of cod;

c) influence of turbulence on larval and 0-group feeding ecology;

d) distribution of larvae, juveniles, and their prey due to migratory patterns in a variable flow field;

e) implications of intermediate-scale physical processes for "match/mismatch" of larvae and their prey;

f) linkage of these processes to enhanced growth, condition, and survival of all life stages of cod.

Prior to the workshop, the co-chairmen identified the lack of information available on the effects of these Intermediate Scale Physical Processes on cod biology. The workshop scope was then expanded to include the effects of these processes on the pelagic stages of fish in general. The rational for this being that information gained from other species may help to elucidate the effects of these processes on the pelagic stages of cod.

3 MEETING PROCEEDINGS

3.1 Introduction

Some of the most intensely studied processes in the marine environment are those resulting from the interaction of bottom topography with circulation patterns generated by tides, wind, runoff and residual circulation. These processes act to generate turbulent mixing of the water column and circulation patterns which may inject nutrients limiting phytoplankton growth into the euphotic zone or entrain and retain organisms in specific water masses or regions. Numerous hypotheses have been generated around the effects of these processes and subsequent plankton production on fisheries recruitment variability (e.g. larval drift hypothesis, match/mismatch hypothesis, larval retention and or member vagrant hypothesis). In general, increased densities of the planktonic prey items of larval fish are observed in these regions. It has been proposed that these aggregations of prey are the result of increased growth rates and or the interaction between organism behaviour with circulation patterns. Phytoplankton production in these regions has rarely been seen to correspond with increased zooplankton biomass or enhanced larval fish condition. This has been proposed to be due to the complex circulations existing in these regions and the difference in generation times and complex life history strategies of the different trophic levels.

This work shop was established to examine the effects of intermediate scale (metres to kilometres on the spatial scale and hours to days on the temporal scale) physical oceanographic processes on the biology of all life history stages of cod. In order to do so, contributors were asked to present information about physical processes on intermediate scales influencing the biology of fisheries stocks in their respective regions. After the completion of these presentations the group was divided into two subgroups, one examining horizontal transport processes and the other focusing on vertical mixing processes. The Working Groups recognized the close connections and inter-

relationships between vertical and horizontal processes, and that the division is somewhat arbitrary. Therefore, discussion in each group was not limited in this manner. In order to clearly represent the content of the discussions in the two groups, information will be presented in this report by specific **Term of Reference** as given by ICES and information on the research performed on these **Processes by Stock** will also be presented. Other discussions not dealing with specific terms of reference but deemed of importance with respect to future research initiatives will be presented in the section titled **Information Gaps.**

3.2 Information With Respect to Specific Term Of Reference

a) physical mechanisms resulting in enhanced nutrient flux;

In general, few studies directly addressed the influence of physical processes on the flux of nutrients into the stratified water column although this process was inferred in many cases. Turbulent vertical mixing occurring in $h/[U]^3$ tidal fronts, wind induced Ekman pumping, and shear instabilities as well as the raising of nutriclines due to eddies which are locally fixed or shed from topographic features have been demonstrated elsewhere to influence the nutrient regime available to resident phytoplankton cells as well as the phytoplankton community composition. In particular, water columns which are mixed due to Ekman pumping and tidal mixing are sites of diatom production which has been proposed to be the basis of the food web contributing to fisheries production. At high latitudes, these regions are of particular interest because they continue to demonstrate high primary production rates and phytoplankton biomass even after the completion of the spring diatom bloom. In general, evidence demonstrating the influence of these mechanisms on higher trophic level production is limited due to the complex circulation patterns in these regions. However, evidence presented during this work shop utilizing lipid biomarkers specific to diatom production in these regions established their importance for condition of larval and juvenile cod.

b) the effects of physical processes on food webs and hence on transfer efficiencies to all stages of cod;

Integrated sampling programs, examining lower trophic level production and the transfer efficiency of biomass between the various trophic levels were not presented during this work shop. In general the need for integrated sampling programs was recognized and it was suggested that in order to determine the importance of intermediate scale processes to larval and juvenile recruitment success a direct linkage of the transfer of lower trophic level production to these stages is required (see also Term of Reference f).

