U.S. GLOBEC: A Component of the U.S. Global Change Research Program

U.S. GLOBEC NEWS

Number 8 March 1995

Cod Fishery Collapses and North Atlantic GLOBEC

by Michael Sinclair and Fred Page

The collapse of the groundfish fisheries in the northwest Atlantic has focused the attention of both management and science on critical gaps in knowledge. Reported landings of Atlantic cod from 1970 to 1992 are shown in Figure 1. There are differences between the patterns for the northeast and northwest Atlantic stocks. Off North America there was some rebuilding of the cod resource following extension of jurisdiction to 200 miles in 1977, and the removal of foreign fishing. However, cod abundance has declined sharply since the late 80s in most areas of its distributional range. For some cod management units, spawning stock biomasses are sufficiently low that fisheries have been closed since 1993.

The socio-economic impacts of the closures of these groundfish fisheries (particularly in Newfoundland, eastern Nova Scotia, and northern New Brunswick) are yet to be fully understood. There is no doubt, however, that the collapse of the groundfish fisheries is a crisis of historic proportions for Atlantic Canada. Perhaps comparison to the Highland Clearances of the late 1700s to early 1800s in Scotland, when crofters were displaced from their rented land to facilitate sheep farming by the property owners, is not inappropriate. Many of the displaced crofters, under great hardship, emigrated to the colonies (including Atlantic Canada). The displaced fishermen and processing plant workers of today, however, have no new frontier to move to. They are experiencing, at a very personal and emotional level, the tragedy associated with inadequate management of renewable resources.

Governments are now faced with the task of how to improve the management of these resources. As part of this, a number of fundamental questions involving population regulation of marine fish must be addressed. In this article, we pose several of these management questions, summarize the relevant conceptual framework in the ecological literature, and discuss how GLOBEC research in the North Atlantic may generate explanatory power and answers. For this latter part, research results from our modelling team are used to illustrate issues.

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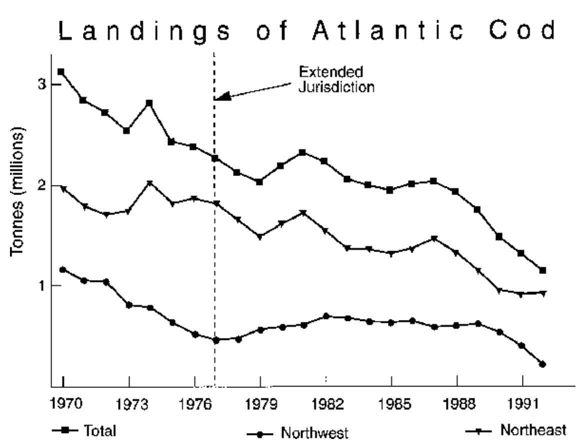

Figure 1. Trends in landings for cod from 1970 to 1992 (from FAO statistics).

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Four Management Questions

What criteria should be used to define and open a species/area management unit to fishing? An ecological issue relevant to this question is an understanding of the patterns of geographically distinct self-sustaining populations and their respective "minimum spawning stock" levels. Population patterns are defined by the spatial location and scale of birth site fidelity and we need to better understand the time scales of recovery of spawning components that have been fished close to commercial, and perhaps biological, extinction.

Does the management strategy need to include a multi-species ecosystem approach in order to meet the objectives of fisheries management? Those who argue in the affirmative infer that the abundance of groundfish population is regulated by food chain interactions, and that the impacts of fishing on one species affects predator/prey relationships of co-occurring commercially important species.

Table 1. Hypotheses that address geographic patterns in populations, their mean abundance, and their year-class variability.

Hypothesis	Pattern	Mean Abundance	Year-class Variability
Migration Triangle (Harden Jones 1968)	X		
Match-mismatch (Cushing 1973)	X	X	X
Stable Ocean (Lasker 1978)			X
Encounter rate (Rothschild and Osborn 1988)		X	
Member-vagrant (Sinclair and Iles 1989)	X	X	X

Does the trawling activity of the groundfish fishery diminish the benthic food supply to commercially important species? Those who infer that there is an impact of trawling on the sustainability of the groundfish fishery assume that groundfish populations are regulated by intra-specific competition for food, in this case at the juvenile and adult stages of the life cycle.

What management objectives are practical given the degree of environmental variability in the North Atlantic? The ecological issue includes the role of physical oceanographic processes on marine fish population regulation, and the degree to which ecosystem regime shifts occur. The practical issue concerns the degree to which we are able to monitor and regulate fishing in light of these population processes and shifts.

Conceptual Framework Underlying Regulation of Marine Populations

Responses to these management questions require scientific understanding of population regulation. This component of ecology was a hot area of debate in the 1950s and 1960s. Unfortunately, the debate produced little

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Table 2. Physical oceanographic processes associated with population regulation under diverse hypotheses.

POPULATION FEATURE	HYPOTHESIS	PHYSICAL OCEANOGRAPHIC PROCESS	KEY BIOLOGICAL FEATURES
Pattern	migration triangle	persistent residual currents	drift from spawning area to nursery area
Pattern	member-vagrant	re-circulation	limitation of dispersal from spawning area
Abundance	match-mismatch	not relevant	density-dependent larval feeding
Abundance	member-vagrant	size of re-circulation feature	density-dependent vagrancy
Variability	match-mismatch	seasonal vertical stratification	larval feeding success
Variability	stable ocean	summer wind mixing	larval feeding success
Variability	encounter rage	summer turbulent mixing	larval feeding success
Variability	member-vagrant	horizontal circulation	vagrancy from appropriate

Collapses—(Cont. from page 2)

explanatory power concerning what factors regulate abundance, and consensus on the relative importance of density-dependent and density-independent factors is still lacking. Eventually ecologists moved on to other issues.

The International GLOBEC program provides an opportunity for renewed focus on population regulation of marine species, with a particular emphasis on cod for the North Atlantic GLOBEC/ICES component. For marine fish there is a rich conceptual literature, including a number of competing hypotheses on various aspects of population biology (Table 1). It is helpful to consider these hypotheses in the context of three aspects of population regulation: pattern, abundance, and variability (Sinclair 1988; Sinclair and Iles 1989). The hypotheses and their associated physical oceanographic processes are listed in Table 2.

The migration triangle hypothesis states that the geographic patterns of marine fish populations are established and maintained by residual currents linking spawning locations to juvenile nursery areas. In contrast, the member-vagrant hypothesis states that the patterns are maintained by areas that limit the dispersal and advection of eggs and larvae during the early part of the early life history (i.e., areas of retention of eggs and young larvae). The competing hypotheses identify different physical/biological coupling processes as being critical to the definition of spawning populations and as such are mutually exclusive.

The match-mismatch hypothesis states that mean population abundance is regulated in a density-dependent manner by the plankton food available along the drift route. At high population levels the larvae become relatively more food limited, and vice versa. The member-vagrant hypothesis states that mean abundance differences between populations of the same species are defined by the size of the physical

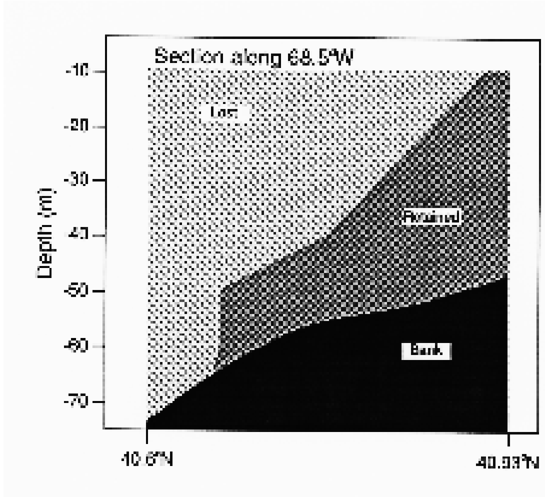

Figure 2. Vertical and meridional dependence of particle retention upstream of the Great South Channel. Particles throughout this section were released every 10 m vertically and every 500 m horizontally. Particles released within the diagonally hatched area were retained; those within the vertically hatched area were lost from the Bank. Black region indicates the Bank's bottom topography.

oceanographic features that restrict dispersal of eggs and early stage larvae. Furthermore, it is argued that density-dependent vagrancy (i.e., an increase in loss rate at higher spawning stock levels, and vice versa) can regulate abundance without density dependent trophic processes. Again, the competing hypotheses identify different oceanographic processes.

Three of the four hypotheses which address temporal variability in the abundance of year-classes focus on food availability during the larval stage. The match-mismatch hypothesis states that the variable timing of the seasonal phytoplankton bloom in relation to a fixed period of spawning generates interannual differences in the match between the zooplankton production cycle and the period of fish larval feeding. The key physical oceanographic process is the seasonal development of vertical stratification in the water column that permits phytoplankton blooms to develop. The stable ocean hypothesis states that vertically stratified (i.e., low mixing) conditions are needed to generate high local concentrations of food at the pycnoclines for favourable larval survival rates. These concentrations, however, are broken down during strong wind events. Thus, the physical process of importance is the frequency and intensity of wind mixing during the larval feeding stage, with low winds being considered favourable for larval survival. The encounter rate hypothesis is almost the opposite of the stable ocean hypothesis; increased turbulence enhances the encounter rate between fish larvae and their prey. Thus, years of increased wind mixing and areas of strong tides should improve larval feeding success and generate relatively higher survival rates.

In the member-vagrant hypothesis both food chain and spatial displacement processes contribute to variable loss rates from the appropriate geographical area for the population. The two categories of processes can act in a density-dependent or a density-independent manner. If vagrancy is itself density dependent for a particular population, then there is no necessity for density dependent trophic limitation of abundance.

In sum, the five hypotheses identified above involve differences in oceanographic processes, physical/biological coupling mechanisms, and their characteristic time scales. Several of the hypotheses assume that larval feeding is the key process. Much of the fisheries research during the past two decades has been on the year-class variability aspect of population regulation. Prediction of the impacts of climate change are dependent upon which hypothesis or hypotheses best capture the realistic dynamics for a given population and time.

