GLOBAL OCEAN ECOSYSTEM DYNAMICS

GLOBEC Special Contribution No. 7

UPDATE OF THE GLOBEC NATIONAL, MULTINATIONAL AND REGIONAL PROGRAMME ACTIVITIES, 2004
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GLOBEC is a Programme Element of the International Geosphere-Biosphere Programme (IGBP). It is co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC).
The GLOBEC Report Series (Ed. Manuel Barange) is published by the GLOBEC International Project Office and includes the following:


No. 11. Small Pelagic Fishes and Climate Change Programme Implementation Plan.


No. 16. Report of a GLOBEC-SPACC/IDYLE/ENVIFISH Workshop on Spatial Approaches to the Dynamics of Coastal Pelagic Resources and their Environment in Upwelling Areas, 6-8 September 2001, Cape Town, South Africa

GLOBEC Special Contributions

No. 1. Predicting and Monitoring of the Physical-Biological-Chemical Ocean. A.R. Robinson (Ed.)


No. 3. GLOBEC Workshop on the Assimilation of Biological data in Coupled Physical/ Ecosystems Models. A.R. Robinson and P.F.J. Lermusiaux (Eds.)


No. 7. Update of the GLOBEC National, Multinational and Regional Programme Activities, 2004. D.M. Ashby (Ed.)

Additional copies of these reports are available from:

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GLOBEC is a Programme Element of the International Geosphere-Biosphere Programme (IGBP). It is co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC).
PREFACE

This report describes the current status, in July 2004, of the implementation activities of the Global Ocean Ecosystem Dynamics (GLOBEC) programme element of the International Geosphere-Biosphere Programme (IGBP). GLOBEC is co-sponsored by the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO.

The primary goal for GLOBEC is:

“To advance our understanding of the structure and functioning of the global ocean ecosystem, its major subsystems, and its response to physical forcing so that a capability can be developed to forecast the responses of the marine ecosystem to global change”.

The research described has been developed under the auspices of the GLOBEC Scientific Steering Committee, and addresses the scientific goals laid out in the GLOBEC Science Plan (IGBP Report No. 40), and the implementation strategy of the GLOBEC Implementation Plan (IGBP Report No 47). It draws on the results and recommendations of workshops, meetings, and reports thereof that have been sponsored under the auspices of GLOBEC.

GLOBEC provides the opportunity for participation in an important multi-disciplinary programme of oceanic research, and recognises that different levels of participation are possible. Therefore, GLOBEC is organised into National and Multi-national Programmes, Regional Programmes, and four Research Foci Activities (see diagram above). This report documents the current National, Multi-national and Regional programmes. Research Foci activities have not been included. It is a living document, describing complete, in progress, and planned activities, and may be updated in future.

It should be born in mind that the six current Regional Programmes, Southern Ocean GLOBEC (SO-GLOBEC), Small Pelagic Fishes and Climate Change (SPACC), ICES-GLOBEC Cod and Climate Change Programme (CCC), PICES-GLOBEC Climate Change and Carrying Capacity Programme (CCCC), CLimate Impacts on Oceanic TOp Predators (CLIOTOP) and Ecosystem Studies of Sub-Arctic Sea (ESSAS) all have strong national contributions. These are reflected under the appropriate section.

The data was gathered from programme websites and National and Regional Programme contacts and representatives. The help of the very many people who contributed information is gratefully acknowledged, particularly Dr Jürgen Alheit, Prof Isabel Ambar, Dr Manuel Barange, Dr Hal
Batchelder, Dr Ulrich Bathmann, Dr Tim Baumgartner, Prof Dave Checkley, Dr François Carlotti, Dr Ruben Escribano, Dr Pierre Freon, Dr Robert Groman, Dr Eileen Hofmann, Dr George Hunt, Dr Suam Kim, Ms Linda Lagle, Dr Patrick Lehodey, Dr Celia Marrase, Dr Oliver Maury, Dr Webjoern Melle, Dr Temel Oguz, Prof Im Sang Oh, Dr Geir Ottersen, Dr Claude Roy, Dr Yasunori Sakurai, Dr Miguel Santos, Dr Ted Strub, Prof Qisheng Tang, Dr Deborah Thiele, Dr Philip Williamson and Dr Marco Zavatarelli.

Due to the varying sizes and natures of the programmes, the data has been organised in formats most appropriate to each individual programme and to the data provided. Similarly, the level of detail reflects the information supplied by the particular programme, and does not necessarily reflect the scale of a particular contribution.

Any errors, changes or additions to the programmes described should be submitted to the GLOBEC IPO for collation and subsequent updating.

The document may be cited as:

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<th>Description</th>
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<tr>
<td>ACC</td>
<td>Alaska Coastal Current</td>
</tr>
<tr>
<td>ADCP</td>
<td>Acoustic Doppler Current Profiler</td>
</tr>
<tr>
<td>ARP</td>
<td>Acoustic Recording Package</td>
</tr>
<tr>
<td>AVHRR</td>
<td>Advanced Very High Resolution Radiometer</td>
</tr>
<tr>
<td>BCMLE</td>
<td>Benguela Current Large Marine Ecosystem</td>
</tr>
<tr>
<td>BENEFIT</td>
<td>Benguela Environment and Fisheries Interactions and Training Programme</td>
</tr>
<tr>
<td>CCC</td>
<td>Cod and Climate Change</td>
</tr>
<tr>
<td>CCCCC</td>
<td>Climate Change and Carrying Capacity</td>
</tr>
<tr>
<td>CCS</td>
<td>California Current System</td>
</tr>
<tr>
<td>CGOA</td>
<td>Coastal Gulf of Alaska</td>
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<tr>
<td>CLIVAR</td>
<td>Climate Variability and Predictability Programme</td>
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<tr>
<td>CPR</td>
<td>Continuous Plankton Recorder</td>
</tr>
<tr>
<td>CTD</td>
<td>Conductivity Temperature Depth Instrument</td>
</tr>
<tr>
<td>CUFES</td>
<td>Continuous Underway Fish Egg Sampler</td>
</tr>
<tr>
<td>ECS</td>
<td>East China Sea</td>
</tr>
<tr>
<td>ENSO</td>
<td>El Niño Southern Oscillation</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>Fte</td>
<td>Full time employee</td>
</tr>
<tr>
<td>GEF</td>
<td>Global Environmental Fund</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographical Information System</td>
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<tr>
<td>GLOBEC</td>
<td>Global Ocean Ecosystem Dynamics</td>
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<tr>
<td>GOOS</td>
<td>Global Ocean Observing System</td>
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<tr>
<td>IBM</td>
<td>Individual Based Model</td>
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<tr>
<td>ICES</td>
<td>International Council for the Exploration of the Sea Cod</td>
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<tr>
<td>IGBP</td>
<td>International Geosphere-Biosphere Programme</td>
</tr>
<tr>
<td>IOC</td>
<td>Intergovernmental Oceanographic Commission of UNESCO</td>
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<tr>
<td>IWC</td>
<td>International Whaling Commission</td>
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<td>JGOFS</td>
<td>Joint Global Ocean Flux Study</td>
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<tr>
<td>LIFECO</td>
<td>Linking hydrographic Frontal activity to ECOsystem dynamics in the North Sea and Skagerrak</td>
</tr>
<tr>
<td>LME</td>
<td>Large Marine Ecosystem</td>
</tr>
<tr>
<td>LTOP</td>
<td>Long-Term Observation Programme</td>
</tr>
<tr>
<td>MOCNESS</td>
<td>Multiple Opening-Closing Net and Environmental Sensing System</td>
</tr>
<tr>
<td>MODIS</td>
<td>MODerate resolution Imaging Spectrometer</td>
</tr>
<tr>
<td>NAO</td>
<td>North Atlantic Oscillation</td>
</tr>
<tr>
<td>NAO</td>
<td>North Atlantic Oscillation</td>
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<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<tr>
<td>NEP</td>
<td>North East Pacific</td>
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<tr>
<td>NERC</td>
<td>Natural Environment Research Council, UK</td>
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<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NPZD</td>
<td>Nutrient, Phytoplankton, Zooplankton, Detritus model</td>
</tr>
<tr>
<td>NSF</td>
<td>National Science Foundation</td>
</tr>
<tr>
<td>OGCM</td>
<td>Ocean General Circulation Model</td>
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<tr>
<td>PICES</td>
<td>North Pacific Marine Science Organisation</td>
</tr>
<tr>
<td>SACW</td>
<td>South Atlantic Central Water</td>
</tr>
<tr>
<td>SCOR</td>
<td>Scientific Committee on Oceanic Research</td>
</tr>
<tr>
<td>SeaWiFS</td>
<td>Sea-viewing Wide Field-of-view Sensor</td>
</tr>
<tr>
<td>SPACC</td>
<td>Small Pelagic Fishes and Climate Change</td>
</tr>
<tr>
<td>SST</td>
<td>Sea Surface Temperature</td>
</tr>
<tr>
<td>TASC</td>
<td>Trans-Atlantic Study of Calanus</td>
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<tr>
<td>VPA</td>
<td>Virtual Population Analysis</td>
</tr>
<tr>
<td>WCRP</td>
<td>World Climate Research Programme</td>
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<tr>
<td>WOCE</td>
<td>World Ocean Circulation Experiment</td>
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</table>
GLOBEC NATIONAL ACTIVITIES

This section covers past, present and planned National Programme Activities. Where programmes have been described in the first edition of the Report on the GLOBEC National, Multi-national and Regional Programme Activities only the updated information is reported here.

GLOBEC provides a framework for the international programme that encourages the fullest participation of national, multinational and regional scientific efforts but does not impose a rigid template. National Activities co-ordinate research in specific countries based on the GLOBEC Science and Implementation Plans. Each country funds its own research programme but benefits from the international context of GLOBEC. The following extract from the GLOBEC Implementation Plan provides some guidance on the benefits and responsibilities associated with involvement in GLOBEC; they are not intended as a formal set of regulations.

Benefits
- Provides the opportunity for participation in the development, planning and implementation of a collaborative international science programme
- Adds to the scientific value of planned work by providing complementary information; for example, by widening the range of studies and extending their spatial and temporal coverage
- Promotes rapid communication of ideas and results, through meetings and publications
- Develops and tests standard methods and protocols for measuring variables, thereby facilitating quality control and meaningful data sharing
- Makes available data sets collected in component studies and develops a common data management strategy
- Enables close working links with other relevant international programmes and studies
- Facilitates process understanding of regional studies through comparisons with other ecosystems.