c) influence of turbulence on larval and 0-group feeding ecology;

Several investigators are studying how turbulence influences the feeding rates and behaviour of larval cod. Evidence presented at the meeting indicated that the gut contents of larval cod captured near Georges Bank were related to both food density and levels of tide- and wind-generated turbulent mixing. In addition, recent studies have shown that (1) larval fish may experience reduced feeding success in conditions of high turbulence, (2) different species of larvae have different search strategies which affect their potential benefit derived from turbulence-related encounter, (3) larger larvae and 0-group juveniles may benefit from turbulence, although this benefit decreases substantially with larval swimming speed. Discussions at the workshop questioned which type of habitat is most suitable for larval survival (e.g. a low food density, turbulent environment or a higher food density, calmer environment) and the appropriate spatial scales of turbulence likely to affect larval fish encounter rates.

The workshop generally felt that turbulence characteristics within and adjacent to intermediate scale physical oceanographic features were important environmental factors which affected prey aggregation, fish - prey encounter rate, and feeding success. No study has yet demonstrated a linkage between turbulence intensity in the larval habitat and cod recruitment, although such linkages are well-established for other species. Nevertheless, the workshop recognizes the numerous important roles that turbulence has on larval and juvenile cod feeding rates (e. g. encounter rate, pursuit success, prey production, and patch dispersal), and therefore supports continued investigations in this area.

d) distribution of larvae, juveniles, and their prey due to migratory patterns in a variable flow field;

The dispersion and transport of the early life stages of cod and their prey results partly from the interaction of vertical distributions (determined by buoyancy and behaviour) with depth-related variations in flow. Does the flow field lead to dispersion or aggregation of the eggs and larvae? At different life stages both processes are important to the survival of the fish. The most important factor determining the response is the spatial structure of the horizontal currents. Also important particularly in frontal regions, is the strength and character of the vertical currents.

On some shelf regions there do appear to be closed circulations that are able to contain, if not to aggregate the larvae. Georges Bank, the Flemish Cap and the Færoe Bank all appear to have retentive circulations. Other large shelf regions, such as the Newfoundland and Norwegian shelves have strong along-shelf flows with

intensified shelf break currents. In these regions, eggs and larvae can be carried significant distances along-shelf. The importance and nature of the cross-shelf flows in these regions are largely unexplored.

Egg buoyancy appears to be variable over the range of observed cod stocks. In general data on egg and larval buoyancy is limited and the influence of environmental variability on the buoyancy is only just beginning to be explored. The best studied eggs (e. g. Norwegian and Baltic cod) show very different characteristics. Norwegian cod eggs are positively buoyant relative to the density of the surface layer and Baltic eggs are negatively buoyant relative to the density of the surface layer.

Studies in Georges Bank and elsewhere show that the vertical distribution and movement of the eggs and larvae can play a critical role in determining the location and concentration of settling juveniles. The workshop concluded that studies of egg and larval buoyancy and vertical distribution and of intermediate-scale circulation features (e. g. bank-scale flows, along- and cross-shelf exchanges) would contribute to our understanding of how variable flow fields influence distributions of eggs, larvae, and juveniles.

e) implications of intermediate-scale physical processes for "match/mismatch" of larvae and their prey;

Linkage of larval and juvenile distribution patterns with specific physical regimes were presented for a number species and regions i.e. North Sea (tidal fronts), Gulf of Alaska (eddy circulations), Mississippi River (Plume dynamics). The importance of the co-occurrence of these features with the larval and juvenile stages was generally recognized as a key process influencing recruitment success. In particular for cod, examples were presented of the association of larval and juvenile cod with $h/[U]^3$ tidal fronts in the North Sea. The results of a stability model to describe frontal dynamics in the North Sea was presented and used to examine historic variations of cod recruitment with timing of the onset of the spring bloom, wind induced turbulent mixing and stratification intensity (frontal mixing intensity). It was suggested that the results of numerical modelling studies be used to link the annual variability of intermediate scale physical processes and recruitment variability. The study group recognized the necessity of understanding underlying processes effecting larval growth and condition in order to adequately model the key processes affecting recruitment variability.

f) linkage of these processes to enhanced growth, condition, and survival of all life stages of cod.