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Report of MARE COGNITUM Meeting in Norway 27-29 February 1995

contributed by Peter Wiebe

MARE COGNITUM is a regional GLOBEC program now getting underway in Norway. Like the U.S. GLOBEC Georges Bank Program, the scientists funded to participate in MARE COGNITUM are from a government funded laboratory and academic institutions. They also have been working during the past couple of years on pilot projects and 1995 is their first major field effort. The meeting described below was the PI meeting that is intended to occur annually.

The meeting was held at the Solstrand Fjord Hotel, about 40 km south of Bergen, Norway. This hotel sits south facing on the edge of Fusafjord which is a small arm of the larger Bjornafjord. The fjord waters, together with the rugged snow capped mountains rising up to the south and east of the fjord, provided a spectacular setting for the meeting. This will almost certainly be the site for next year's annual MARE COGNITUM meeting.

In attendance were individuals from a number of Norwegian institutions and universities who represented groups that were funded by the Norwegian Research Council to participate in MARE COGNITUM. Also in attendance were representatives from adjoining countries who will be collaborating in this International GLOBEC project. The countries represented were the Faroe Islands, Iceland, and Russia. In addition, Piers Chapman represented U.S. WOCE interests in the Norwegian Sea, and I represented U.S. GLOBEC's Georges Bank Program. The official language of the meeting was English.

The principal objectives of the meeting were 1) to provide a forum for collaborating investigators to present their ideas and any preliminary results that they might have with regard to the MARE COGNITUM research program, and 2) to meet together in smaller groups to refine the cruise plans for 1995, 96 and 97, to discuss the modelling activities, and to consider what steps need to be undertaken to foster international aspects of the research.

The meeting started at noon on Monday the 27th and finished at noon on Wednesday the 29th. During the first two days, the investigators made their presentations. The last half-day was used for working group sessions.

Hein Rune Skjoldal reviewed the goal of the program and major programmatic components. The goal is to identify and quantify the most important factors and mechanisms causing variability in the ecology of the Nordic Seas with the aim to predict fluctuations in ocean circulation, production, and fish stocks. There are three programmatic components—ocean climate, resource ecology, and carbon cycling—each with a specific goal and objectives.

Ocean Climate aims to describe and understand the most important mechanisms responsible for variability in ocean climate. Some objectives are:

- To describe variations in the influx of Atlantic water to the Norwegian Sea.
- Establish quantitative relationships between the variation of influx and the different branches of Greenland and Norwegian Seas.
- To establish quantitative relationships for interactions between ocean and atmosphere (heat flux, wind stress).
- To identify and quantify mechanisms causing or influencing periodic variations in ocean climate.
- To construct models based on fundamental knowledge of mechanisms, which can be used to forecast the development of ocean climate on time scales from one to several years.

Resource Ecology's goal is to describe the structure and function of the ecosystem in the Norwegian Sea and quantify chief mechanisms regulating the effect of climate variation on production and size of fish stocks (herring and cod). Some objectives are:

- To describe pelagic food webs of the Norwegian Sea.
- To quantify new harvestable production and its spatial/temporal variation.
- To describe the structure and dynamics of key zooplankton and fish (mesopelagic) and how these populations are adapted to or influenced by the large-scale circulation in the Greenland and Norwegian Seas.
- To establish relationships between growth, maturation, and migration of herring as a function of stock size, predation, and ocean climate.
- To determine trophic interactions between blue whiting, herring, and mesopelagic fish and the effects of a herring stock increase on other stocks (the last herring crash, blue whiting increased).
- To determining food requirements for salmon and establish relationships between variations in its food conditions and its growth in the Norwegian Sea.
- To identify regulatory mechanisms and quantify effects of variations in ocean climate and zooplankton populations in the Norwegian Sea on recruitment and year-class strength of herring and cod.
- To determine the effects of life cycle and migration of zooplankton and fish on the distribution and feeding ecology of marine mammals and sea birds.
- To construct models to capture the essence of regulatory forces and mechanisms controlling stocks.

The **Carbon Cycling** effort is concerned with quantifying the vertical flux of carbon and pathways for the sinking of CO_2 to depth. Objectives are:

- To specify and quantify the effects of meteorological and physical oceanographic factors on the spring phytoplankton bloom and annual primary production.

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MARE COGNITUM—(Cont. from page 4)

- To specify and quantify the role of zooplankton and fish on the magnitude and variability of the sedimentation of biogenic matter to great depths and the sea floor.
- To specify the mechanisms regulating the interaction of physical and biological processes determining the degree of new (nitrate-based) production.
- To specify the mechanisms regulating the dominance of certain phytoplankton taxa (e.g. diatoms, *Phaeocystis*, coccolithophorids) and quantify the role of algal type for the sedimentation of biogenic material out of the euphotic zone.
- To develop models of the biological pump based on knowledge of mechanisms and vertical structure of the water column.

Individual investigators made presentations on fish ecology and fisheries (13 presentations), international collaboration and activities (6), plankton dynamics (7), and physical oceanography (5).

The Nordic Seas area (Norwegian Sea (2 basins), Icelandic Sea, and Greenland Seas) is substantial—about 2.5 million km^2. For comparison, the Georges Bank study area is about 150 thousand km^2 or approximately six percent of the Norwegian Sea area. Thus, there is a substantial requirement for shiptime to cover this sea area. In 1995, a number of ships are scheduled to participate in MARE COGNITUM. Norwegian cruises will cover the late winter, spring, and summer period (February to August) (see Box).

The top three ships will be used to conduct a mix of large-scale surveys of the Norwegian Sea and smaller scale process work. The specific MARE COGNITUM cruises are marked with an MC; the others represent cruises where samples relevant to MARE COGNITUM will be collected and shared. The other two ships will conduct more local shelf/slope studies off northern Norway. Iceland will conduct four large-scale surveys in the waters around the island, and will occupy several transect lines 10 times during the year. The Faroes will conduct 3 surveys around their waters with one cruise specifically directed towards herring. The Russians will conduct a survey of the southern Norwegian Sea in June which will focus on herring, but will include other pelagic fish, plankton, and hydrography.

International cooperation of both logistics and science was discussed. **Logistical** cooperation issues that arose were:

- Common Sampling Protocols: WOCE and JGOFS have protocols that should be followed wherever possible. Measurements or use of instrumentation not covered should have agreed upon protocols developed.
- Common data bases. Need to establish ways to exchange information and data.
- Exchange of cruise personnel.

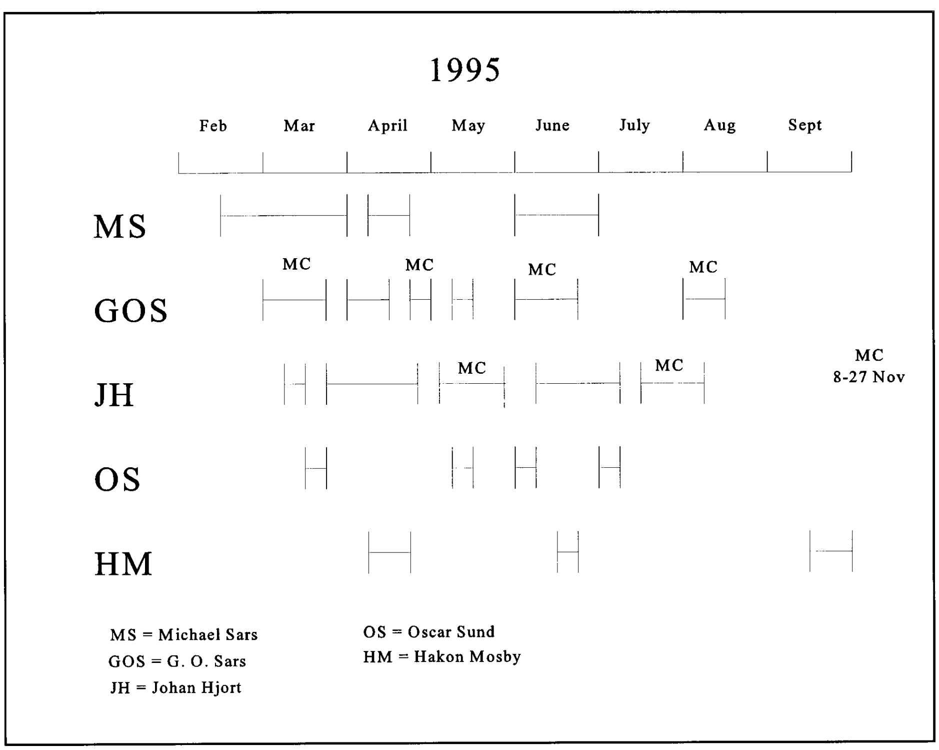
Scientific cooperation issues that arose were:

- Large-scale modelling
- Linking regional models with basin scale/global models.
- Genetics, otoliths: need to exchange material.

What is envisioned as the next step is a series of small meetings or workshops attended by representatives of the collaborating countries to focus attention on:

- Common protocols and analysis
- Data management and documentation.
- The North Atlantic Teleconnections (SeeSaw - NS/EW)
- Genetics [zooplankton/fish (cod/herring)]
- Otoliths [gadids and clupeiids)
- Exchange of personnel between programs (emphasis on young scientists).

One point that was emphasized was that ICES was going to establish a secretariat for GLOBEC (and cod and climate change?) which is intended to help coordinate activities in the North Atlantic and foster fruitful interactions. *(Peter Wiebe is a senior scientist at the Woods Hole Oceanographic Institution and is chair of the U.S. GLOBEC Georges Bank Executive Committee)* ΔΔΔ



The ATOLL Laboratory and other Instruments Developed at Kiel

by Uwe Kils

(Editors Note: Technology Forum is intended to stimulate thought and discussion on diverse oceanographic technology issues. We welcome contributions on technological issues relative to ocean science, but particularly to U.S. GLOBEC.)

The ATOLL Laboratory consists of three banana-shaped fiberglass hulls (Fig. 1). These 25 meter long hulls can be connected in series for transportation. At the measuring site they are switched into a horseshoe-shaped arrangement. In this operational mode the structure surrounds 150 m^3 of the sea. Although the 5 meter wide hulls offer 75 m^3 of laboratory space, 220 m^3 of supply- and storage-facilities and 350 m^3 deck area, they project only 38 cm below the surface and have a 2.8 m wide flat curved cross-section. The small submergence minimizes disturbances of the natural turbulence regime. The lagoon opening is oriented towards the sun for natural light regime. The hulls are not coated with antifouling paints and are constructed only from fiberglass, stainless steel, aluminum and wood to minimize chemical interference. The main instrumentation room (25 m^3) is air-conditioned to protect the electronics. All displays and controls are centralized in a glasshouse on deck (30 m^3) to give a good overview for the operators. The lab can accommodate three scientists easily. A small lecture room is available for teaching.