Responsibilities
- Acceptance of general principles and goals outlined in the GLOBEC Science Plan
- Carry out a programme in general accordance with relevant aspects of the GLOBEC Implementation Plan
- Participation in the activities of the GLOBEC SSC, by assisting in the planning and development of the programme as a whole
- Make data collected within the programme available to the wider GLOBEC community, in accordance with GLOBEC protocols for international data exchange
- Assist in programme co-ordination in the provision of central services; for example, data management

For each entry information is presented wherever possible in a standard format (below), but is dependant on the information submitted by the national programme representatives:

Project Title:
Source of Information:
Project Description:
Systems Types Studied:
Target Organisms:
Physical Processes:
Key Questions, Issues and Hypotheses:
Participating Institutions:
Number of Scientists:
Duration:
Funding Agency:
Budget:
For more information:
Project Title:
DEPROAS - Ecosystem Dynamics of the continental shelf of the SW Atlantic

Source of Information:
DEPROAS website, March 2004 and Dr. Yasunobu Matsuura, March 2000

National Representative/ Contact
Instituto Oceanográfico
Universidade de São Paulo
Butantã, São Paulo
05508-900, SP
Brazil

Project Description:
DEPROAS is a multi-disciplinary program, involving physical oceanography, biological oceanography, geological oceanography, and meteorology. It is also a multi-institutional (IOUSP, INPE) enterprise with collaborations with the University of Maryland, SCIO and Centre ORSTOM. Several social benefits are expected. For example, the results will contribute to a better understanding of the cause and effects of fluctuations in fish populations, to obtain proper information for adequate coastal management, and to assess the economical relevance of policies (ports, oil, fishing potential and tourism).

DEPROAS has two main goals:

- To examine the physical mechanisms responsible for seasonal variations of the penetration of the South Atlantic Central Waters (SACW) onto the continental shelf between Cabo de São Tomè and São Sebastião on the coast of Brazil.
- To understand the impact of the seasonal penetration of the SACW on the biological processes of the region's ecosystem.

Website:
http://www.io.usp.br/brasil/projetos/deproas.html

System Types Studied:
Southeastern coast of Brazil between Sao Tom Cape (22°S) and Sao Sebastian Island (25°S). Coastal upwelling and its relation to dynamics of the Brazil Current.

Target Organisms:
Sardinella brasiliensis
Paracalanus spp.
Sciaenid fish assemblage
Benthic fauna

Physical Processes Examined:
Coastal upwelling
Penetration of the South Atlantic Central Water (SACW) in the coastal region
Water column stratification
Meandering movement of the Brazil Current

Key Questions, Hypotheses and Issues:
- Input of nutrients in coastal region by intrusion of the SACW
- Concentration process of prey organisms by water column stability between cool SACW and warm tropical water
- Interannual and seasonal variation of intrusion of the SACW
Chief Scientist:  
Dr. Belmiro Mendes de Castro Filho  
bmcastro@usp.br

Participating Institutions:  
Instituto Oceanográfico da Universidade de São Paulo (IOUSP)  
Instituto de Pesquisas Espaciais (INPE)  
Instituto de Estudos do Mar Almirante Paulo Moreira (IEMAPM)  
University of Maryland  
Scripps Oceanography Institution  
ORSTOM

Number of scientists and fte:  
22

Duration:  
4 years

Budget:  
US$ 2,300,000 (approved in 1996 and started in December 2000)

Funding Agency:  
Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)  
PRONEX (Programa de Núcleos de Excelência)  
FINEP (Financiadora de Estudos e Projetos)  
CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico)
**COUNTRY: CANADA**

**Project Title:** GLOBEC Canada

**Source of Information:**
Ian Perry, June 2004

**National Representative/ Contact:**
Dr. Brad de Young  
Dept. of Physics and Physical Oceanography  
Memorial University  
St. John’s, Newfoundland  
A1B 3X7 Canada

**Project Description:**
GLOBEC Canada seeks to examine how living marine resources are affected by variability of their physical environment. Marine ecosystems undergo large interannual to decadal fluctuations. These large swings affect almost every fishery, and are becoming apparent in time series of ocean climate and plankton indices. The time scale is such that human impacts in terms of economic and societal dislocation, can be very large. There is much evidence for an underlying causal connection through physical environmental forcing of variations in ocean productivity. Unfortunately, timely diagnosis and management response are hampered by insufficient knowledge of intermediate causal linkages.

The multidisciplinary integration of field and modelling studies in GLOBEC Canada will increase our causal-level understanding. The relevance of GLOBEC includes, but is not limited to, climate change trends associated with global warming. A major focus will be on interannual to interdecadal fluctuations and their effects on target populations through recruitment variability of individual species and changes in overall community structure. Simultaneous research programs are being conducted for the Atlantic and Pacific coasts of Canada.

**Website:**
http://www.globec-canada.mun.ca/globec/index.html

**2004 Update:**
Funding for the initial 4 year programme (Phase 1) finished in 1999, a detailed description of the project can be found in GLOBEC Special Contribution No.4. A proposal for a second 4 year programme which built upon the first phase was rejected by the Canadian Academic funding agency. Project results have been published in a number of journal articles, including several special collections (e.g. see Canadian Journal of Fisheries and Aquatic Sciences 56(12), 1999; and 58(4), 2001). "GLOBEC-like" activities are presently being conducted as regional or individual projects (see for example http://www.stratogem.ubc.ca/). For further information on GLOBEC Canada please contact:

Dr. David Mackas  
Fisheries & Oceans Canada  
Institute of Ocean Sciences  
Sidney, B.C.  
Canada
COUNTRY: CHILE

Project Title:
Center of Oceanographic Research in the South Eastern Pacific (FONDAP-COPAS)

Source of Information:
Dr. Ruben Escribano, July 2004

National Representative/Contact
Dr. Ruben Escribano  rescribano@udec.cl
COPAS Center, University of Concepcion  Tel: +41 683247
PO 42, Dichato, Concepcion  Fax: +41 683902
Chile

Project Description:
The FONDAP-COPAS Center focuses its main multi- and interdisciplinary research on the physical, biogeochemical, ecological and paleoceanographic processes that occur in the systems of the Eastern South Pacific (ESP) region. COPAS has a robust outreaching and information transference program both to decision and policy makers as well as to the general public and students at all levels on oceanographic and climate issues.

The nucleus of the COPAS initially is formed by the Research Programs whose goals are described below.

1. General Goals
   • To create new multidisciplinary knowledge regarding the Eastern South Pacific.
   • To create a motivating and pleasant environment conducing to the highest possible scientific productivity in advanced research on regional oceanography and paleoceanography aspects in the ESP, and the role of this ocean in the global climate system.
   • To consolidate a Center of Excellence in Oceanography with international recognition.
   • To strengthen the capacity to carry out scientific oceanographic research in Chile and the Latin American region.
   • To encourage interdisciplinary ocean and climate research projects and international collaboration in the ESP region.
   • To raise the level of awareness in policy makers and the general public of the region regarding oceans and climate change.

2. Specific goals
   • To train young students in oceanography and related disciplines.
   • To attract young researchers, post-doctoral fellows, graduate students and oceanographers, and climate scientists from all over the world to participate in the research and educational activities of the Center.
   • To improve the quality of graduate education in oceanography at the University of Concepción
   • To contribute in the increase of the number and quality of the oceanographers in Chile and Latin America.
   • To contribute in opening new interdisciplinary research areas related with oceanography interacting with disciplines such as meteorology, geology, geophysics, applied mathematics, engineering, molecular biology, biogeochemistry and ecology.
   • To inform and educate policy makers and the general public with regard to oceanography and climate issues.

Website:
http://www.profc.udec.cl/fondap/english/
Target Organisms:
Dominant planktonic species from pico-, nano-, micro-, meso- and macrozooplankton
Soft-bottom benthic species

Physical Processes Examined:
Remote forcing of El Niño/La Niña
The Oxygen Minimum Zone
Large scale patterns of circulation at mesopelagic depths

Key Questions, Hypotheses and Issues:
The scientific goals in the medium-term (5 years) are: i) to analyze and understand the impact of the ENSO (El Niño Southern Oscillation) cycle and other large scale phenomena in the region and its feedback on the climatic system, ii) to study the structure and function of the Oxygen Minimum Zone and its impact on the climatic system, and iii) to identify the role that the Antarctic Intermediate Waters play in the physical, chemical and biological characteristics of the region and their modification due to global climate change.

Funding Agency:
Chilean National Commission for Science and Technology.
COUNTRY: CHINA

Source of Information:  
Prof. Qisheng Tang, October 2003

National Representative/Contact:  
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Yellow Sea Fisheries Research Institute  
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P.R. China  
ysfri@public.qd.sd.cn  
Tel: +86 532 5823175  
Fax: +86 532 5811514

Chief Scientist:  
Prof. Qisheng Tang  
(see above)

Scientific Consultant:  
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P.R. China  
sujil@zgb.com.cn  
Tel: +86 571 8840332  
Fax: +86 571 8071539

Participating Institutions:  
Yellow Sea Fisheries Research Institute, Qingdao  
Second Institute of Oceanography, Hangzhou  
Institute of Oceanology, Qingdao  
Ocean University of Qingdao, Qingdao

EYSEC (China GLOBEC II): Ecosystem Dynamics and Sustainable Utilization of Marine Living Resources in the East China Sea and Yellow Sea

Project Description:  
The programme goals are:  
• to identify key processes of ecosystem dynamics, and improve predictive and modelling capabilities in the East China Sea and the Yellow Sea.  
• to provide scientific underpinning for the sustainable utilization of the ecosystem and rational management system of fisheries and other marine life.  

The scientific objectives of the programme are to determine the:  
• impacts of key physical processes on biological production.  
• cycling and regeneration mechanisms of biogenic elements.  
• basic production processes and role of zooplankton in the ecosystem.  
• food web trophodynamics and shift in dominant species.