During this meeting, data was presented linking diatom production associated with tidal mixing in the North Sea with increased fitness of juvenile cod. Fatty acid biomarkers specific to diatom cells found in the frontal regions of the North Sea were demonstrated through lab studies to be transferred conservatively through a copepod intermediary to larval cod. The establishment of this relationship in the lab allowed the utilization of fatty acid content in field caught larvae and juveniles to determine the respective food webs and physical regimes contributing to the condition in individual fish. Research presented demonstrated that larval and juvenile cod displaying fatty acid content indicative of the utilization of diatom production resulting from frontal mixing in the North Sea were in significantly better condition (as determined by storage lipid content) than individuals not utilizing this food web.

The conservative nature of these markers in the marine environment was demonstrated in this study and the utility of these markers for identifying the contribution of specific physical regimes to larval and juvenile cod condition was established. It was suggested during the workshop that the utilization of these lipid biomarkers and other biological tracers may present a mechanism to link variations in fisheries recruitment success to variability in intermediate scale physical oceanographic processes. The group supported future research initiatives in this area.

3.3 State of Knowledge by Stock

The Work Shop examined individual cod stocks briefly in an attempt to identify which intermediate-scale physical processes might influence larval cod growth and subsequent recruitment.

A) LABRADOR AND NEWFOUNDLAND COD

- spawning occurs over the entire shelf, including the banks, and in deep water. There is no evidence of a strong association with specific water masses of other hydrographic features.

- spawning is protracted in time (late winter through early summer) and generally progresses from north to south in time. Spawning activity within regions occurs over the period of approximately 2 months. The variability in timing of spawning is of the order of one month.

- egg and larva dispersion is known to be important but the details are very sketchy. For example, what is the role of the shelf break current under which most of the spawning occurs?

- mean circulation field suggests that many eggs and larvae would be advected off the shelf during the period of development. Simulation studies indicate that short term variations in wind forcing could move eggs and larvae onto the shelf towards inshore

areas where the majority of juveniles appear to be distributed.

- although inshore areas are one nursery region, its importance relative to other regions has not been established.

- there is no direct evidence of the importance of mesoscale processes on recruitment variability.

B) NORTHERN GULF OF ST. LAWRENCE COD

- spawn on a small bank in the northern Gulf of St. Lawrence, along the western coast of Newfoundland, at about 200 m depth.

- this position may at times be related to the edge of the winter sea ice edge, as it begins to break-up in spring.

- no obvious intermediate scale physical oceanographic features related to this location and it was suggested that this was due to the lack of studies examining processes at these scales.

- spawning may be timed for optimum formation of a stable upper layer, e.g. as the ice melts. However, in recent years cod eggs were associated with the very cold (less than 0° C) intermediate water mass layer. It is doubtful whether these eggs could survive.

- eggs likely drift in the slow currents along western Newfoundland, and do not experience extensive transport.

- information on larval and juvenile distributions, and mesoscale features such as fronts and eddies, are generally lacking for this area.

C) SCOTIAN SHELF

- both spring and fall spawning have been observed
- retention of larvae on banks at the outer shelf has been observed.

D) GEORGES BANK

- the importance of frontal regions to cod recruitment has been suspected, and is currently being investigated. One method for assessing the importance of fronts to cod growth is to use the technique of lipid spectrum analysis, to identify whether cod utilize a diatom-based food-web, likely associated with the frontal regions.

E) NORTH SEA AND ADJACENT STOCKS

- cod spawn in many parts of the North Sea, but the magnitude of the contribution of the different spawning areas to the total population is not known. It is therefore difficult to relate events in particular areas, such as fronts, to the recruitment calculated for the whole population.

- spawning appears related to the annual production cycle. It seems to start earlier in areas with early spring blooms, and is delayed in areas like the Bristol Channel which is strongly tidally mixed. If spawning is adapted to the timing of production, then it must be adapted to climatological conditions rather than conditions for any particular year, providing a source of interannual variability in the match between production and spawning.