An underwater observation room allows for a direct inspection of the investigated scenery and control of the instrumentation via two 40 x 40 cm windows located 20 cm below the water surface. The water around these windows is accessible with scientific equipment via four portholes. Air pressure in the observation room can be increased to allow opening of the underwater portholes to change the glasses or mount equipment onto the outside of the windows without docking the lab. Five balconies give access 10 cm above sea level; four of these are sheltered. Underwater bubble curtains softly guide the fish schools into the scanned areas, or prevent their escape during disturbances. After the *in situ* measurements are complete, the organisms can be captured by raising a pop-up-net from below. This provides animals for taxonomic identification and for estimation of condition indices, enzymatic activity, and RNA/DNA relations.

A crane-deployed boat is available to assist in mounting instrumentation near the lab and for monitoring the nearby environment. The boats systems are connected to the laboratory computer via a radio link. Positioning and tracking of the boat is done by RADAR or SONAR from the lab. The laboratory is also equipped to support diving. Air is supplied from a light umbilical for extended and relatively quiet underwater inspections.

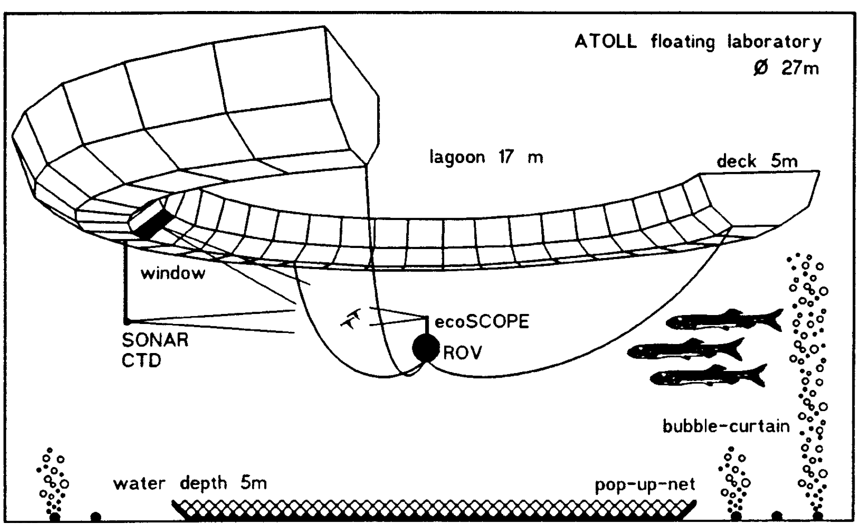


Figure 1. The ATOLL floating laboratory showing tethered ROV with attached ecoSCOPE.

The central processing unit (CPU) is a CMOS industry microcontroller, communicating on a private and exclusive frequency with the mainframe of the institute. Several functions can be remotely controlled and evaluated by telephone. The CPU system performs all alarm functions as well as a “call on event” system triggering an EUROCALL beeper. The lab has been working autonomously for months with only occasional checks for retrieving tapes and disks. Processed data and selected images are transferred by radio communication. On-line data processing of the acoustics, optics and physics is done on a UNIX workstation (NeXT cube, RAM capacity 40 Mbyte) and several MOTOROLA 680XX subsystems. Data compression (Delta- and JPEG) is conducted on board and processed data are stored on rewritable optical disks. Because data inspection and image analysis can be completed shortly after data acquisition, small adjustments of the scanning setups can readily be performed. SP highband u-matik and HI8 machines are used for mass storage of the raw optical and acoustical data.

Some instruments are mounted directly on the hulls of the lab; others are carried by remotely operated vehicles (ROVs). For some types of experiments, e.g., behavioral studies, the propulsion systems of the ROVs

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cause disruption of the natural hydrodynamic environment. We minimize the hydrodynamic disturbances by positioning the ROV using three negatively buoyant thin rubber bands and a variable buoyancy system (see Fig. 1). This operational mode allows for a quiet approach from below towards the highly evasive organisms with minimum disturbance to the natural turbulence- and light-regime.

A scanning SONAR is used to locate the juvenile herring schools, guide the ROV, and for quantifying positions, distances and speeds. Salinity, temperature and oxygen are measured with probes, water velocity with acoustics and microturbulences with optics. Plankton-, particle- and bubble-concentrations and their size distributions are measured with an optical plankton recorder (OPR) (KILS 1981, 1989), with high resolution acoustics (KILS et al. 1991), or with net- and pump-samples. Low-light cameras and high speed video cameras with shuttered LASER-sheet or infrared LEDs are used for quantification of animal behavior and for control of the experimental setup (STRICKLER et al. 1992). The ecoSCOPE (KILS 1992), an endoscope-system for non-invasive optical measurements, is used to record the microscale dynamics and behavior of the highly evasive herring. The disturbance of the microturbulences by this sensor is relatively low, and its data make possible evaluation of microstructures of the flow field. The ecoSCOPE can be mounted directly to the floating platform or can be deployed using an ROV.

For the evaluation and visualization of ocean- and bio-dynamics, dynIMAGE software has been developed (KILS 1992). First, dynIMAGE compensates for the swaying and rolling of the optics due to low-frequency microturbulences and prepares the raw data for evaluations of animal-motion and high-frequency microturbulences. Then, video-clips are reconstructed from the processed images for visualization of the fast oceanographic processes.

Investigations to date have concentrated on one of the most important food chain transitions: the linkages between the early life stages of herring (*Clupea harengus*) and their principal prey (copepods). A major hypotheses of fisheries ecologists is that the microdistribution of prey, the microturbulence of the ocean, or the retention conditions are normally not suited to allow strong year classes of fish to develop. In most years more than 99% of herring larvae do not survive. Occasionally however, physical and biotic conditions are favorable, larval survival is high, and large year-classes result. The aim of our investigations using the ATOLL laboratory and the instrumentation described above is to improve our understanding of the effects of small-scale dynamics on fish feeding, predator avoidance, and year-class strength.

Scientific Questions

What are the effects of the natural light gradient on predator-prey interactions? How can the predator best see the prey without being seen? How does the focussing of small waves oscillating light regime influence camouflage and attack strategy? What are the influences of the different frequencies of microturbulences? How do such effects change at the moment when herring larvae join into schools? What role does the phenomenon of aggregation play? Does ocean physics create or alter organism-aggregations? Can the dynamic of aggregations effect ocean physics at the microscales? Are there effects of the surface waves? What are the distribution and dynamics of microbubbles caused by turbulences and gas-oversaturations? How can the organisms orientate in respect to micro-gradients of the ocean physics? How do they survive in the direct vicinity of undulating anoxia and hypoxia? Why are eelpouts, sticklebacks and herrings so extremely successful in the Baltic while cod is not? What are the effects and functions of schooling for feeding and microscale-orientation? All this can best be investigated *in situ.*

The areas of investigation are the estuaries of the western Baltic. The drastic ecological shifts during the last decades qualify this area as an excellent experimental site for the examination of global change effects on marine ecosystems. Plankton concentrations of up to 800,000 cells *Prorocentrum minimum* per milliliter are a challenge for herrings searching prey under the drastically deteriorated visibility — and a challenge for the scientists to quantify their strategies.

The laboratory has been in operation since 1982. It was a donation from the ATOLL Swimming Structure Development Company, München, Kaiserplatz 8. The company is based on the ATOLL trademark and the ATOLL international patents. The BMFT Ministry of Science and Technology funded the first scientific experiments on behavioral studies in marine aquaculture. It has been run for the last four years under the VOLKSWAGEN Bio-Science-Award and by inputs from SONY, NeXT, ATARI, BP, ARD, ZDF, SAT1, RTLplus, GREENPEACE, the Ministry for Nature and Environment Schleswig-Holstein, the Kiel-Canal Administration, and some private sponsors.

Summary of Optics Developments at the IfM, Kiel:

Optical Ichthyoplankton Recorder (Schnack, Welsch, Wieland, Kils): Towed GULF III type net similar to Ortner et al. (1981) but with a video camera mounted at the net end, image and data transmission via single conductor cable, prototype employed since 1990 on herring and cod surveys in the North Sea and Baltic. Distribution, large scale long time series monitoring.

Optical Zooplankton Profiler (Lenz): Vertical towed net-system, image and

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U.S. GLOBEC Calendar

1995

5-6 April: U.S. GLOBEC Scientific Steering Committee meeting, Corvallis, OR, USA. Contact: H. Batchelder, Department of Integrative Biology, University of California, Berkeley, CA 94720-3140 (Phone: 510-642-7452; FAX 510-643-6264; Internet: halbatch@violet.berkeley.edu)

5-6 April: Understanding Earth: Retrospectives and Visions, A conference to be held at the National Press Club in celebration of the 25th anniversary of Earth Day, Washington, DC. Contact: ERIM/Global Change Conference, P.O. Box 134001, Ann Arbor, MI, USA (Phone: 313-994-1200 x3234; FAX: 313-994-5123; Internet: wallman@erim.org)

18-21 April: The Oceanography Society's (TOS) Fourth Scientific Meeting, Newport, Rhode Island, USA. Contact: J. Rhodes, The Oceanography Society, 4052 Timber Ridge Drive, Virginia Beach, VA 23455 (Phone: 804-464-0131; FAX: 804-464-1759; Internet: jrhodes@ccpo.odu.edu)

19-20 April: U.S. GLOBEC Workshop on Climate Change and Carrying Capacity in the North Pacific, Seattle, WA, USA. Contact: A. Hollowed, Northwest and Alaska Fisheries Science Center, 7600 Sand Point Way, Seattle, WA 98115-0070 (Phone: 206-526-4223; FAX: 206-526-6723; Internet: hollowed@afsc.noaa.gov)