System Types Studied:  
East China and Yellow Sea: shelf area

Target Organisms: 
*Calanus sinicus*  
*Engraulis japonicus*  
and other key species in each trophic level
Physical Processes Examined:
Contribution of stratification, frontogenesis, upwelling and bottom boundary interaction to trophodynamics

Key Questions, Hypotheses and Issues:
• Energy flow and conversion of key resource species; dynamics of key zooplankton populations; cycling and regeneration of biogenic elements; ecological effects of key physical processes; pelagic and benthic coupling; the contribution of microbial loops to the main food web.
• Key physico-chemico-biological processes in highly productive areas
• Exchanges contributing to the dominant species shift and population dynamics

Number of scientists and fte: 94 scientists

Duration: October 1999 - September 2004

Budget: US$4.7 Million

Funding Agency: The Ministry of Science and Technology, P.R. China
COUNTRY: France

Source of Information: François Carlotti and Claude Roy, June 2004

National Representative / Contact:
Dr. François Carlotti
Unité Mixte de Recherché 6535 - C.N.R.S.
Université de la Méditerranée
Observatoire des Sciences de l’Univers (OSU)
Centre d’Océanologie de Marseille (COM)
Rue de la Batterie des Lions
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France
carlotti@com.univ-mrs.fr
Tel: 04 91 04 16 44
Fax: 04 91 04 16 35

Organisation and funding agencies
There is not one French- GLOBEC program, but several GLOBEC- projects which are funded through national, institutional and regional programs

National programs:
• National Program of Coastal Environment (PNEC) Phase II 2004-2008. This program covers site-specific projects and thematic projects.
• National Program of Oceanic Processes and Fluxes (PROOF). (http://www.obs-vlfr.fr/proof)
• National Program on Impact of Climate Change. (http://medias.obs-mip.fr/gicc)

Funding
Funded by different ministries and agencies including: Ministry of Research, Ministry of Environment and Durable Development, Ministry of Cooperation and the Foreign Office through National institutes.

DRAST: Direction de la Recherche et des Affaires Scientifiques et Techniques (http://www.equipement.gouv.fr/recherche/drast/)
Ministère de l’Agriculture & de la Pêche (http://www.agriculture.gouv.fr)
Ministère de la Recherche (http://www.recherche.gouv.fr)
Ministère de l’Ecologie et du Développement Durable (http://www.environnement.gouv.fr)
Mission Interministérielle de l’Effet de Serre (http://www.effet-de-serre.gouv.fr)

Participating Scientific Institutions to these national programs are:
CIRED: Centre International de Recherche sur l’Environnement et le Développement (http://www.centre-cired.fr)
CNRS (http://www.insu.cnrs-dir.fr)
IFREMER: Institut Français de recherche pour l’exploitation de la mer (http://www.ifremer.fr)
INSU: Institut National des Sciences de l’Univers (http://www.insu.cnrs-dir.fr)
IRD: Institut de Recherche pour le Développement (http://www.ird.fr)
Météo-France (http://www.meteo.fr)
Institutional program (funded by each Institute for its research laboratories)

- IFREMER: Integrated project on the Bay of Biscay. (http://www.ifremer.fr/anglais/program)
- IRD: Research Unit R097 on upwelling ecosystems (http://sea.uct.ac.za/marine/idyle/)

Regional programs

There are several regional programmes funded by each of the regions which usually complement the national programmes. Regional programmes include:

- Bay of Biscay
- North Western Mediterranean ecosystem
- English Channel ecosystems
- Upwelling systems
- Tropical areas

Further details for each regional programme are given below.

Bay of Biscay Ecosystem

System Types Studied:
Bay of Biscay
Gironde River

Target Organisms:
European anchovy (Engraulis encrasicolus)
Common sole (Solea solea)
European Seabass (Dicentrarchus labrax)

Physical Processes Examined:
Eddies
Fresh water flux
Fronts
Gyres
Ocean circulation
Upwelling

Key Questions, Hypotheses and Issues:
- Spatial structure of the population: identification of habitats and spatial units relevant to each life stage; identification of hydrological and hydrodynamical structures connected with these habitats.
- Identification of the linkages between meso-scale physical structures, trophic structure and fish response (i.e. larval survival, growth, condition, fecundity). Reconstruction of the links between population and environment at the scale of the population by aggregation of meso-scale relationships.
- Characterisation of the relationship between large scale climatic situations and the activation of meso-scale physical structures. Hindcasting of specific environmental features in the Bay of Biscay from available historical climate records, identification of climatic trends and changes in biological reference points.
- Development of short-term recruitment forecast indices based on observed environmental conditions.
• Analysis of combined environmental and fishing effects, using a meso-scale model of the population dynamics.

**Participating Institutions:**
IFREMER, CNRS, IRD, Universities

**Duration**
1999 – on-going

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**Bay of Biscay Ecosystem Projects:**

1. **Integrated project in the Bay of Biscay**

   **Source of Information:**
   Benjamin Planque (benjamin.planque@ifremer.fr)

   **Website:**
   http://www.ifremer.fr/gascogne

   **Contact:**
   Jean Boucher (jean.boucher@ifremer.fr)

   **Project Description:**
   The "Integrated Bay of Biscay project" is an institutional trans-disciplinary project based in IFREMER. The main objectives are 1) to understand interactions between fisheries resources, the environment and anthropogenic activities (including fisheries) at the regional scale of the Bay of Biscay, 2) to determine how social and economical factors control the behaviour of human factors, and 3) to understand and predict the behaviour of the Bay of Biscay anthroposystem under different climatic and economical scenarios.

   The project is organized along 5 major themes: a) climate and hydroclimate, b) physical-biological interactions, c) impact of anthropogenic activities on resources, d) interaction between human activities and the environment and e) medium term social and economical scenario building. In addition, a major effort is devoted to technological development in support to all themes of the project.

   Key actions relevant to GLOBEC include:
   - Coupled biological-hydrodynamical modelling
   - Dynamics of sea bass populations and their exploitation
   - Dynamics of sole populations
   - Dynamics of small pelagic populations (Action Forevar)
   - Dynamics of fish assemblages
   - Spatial-seasonal fisheries modelling
   - Phytoplankton dynamics

2. **Action Forevar on small pelagics**

   **Contact:**
   Pierre Petitgas (pierre.petitgas@ifremer.fr)

   **Project Description:**
   This project focuses on the correspondence between the hydrodynamical concept of mesoscale structures and the biological concept of habitat. The project concentrates on the investigation of the relationships between mesoscale hydrodynamical structures and a populations' life cycle. A particular population is described as an ensemble of mesoscale spatial units and the global response of the population to environmental forcing is then analysed as the result of the multiple mesoscale
responses. The project particularly concentrates on two types of population response: recruitment and spatial organization.

The target population is the anchovy in the Bay of Biscay. The spatial distribution of this population is relatively limited (in comparison with highly migratory species in the same area), its life duration is short, it is highly dependent on hydroclimatic variations and it is an economically important stock. The Bay of Biscay is constituted by a collection of mesoscale features which can be activated or not, depending on meteorological conditions. 3D hydrodynamical models, such as the one developed at IFREMER allow for realistic reconstruction of the key mesoscale structures so that it is possible to study the details of the bio-hydrodynamical coupling between anchovy habitats during successive life stages (e.g. spawning, larval stages) and the activation/de-activation of physical structures.

The current results from the programme include the determination of:
- Spatial distribution of spawning areas
- The influence of wind regimes on transport and retention of eggs and larvae
- Regional variations in larval growth and food web structures
- Spatial structures of fish schools
- A recruitment forecast index

Evaluation of the anchovy stock and cartography of adult distribution and spawning areas are currently produced annually and used for management advice.

3. PNEC project: Site study Bay of Biscay

Contact: Alain Herbland (aherblan@ifremer.fr) and Christine Dupuy (Christine.Dupuy@univ-lr.fr)

Project Description:
The objective is to evaluate the impact on marine ecosystems of climatic phenomena and various anthropic effects on various scales of space and time. The activities include regular surveys.

4. PNEC project: Modelling physical-biological processes

Contact: Benjamin Planque (benjamin.planque@ifremer.fr) and Pascal Lazure (pascal.lazure@ifremer.fr)

Project Description:
The aim of this thematic project is to build a forum of exchange and interaction between ecologists and hydrodynamical modellers. The project specifically works towards:
- developing biogeochemical (e.g. NPZD) and biological (e.g. IBM) modules coupled with hydrodynamical models,
- developing methods and tools for the interpretation and validation of model simulations,
- developing new approaches towards a better description, understanding and forecasting of the influence of hydroclimatic and anthropogenic changes on marine ecosystems.

The thematic project is built on 11 research actions which are devoted to (1) the construction of indices derived from hydrodynamical simulations (habitats, key processes such as enrichment, retention or concentration, ecosystem indicators), (2) the development and validation of NPZ models, biogeochemical and IBM modules, and (3) the development of novel approaches for the calibration and validation of hydrodynamical models applied to ecology. Five of these actions are located in the Bay of Biscay region. Others take place in the English Channel, Mediterranean Lagoon, and open Pacific and Atlantic oceans.
5. GiCC project: Fishing and Climatic warming impacts on spatial fish distributions in the Bay of Biscay

Contact:
Fabian Blanchard (Fabian.Blanchard@ifremer.fr)

Project Description:
This project includes and expands beyond the Bay of Biscay area. The main objective is to assess the effects of climatic forcing on exploited fisheries resources. The first part of the project is based on retrospective studies and the use and development of original time-series analyses techniques. The second part focuses on predictive aspects, using ecosystem and bio-economical models.

North Western Mediterranean ecosystem (2004-2007)

Source of Information:
François Carlotti (carlotti@com.univ-mrs.fr)

System Types Studied:
North western Mediterranean gyre
Ligurian jet
Gulf of Lion
Rhône river

Target Organisms:
Key Mediterranean zooplankton species (copepods, salps, jellyfish, fish eggs)

Physical Processes Examined:
Ocean circulation
Eddies
Fresh water flux
Fronts
Gyres

Key Questions, Hypotheses and Issues:
- To review the available time-series and predictive models
- To suggest improvements in terms of sampling and modelling strategy, and the addition of new time-series observations that are not yet part of the monitoring system
- To determine physical influences and biophysical interactions in planktonic communities
- To understand the dynamics of zooplankton (i.e. holoplankton, meroplankton and ichthyoplankton) and their interactions with both lower and higher trophic levels
- To identify probable changes in living marine resources resulting from climate change

Participating Institutions:
IFREMER, CNRS, IRD, Universities
North Western Mediterranean ecosystem Projects:

1. PNEC project: ZOOPNEC

Contact:
Gabriel Gorsky (gorsky@obs-vlfr.fr)

Duration:
2004-2007

Project Description:
Nationally funded projects with cooperation from Italy and Spain
The objective is to provide:

- Optimised approaches for the acquisition and treatment of data related to the zooplankton population dynamics and their environment
- Proxies for the definition of structures, diversity and function of these populations related to other ecosystem components

In order to estimate zooplankton distribution and abundance as close as possible to the reality we propose to proceed as follows:

- To apply these methods to past zooplankton sample series from seven NW Mediterranean sites
- To group French field and laboratory instrumentation to define the best links between existing and new methods in order to optimize procedures for data acquisition and treatments allowing the estimation of the temporal and spatial properties of zooplankton communities
- To apply these methods on new data sets collected in the NW Mediterranean during the ZOOPNEC project

An international working group MEZOTIS (Mediterranean Mesozooplankton Time Series) of ICESM sub-committee “Living resources and marine ecosystem”, will meet first in Barcelona in June 2004. There are ZOOPNEC Bilateral Co-operation Projects (PAI) that are funded by the Foreign Office with Belgium, Spain and Italy and a ZOOPNEC Regional Programme in the PACA region.