- larvae are not transported long distances (as they are in the Norwegian coastal current), but it is unclear whether they are "retained".

- cod do not seem to spawn in turbid regions of the North Sea.

F) NORWEGIAN COASTAL COD

- there appears to be a gradient in cod stocks on the coast of Norway, with small stocks occurring in the fjords, larger stocks along the continental shelf, and the very large and broadly distributed stock of NE Arctic (Arcto-Norwegian) cod. Gradients in productivity also occur in similar ways.

G) ARCTO-NORWEGIAN COD

- spawning period extends from beginning of March to the beginning of May and is normally distributed. Peak spawning (i. e. the date when 50% of eggs have been spawned) occurs at a very constant time each year (ca. 1 April).

- eggs and larvae drift north, so that the nursery grounds (in the Barents Sea) are very distant from the spawning grounds.

- within these areas, and along the drift path, there are large banks with topographically-steered currents and high concentrations of larvae. Iceland cod have a similar situation. The transport and spread of eggs to juveniles is influenced by biotic effects (e.g. buoyancy and vertical migrations) and by abiotic effects (e.g. dispersion, wind, tide, topographic steering).

H) BALTIC COD

- eggs spawned early are very buoyant with a large

diameter, while later spawning eggs tend to be smaller and less buoyant. Buoyancy and vertical position of cod eggs is crucial in the Baltic because of the low oxygen bottom layer. Therefore, lower survival for the later-spawned eggs is predicted. However, recently the salinity of the Baltic has decreased, and the eggs occur in deeper water, although the low oxygen layer has also become smaller with increased vertical mixing.

- why has the spawning period been displaced towards autumn? At the same time, there has been a shift in size of cod towards smaller (and younger) fish.

- the Baltic has weak internal mixing, except at the halocline which is dominated by internal waves. However it appears that larvae and juveniles (0-group) are found predominately in shallow coastal areas, possibly due to wind-driven circulation.

- intermediate-scale processes (e. g. upwellings, fronts) are transient, and their possible effects on cod distribution and growth will be difficult to determine.

3.4 Information Gaps

Several data gaps prevent rigorous testing of the hypothesis that variability in cod recruitment and intermediate scale physical oceanographic features are linked. In general, the sites and characteristics of the nursery grounds are unknown. In order to clarify this situation, the following gaps in knowledge were identified by the group:

1) Survival probability of eggs as influenced by spawning time and site, as well as adult characteristics (e. g. size, age).

It was recognized for a number of stocks that information on the timing of spawning and the influence of adult characteristics (e. g. size and age at first maturity, size at spawning) on egg quality and survival probability was unavailable or had changed dramatically (e.g. Baltic cod). This information is required to facilitate drift model studies to examine larval drift/retention, changes in food webs contributing to larval and juvenile prey fields, and mortality due to predation. Future research involving these aspects of cod reproductive biology is required to determine how intermediate scale processes influence recruitment success.

2) Circulation patterns at mesoscales.

The focus of future research involving intermediate scale physical processes should emphasize the role of banks and other topographic features on intermediate scale circulation features and transport. Better circulation models need to be developed and measurements of small scale circulation patterns must be obtained. These results must be utilized to describe the influence of circulation on the aggregation, dispersion and growth of cod and their prey. It was recommended that indices derived from such models should be used instead of raw environmental descriptors (e.g. depth averaged water temperature) when conducting exploratory statistical analyses of the effects of such processes on cod recruitment.

3) Egg, larval and juvenile buoyancy, behaviour and vertical distribution.

During discussions the lack of information available on the vertical distribution of egg, larval and juvenile stages for utilization in physical advection diffusion models was made evident. The lack of quality data on these stages severely limits modelling the distribution of these stages and as such should be incorporated into existing field programs where possible.

4) Comparative studies of larval and juvenile growth and condition along gradients between and in adjoining oceanographic regimes.