2-5 May: The 12th Annual Pacific Climate (PACLIM) Workshop, Pacific Grove, CA, USA, This years theme session is "Interdecadal Climate Variability over the Pacific and Western Americas". Contact: D. Gautier, U.S. Geological Survey, Box 25046, MS 934, Federal Center, Denver, CO 80255 (Phone: 303-236-5740; FAX: 303-236-8822; Internet: gautier@bpgsvr.cr.usgs.gov)

9-12 May: First International Joint Global Ocean Flux Study Scientific Symposium, Villefranche-sur-mer, France. Contact: E. Gross, Executive Director SCOR, Dept. Earth and Planetary Sciences, The Johns Hopkins University, Baltimore, MD 21218 USA (Phone: 410-516-4070; FAX: 410-516-4019; Internet: scor@jhuvms.hcf.jhu.edu)

May (tentative): Living Resources of the Azov-Black Seas and their Rational Use, Kerch, Crimea, Ukraine. Contact: V. Yakovlev, Director, YugNIRO, 2 Sverdlov Street, Kerch 334500, Crimea, Ukraine (Phone: (06561) 210-65; FAX: (06561) 215-72; Internet: jug!niro@mastak.msk.su)

1-3 June: First Open Meeting of the Human Dimensions of Global Environmental Change Community, Durham, NC, USA Contact: Global Environmental Change Program, Social Science Research Council, 605 Third Avenue, New York, NY 10158, USA (Phone: 212-661-0280; FAX: 212-370-7896; Internet: gordon@cfcluster.nyu.edu or major@acfcluster.nyu.edu)

11-15 June: American Society of Limnology and Oceanography Summer Meeting, Reno, NV, USA. Contacts: R. Wharton, Jr., Desert Research Institute, P.O. Box 60220, Reno, NV 89506 (Phone: 702-673-7300; FAX: 702-673-7397; Internet: wharton@maxey.unr.edu) or D. Garrison, Institute of Marine Sciences, University of California, Santa Cruz, CA 95064 (Phone: 408-459-4789; FAX: 408-459-4882; Internet: digarris@cats.ucsc.edu)

12-16 June: ICES International Symposium on Fisheries and Plankton Acoustics, Aberdeen, Scotland. Contact: E. J. Simmonds, Marine Laboratory, P.O. Box 101, Victoria Road, Aberdeen, Scotland AB9 8DB, United Kingdom (Phone: +44 224 876544; FAX: +44 224 295511)

19-24 June: PICES Workshop on the Okhotsk Sea and Adjacent Areas, Vladivostok, Russia. Contact: Pices Secretariat, c/o Institute of Ocean Sciences, Sidney, B.C., Canada. V8L 4B2 (Phone: 604-363-6366; FAX: 604-363-6827; Internet: pices@ios.bc.ca)

26 June-2 July: International Larval Fish Conference, Sydney, Australia. Contact: C. Jones, Applied Research Laboratory, 1034 W 45th St., Old Dominion University, Norfolk, VA 23529 USA (Phone: 804-683-4497; Internet: cmj100f@oduvm.cc.odu.edu)

2-14 July: International Union of Geodesy and Geophysics, XXI General Assembly, Boulder, Colorado, USA. Contact: American Geophysical Union, 2000 Florida Avenue NW, Washington, DC 20009 (Phone: 202-462-6900; FAX: 202-328-0566; Internet: iugg_xxiga@kosmos.agu.org)

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22-25 August: International Conference on Past, Present and Future Climate, Helsinki, Finland. Contact: P. Heikinheimo, Academy of Finland, P.O. Box 57, FIN-00551, Helsinki, Finland (Phone: 358-7748-8338; FAX: 358-7748-8299; Internet: pirkko.heikinheimo@aka.fi)

21-26 September: ICES Statutory Meeting: Special Theme Session on Intermediate-Scale Physical Processes and their Influence on the Transport and Food Environment of Fish, Copenhagen, Denmark. Contacts: B. MacKenzie, Danish Institute for Fisheries and Marine Research, Charlottenlund Castle, DK-2920 Charlottenlund, Denmark (Phone: +45-3396-3403; FAX: +45-3396-3434; Internet: brm@fimdfh.fin.dk) OR Francisco E. Werner, University of North Carolina, Chapel Hill, North Carolina 27599-3300, USA (Phone: 919-962-0269; FAX: 919-962-1254; Internet: cisco@hydra.chem.unc.edu)

24-29 September: First Global Analysis, Interpretation, and Modelling (GAIM) Conference, Garmisch-Partenkirchen, Germany. Contact: D. Sahagian, GAIM Task Fore Office, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH 03824 (Phone: 603-862-3875; FAX: 603-862-0188; Internet: gaim@unh.edu)

5-6 October: U.S. GLOBEC Scientific Steering Committee meeting, Washington, DC, USA. Contact: H. Batchelder, Department of Integrative Biology, University of California, Berkeley, CA 94720-3140 (Phone: 510-642-7452; FAX 510-643-6264; Internet: halbatch@violet.berkeley.edu)

11-13 October: International Symposium on Biology, Management, and Economics of Crabs from High Latitude Habitats, Anchorage, AK, USA. Contact: B. Baxter, Alaska Sea Grant College Program, University of Alaska Fairbanks, P.O. Box 755040, Fairbanks, AK 99775-5040 (Phone: 907-474-6701; FAX: 907-474-6285; Internet: fnbrml@aurora.alaska.edu)

16-22 October: North Pacific Marine Science Organization (PICES) Fourth Annual Meeting, Qingdao, Peoples Republic of China. Contact: Pices Secretariat, c/o Institute of Ocean Sciences, Sidney, B.C., Canada. V8L 4B2 (Phone: 604-363-6366; FAX: 604-363-6827; Internet: pices@ios.bc.ca)

31 October-2 November: California Cooperative Fisheries Investigations (CalCOFI) Annual Meeting, Lake Arrowhead, CA, USA. Contact: G. Hemingway, Marine Life Research Group, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093-0227 (Phone: 619-534-4236; FAX: 619-534-6500; Internet: ghemingway@ucsd.edu) ΔΔΔ

TransAtlantic Studies of Calanus (TASC) Working Group

by Charles Miller

GLOBEC International now has offspring. The baby was born on the 7th of April 1994 at Oslo, Norway. Its name is the TransAtlantic Study of *Calanus* Working Group. In October it was recognized by ICES, which included TASC activities as a function of the ICES Zooplankton Productivity Working Group under Heine Rune Skjoldal. Attending the birth in Oslo were 25 scientists from Norway, Sweden, Denmark, Germany, Scotland, England, The Faroes Islands, Iceland, France, Canada and the United States. We were hosted by Stein Kaartvedt of the University of Oslo for a GLOBEC/ICES workshop designed to foster cooperation in the study of *Calanus finmarchicus* all across its North Atlantic range from New England to Northern Norway. Convenors were Kurt Tande of the University of Tromso and myself. Funding for the workshop came from the Norwegian Research Council, the European Union, the U.S. GLOBEC Office, and from marine research programs of several nations. Everyone attending is actively working on the biology of *C. finmarchicus*.

In preparation for the workshop, most of the participants wrote manuscripts on a wide range of topics, including distribution, feeding, growth, reproductive rates, genetics, the resting stage and methods for mortality estimation. Everyone received those in advance so that we arrived prepacked with relevant information, not to mention points to argue with erring authors. Our first day was spent presenting and discussing those papers, then celebrating our new (or renewed) acquaintance in one of the world's most expensive restaurants (which cluster in Oslo). Many of the papers have been revised after the meeting and are in review for publication together as an issue of Ophelia. The second day we spent on both plenary and working party debates about the priorities for research on *C. finmarchicus*. An amorphous mass of prose was produced which was later hammered into a report to ICES by Kurt Tande. We divided the discussion and report into four themes, which I list here with precis of the conclusions about each:

I. The Interplay between Generation Cycles and Large-Scale Circulation Patterns in Oceanic and Shelf Areas.

Calanus finmarchicus is a prominent component of shelf

(Cont. on page 10)

TASC—(Cont. from page 9)

zooplankton during late winter and spring in sites like the Northern North Sea and Georges Bank. However, it seems to be entirely missing from those regions in summer and autumn. Thus, the abundant stocks of winter-spring must be imported by advection from oceanic areas where resting stocks at depth maintain the species existence through the late summer and autumn. It was recommended as a priority that we work out the population budgets for several of these exchanges. This will allow us to distinguish between several alternative population histories. Are the resting stocks in oceanic sectors strongly dependent upon production over the shelves? Or, are the resting stocks produced entirely in the oceanic sector and simply 'feeding' the shelf production with no strong return.

For the North Sea shelf an interaction between late winter inflow in the Faroes-Shetland Channel and upward ontogenetic migration of maturing *Calanus* have been suggested by Jan Backhaus, Mike Heath, Katherine Richardson and others as a supply mechanism. That will be the subject of an European Union Marine Science and Technology study during early 1995. The U.S. GLOBEC Georges Bank program is tackling a similar problem on the west side of the Atlantic.

II. Strategies of Diapause and Reproduction

The control of entry to and emergence from diapause are not well understood for any species of Calanidae. We produced several recommendations aimmed at producing clues about the control mechanims:

- TASC projects should select an indicator of diapause condition [gonad development, jaw facies, enzyme status] and trace its appearance in *Calanus* stocks as function of season, temperature history, depth and photoperiod.
- TASC projects should sample resting stocks for stage composition [which varies] over at least several years. Basic habitat data, particularly water column temperature patterns, should be recorded through the period prior to and during diapause phases.

Laboratory studies were also recommended. Reproduction in *C. finmarchicus* has been a very active area of research recently. The TASC recommendation was that this effort be sustained.

III. Population Coherence and Latitudinal Impact on Growth Patterns

- We recommended evaluation of the diversity of the *C. fimarchicus* stock across its range by studies of its molecular genetics.
- A renewed study of the growth response to food, temperature and other habitat factors is needed. Sophisticated data are available for related species, but not *C. finmarchicus.*

IV. Trophic Interactions and Mortality

From a practical standpoint (support for our studies) we need to establish whether interannual variability in fishery recruitment depends directly upon variations of *Calanus* productivity. It may be hard to believe that isn't established, but it's not.