2. PNEC project: Modelling physical-biological processes

Contact:
Benjamin Planque (Benjamin.planque@ifremer.fr), Pascal Lazure and J.C. Poggiale

Project Description:
The objective is to evaluate the impact on marine ecosystems of climatic phenomena and various anthropogenic effects on various scales of space and time. The activities include regular surveys and methodology (modelling, statistics) processing.

Biophysical coupling and coupling between lower and higher trophic levels will be targeted actions to model plankton succession in the northern Western Mediterranean sea.

3. PROOF project PECHE (Production and Exportation of Carbon: control by HEterotrophic organisms at small time scales)

Contact:
V. Andersen (andersen@obs-vlfr.fr) and M. Goutx (goutx@com.univ-mrs.fr).

Website:
http://www.obs-vlfr.fr/proof/vt/op/ec/peche/pec_plan.htm

Project Description:
The objective is to examine the natural variability of the structure and the dynamics of pelagic ecosystems at small time scales and in response to transient events. The project addresses a major question concerning the functioning of biological systems in the open ocean and the biogeochemical responses to global change.
English Channel ecosystem

Source of Information:
François Carlotti (carlotti@com.univ-mrs.fr)

System Types Studied
English Channel, Seine river, Bay of Mont St Michel

Target Organisms
Meroplanktonic larvae

Physical Processes Examined:
Jet
Eddies
Tides
Estuarine hydrodynamics

Key Questions, Hypotheses and Issues
• Analyse how hydrodynamics control dispersion or retention of meroplankton larvae, and the consequences for benthic population dynamics.
• Quantify the gene exchanges between local populations over English Channel system.

Participating Institutions:
CNRS, Universities, IFREMER

English Channel ecosystem projects

1. PNEC project: Hydrodynamics, genetics and biology controlling the distribution patterns of benthic populations

Contact:
Eric Thiébault (eric.thiebaut@snv.jussieu.fr)

Duration:
1999 - on-going

Upwelling systems

Source of Information:
Claude Roy (claude.roy@ird.fr)

System Types Studied
Upwelling ecosystems

Target Organisms
Small pelagic fish
Zooplankton

Physical Processes Examined
Upwelling process
Meso-scale circulation dynamics
Cross-shore exchanges
Climate and open ocean forcing on coastal systems
Key Questions, Hypotheses and Issues

The aim of the project is to provide an adapted methodology to analyse the structure and functioning of upwelling ecosystems in order to implement an ecosystem approach to fisheries. By using an integrative and comparative approach, the project studies the dynamics of pelagic fish and their ecosystem, in relation to global and regional changes in their exploitation and the environment.

The project focuses on the following questions:

- global change and its impact on upwelling regions;
- exploitation and its effects on the structure and functioning of the upwelling ecosystems: spatial interactions between marine resources and the physical environment, adaptive strategies of the populations and communities;
- regime shifts in upwelling ecosystems;
- socio-economic aspects of the pelagic fisheries in the world.

The project is implemented in three upwelling regions: the Benguela current, the Humboldt current and the Canary current.

The methods that are developed, used and integrated include:

- analysis and modelling of the physical (hydrodynamic) processes which are essential to the dynamics of biological processes such as primary and secondary production, recruitment and distribution of resources;
- Lagrangian approaches to analyse the links between the physical environment and the various upper trophic levels;
- tropho-dynamic models to analyse the spatio-temporal dynamics of species interactions in the ecosystem;
- geographical information systems (GIS) and ecosystem indicators to incorporate all the available knowledge within one or two ecosystems;
- in situ experiments to study how space is utilised by pelagic species as a function of their biology and the environment sensu lato.

Participating Institutions:
IRD groups at Centre de Recherche Halieutique Méditerranéenne et Tropicale (CRHMT), Sète, France
Centre IRD de Bretagne, Brest, France
Université de Bretagne Occidentale, Brest, France
Laboratoire de Physique des Océans, Brest, France
Marine and Coastal Management, University of Cape Town, South Africa
Ministry of Fisheries and Marine Resources (MFMR), Namibia
Benguela Current Large Marine Ecosystem (BCLME), Namibia
Benguela Environment and Fisheries Interaction and Training Programme (BENEFIT), Namibia
Instituto del Mar del Perú (IMARPE), University of San Marcos, Peru
University of Concepcion, Chile
Instituto de Fomento Pesquero (IFOP), Chile
Instituto de Investigación Pesquera (INPESCA), Chile
Pontificia Universidad Catolica de Valparaiso (PUCV), Chile
Institut National de Recherche Halieutique (INRH), Morocco
Laboratoire de Physique de l’Atmosphère (LPA), Senegal
Upwelling Systems Projects

1. IRD Project: Upwelling Ecosystems

Contact:
Pierre Fréon IRD, CRHMT, Sète (pierre.freon@ird.fr)

Project Description:
A study of the structure and functioning of exploited upwelling ecosystems: comparative analyses within the framework of an ecosystem approach to fisheries

Duration:
2005-2008 (a follow up to the IDYLE project)

Tropical areas

Source of Information:
Olivier Maury (maury@ird.fr)

System Types Studied
Tropical regions Indian Ocean, Atlantic Ocean, Pacific Ocean

Target Organisms:
Tuna

Physical Processes Examined
Frontal systems
Tropical instability waves

Key Questions, Hypotheses and Issues
Coupling between the environmental variability and spatial stock dynamics
Fish trophodynamics
Exploitation strategies

Participating Institutions:
IRD
IFREMER
Universities
CNRS

Tropical Areas Projects

1. IRD THETIS: Tropical ecosystems; environment, exploitation, and interactions.
Contact: Olivier MAURY (maury@ird.fr)

2. IRD Ecosystem dynamics linked with tropical instability waves
Contact: Menkes Christophe (menkes@lodyc.jussieu.fr)

3. PNEC: Modelling habitat and spatial dynamics of bluefin tuna population
Contact: Jean-Marc Fromentin (Jean.Marc.Fromentin@ifremer.fr)
COUNTRY: GERMANY

GLOBEC Germany activities also contribute to the Small Pelagics and Climate Change (SPACC) Regional Programme, see page 176.

Project Title:
Trophic Interactions between Zooplankton and Fish under the Influence of Physical Processes

Source of information:
Jürgen Alheit, October 2003

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Project Goal:
Clarification of trophodynamic interactions between zooplankton and planktivorous fish in relation to reproductive success under the impact of physical forcing.

Project Description:
The project aims for a better understanding of the interactions between zooplankton and fish under the influence of physical processes in order to elucidate the principal mechanisms accounting for the high variability of copepod production and of reproductive success of fish. The results will form the basis for strategic modelling of the recruitment success of fish. Over the last several decades, herring and sprat, but also numerous copepod populations, in the Baltic and in the North Sea have experienced high fluctuations in recruitment and biomass. Whereas a substantial decrease of individual weight of herrings and sprats at high biomass was documented in the Baltic Sea, a similar relationship was not observed in the North Sea. It is assumed that this phenomenon is caused by food (mainly copepods) limitation in the Baltic Sea. However, it is not clear whether this is due to direct effects of trophic interactions (internal dynamics) in the rather simple Baltic food web or whether the decrease of some copepod populations is a reaction to physical processes (external forcing). An interdisciplinary team of fisheries biologists, planktologists, physiologists, geneticists, physical oceanographers and modellers are required to investigate these hypotheses.

The influence of physical processes on zooplankton and on the spawn of two planktivorous fish species with different life histories, herring and sprat, and on their trophodynamic interactions will be studied in the Baltic and the North Sea, two ecosystems with very different oceanographic characteristics. This will be done using a combination of field studies, experimental investigations and modelling. The two seas under investigation exhibit a gradient from marine to almost fresh water conditions. Top-down and bottom-up processes will be studied comparatively in both ecosystems. As the Baltic Sea has a considerably lower number of species, the importance of food web complexity for ecosystem functioning can be studied in a comparative manner between the two systems. The same suite of species will be investigated in both areas: the planktivorous clupeids, herring and sprat, and their main food basis, the copepods *Pseudocalanus* spp., *Acartia* spp. and *Temora longicornis*. The focus will be on an intra-seasonal and regional comparison of the reactions of egg and larval cohorts of herring and sprat produced at different periods over the entire spawning season with respect to their continually changing physical and biological environments.

A tight coupling between field research and modelling is required to enhance our understanding of the two ecosystems. We expect that an improved understanding of the mechanisms governing population fluctuations at short time scales will finally give us insight into the causal relationships of major population fluctuations and ecosystem changes on the decadal scale.