In order to determine the temporal and spatial importance of specific intermediate scale oceanographic features on larval growth, condition and survival comparative studies must be performed. For example, determining variation across oceanographic regimes of larval feeding and growth on different time scales, utilizing estimators as stomach contents, lipid energy reserves, protein growth rate estimates, morphometrics, and otolith growth histories, digestive enzyme analysis would permit an assessment of how long samples of larvae may have been influenced by a specific physical regime.

5) Temporal variability of vertical mixing and importance of scaling to biological rates.

Vertical mixing must be recognized as a very dynamic process. What may ultimately be important for production of phytoplankton, zooplankton and larval and juvenile fish is the periodicity of stabilization and intensity of mixing. The frequency of this alternation may be important for favouring different biological processes, e.g. frequent mixing and stratification periods may favour diatom production, while it may be that less frequent mixing periods favour feeding success of larval cod. Long periods of strong stability were recognized as generally unfavourable for high production (of phytoplankton or cod), while it is less clear of the impact of periods of strong and frequent mixing. Future research should examine the period of stabilization-destabilization and the optimization of phytoplankton growth rates and efficiency of transfer of primary production to higher trophic levels.

6) Effects of intermediate scale physical processes on distribution and abundance of prey and predators of cod early life history stages.

Most of the intermediate scale physical processes that were discussed in the group session also have effects on rates of production of larval prey, as well as prey and larval transport. There was no consensus on how much variability in zooplankton abundance and production rates could be attributed to localized production (e. g. at a tidal front) or to convergent circulation patterns. Expertise on this matter may be available from other ICES or GLOBEC committees, and collaboration with these committees is encouraged.

7) Time scales of aggregation and dispersion of larval cod and their prey relative to time scales of production of zooplankton prey.

The ability of larvae to locate, recognize and remain associated with patches (m to 10's of m spatial scale) of prey is not well understood, particularly in open sea conditions, where such patches can form and disperse at short time scales (e. g. due to storm passage). One of the group's suggestions for studying this problem was to conduct patch studies with sampling conducted inside and outside the patch. Such studies would also help to quantify components of prey availability (e. g. prey densities, turbulence) required by larval cod within and outside regions influenced by intermediate scale physical oceanographic processes.

8) Feeding rates and success of larval cod near and away from intermediate scale oceanographic features, and how these characteristics can be modified by small-scale turbulence.

There is increasing evidence that larval cod feeding rates and behaviour is sensitive to the turbulent motion that is inherent to the regions where intermediate scale physical processes occur. Feeding and growth rates of larvae may therefore be unexpectedly high in areas having low food densities but moderate to high levels of turbulence, compared to feeding rates in transition areas between frontal and stratified water columns and at the base of the mixed layer in the region of the chlorophyll or zooplankton maximum. The possibility that larvae choose habitats (e. g. depth ranges) to maximize feeding rates should be investigated.

9) Utilization of biotracers.

Due to the spatial and temporal variability of tidal fronts, wind mixing, shelf break fronts etc. as well as organism behaviour the linkage of enhanced growth rates and condition to mixing features is often not demonstrated. The utility of biotracers for linking growth and condition to specific food webs has been demonstrated here and future utilization of these techniques is required in order to establish the importance of these mixing processes to larval and juvenile growth and condition.

10) Community data bases of environmental parameters to aid in intercomparison of modelling initiatives.

A need for standardized environmental data sets was recognized, particularly for data which are used as input to models of circulation and biological processes, such as meteorological data. These data are not always readily available in usable formats. Use of different input data, or the same data but converted in different ways, makes evaluation and comparison of models very difficult.

3.5 Recommendations

1) Develop improved descriptions of egg, larval and 0-group cod buoyancy and behaviour (e. g. vertical migration, feeding activity in vicinity of patches) and include these descriptions in transport and circulation models of larval and juvenile distribution.

2) Identify characteristics of adult cod which result in high probability of egg survival, and establish the timing and location of spawning for those cod populations having flexible or multiple spawning periods (e. g. Baltic cod).

3) Continue to support physical oceanographic modelling programs examining dispersion and retention of eggs, larvae and juveniles, particularly those which focus on processes at intermediate scales.