Mortality rates are almost always unconstrained tuning variables in our models of *Calanus* population processes. It was recommended that TASC projects should invent and adopt strategies for determining the partitioning of mortality among the developmental stages of *C. finmarchicus* cohorts.

On our third and final day, we decided to appoint ourselves as a long-term working group to continue communication about research on *Calanus finmarchicus* all across its range. We also hope to promote cooperative studies among laboratories and scientists so that knowledge of *Calanus* biology can increase at the fastest possible rate. We warmly invite anyone not at the workshop to join in this effort. We are the TransAtlantic Studies of *Calanus* (TASC) Working Group. I am the initial chair for interchange of information, principally through a newsletter. Yes, another newsletter. Issues No. 1 and 2 have been distributed to members. Copies can be obtained by writing (use email) to me. We also have an internet mail list and internet reflector address so that members can communicate rapidly with the entire group. We hope that will be useful, not another source of electronic junk mail. *(Charles Miller is Professor of Oceanography at the College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, OR 97331-5503, Internet: cmiller@oce.orst.edu)* ΔΔΔ

U.S. GLOBEC

GLOBAL OCEAN ECOSYSTEMS DYNAMICS

U.S. GLOBEC NEWS

U.S. GLOBEC NEWS is published by the U.S. GLOBEC Scientific Coordinating Office, Department of Integrative Biology, University of California, Berkeley, California 94720-3140, telephone (510) 642-7452, FAX (510) 643-6264. Correspondence may be directed to Hal Batchelder at the above address. Articles, contributions to the meeting calendar, and suggestions are welcomed. Contributions to the meeting calendar should contain dates, location, contact person and telephone number. To subscribe to U.S. GLOBEC NEWS, or to change your mailing address, please call Hal Batchelder at (510) 642-7452, or send a message to Internet address halbatch@violet.berkeley.edu, or write to the address above.

U.S. GLOBEC NEWS Staff
Hal Batchelder
Tom Powell

ATOLL—(Cont. from page 7)

data transmission (two cameras) via fiber optics, prototype planned for October 1992: Distribution, large scale long time series monitoring

ecoSCOPE (Kils): Remotely operated or free floating vehicle, image transmission via fiber optics or onboard storage, several prototypes employed in herring schools for predator prey interaction studies. Microscale behavior, microdistribution. See Figure 2.

Optical Plankton Recorder (Kils): General purpose compact instrument with optional preconcentration-nets, image and data storage onboard (1-3 cameras), employed since 1979 in anarctic krill studies, hand operated from small working boats in school studies, anchored for orientation- and ecotoxicology-studies, in aquaculture for particle-flow-studies. Mesoscale monitoring, environmental impact on behavior. *(Until recently, Uwe Kils was a research scientist at the Institute für Meereskunde, Universität Kiel. Dr. Kils is now at Rutgers University Institute of Marine and Coastal Sciences.)*

More details of the cited instrumentation are described in:

Kils U (1981) Swimming Behaviour, Swimming Performance and Energy Balance of Antarctic Krill, *Euphausia superba*. BIOMASS Sci Ser, 3, 1-122

Kils U (1989) On the Micro-Structure of Micro-Layers — Results of an *in situ* Zooplankton-Counter. Coun Meet Int Coun Explor Sea 1989/ L15:1-4

Kils U, Ruohonen K., Mäkinen T (1991) Daily feed intake estimates for rainbow trout (*Oncorhynchus mykiss* Wahlbaum) evaluated with SONAR and X-ray techniques at commercial net cage farms. Coun Meet Int Coun Explor Sea 1991/F3:1-8

Kils U (1992) The ecoSCOPE and dynIMAGE: microscale tools for *in situ* studies of predator prey interactions. Int Rev gesamten Hydrobiol (in press)

Strickler R, Schulz P, Bergstroem B, Berman M, Donoghay P, Gallager S, Haney J, Hargreaves B, Kils U, Paffenhofer G, Richman S, Vanderploeg H, Welsch W, Wethey D, Yen J (1992) Video based instruments for *in situ* studies of zooplankton abundance, distribution and behavior. Arch Hydrobiol (in press)

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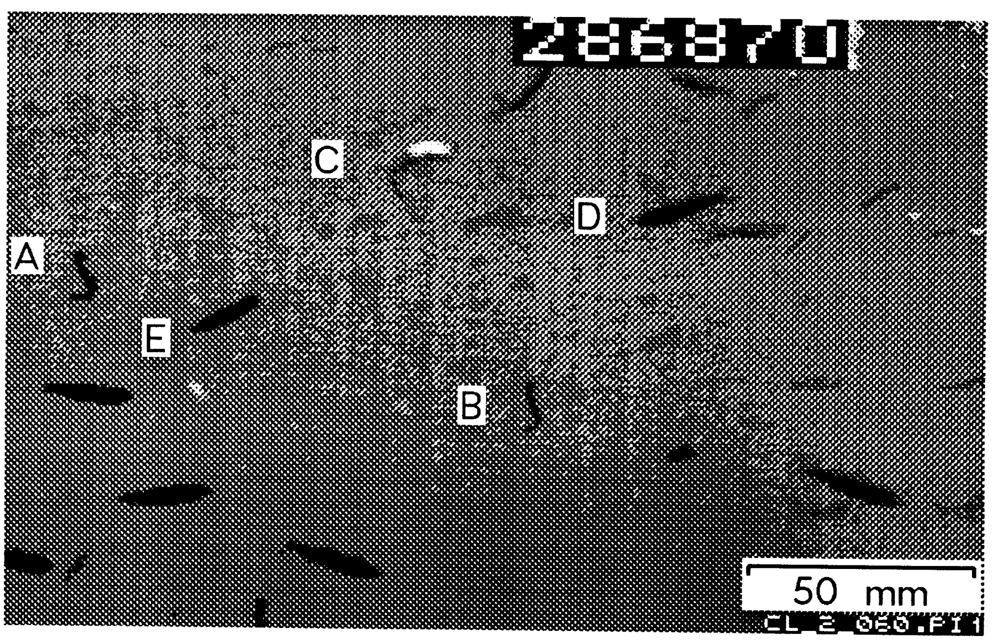

Figure 2. Image from the ecoSCOPE showing a school of juvenile herring <u>*Clupea harengus*</u> *feeding in a micropatch of copepods. Herring A and B in typical s-shape shortly before attacking a copepod upwards. Herring C shortly after an attack during a u-turn. In this position the silvery sides produce an intense light-flash. Herring D shortly later on his downward return to his old school position. Herring E starting a new attack upwards. Due to the deflection of light by phytoplankton and microparticles the copepods are not visible from the distance of the optics.*

Announcement of Opportunity: Modeling Studies in Support of U.S. JGOFS and U.S. GLOBEC in the Southern Ocean

Introduction

As part of the U.S. Global Ocean Ecosystems Dynamics (U.S. GLOBEC) and the U.S. Joint Global Ocean Flux Study (U.S. JGOFS) science programs the National Science Foundation's (NSF) Office of Polar Programs and Division of Ocean Sciences announces a call for proposals for modeling studies related to the developing science programs in the Southern Ocean. All proposals should be submitted to the NSF as detailed below.

The Southern Ocean programs of U.S. GLOBEC and U.S. JGOFS will take place in the late 1990s. This announcement is to encourage modeling studies that will advance the understanding of the biogeochemistry and the interactions between marine populations and physical processes in Southern Ocean ecosystems. In particular, modeling studies are encouraged that will advance the planning and design of multidisciplinary field programs. The goal is to develop the capability to predict the response of oceanic biogeochemical processes and marine animal populations to, as well as their influence upon, climatic change.

U.S. GLOBEC and U.S. JGOFS have held workshops to define science issues that are of importance in the Southern Ocean. Results of these workshops are available in U.S. GLOBEC Report No. 5 and U.S. JGOFS Report No. 16. These documents may be obtained from U.S. GLOBEC, Science Steering Committee Coordination Office, Department of Integrative Biology, University of California, Berkeley, Berkeley, CA 94720 and U.S. JGOFS Planning and Coordination Office, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, respectively. International plans for Southern Ocean GLOBEC studies are described in GLOBEC International Report No. 5, which is available from GLOBEC-International Secretariat, Chesapeake Biological Laboratory, P.O. Box 38, Solomons, MD 20688. All of these documents highlight modeling as an important aspect of developing Southern Ocean research programs and discuss modeling needs in light of the stated program goals.

Description

The long-range goal for the U.S. GLOBEC program is to understand the interactions between physical processes and marine animal populations with an emphasis on predicting the effects of global change on population abundance and variability in marine ecosystems. Long-range goals for the U.S. JGOFS program are to evaluate and understand on a global scale the processes controlling the fluxes of carbon and associated biogenic elements in the ocean and to develop a capability to predict the response of oceanic biogeochemical processes to climate change. The Southern Ocean provides an opportunity to combine the goals of these two programs to address issues of climate change effects on biogeochemical cycling and marine food web processes and how these interact to control and regulate biological production.

The Southern Ocean has long been believed to be a region of significant biological production globally. However, it is not well understood how primary production in the Southern Ocean is controlled. The biological and chemical processes suggested as regulating primary production in the Southern Ocean range from nutrient and trace metal effects, physical processes such as light and turbulent mixing, and biological interactions such as grazing. It's increasingly apparent that many of the animal populations in the Antarctic marine food web have life histories that are closely tied to the large seasonal fluctuations in ice cover in the Southern Ocean. Hence, habitat variability is potentially a strong control on biological production in the Southern Ocean. Full descriptions of each of these issues and their relation to climate change are given in the reports listed above.

Following the recommendations of the national and international workshops and those from the Scientific Steering Committees for U.S. GLOBEC and U.S. JGOFS, proposals for modeling studies are solicited by this announcement in advance of field programs in the Southern Ocean. It is anticipated that modeling studies will provide guidance for the design and implementation of the field programs, both by addressing issues of sampling strategy, and by highlighting key processes and measurements necessary to understand the coupling among physical and biogeochemical processes. Modeling studies might include (but are not limited to):

- trace metal controls on primary production,
- sea-ice and biological interactions,
- mixed layer and biological interactions,
- biological and physical controls on air-sea carbon exchange,
- aggregation dynamics and the role of patchiness,
- top predator population dynamics and control,
- behavioral responses of predator and prey,
- paleoclimate and paleoceanographic processes,
- microbial controls on material cycling,
- coupled large and regional scale physical-biological models, and
- models as the primary tool for historical data analysis.