Website:
http://www.globec-germany.de/
Subprojects:

1. Spatial and temporal distribution, growth and mortality rates of fish spawn under the influence of physical processes (Dietrich Schnack, Kiel)

2. Predation pressure of fish on zooplankton and fish larvae and zooplankton abundance (Axel Temming, Hamburg)

3. Influence of meso-scale physical structures and processes on population dynamics of copepods, micro-zooplankton and trophodynamic relationships between fish larvae and their prey (Jürgen Alheit, Warnemünde)

4. Copepod population dynamics (Hans-Jürgen Hirche, Bremerhaven)

5. Interactions between phytoplankton and zooplankton dynamics under the influence of hydrographic conditions (Justus van Beusekom, Sylt)

6. Food preferences, food quality and condition of target species of zoo- and ichthyoplankton (Wilhelm Hagen, Bremen)

7. Coupled modelling of trophodynamics and advection (Dietrich Schnack, Kiel)

8. Modelling of the Baltic Sea ecosystem with particular emphasis on zooplankton (Wolfgang Fennel, Warnemünde)

9. Regional ecosystem model of the lower trophic levels of the North Sea including population dynamics of zooplankton and fish larvae (Andreas Moll, Hamburg)

10. Modelling drift and development of fish larvae based on active tracers and of the 3D current field of the southern North Sea (Thomas Pohlmann and Günther Radach, Hamburg)

11. Data organisation of German GLOBEC Project (Stefan Zabanski, Hamburg)

System Type Studied:
Shelf seas (Baltic Sea and North Sea)

Target Organisms:
Fish (sprat, herring)
Copepods (*Pseudocalanus* spp., *Acartia* spp., *Temora longicornis*)

Physical Processes Examined:
Shelf sea processes

Co-ordinator:
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Participating Institutions:
Alfred-Wegener-Institute for Polar and Marine Research, Bremerhaven and Sylt
Baltic Sea Research Institute, Warnemünde
Federal Research Institute for Fisheries, Hamburg and Rostock
Institute for Hydrobiology and Fisheries Science, Hamburg University
Marine Science Institute, Hamburg University
Marine Science Institute, Kiel University
Marine Zoology Department, Bremen University
Number of Scientists: 
80

Duration: 
3 years (1st phase)

Budget: 
10 Million EURO

Funding Agency: 
Federal Ministry for Education and Research and participating institutions

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**German Southern Ocean GLOBEC Participation**

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The German Southern Ocean Programme is described in the Regional Programmes Section under Southern Ocean GLOBEC
COUNTRY: ITALY

Project Title:
SINAPSI (Seasonal Interannual and Decadal Variability of the Atmosphere, Oceans and Marine Ecosystems)

Source of information:
Dr. Nadia Pinardi, June 2000, updated by Dr. Marco Zavatarelli, December 2003

National Representative/ Contact:
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40127 Bologna  
Italy

Project Description:
The project contributes to the analysis of the observed climate variability both at the global and regional scales and to the development of global and regional numerical models of the atmosphere, ocean and marine ecosystems. The project aims to stimulate the development and the utilisation of state-of-the-art numerical models of the global atmosphere and ocean for the scientific, academic and operational Italian communities. It concentrates on the global atmosphere-ocean interactions and in particular on the Mediterranean Sea ecosystem dynamics. The Mediterranean is now recognized as a “climatic laboratory” where important interactions between atmosphere, hydrosphere and biosphere occur at high intensity and they can be used as indicators of more general fluctuations and trends. The proposed research is based upon both existing observational data sets and modelling work and the collection of new observations and development of new models in order to be able to better understand and predict the climate fluctuations at seasonal, interannual and decadal time scales.

The main goals will be achieved through a number of more specific objectives, namely:

1. The understanding and simulation of the seasonal to interannual variability of the atmospheric and coupled ocean-atmosphere systems, through coupled ocean-atmosphere numerical simulations, model developments, diagnostic and theoretical studies. In particular the climate anomalies over the European sector and the Mediterranean area will be investigated;

2. The investigation of the seasonal, interannual and decadal variability of the Mediterranean Sea ecosystem structure through the collection of new observations in key areas of climatic response, the study of existing observational time series, the modelling of the interactions between the atmosphere and the ocean and the numerical modelling of the general circulation variability;

3. The study of the seasonal and interannual variability of primary productivity in the Mediterranean together with the study of benthic, pelagic organism and fish stocks fluctuations through the analysis of existing observational long time series and the modelling of the response of biota to geophysical forcing variability;

4. The study of the paleoclimatic records in the terrestrial and marine ecosystems in order to detect the seasonal/interannual and decadal changes in past climatic regimes and intercompare the conceptual models of the recent and past climate variability.

Website
http://sinapsi.cineca.it/

System Type Studied:
Coastal and open ocean ecosystems in the Mediterranean Sea

Target Organisms:
Zoobenthic and phytoplankton communities, small pelagic fishes (sardines and anchovies)
Physical Processes Examined:
Large scale upwelling and primary production
Coastal versus open ocean ecosystem dynamics

Key Questions, Hypotheses and Issues:
- To increase our capability to predict climate fluctuations in the atmosphere, ocean and marine ecosysytems at the relevant time scales;
- To define key climatic biogeochemical and physical parameters and key marine areas for monitoring the Mediterranean basin fluctuations in terms of ecosystem response at the seasonal, interannual and decadal time scales.

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80121 Napoli, Italy

Participating Institutions:
Agenzia Regionale Prevenzione e Ambiente dell’Emilia Romagna (ARPA-SMR).
Centro di Ricerca Interdipartimentale delle Scienze del Mare (CRISM)
Consorzio Interuniversitario CINECA
Consorzio Nazionale Interuniversitario per le Scienze del Mare (CONISMA)
Laboratorio di Biologia Marina (LBM-TS)
Dipartimento di Biologia, Universita’ di Padova (BIOL-PD)
Dipartimento di Biologia ed Economia Agro-Industriale, Universita’ di Udine (BIOL-UD)
Dipartimento di Scienze dell’Uomo e dell’Ambiente, Universita’ di Pisa (DAU-UNIP)
Dipartimento di Biologia Animale e dell’Uomo, Universita’ di Roma “La Sapienza” (DBA-ROMA)
Dipartimento di Fisica, Universita’ degli Studi di Roma “La Sapienza” (DIFIS-ROMA)
Dipartimento di Scienze Ambientali, Universita’ di Venezia (DSA-UNIVE)
Dipartimento di Scienze Botaniche, Universita’ di Padova (DSB-UNIPA)
Dipartimento di Scienze della Terra e Geologico-Ambientali, Universita’ di Bologna (DSTGA)
Ente per Nuove tecnologie l’Energia e l’Ambiente (ENEA)
Istituto delle Scienze dell’Atmosfera e dell’Oceano (ISAO-CNR), Bologna
Istituto di Biofisica (IB-CNR), Pisa
Istituto di Biologia del Mare (IBM-CNR), Venezia
Istituto Centrale per la Ricerca scientifica e tecnologia applicata al Mare (ICRAM)
Istituto Nazionale di Geofisica (ING)
Istituto di Fisica dell’Atmosfera (IFA-CNR)
Istituto di Geologia Marina (IGM-CNR)
International Marine Center (IMC)
Istituto per lo studio dell’Oceanografia Fisica (IOF-CNR)
Istituto di Ricerche sulla Pesca Marittima (IRPEM-CNR)
Istituto Sperimentale Talassografico (IST-CNR)
Istituto Sperimentale Talassografico “A. Cerruti” (ITA-CNR)
Istituto Talassografico di Trieste (ITT-CNR)
Istituto Universitario Navale di Napoli (IUN)
Orto botanico, Sez. del dipartimento di Biologia Animale, Universita’ di Modena (IB-MO)
Osservatorio Geofisico Sperimentale (OGS)
Stazione Zoologica Anton Dohrn (SZN)
Universita’ Ca’ Foscari di Venezia, Dip. di Scienze Ambientali
Universita’ degli studi di : Tor Vergata, Ancona, Firenze, Genova, Lecce, Milano, Trieste.

Number of scientists and fte:
70
Duration:
3 years

Budget:
Lit. 3,500,000,000 (approved in 1998 and started in 2000)

Funding Agency:
Ministero dell'Universita' e della Ricerca Scientifica e Tecnologica (MURST)
**COUNTRY: JAPAN**

**Project Title:**
Japan GLOBEC

**Source of information:**
Dr Yasunori Sakurai and Japan GLOBEC website, May 2004

**National Representative/ Contact:**
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Website:
http://j-globec.fish.hokudai.ac.jp/MainGate-e.htm

**System Type Studied:**
Kuroshio, Oyashio and their transition region, the Sea of Japan, the East China Sea, Western North Pacific

**Target Organisms:**
Pacific saury, Pacific sardine, Pacific anchovy, walleye pollock, horse mackerel, mackerels, Japanese common squid, salmons, phytoplankton, zooplankton, micronekton

**Physical Processes Examined:**
Climatic regime shifts
Variation in ocean currents and winter monsoon
Stratification, winter mixing and upwelling
Cross frontal exchange/coastal retention
Effect of frontal eddies and warm streamers

**Key Questions, Hypotheses and Issues:**
- How physical forces are linked with the marine ecosystem dynamics in the western North Pacific and the adjacent waters at regional and basin scales.
- How changes in ocean climate will alter the productivity of keystone species in the sub-tropic and sub-arctic seas, including walleye pollock, salmon and pelagic migratory fishes and squids.
- To develop acoustic, sampling and observation systems to assess and forecast stock fluctuations.
- Changes in physical and anthropogenic forcing mechanisms influence the relative importance of top down vs. bottom up control of energy flow in the Kuroshio/Oyashio ecosystem.
- How do large, regional and local-scale atmospheric patterns cascade into spatio-temporal changes in the ocean physics that are important for ecosystem dynamics in the Kuroshio, Oyashio and their transition region?
- What are the mechanisms that link physical forcing to biological processes and their spatial and temporal scales of interaction?
- To what extent do biological processes regulate the structure, energy flow, and dynamics of the food webs in the Kuroshio/Oyashio ecosystem.
- What are the societal and economic impacts of climate variability on the Kuroshio/Oyashio marine ecosystems and the feedbacks from changes in ecosystem use on these impacts?
Participating Institutions:
Hokkaido National Fisheries Research Institute
Hokkaido Tokai University
Hokkaido University
Japan Marine Science and Technology Center
Japan Sea National Fisheries Research Institute
Kyoto University
Nagasaki University
National Research Institute of Far Seas Fisheries
National Research Institute of Fisheries Science
National Fisheries University
Ocean Research Institute of Tokyo University
Seikai National Fisheries Research Institute
Tohoku National Fisheries Research Institute
Tokai University
Tokyo University of Marine Science and Technology
Tohoku University

Duration:
Phase 2: 2004-2009
**COUNTRY: KOREA**

**Source of Information:**
Prof. Im Sang Oh, May 2004

**National Representative/ Contact:**
Prof. Im Sang Oh  
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School of Earth and Environmental Science  
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Gwanak-gu  
Seoul 151-742  
Korea

**Participating Institutions:**
Korea Ocean Research & Development Institute (KORDI), Ansan  
National Fisheries Research & Development Institute (NFRDI), Busan  
Pukyong National University (PKNU), Busan  
Seoul National University, Seoul

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**Research Project I: A study on the climate regime shift and fisheries resources in Korean waters**

**Chief Scientist (Research Project I):**
Prof. Chang-Ik Zhang  
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Department of Marine Production and Management  
Pukyong National University  
Nam-gu, Busan 608-737  
Korea

**Project Description:**
The major objectives are to:
- examine the effects of the variations of the marine ecosystem caused by climate change on fisheries resources in Korean waters;
- suggest the research direction for identifying variations in fisheries resources.