4) Identify potential data sets that could be used to assess effects of intermediate scale physical oceanographic processes on the aggregation of cod and their prey, and encourage investigators to develop models of dynamic processes (e. g. retention times on banks) that can be related to the distribution, aggregation and dispersion of eggs, larvae and pelagic juveniles.

5) Conduct patch studies designed to identify specific processes beneficial or detrimental to larval survival. Such studies could, for example, use biotracers to investigate time scales of prey aggregation and production in frontal regions, relative to the time scales of larval feeding (e. g. patch recognition) and growth.

3.6 Terms of Reference For Next Cod and Climate Change Working Group Meeting:

1) review statistical attempts to relate indices derived from mechanistic physical oceanographic models to

variations in cod distribution, growth, condition and recruitment.

2) review advances in physical oceanographic models of the mesoscale transport of eggs, larvae and juveniles from spawning grounds to potential nursery areas.

3) review advances in understanding retentive circulation patterns occurring in and around fronts and banks.

4) examine field evidence of linkages between plankton production at intermediate scale physical oceanographic features, cod condition, growth and recruitment.

5) review progress on the understanding of how turbulence intensities in different hydrodynamic regimes affect larval and juvenile cod feeding (pursuit success, ingestion rate, prey patch dynamics and prey production).

APPENDIX 1

Aggregation Workshop Program

22 August, 1994

Location: Riddersalen, Charlottenlund Castle

0930 **Jørgen Møller Christensen** (Greetings)
Director of Danish Institute for Fisheries and Marine Research

0945 **Keith Brander** (Update on ICES/GLOBEC Cod and Climate Change Activities)
Chairman of ICES /GLOBEC Cod and Climate Change Working Group

1005 **Mike St. John** (Meeting Outline)

Session 1: Opening talks *(45 minutes: 40 minutes for presentation and 5 minutes for discussion)*

1015 **Eskild Kirkegaard:** Stock-recruitment and management advice.

1100 **Coffee Break**

1115 **Thomas Kiørboe:** Effects of meso- and microscale hydrodynamics on plankton production and trophic interactions.

1200 **Larry Hutchings:** A structured approach to using biological and environmental parameters to predict anchovy recruitment.

1300 **Lunch**

Session 2: Process-Oriented Studies *(20 minutes each: 15 minutes for presentation and 5 minutes for discussion)*

1. Shelf-break and tidal fronts

1400 - **Andy Visser:** Physical oceanographic characteristics of frontal environments.

1420 - **Peter Munk:** Aggregation of larval and juvenile cod along a hydrographic front.

1440 - **Greg Lough:** The vertical distribution of cod and haddock larvae and their zooplankton prey in relation to stratification (turbulence) on Georges Bank.

2. Coastal Upwelling

1500 - **Brian MacKenzie:** Upwelling events, temporal and spatial plankton distributions, and capelin recruitment.

1520 - **Titt Raid:** Frontal structures and the distribution of young pelagic fish in the Baltic Sea.

1540 **Coffee Break**

3. Taylor Columns

1555 - **John Dower:** Are Taylor columns important to plankton aggregation near sea mounts and banks?

1615 - **Harry Dooley:** Interaction of Rockall Bank Taylor column with haddock.

4. Freshwater influences

1635 - **Stig Skreslet:** Freshwater discharge variability, biological productivity, and year class strength in Norwegian cod.

1655 - **John Govoni:** Mississippi River discharge and the distribution and recruitment of Gulf menhaden. (End of Day 1)

August 23 Session 3: Process-Oriented Studies Continued

5. Transport and circulation processes

0900 - **Brad deYoung:** Dispersion of eggs and larvae and spawning strategies: applications to the Newfoundland Shelf.

0920 - **Lewis Incze:** Mesoscale features of the Alaska Coastal Current: larval fish distributions and possible ecological consequences.

0940 - **Pierre Pepin:** Modelling the evolution of fish egg distributions in a coastal embayment using HF radar.

1000 - **Cisco Werner:** Coupled circulation and trophodynamic models for larval cod and haddock on Georges Bank. I.