In addition, studies that address issues that will advance the state of

(Cont. on page 13)

Opportunity—(Cont. from page 12)

knowledge of modeling as well as provide understanding of the Southern Ocean system are encouraged. Such studies might include ecological models for data assimilation and management, and modelling techniques for matching scales between models.

Proposal Format

Proposals should be clearly identified as being in response to this Southern Ocean program opportunity announcement. Requirements for proposal content and format should conform to the guidelines given in Grant Proposal Guide (NSF 94-2). Single copies of this document are available at no cost from the Forms and Publications Unit, National Science Foundation, 4201 Wilson Boulevard, Arlington VA 22230 or via the on-line Science and Technology Information System (STIS).

Proposal Submission

Twenty completed copies should be marked "Do not open in mail room" and sent directly to the address below. Proposals must be received at NSF by May 1, 1995. Proposals will not be forwarded to other Programs if found to be inappropriate for this announcement. Proposals received after the deadline will be returned to the sender unreviewed.

Polar Biology and Medicine Program
Office of Polar Programs, Room 755
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230

For further information contact: Dr. Polly Penhale, Polar Biology and Medicine Program, (703) 306-1033, ppenhale@nsf.gov; or Dr. Bernhard Lettau, Polar Ocean and Climate Systems, (703) 306-1033, blettau@nsf.gov; or Dr. Neil Andersen, Chemical Oceanography Program, (703) 306-1587, nanderse@nsf.gov; or Dr. Phillip Taylor, Biological Oceanography Program, (703) 306-1587, prtaylor@nsf.gov.

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Okhotsk Sea Workshop

June 19-24, 1995, Vladivostok, Russia, is the venue for a North Pacific Marine Science Organization (PICES) workshop on the oceanography and living marine resources of the Okhotsk Sea and its adjacent areas. PICES is principally interested in the North Pacific Ocean and adjacent seas from 30°N latitude and including the Bering and Okhotsk Seas. The purpose of PICES is to promote and coordinate marine scientific research in order to advance scientific knowledge of this area and its living resources.

The purpose of the workshop is to bring together scientists studying or having interest in the Okhotsk Sea, northern Japan Sea, and Kuril Island region of the North Pacific. The workshop will review current marine science knowledge and the availability and exchange of data for implementing collaborative oceanographic research projects in the region. Vladivostok was chosen as the venue to maximize the opportunity for interaction between Russian scientists and those from other countries. The focus of the physical oceanography portion of the workshop will be on circulation, sea ice and water mass modification in the Okhotsk and northern Japan Seas. The workshop will produce an overview of the fisheries of the Okhotsk Sea, especially on how fishing and the environment affect abundance trends of walleye pollock and other non-salmonid species. The workshop will also review the distribution and survival of Pacific salmon in the Sea of Okhotsk with particular emphasis on the survival, abundance and stock identification of chum salmon.

For more information about the Okhotsk Sea workshop contact the PICES Secretariat c/o Institute of Ocean Sciences, P.O. Box 6000, Sidney, BC, Canada V8L 4B2 (Phone: 604-363-6366; FAX: 604-363-6827; Internet: pices@ios.bc.ca).

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First Open GAIM Science Conference

The first Global Analysis, Interpretation, and Modelling (GAIM) Science Conference of the International Geosphere Biosphere Program (IGBP) will be held Sept. 24-29, 1995 in Garmisch-Partenkirchen, Germany. The Science Conference will focus on papers in the areas of global data analysis and assessment, modelling of biogeochemical systems and their relationship to physical climate and hydrologic systems, and interpretation of current trends as indicated by global databases and model results for extrapolation with regard to future global change. The new and continued research directions which arise from these results should eventually lead to answers regarding the measurement, causes and consequences of natural and anthropogenic global change factors.

Abstracts are solicited from all interested scientists conducting relevant research. Abstracts are due by May 1, 1995; abstract format information is available from the GAIM Task Force Office. Presentations may be in oral, poster or video poster format. Oral and poster session topics will be grouped by time periods, including "Paleo" <20k years), "Historical" (<2000 years), "Contemporary (<20 years), and "Future". Morning sessions will concentrate on measurements and data analysis, and afternoon sessions will focus on modelling. There will also be a special session on Global Systems Integration. For further information contact Dr. Dork Sahagian, GAIM Task Force Office, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH 03824 USA (Phone: 603-862-3875; FAX: 603-862-0188; Internet: gaim@unh.edu).

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Berkeley U.S. GLOBEC Web Site Goes Online

After many delays, the U.S. GLOBEC WWW site at Berkeley has been established and is on-line. Using a web client (e.g., Mosaic, Netscape[my favorite]) access the following URL:

http://www.usglobec.berkeley.edu/usglobec/globec.homepage.html

Since this site is only in its infancy, it will continue to undergo development. To begin, the site has general info on the U.S. GLOBEC program , complete hyper-text formatted versions of the most recent U.S. GLOBEC reports #8 (Optics Technology), #9 (Arabian Sea), #10 (Data Policy), and #11 (California Current Science Plan; complete except for Tables--which are a nightmare to format). Also online are html versions of U.S. GLOBEC NEWS #5 and #7. Minutes of past and agenda's of upcoming Scientific Steering Committee meetings are also available. As time permits in the coming months, we will attempt to "backfill" the WWW site with some of the older (but still relevant) reports (specifically #6 (Georges Bank IP) and #7 (EBC background document)), and Newsletters, and add forthcoming reports (Long Range Plan; Secondary Production Workshop; Open Ocean Workshop). Links to both the Southern Ocean GLOBEC site (at ODU) and the Georges Bank WWW site (now at WHOI--the one at MIT is out-of-date) are provided along with links to other Oceanographic Servers.

Eventually, but not in the near future, the complete U.S. GLOBEC mailing list may be added with a front-end searching engine, so that addresses can be obtained from your remote site.

Please visit our WWW site and provide comments/criticism or feedback to Hal Batchelder at halbatch@violet.berkeley.edu. Suggestions for additional info that should be available on-line are always welcome. Since we are new to this game, there may be times when the material is being updated and you cannot connect to the server—please try again an hour or so later. ΔΔΔ

12th Annual PACLIM Workshop

The 12th annual PACLIM Workshop will be held May 2-5, 1995 at the Asilomar Conference Center in Pacific Grove, California. The workshop considers multidisciplinary issues of climate variability from weather to geological time scales with a focus on the Pacific and western Americas. This year's theme session will be "Interdecadal Climate Variability Over the Pacific and Western Americas." Tim Baumgartner and Dan Cayan have put together an exciting theme session with invited keynote speakers. Most of the first day (May 3) will be devoted to this theme, but the rest of the workshop will be devoted to contributed oral and poster presentations covering the many aspects of climate that have become the hallmark of PACLIM workshops.

The theme session will highlight:

- ocean-atmosphere variability from the instrumental record—natural variability and possible anthropogenic change
- modelling interdecadal climate variability in the North Pacific
- hydrological and terrestrial ecosystem response in western North America
- ocean ecosystem response in the eastern North Pacific
- terrestrial and marine paleorecords from the eastern Pacific and western North America
- societal impacts of interdecadal climate variability,
- and more.

The informal atmosphere that has prevailed in past workshops will be maintained. Students are encouraged to attend and present their research. Most oral presentations will be allotted approximately 20 minutes. Longer invited talks will be given in the special keynote theme session. Because there will not be sufficient time for everyone to give a talk, we ask you to consider the poster format for highlighting your research. To assure that each poster receives attention, time will be allotted for a 1-minute introduction for each poster.

Lodging and meals will be provided from funding by several sponsors. Limited travel funds may be available, but please don't ask for travel assistance unless you cannot pay your own travel. An $80 registration fee is required to help defray expenses for the workshop. Due to the constraints of lodging at the Asilomar Conference Center, a maximum of about 100 participants will be admitted, and you will be expected to share a room.

For further information on the theme session contact Tim Baumgartner (Phone: 619-534-2171; FAX: 619-534-7641; Internet: trbaumgartner@ucsd.edu) or Dan Cayan (Phone: 619-534-4507; FAX: 619-534-8561; Internet: cayan@seaaira.ucsd.edu), both at Scripps Institution of Oceanography, La Jolla, CA. For further information on registration contact Don Gautier, U.S. Geological Survey, Box 25046, MS 934, Federal Center, Denver, CO 80225 (Phone: 303-236-5740; FAX: 303-236-8822; Internet: gautier@bpgsvr.cr.usgs.gov). ΔΔΔ

MEETING ANNOUNCEMENT

CLIMATE CHANGE AND CARRYING CAPACITY

(CCCC) WORKSHOP

April 19 - 20, 1995
Battelle Laboratory
Seattle, WA

Workshop Sponsor: U.S. GLOBEC, NSF, NOAA

Workshop Organizers: Anne B. Hollowed and Art Kendall

The Global Ocean Ecosystem Dynamics organization (GLOBEC International) and the international North Pacific Marine Science Organization (PICES) approved an initial science plan for a multi-national research effort on Climate Change and the Carrying Capacity (CCCC) of the Sub-Arctic Pacific and coastal waters of the North Pacific and its adjacent seas. The PICES-GLOBEC, CCCC program hopes to implement programs to evaluate climate change effects on living marine systems during the next decade.

To develop the next stage of GLOBEC research related to the CCCC program, the U.S. GLOBEC program is sponsoring a two-day public workshop April 19-20 at Batelle Laboratory. The goal of this workshop will be to identify and discuss key scientific issues relevant to the CCCC program and to make recommendations for initial research activities. Interested participants are encouraged to contact the workshop organizers or Kay Goldberg of the U.S. GLOBEC Coordinating Office at the following addresses.