**System type studied:**
Korean waters

**Methodology used:**
Retrospective analysis with currently existing data sets including fisheries, oceanography and meteorology.

**Participating Institutions:**
Pukyong National University  
Korea Ocean Research and Development Institute  
Meteorological Research Institute (MRI)

**Number of scientists and fte:** 3

**Duration:** Two years (1997-1999)

**Budget:** US$ 40,000/yr

**Funding Agency:**
Korea Science & Engineering Foundation, Korea
Research Project II: Relationship and dynamics between climate change and fishery resources in the East Sea of Korea

Chief Scientist:
Prof. Suam Kim  suamkim@pknu.ac.kr
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Korea

Project Description:
The major objectives are to:
• conduct retrospective analysis on climate, oceanographic, biological, and fisheries data sets in the East Sea,
• provide the basis for the “Science and Implementation Plan” of Korea GLOBEC.
The major purposes and findings are to:
• describe variations in time-series production of fisheries resources,
• conduct researches on the shifts of habitat distribution of major pelagic species by climate changes, and structure of the East Sea ecosystem,
• figure out the relationship between fishery products and environmental effect,
• develop the basis for an ecosystem-based fisheries resource management procedure.

System Types Studied:
East Sea

Target Organisms:
Yield and distribution of macro-algae, plankton, and fish resources

Physical Processes Examined:
Seawater temperature (surface, 50m and 200m), precipitation, wind, PDO

Participating Institutions:
Pukyong National University

Number of Scientists: 19
Duration: 2 years (2001 – 2003)
Budget: US$ 50,000/yr
Funding Agency:
Ministry of Maritime Affairs and Fisheries, Korea

Research Project III: Climate effects on marine ecosystem and fisheries resources

Chief Scientist:
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Korea
**Project Description:**
The purposes of this project are to:
- find an abnormal phenomenon due to climate change,
- describe variations in time-series production of fisheries resources,
- identify the organisms’ response to the temperature increase,
- understand cause-effect relationship between environmental changes and responses of cold water fish species (walleye pollock, chum salmon, and macro-algae).

**System Types Studied:**
East Sea and Kuroshio system

**Key Questions, Hypotheses and Issues:**
Spatial, temporal, and vertical seawater temperatures
Stable isotopes in pollock otolith, trace elements in salmon otolith
Algal production and disease in relation to climate change

**Participating Institutions:**
Pukyong National University
East Sea Fisheries Research Institute, NFRDI

**Number of Scientists:** 19

**Duration:** 1 yr (2002 – 2003)

**Budget:** US$ 70,000/yr

**Funding Agency:**
Ministry of Maritime Affairs & Fisheries, Korea

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**Research Project IV: Study on fluctuation and prediction of fisheries resources**

**Chief Scientist:**
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**Project Description:**
The purposes of this project are to:
- describe variations in time-series production of chub mackerel resources,
- provide basic information concerning distribution, migration, and abundance of Pacific saury in relation to climate/ocean change,
- forecast chub mackerel catch with response to the changes in climate/marine environments,
- examine fluctuation tendency for recruitment and biomass of chub mackerel.

**System Types Studied:**
Northwestern Pacific from Taiwan to the East Sea

**Physical Processes Examined:**
SST, location of polar front

**Target Organisms:**
Catch, distribution, recruitment, biomass of fish species
Participating Institutions:
Pukyong National University

Number of Scientists: 10


Budget: US$ 30,000/yr

Funding Agency:
National Fisheries Research & Development Institute
Ministry of Maritime Affairs & Fisheries, Korea

Research Project V: Long term change of the biogeochemical cycling and biological processes in the East China Sea: Observation and Prediction

Chief Scientists:
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Project Description:
The final purposes are to:
• detect changes both in the oceanic environment and lower-level ecosystem due to long-term climate change in the East China Sea (ECS), and to clarify their changing mechanisms,
• enhance the understanding capability for the physical and biogeochemical processes in the ECS,
• develop the prediction model for ecosystem change,
• predict the impact of future climate change on the physical and chemical environment and ecosystem in the ECS.

System Types Studied:
East China Sea and Yellow Sea: shelf area

Physical Process Examined:
Mixing of the Chinese Coastal Water and the Kuroshio

Key Questions, Hypotheses and Issues:
• Mixing processes of the Chinese Coastal Water (CCW) and the Kuroshio in the ECS continental shelf area.
• Dynamical influence of monsoonal wind on the distribution of the fresh CCW.
• Influence of ocean environmental change on the ocean carbon cycle and biogeochemical cycling of organic/non-organic nutrients, and understanding its controlling mechanisms in the ECS.
• Understanding of lower-level ecosystem structure and its interaction with ocean environmental changes.
• Primary production and energy transfer process through lower-level food-web in the study area.
• Questions on the process how the long-term ocean environmental change influences on the fluctuation of squid resources and its distribution.
• Recruitment processes of common squid in Korean waters.
Participating Institutions:
Korea Ocean Research and Development Institute
Pukyong National University

Number of Scientists: 18
Duration: 2003 - 2006 (first stage of the project)
Budget: US$ 345,000; first year (August 2003 – May 2004)
Funding Agency:
Ministry of Science and Technology, Korea

Research Project VI: Impact of climate changes on oceanographic conditions and fisheries resource

Chief Scientists:
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Project Description:
The purposes are to:
• monitor the long-term variability in oceanographic conditions and its impact on the marine ecosystem,
• find out the relationship between fisheries resources distribution and oceanographic conditions,
• analyse marine ecosystems in Korean waters and predict the migration and distribution of fisheries resources,
• suggest the oceanographic implications for strategic fisheries planning.

System Types Studied:
Korean waters

Physical Processes Examined:
CTD cast, dissolved oxygen, nutrients, suspended solids, chlorophyll-a, optic properties, zooplankton biomass, pCO2, fisheries assessment in target area, common squid distribution

Participating Institutions:
National Fisheries Research and Development Institute
Pukyong National University

Number of Scientists: 40
Duration: 15 yrs (2003 – 2017)
Budget: US$ 160,000/yr
Funding Agency:
National Fisheries Research and Development Institute, Korea
COUNTRY: MEXICO

Project Title:
IMECOCAL (Investigaciones Mexicanas de la Corriente de California)

Source of Information:
Dr. Tim Baumgartner and Oc. Daniel Loyasa, March 2004

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Project Description:
A program of ocean monitoring in the southern region of the California Current—off Baja California, MEXICO—has been underway since autumn, 1997. It is modelled after the CalCOFI program (California Cooperative Oceanic Fisheries Investigation, see Note) covering the region off southern and central California to the north. Establishing a program of regular observations for the Mexican sector provides the extended coverage needed to match the scales of scientific sampling and analysis to the natural scales of variability in the California Current. It will also provide information relevant to understanding the behaviour of transboundary pelagic resources inhabiting both the waters off Mexico and the United States. This program is known as Investigaciones Mexicanas de la Corriente de California (IMECOCAL).

The long-term goal of IMECOCAL is to improve our capability to predict the response of the pelagic ecosystem to regional and global climate change, as well as to the combined effects of harvesting practices by Mexico and the United States.

The IMECOCAL program has been conducting ocean monitoring cruises every three months since October, 1997. The IMECOCAL observations are scheduled in collaboration with the CalCOFI program. The IMECOCAL survey design is based on the original CalCOFI Basic Station Plan. The cruises cover a subset of the original CalCOFI grid, with stations spaced 20 nautical miles apart extending a maximum distance of 220 nautical miles offshore on the two long central lines and roughly 120 nautical miles on the other lines. The distance between lines is 40 nautical miles.

The core sampling activities of IMECOCAL cruises include routine CTD casts to 1000m depth. There are also sensors to measure dissolved oxygen and fluorescence profiles to complement the CTD data. Water samples are taken from the surface to 200m at standard depths, using 5 litre Niskin bottles mounted on the CTD sampling rosette system. The water is used to analyse the concentrations of dissolved oxygen, inorganic nutrients and chlorophyll. At each station, standard oblique bongo tows are made to capture macrozooplankton, including the ichthyoplankton (fish eggs and larvae). Vertical CalVET tows are also made at each station for quantitative collection of fish eggs through a depth of 70m. Casts for in situ measurements of primary productivity, as well as measurements profiling photosynthetic radiation are carried out daily at the mid-day stations. Continuous underway sampling of surface temperature and salinity, as well as continuous ADCP profiling for mapping the currents in the upper 200 metres is done. A CUFES system (Continuous Underway Fish Egg Sampler) was installed on the R/V Francisco de Ulloa and has been operational since January, 2000.

In addition to the monitoring cruises, IMECOCAL maintains sea level pressure gauges at Guadalupe Island, about 280km offshore at 29°N, and at a coastal location at San Quintin (about 31°N). The location of Guadalupe Island provides a unique opportunity to continuously measure the mean flow of the California Current, in a way not available at any other place along the West Coast of North America. These paired instruments permit us to monitor the sea surface pressure gradient between the island and the coastal stations to provide a measure of the mean flow in the upper ocean associated with the California Current. They have been operating since January 1999 and we would like to maintain them for at least ten years to provide continuous measurements from which to develop a long-term climatology of the flow across the main axis of the California Current in this region.
The IMECOCAL research program also includes the retrospective analyses of available paleoecological records from near coastal sites off southern Baja California. These provide a regional historical context of interdecadal to centennial variability as seen of the past 500 to 1500 years to compare to records collected off southern California.

Website:
http://imecocal.cicese.mx/

System Type Studied:
Southern region of the California Current—off Baja California, Mexico

Target Organisms:
Zooplankton, ichthyoplankton and pelagic fish

Key Questions, Hypotheses and Issues:
- What is the response of the pelagic ecosystem to regional and global climate change, as well as to the combined effects of harvesting practices by Mexico and the United States and can this response be predicted?
- What are the characteristics of the spawning habitats of small pelagic species of fish populations? How can we enhance our understanding of space-time changes in distributions, abundances and production of the small pelagic fish populations in relation to environmental variability?
- How can collaboration between IMECOCAL and CalCOFI in the employment of the CUFES system increase understanding of the response of the transboundary population of the Pacific sardine to climate change and address the combined effects of harvesting by México and the U.S.