1020 - **Ian Perry:** Coupled circulation and trophodynamic models for larval cod and haddock on Georges Bank. II.

1040 **Coffee Break**

6. Vertical boundary-related processes

1055 - **Bill Peterson:** Copepods and pycnoclines.

1115 - **Patrick Oullett:** Cod egg quality, incubation temperature and water column hydrographic structure.

1135 - **Jan Beyer:** A simple stochastic model of larval foraging in patchy environments.

1155 - **Henrik Mosegaard:** The influence of food distribution and reactive distance on bioenergetically determined size selective predation.

Session 4: Process-Oriented Studies Continued

7. Proxy variables and time series analyses

1215 -**Svein Sundby:** Fish recruitment, the variation of scales, and the match-mismatch concept.

1235 - **Mike St. John:** Linking variation in larval and juvenile fish condition to mixing processes.

1300 **Lunch**

1400 **- Form Into Groups to Begin Discussion and Report Writing Sessions Based on The Following Topics:**

1) Horizontal Transport and Circulation Processes
2) Vertical Mixing Processes

During this time, each group will be asked to identify:

a) key mechanisms influencing aggregation and condition of larval, juvenile and adult fish in specific processes.
b) areas where knowledge gaps exist and how these can be addressed.
c) environmental variables that can potentially be included in fisheries forecast models.

1500 -**Coffee Break**

1515 **Session 5: Discussion and Report Writing Sessions**
- Reform into groups

1800 - Bus to Tivoli for group dinner and sight seeing.

(End of Day 2)

August 24

Session 5: Discussion and Report Writing Sessions Continued

0900 - Commence in Discussion Groups

1100 - **Coffee Break**

1115 - Reconvene

1300 **Lunch**

Break until 1600, Chairperson and Rapporteurs to prepare final draft of discussion topics.

1600 - Presentation of Results of Discussion Groups, Open discussion.

1800 ???? - **Workshop Ends**

APPENDIX 2

AGGREGATION WORKSHOP Attendees

Dr. Jan Beyer
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK-2920 Charlottenlund
DENMARK
TEL: 45-3396-3445
FAX: 45-3396-3333
E-mail: jeb@fimdfh.fim.dk

Dr. Keith Brander
Ministry of Agriculture, Fisheries and Food
Fisheries Laboratory
Lowestoft, Suffolk NR33 OHT
UNITED KINGDOM
TEL: 502-524-252
FAX: 502-524-511
E-Mail: MAFF.LOWESTOFT

Dr. Brad deYoung
Department of Physics
Memorial University of Newfoundland
St. John's, Newfoundland A1B 3X7
CANADA
TEL: 709-737-8839
FAX: 709-737-8739
E-mail: bdeyoung@crosby.physics.mun.ca

Dr. Harry Dooley
ICES Oceanography Secretary
ICES
Palægade 2-4
DK-1261 Copenhagen K
DENMARK
TEL: 45-33154225
FAX: 45-33934215
EMAIL: harry@server.ices.inst.dk

Dr. John Dower
Department of Biology
Queen's University
Kingston, Ontario
CANADA
TEL:
FAX:
E-mail:

Dr. John J. Govoni
National Marine Fisheries Service, NOAA
The Beaufort Laboratory
101 Divers Island Rd
Beaufort, NC 28516
USA
TEL: 919-728-8727

Dr. Peter Grøndkjær
Biologisk Institut
Afd. for Populationsbiologi
Bygn. 540, Ny Munkegade
DK-8000 Århus C
DENMARK

Dr. Morten Holtegaard Nielsen
ISVA
DTU, Bygning 115
DK-2800 Lyngby
DENMARK
TEL: 45-931222-1453
FAX: 45-932860
E-mail: mhn@isva.dtu.dk

Dr. Larry Hutchings
Sea Fisheries Research Institute
Private Bag X2, Roggebaai
Cape Town
SOUTH AFRICA 8012
TEL: (0)21-4396160
FAX: (0)21-4399345
E-mail: lhutchin@sfri_2.sfri.ac.za