Anne B. Hollowed/Art Kendall
Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle, WA 98115
Phone: 206-526-4223
Internet: hollowed@afsc.noaa.gov

Kay Goldberg
U.S. GLOBEC SSC Coord. Office
University of California, Berkeley
Department of Integrative Biology
Berkeley, CA 94720
Phone: 510-643-0877
Internet: kaygold@uclink2.berkeley.edu

Collapses—(Cont. from page 3)

Georges Bank Modelling Study

In the North Atlantic component of U.S. GLOBEC there is an opportunity to generate consensus on which processes are critical to the three aspects of population regulation of cod, and thus to enhance our explanatory power and predictive capability. We will briefly describe the approach that our modelling team is taking and some of the results to date[1]. Our approach is to develop a suite of physical and biological models using realistic geography, forcings, and boundary conditions for the Georges Bank cod and haddock populations that capture the processes implied under the various hypotheses. In this way, we hope to evaluate which of the hypotheses are more appropriate for explaining population regulation processes for this geographic area. The results to date are described in Lough et al. (1994), Lynch and Naimie (1993), Naimie et al. (1994), Lynch et al. (1992), Ridderinkhof and Loder (1994), Tremblay et al. (1994), Werner et al. (1993), and Werner et al. (1994). Here we discuss several of the biological results of significance to the conceptual literature on marine population regulation.

Werner et al. 1993 investigated the relative importance of circulation and behaviour on the distribution at age of eggs and larvae of cod and haddock that spawn on the northeast peak of Georges Bank. A 3-d flow field comprising the dominant M_2 tidal current and the seasonal-mean circulation associated with tidal rectification, winter-spring wind stress, and Scotian Shelf inflow was used. Eggs released in the surface layer are rapidly advected off the bank, whereas a large proportion of eggs released at mid-depths persist on the bank for a couple of months. Losses of deeper releases are along shelf into the mid-Atlantic Bight, whereas surface releases are lost in the cross bank direction into slope water. The position of larvae on the southern flank of Georges Bank, both with respect to depth in the water column and cross-bank horizontal position, influences their subsequent fate (Figure 2). With the inter-annual differences in circulation on the bank, one would expect variable distributions on the southern flank, and thus variability in loss rate from the bank.

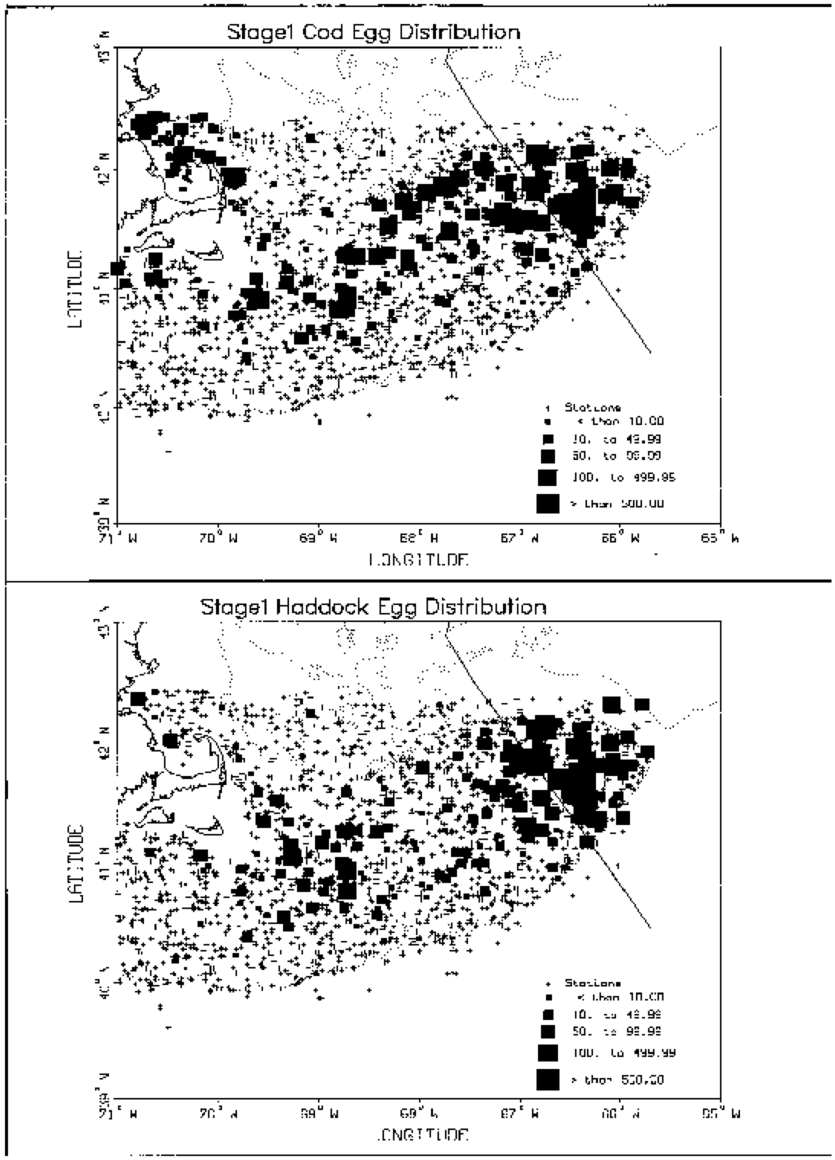

Figure 3. Distribution of stage 1 cod and haddock eggs (mean age of 2.5 days) on Georges Bank (from the overall MARMAP data base).

Simulations using the observed vertical distribution of eggs, and realistic vertical migration behaviour of larvae, result in considerable losses of eggs and larvae from the bank, and are not consistent with empirical observations on larval distributions older than

(Cont. on page 17)

[1] The title of the GLOBEC project is "Importance of Physical and Biological Processes to Population Regulation of Cod and Haddock on Georges Bank: a Model-Based Study". The principal investigators are Dan Lynch (Dartmouth College), Cisco Werner (Univ. North Carolina), John Loder, Dave Greenberg, Peter Smith (all at the Bedford Institute of Oceanography), Greg Lough (National Marine Fisheries Service (NMFS), Woods Hole), Wally Smith (NMFS, Sandy Hook), Ian Perry (Nanaimo Biological Station), and ourselves.

Collapses—(Cont. from page 16)

about 60 days. An important behavioral characteristic that influences on-bank retention is the depth at which fish spawn (i.e., egg release depth). Vertical migration of the larvae does not influence loss rates. However, for the model results to reflect the on-bank displacement of older larvae that is observed from field studies, some horizontal swimming behaviour is required. With realistic swimming speeds, the distribution of larvae that swim in the on-bank direction is similar to field observations of two-month-old larvae.

Summary points for the first cod study are as follows:

- During the first 60 days, circulation has a greater influence on egg and larval distributions than does behaviour.
- Vertical migration of larvae is not important to horizontal distribution, but the mean depth of the larvae is.
- The precise horizontal and vertical location of older larvae on the southern flank is critical to subsequent persistence on the bank.
- If the physical model is correct, some horizontal swimming is required for larvae to persist on the bank longer than about two months; or alternatively, an on-bank flow component is missing from the circulation model.

We are presently examining the MARMAP data on cod and haddock egg and larval distributions to better define the location and time of spawning, and how spawning features change as a function of abundance. In addition, we are summarizing the composite distributions of eggs and larvae at age for the entire eleven years of data. The aim is to evaluate whether spawning is associated with periods and sites of minimal dispersal and to investigate the degree to which density-dependent vagrancy may regulate abundance of these spawning populations.

The composite distribution of stage 1 eggs shows interesting differences between the location of spawning of cod and haddock. Cod spawn more broadly along the northern flank of the bank, whereas haddock spawning is concentrated on the northeastern peak (Figure 3). From an analysis of the composite centers of mass of eggs and larvae at, respectively, 2.5, 8, 15, 24, 37, 51, and 60 days for cod and haddock, the horizontal scales of displacement with time can be summarized. There are differences in the composite distributions at age between cod and haddock, but key similarities are the limited horizontal displacement over the three-month time period and the on-bank movement of the older larvae (Figure 4).

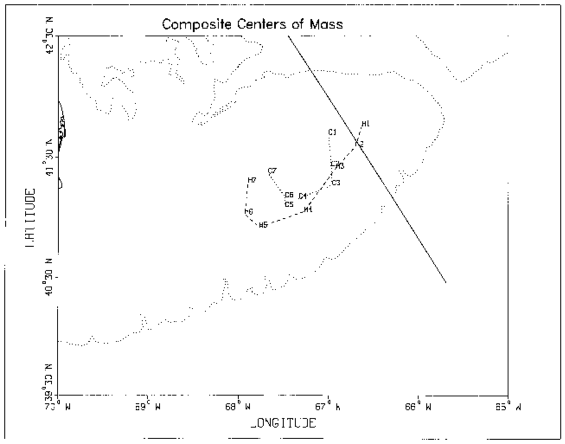

Figure 4. Center of mass of the distribution of different egg and larval stages of cod and haddock on Georges Bank. Mean ages of stages 1 to 7 are 2.5, 8, 15, 24, 37, 51 and 60 days.

Using the bimonthly circulation results of Naimie et al. (1994), in which seasonal baroclinic circulation is included with the flow components in Werner et al. (1993), the whole bank was seeded with eggs and seasonal loss rates from different parts of the bank estimated (Figure 5). If persistence of eggs and larvae on the bank is a "good thing," model results infer that the observed time and location of spawning are about optimal. Eggs released on the northern flank of Georges Bank at intermediate depths during the late winter/early spring have a high probability of being retained on the bank for a couple of months. We are presently modelling the loss rate of eggs and larvae from the bank as a function of spawning stock biomass, assuming that there is an expansion and contraction in time and space in spawning as a function of abundance.

Lough et al. (1994) compare year-class strengths with egg and larval distributions from the MARMAP database. They show that some of the years with good recruitment were associated with low losses of eggs and larvae from the bank due to favourable wind conditions, and vice versa. For example, loss of eggs and larvae in 1982 was high, there was a strong and unfavourable northeastward wind stress in April, and the year-class was weak. In contrast, in 1985 the losses were relatively low, the winds more favourable, and the year-class strong. Modelling work evaluated the degree to which contrasting winds of 1982 and 1985, as well as variable inflow from the Scotian Shelf, generated differences in egg and larval distributions. There was a considerably higher loss of cod eggs and larvae from Georges Bank in 1982 than 1985. The results indicate that between year differences in circulation and mixing can substantially impact retention of early life-history stages on Georges Bank, and that such processes contribute to variable recruitment.