 Participating Institutions:
There are five Mexican academic institutions participating in IMECOCAL:
CICESE (Centro de Investigación Científica y de Educación Superior de Ensenada)
UABC (Universidad Autónoma de Baja California, in Ensenada)
CICIMAR (Centro Interdisciplinario de Ciencias Marinas, in La Paz)
UNAM (Universidad Nacional Autónoma de México, in México City)
CIBNOR (Centro de Investigaciones Biológicas del Noroeste, in La Paz).
The government agency participating is:
INP/SEGARPA (Department of Agriculture, Livestock, Rural Development, Fisheries and Nutrition).

Number of scientists and fte: 40 scientists
Duration: 1998 onwards
Funding Agency:
CONACYT (Consejo Nacional de Ciencia y Tecnología)
IAI (Inter-American Institute for Global Change Research)

Note:
The CalCOFI program began in 1951 with extensive monthly, and then quarterly cruises which covered the region from northern California to the tip of the Baja California peninsula. With the few exceptions (lines greater than 500 nautical miles) the original CalCOFI station pattern extends roughly from 300 to 350 nautical miles offshore. Between the early 1970s and the early 1980s the timing and coverage of the surveys became somewhat sporadic creating large gaps in the data series due to changing strategies and goals. Integration and analysis of the accumulated data plus the very large El Niño of 1982-83 finally brought on the realization that significant ecosystem changes over interannual time scales could not be sampled without systematic yearly cruises. Consequently, the present design of the CalCOFI surveys consists of quarterly cruises (normally in January, April, July and October) covering the region from the U.S.-Mexican border north to just above Point Conception. This strategy maintains a sampling frequency able to capture the temporal variability critical to describing
biophysical response down to interannual-scale climate forcing but compromises knowledge of spatial variability over the system by severely reducing the active area of the sampling grid.

Awareness of the importance of multi-decadal variability has been steadily increasing since the 1980s, accompanied by the realization that not only temporal changes in abundance and productivity are important, but that there are significant latitudinal shifts in the ranges of ecologically and commercially important species. Recognizing the complexity of space-time variability over decadal and longer time scales made it increasingly clear that the reduced CalCOFI sampling design does not adequately describe the fundamental changes in physical and biological structure in which significant spatial variability is embedded within the temporal variability. The IMECOCAL program was initiated to improve our understanding of the overall response of the pelagic ecosystem of the California Current to regional and basin-scale climate change by extending the latitudinal scope of sampling. It also has the practical purpose of tracking ecosystem changes that impact the abundance and productivity of small pelagic fish species off Baja California that are important resources for México.
The Netherlands contribution to GLOBEC ended in 2002, for details of past projects see Report of the GLOBEC National, Multinational and Regional Programme Activities, 2001. GLOBEC Special Contribution No.4, p.41-44.
COUNTRY: NORWAY

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Norway

Project title:
ECOBE – Effects of North Atlantic Climate Variability on the Barents Sea Ecosystem

Source of Information:
Dr Geir Ottersen, August 2003

Project Manager:
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Project Goal:
Understand and quantify the impacts of Arctic climate variability on trophic transfer and ecosystem structure of the Barents Sea in order to improve the prediction of growth and recruitment on key fish species.

Project Description:
The project addresses how Arctic climate variability and change influence biomass production and trophic transfer in Barents sea ecosystem. The population of copepods in the Norwegian Sea, particularly Calanus finmarchicus, plays a key role in the transformation of biomass from lower to higher trophic levels in the Arctic. The advection of copepod-rich water from the Norwegian Sea into the Barents Sea is hypothesized to be of great importance to the Barents Sea biomass production. The first emphasis will be on analyses of a large variety of time series from hydrography, currents, zooplankton, to 0-group fish, in addition to paleo data on water mass properties. The second emphasis will be on development of a model system that integrates and quantifies the effects of climate variability on biomass production and trophic transfer from copepods to fish recruitment. The model results will be evaluated against time series on abundance and distribution of 0-group fish. The project is an interdisciplinary approach with 7 partner institutions.

Website:
http://ecobe.imr.no/

System Types Studied:
Northern Norwegian Shelf
Barents Sea

Target Organisms:
Gadus morhua (cod)
Mallotus villosus (capelin)
Clupea harengus (Norwegian spring-spawning herring)
Melanogrammus aeglefinus (haddock)
Calanus finmarchicus
**Physical Processes Examined:**
Ocean climate fluctuations: sea temperature; wind mixing; turbulence; vertical stability; light conditions; advection of water masses

**Key Questions, Hypotheses and Issues:**
- Explore the linkages between large-scale weather patterns, such as the NAO, and the regional and local climate, and investigate how such patterns cascade into spatio-temporal changes in the ocean climate parameters that are of importance for biomass production.
- Explore the effects of ocean climate and circulation on the production and advection of *Calanus finmarchicus* onto the northern Norwegian Shelf and the Barents Sea.
- Develop an integrated model system based on first-principles physics and biology to simulate distribution, transport, growth and survival of fish larvae from the spawning areas in spring to 0-group distribution in autumn when year-class strengths are largely determined.
- Develop egg production models for the key fish species, with special focus on Arcto-Norwegian cod, Arcto-Norwegian haddock and Norwegian spring-spawning herring, based on the combined effects of food abundance and temperature on gonad production and maturation.
- Develop a trophodynamic model system that integrates the models described above to simulate growth and recruitment of Barents Sea fish stocks.

**Participating Institutions:**
Aalesund University College  
Geophysical Institute, University of Bergen  
Institute of Fisheries and Marine Biology, University of Bergen  
Institute of Marine Research, Bergen  
Nansen Environmental and Remote Sensing Centre, Bergen  
Physical Institute, University of Oslo  
Bjerknes Centre for Climate Research

**Duration:**
2003-2006

**Budget:**
50,030,000 NOK

**Funding Agency:**
Research Council of Norway

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**Project title:**
CLIMAR – Climate and Production of Marine Resources

**Source of Information:**
Dr Geir Ottersen, August 2003

**Project Manager:**
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**Project Description:**
From a stock size of >12MT in the mid-20th century, the Norwegian spring spawning herring was driven almost to extinction in the early 1970’s, with significant social, economic and ecological consequences. The stock began to recover in the 1990’s, but with radically different seasonal
migration patterns from those prior to the collapse. There is provisional evidence for a link between the stock collapse and an abrupt change in North Atlantic climate that occurred in the mid-1960's. This project will analyse available long term time series of herring growth and abundance in relation to climate, hydrography and biological production at lower trophic levels. The project will seek a process orientated oceanographic and ecological justification for the statistical relationship between herring and climate, and develop state-of-the-art mathematical models to aid prediction of the consequences of climate changes in the future.

The project will comprise three interlinked tasks, split into smaller sub-tasks:

1. Historical data analysis
   i) assemble the oceanographic and plankton data from surveys in the 1960's – 1990's which have not been fully analysed,
   ii) assemble data from the 1930's to the 1990's on herring individual weight,
   iii) conduct statistical time series analyses of the hydrographic, plankton and fisheries data to identify trends, and covariance between climatic factors, plankton and the characteristics of the herring stock.

2. Targeted process studies
   i) obtain large scale data on interannual variability in Calanus production, herring migration and feeding in relation to water mass distribution and circulation,
   ii) explore the relationship between migration and feeding of herring and the temporal and spatial characteristics of Calanus production,
   iii) relate interannual variability in Calanus production and herring feeding to climate.

3. Development of ecological models
   i) simulate the 3-dimensional ocean circulation, temperature, salinity, and primary production of the Nordic Sea using an existing hydrodynamic model, for contrasting climate phases in the second half of the 20th century, and for possible future climate scenarios,
   ii) analyse the numerical results to gain insight and to quantify the differences in the marine climate (circulation, temperature, salinity, primary production) between the simulated periods of contrasting climate phases and for future climate scenarios,
   iii) develop a 3-dimensional population dynamics model of Calanus, driven by output from the circulation model, to simulate patterns of production and abundance under the contrasting climate phases,
   iv) develop an individual based model of herring feeding and migration for coupling to the Calanus population model, to simulate the fluctuations in condition and migration patterns of herring in the Nordic Seas under contrasting phases of climate,
   v) evaluate the performance of the models by comparison with historical data, and conduct prognoses of the likely state of the Calanus-herring ecosystem under possible future climate scenarios.

System Types Studied:
Ecosystem of the Nordic Seas (Norwegian, Icelandic and Greenland Seas)

Target Organisms:
Clupea harengus (Norwegian spring-spawning herring)
Calanus spp.

Physical Processes Examined:
Climate variability
Ocean circulation
Key Questions, Hypotheses and Issues:

- Establish the processes which constitute the coupling between climate fluctuations and the growth and migration patterns of the Norwegian spring spawning herring in the Nordic Seas.
- Develop models of the oceanography, plankton food web, and fish growth and migration that will allow a quantitative analysis of the climatic factors involved, and prognoses of the consequences of future climate scenarios.

Number of scientists and fte:
6

Participating Institutions:
Institute of Marine Research
University of Bergen
University of Oslo

Duration:
2003 – 2006

Budget:
14,305,000 NOK

Funding Agency:
The Research Council of Norway

Project title:
ADAPT – Adaptation to the Ecosystem: Co-evolution of Life Histories and *Calanus* and Herring in the Norwegian Sea

Source of Information:
Dr Geir Ottersen, August 2003

Project Manager:
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Project Description:
At present, there exists a conceptual model of the effects of the physical and seasonal environment in the Norwegian Sea on the feeding behaviour, vertical and horizontal migrations, growth and life cycle of *Calanus finmarchicus* and herring, and also of the effects of these two populations upon each other. ADAPT aims at exploring this model in detail, and to move from a conceptual to a numerical model of the adaptation of these two populations to the environment and each other. ADAPT will also challenge the conceptual model by analysis of field data for the hydrography-phytoplankton-*Calanus* and the *Calanus*-herring interactions. The quality of the numerical model will be studied by comparison with the field data. An adaptive model of several trophic levels in a large-scale ecosystem has not been attempted before. A numerical simulations model of hydrodynamics, phytoplankton, zooplankton and fish will be valuable for later studies of the impact on environmental variation and change.