Dr. Lewis Incze
Bigelow Laboratory for Ocean Sciences
P. O. Box 475
McKown Point
West Boothbay Harbor, Maine 04575
USA
TEL: 207-633-9600
FAX: 207-633-9864
E-mail: incze@saturn.caps.maine.edu

Dr. Eskild Kirkegaard
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK-2920 Charlottenlund
DENMARK
TEL: 45-3396-3350
FAX: 45-3396-3333

Dr. Thomas Kiørboe
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK-2920 Charlottenlund
DENMARK
TEL: 45-3396-3401
FAX: 45-3396-3434
E-mail: tk@fimdfh.fim.dk

Dr. Tomasz Linkowski
Sea Fisheries Institute
Dept. of Oceanography
ul. Kollataja 1
PL-81-332 Gdynia
POLAND
TEL: 48-5821-7195
FAX: 48-5820-2831

Dr. R. Gregory Lough
Northeast Fisheries Science Center
Woods Hole Laboratory
Woods Hole, MA 02543
USA
TEL: 508-548-5123
FAX: 508-548-5124
E-mail: glough@whsun1.wh.whoi.edu

Dr. Brian MacKenzie
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK-2920 Charlottenlund
DENMARK
TEL: 45-3396-3403
FAX: 45-3396-3434
E-mail: brm@fimdfh.fim.dk

Dr. Henrik Mosegaard
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK-2920 Charlottenlund
DENMARK
TEL: 45-3396-3425
FAX: 45-3396-3434

Dr. Peter Munk
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK-2920 Charlottenlund
DENMARK
TEL: 45-3396-3409
FAX: 45-3396-3434
E-mail: pm@fimdfh.fim.dk

Dr. Patrick Oullett
Institut Maurice-Lamontagne
Dept. of Fisheries and Oceáns
C. P. 1000
Mont-Joli, Québec G5H 3Z4
CANADA
TEL: 418-775-0675
E-mail: poullet@iml1.iml.dfo.ca@pmdf@bionet

Dr. Pierre Pepin
Department of Fisheries and Oceans
P. O. Box 5667
St. John's, Newfoundland A1C 5X1
CANADA
TEL: 709-772-2081
FAX: 709 772-4188
E-mail: pepin@nflorc.nwafc.nf.ca

Dr. Ian Perry
Dept. of Fisheries and Oceans
Pacific Biological Station
Nanaimo, BC V9R 5K6
CANADA
TEL: 604-756-7137
FAX: 604-756-7053
E-mail: perryi@pbs.dfo.ca

Dr. Tiit Raid
Estonian Marine Institute
32 Lai Str
Tallinn EE0001
ESTONIA
TEL: 372-2441198
FAX: 372-6313004

Dr. Katherine Richardson
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK-2920 Charlottenlund
DENMARK
TEL: 45-3396-3400
FAX: 45-3396-3434
E-mail: kr@fimdfh.fim.dk

Dr. Mike St. John
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK-2920 Charlottenlund
DENMARK
TEL: 45-3396-3424
FAX: 45-3396-3434
E-mail: msj@fimdfh.fim.dk

Dr. Stig Skreslet
Department of Fisheries and Science
Nordland College
N-8002 Bodø
NORWAY
TEL: 47-7551-7200
FAX: 47-7551-7484

Dr. Svein Sundby
Institute of Marine Research
P. O. Box 1870
N-5024 Bergen
NORWAY
TEL: 47-5523-8500/8468
FAX: 47-5523-8584
E-mail: sveins@imr.no

Dr. Jonna Tomkiewicz
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK-2920 Charlottenlund
DENMARK
TEL: 45-3396-3395
FAX: 45-3396-3333

Dr. Andrew Visser
IMAU, RUU
PO Box 80005 Utrecht
NETHERLANDS
TEL: 31-70-533259
E-mail: visser@ruunfs.ruu.nl

Dr. Cisco E. Werner
Marine Sciences Program
12-7 Venable Hall, CB #3300
University of North Carolina
Chapel Hill, NC 27599-3300
USA
TEL: 919-962-0269
FAX: 919-962-1254
E-mail: cisco@hydra.chem.unc.edu