The final cod/haddock biological study completed by the team establishes a modelling framework to evaluate the importance of circulation and mixing on larval feeding success (Werner et al. 1994). This study was summarized in U.S. GLOBEC News No. 7. The principal conclusions are:

- Losses of cod larvae due to

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starvation dominate the model at low food densities, while at high food concentrations the rates of starvation loss and advective loss are similar.

- Using estimates for late winter/ early spring mean prey fields, the model predicts insufficient food for larval growth on the bank. A fivefold increase in mean concentration of small prey is necessary for cod larvae to grow. Including turbulence allows a small proportion of cod larvae to grow and survive at the initial prey concentration estimates.
- The region of highest retention due to circulation processes coincides with the region of highest growth rates, i.e., shoalward of the 60 m isobath at subsurface depths of 25 m or greater.

These modelling results give a flavour of one aspect of the Georges Bank work. Overall GLOBEC activities on the bank include a broad range of field studies on processes underlying population regulation of zooplankton, cod, and haddock, with an emphasis on early life-history stages. In addition, circulation is being monitored at key locations. This mixture of field observations on processes, along with the long-term monitoring of distributions of fish, plankton, and the oceanographic environment, allows the modelling activities to focus on central problems.

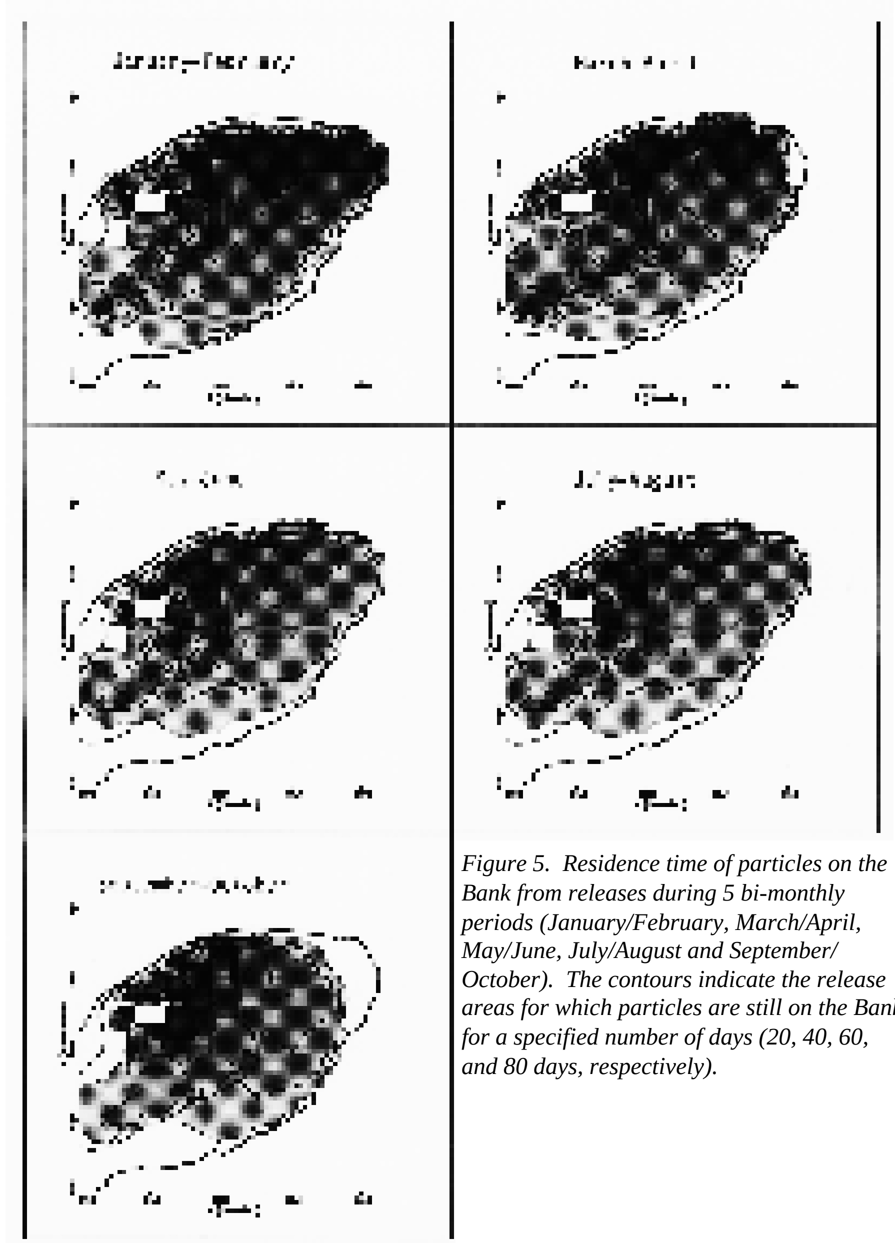

Figure 5. Residence time of particles on the Bank from releases during 5 bi-monthly periods (January/February, March/April, May/June, July/August and September/ October). The contours indicate the release areas for which particles are still on the Bank for a specified number of days (20, 40, 60, and 80 days, respectively).

Links Between GLOBEC and Management Questions

How are the above results, and the North Atlantic GLOBEC program on cod, relevant to the four management questions posed above? In Tables 1 and 2, the theoretical framework underlying population regulation of marine species is outlined. There are a number of competing hypotheses for the three characteristics of populations. Reaching consensus on which of the hypotheses are more appropriate for particular areas and populations is a prerequisite to providing answers that are broadly accepted by the scientific community. The circulation and mixing models are becoming sufficiently realistic that they can be used to help generate consensus.

To answer the first question requires a better understanding of the oceanographic processes that sustain spawning components. If the member-vagrant interpretation of pattern is more realistic than the migration triangle interpretation, then a different approach is needed to define geographic management units and protect individual spawning components. The drift route concept involving large scale residual currents infers that birth site fidelity is defined at the scale of the currents linking spawning areas to juvenile nursery areas. In contrast, the retention concept infers that fidelity is defined at smaller scales, such as re-circulation features on banks, and within bays and inlets.

The approach to defining minimum spawning stock biomass and its geographical distribution varies according to our understanding of the

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control of population pattern. Thus, the modelling results indicating why cod spawn in particular areas on Georges Bank are of importance to the broader conceptual issue of maintenance of geographic patterns of spawning. Practical measures such as the location of spawning closures, the minimum spawning biomass needed for each component prior to the opening of fisheries, and the time scale of recovery of extinct components, depend on understanding how population patterns are regulated. Perhaps some cod fisheries collapses have been due to gradual elimination of spawning components within a regulatory approach that does not consider this level of complexity in the biology and physics.

Under GLOBEC, a comparative modelling approach throughout the distributional range of cod in the North Atlantic is envisioned. The increased understanding of the physical/biological coupling processes that establish and maintain geographic patterns in cod spawning will aid managers in dealing with the first question and to implement measures to protect the reproductive potential of the species.

The second and third questions (need for ecosystem management and impacts of dragging) require an improved understanding on the regulation of abundance. The management implications of the two competing hypotheses for regulating abundance (Tables 1 and 2) are quite different. The match-mismatch hypothesis infers a tightly coupled community with density dependence operating through food chain interactions. Thus, one would infer linkages between commercial species, and multispecies or ecosystem management would be needed. In contrast, the member-vagrant hypothesis infers relatively uncoupled marine food chains with each population abundance being primarily controlled by physical oceanographic processes in a density-dependent manner. The populations, in essence, are interpreted to be responding independently to the physics; thus, an ecosystem management approach is not warranted. A caveat, however, should be added for species with more collapsed life histories such as marine mammals. Under the member-vagrant hypothesis, abundance of whales, seals, and porpoises should be more influenced by food chain interactions than is the case for the commercially important finfish.

All of the hypotheses in Table 1 assume that the regulation of population features occurs in the pelagic domain, predominantly during the early life-history stages. If correct, one would not expect dramatic impacts of dragging, which might impact food resources for juveniles, on the abundance of groundfish. GLOBEC research may clarify whether most management objectives can be achieved without taking an ecosystem approach, and the degree to which benthos impacts of dragging can be ignored.

There is good evidence that large scale inter-decadal climate change has an impact on ocean productivity (see Beamish 1994 for a North Pacific synthesis) and on the relative abundance of commercially important species (see Baumgartner et al. 1992 for an analysis of sardine/anchovy fluctuations off California). In the North Atlantic, however, there is considerable evidence of resilience in the biological distributions at both the community and population level. For example, since systematic monitoring of fisheries began off northern Europe in the late 19th century, some populations of cod have been spawning at the same time and locations. However, there is also evidence for dramatic changes in dispersal and migration (Greenland, Iceland cod, Scotia Shelf haddock, northern cod), and cod availability (eastern Scotian Shelf cod).

The GLOBEC studies on cod in the North Atlantic should provide an understanding of which oceanographic processes contribute to the establishment and maintenance of population pattern, as well as the relative abundance of the different populations. From knowledge of key physical features, modelling studies will allow some predictability of the degree to which environmental variability limits the attainment of fisheries management objectives. To accomplish this will also require accurate estimates of abundance and distribution of commercially exploited resources.

In sum, the focus of the North Atlantic component of GLOBEC on population regulation of cod should generate answers to some of the key questions that fisheries managers are asking. There is a need for increased consensus by the scientific community on which of the hypotheses best capture the critical mechanisms. The mix of historical data analysis, field experiments, and modelling studies in GLOBEC provides us with a unique opportunity to make progress in a component of ecology that has remained contentious for several decades. Ecology now needs a culling of competing interpretations, with a concomitant increase in explanatory power. *(Mike Sinclair is the director of the Biological Sciences Branch at the Bedford Institute of Oceanography in Halifax, Nova Scotia, and Fred Page is a research scientist at the Department of Fisheries and Oceans at the St Andrews Biological Station in New Brunswick)*

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University of California
U.S. GLOBEC Scientific Steering Coordinating Office
Department of Integrative Biology
Berkeley, CA 94720-3140