System Types Studied:
Norwegian Sea ecosystem
**Target Organisms:**
*Calanus finmarchicus*
*Clupea harengus* (Norwegian Spring-Spawning herring)

**Key Questions, Hypotheses and Issues:**
ADAPT aims at quantifying the effects of the physical environment and the other biological populations for the evolutionary adaptation of the populations of *Calanus finmarchicus* and Norwegian spring spawning herring in the Norwegian Sea. The project consists of two parts, which through field work and modelling, respectively, both will address these two sub-goals:

- Demonstrate the effects of the seasonality and physical environment on the life histories and spatial behaviour of *C. finmarchicus* and herring
- Quantify the effect of the other adaptive population on the behaviour and life history of the same two populations.

**Number of scientists and fte:**
6

**Participating Institutions:**
- Institute of Marine Research, Bergen
- University of Bergen
- University of Oslo

**Duration:**
2003-2006

**Funding Agency:**
The Research Council of Norway
Project Title:
Dynamics of the Peruvian Upwelling Ecosystem

Source of Information:
Instituto del Mar del Perú (IMARPE), August 2004

National Representative/ Contact:
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Project Description:
The importance of the Peruvian upwelling ecosystem, subjected to strong environmental variability (as El Niño and La Niña events, interdecadal changes, etc.), and large fluctuations of its main populations allows us to propose a large national project. The duration of the project will be several years, consisting of detailed monitoring of the abiotic environment, planktonic and benthic communities, pelagic and demersal populations.

In some upwelling systems, anchovy and sardine populations have been alternating mutually as dominant species in different periods of time. Kawasaki (1983) proposed the synchrony in fluctuations of three sardine populations in the Pacific Basin, and by 1988, during a Workshop in La Paz, Baja California, Mexico, synchronous changes in abundance of pelagic resources were described as manifestations of “regime shifts” which had global manifestations in the fishery (Lluch-Belda, et al, 1989).

Similarly, these changes have also been observed in the Peruvian upwelling ecosystem. Until the early 1970’s, the Peruvian industrial fishery was dominated by anchovy (Engraulis ringens) which represented, in times of maximum abundance, close to 98% of catches in Peru and more than 15% of the world catches. In the following two decades an alternation took place in the domain. Although sardine catches did not reach the same level as anchovy catches, it took place an increase of sardine stock levels during the mid 1970s and 1980s. Inversely during the 1990’s an increase of anchovy stock levels was observed. This situation was accentuated at the beginning of the 2000 decade, indicating to us that the stock balance of “anchovy-sardine” in the Peruvian sea is currently in the similar to the 1960’s. It is an interesting scientific phenomenon, and one of maximum importance for the Peruvian industrial fishery (Csirke et al, 1994). Recently, Ayón, et al. (2004) have shown long term fluctuation of zooplankton volumes off Peru from 1960 – 2001, in a quasi similar trend of the anchovy fluctuation.

For understanding the causes and mechanisms of these fluctuations, we consider that not only the pelagic resources but also the ecosystem interactions should be investigated within a national GLOBEC program. This program will allow us to understand those processes with the purpose of a better management of the ecosystem in the future.

This study is only possible because of the IMARPE´s capacity to monitor the main environmental and biological variables through an intensive sampling program along the year, in parallel to fisheries monitoring. In fact, this is the approach of its annual working plan.

System Types Studied:
The study area is the Peruvian sea between 03º23´ - 18º20´S and 72 - 84ºW, including the surface and subsurface circulation and the continental margin. This area presents very particular features, partly originated by the complex system of surface and subsurface currents. The whole system responds to coastal upwelling which is forced by the southeasterly trade winds. The usual moderate wind stress coupled with low-latitude location, aperiodic El Niño events, among other processes, may explain the very high productivity of the ecosystem, enabling the existence of great stocks of small
pelagic species. At the same time, local high production of organic matter and large-scale circulation result on the existence of a shallow well-developed oxygen minimum zone whose temporal variability and influence on the living cycles of pelagic and marine resources has not been studied enough. In turn, high organic sedimentation rates, bottom water oxygen deficiency and low terrigenous dilution have enabled the preservation of high-resolution sedimentary records of the past variability of the ecosystem, probably through the last 2000 years.

**Target Organisms:**
The program will focus on the following biological groups:

- Pelagic fauna (Anchovy *Engraulis ringens*, sardine *Sardinops sagax*, jack mackerel *Trachurus murphyi*, Pacific mackerel *Scomber japonicus*, longnose anchovy *Anchoa nasus* and giant squid *Dosidicus gigas*).
- Demersal fishes: hake (*Merluccius gayi peruanus*) and gurnard (*Prionotus stephanophrys*).
- Large predators: Sea lion (*Otaria flavescens*), fur seal (*Arctocephalus australis*), cormorants (*Phalacrocorax bougainvilli*), gannets (*Sula variegata*) and pelicans (*pelecanus thagus*).
- Zooplankton and phytoplankton communities
- Benthic communities

**Physical Processes Examined:**

- The main currents off Peru come from subtropical, tropical, equatorial and sub-antarctic regions. The Peruvian current is divided into a coastal and oceanic component.
- Coastal upwelling, the essential mechanism of the high biological production which is particularly intense in the 4°-5°S, 7°-8°S, 11°-12°S and 14°-15°S regions.
- Presence of two events of opposite features: “El Niño” and “La Niña” that happen alternately, with different intensity and duration (ENSO).
- Propagation of Kelvin and Rossby waves.
- Dynamics of the Peruvian undercurrent and link with the Cromwell undercurrent.

**Key Questions, Hypotheses and Issues:**

- How does coastal upwelling interact with the ENSO equatorial dynamics, e.g. weakening or reinforcing the development of El Niño conditions off the Peruvian coast?
- What is the meso - and macroscale spatial and temporal variability of the circulation off the Peruvian coast?
- How does remote forcing (equatorial or Antarctic) influence the subsurface dynamics, specifically the oxygen minimum zone?
- How do environmental fluctuations modulate inter-annual changes of pelagic biomass (anchovy, sardine, jack mackerel, and Pacific mackerel) and what is the role of the La Niña and El Niño events on them?
- What are the direct and indirect effects of the physical environment on the reproductive success (encompassing fecundity success, spawning success and larval survival) and other biological parameters of the main pelagic species?
- How do large predators (seabirds and marine mammals) respond to their environment and food availability, mainly anchovy?
- Can we quantify the trophodynamics of the Peruvian upwelling ecosystem?
- Can we use remote sensing techniques to direct or/predict fishing effort?
- What is the role of the Peruvian undercurrent on the dispersion and recruitment success of the benthodemersal populations?
- How do the dynamics of the oxygen minimum zone constrain the living cycles and population dynamics of pelagic and benthic-demersal communities?
- Is there evidence of regime shifts in the Peruvian Upwelling Ecosystem in the past and how can they be characterized using an ecosystem approach?
Participating Institutions:
Instituto del Mar del Perú (IMARPE)

Number of Scientists:
36

Duration:
This will be an ongoing project.

Funding Agency:
Peruvian Government
International Cooperation

Budget:
US $5,000,000 per year
**COUNTRY:** PORTUGAL

**Project Title:**
Portugal GLOBEC

**Project Contact and Source of Information (November 2003):**
Dr. A. Miguel P. Santos    amsantos@ipimar.pt
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**National Representative:**
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Campo Grande
1749-016 Lisboa
Portugal

1. **ProRecruit - Shelf processes controlling recruitment to littoral populations in an eastern oceanic boundary: using barnacles and crabs as models.**

**Project Description:**
To describe the temporal variability of recruitment of coastal invertebrate species (crabs and barnacles) having a planktonic larval phase in their life cycle, and to understand the interactions of physical forcing and larval biology that control the supply of larvae to coastal systems, with a special focus on process studies off northern Portugal.

**System Types Studied:**
North-eastern Atlantic upwelling

**Target Organisms:**
Crabs, barnacles and other crustaceans

**Physical Processes Examined:**
Upwelling, downwelling, dispersion, retention, transport

**Key Hypotheses and Issues:**
The Western Iberia coast is affected by seasonal upwelling. The increase and relaxation of northerly, upwelling favourable winds result in alternation of: equatorward/offshore flow and poleward/onshore flow, respectively. These effects change with depth and with the intensity and duration of the wind events.

This project will examine the following hypotheses:

- During upwelling events, larvae are transported southward and offshore.
- During relaxation of upwelling favourable winds or during southerly winds, larvae are transported northward and onshore.
- Supply of larvae to systems on the western Portuguese coast occurs mainly during relaxation of upwelling.
- Interaction between vertical distribution of the larvae and physical forcing affects onshore patterns of recruitment.
Chief Scientist:
Henrique Queiroga      hqueiroga@bio.ua.pt
Departamento de Biologia
Universidade de Aveiro
Campus Universitário de Santiago
3810-193 Aveiro
Portugal

Participating Institutions:
University of Aveiro
INIAP-IPIMAR
University of Lisbon
University of Évora

Duration:
36 months (Started: October 2001)

Number of scientists and fte:
21

Budget:
224,459 Euros

Funding Agency:
Portuguese Foundation for Science and Technology (FCT)

2. PELAGICOS - Reinforcing the capacity of investigation in the area of oceanography and fishery biology applied to the management of pelagic marine resources

Source of Information:
Xabier Irigoien, January 2003

Contact details:
Yorgos Stratoudakis
Avenida de Brasilia s/n,
1449-006
Lisboa
Portugal
E-mail: yorgos@ipimar.pt
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Fax: +351 21 3015948

Project Description:
This programme involves applied research in areas of interest to fisheries science and the fishing sector of small pelagic fish in Portugal. The aims of this programme are to develop and synthesize research from distinct viewpoints (fisheries biology, oceanography and climatology, population dynamics and stocks management, fisheries technology and sociology), in order to improve the scientific knowledge and the advice provided for the management (nationally and internationally) of pelagic resources.

A primary objective of this programme is the establishment of a direct channel of communication between scientists and resources users. This exchange of information and experience can open new perspectives in research, alert users to problems related to the state of resources and the associated research, and allow them to participate in the formulation of possible answers. To achieve this goal one representative from the purse seine fishing sector forms part of the research team, acting as a link between scientists and fishermen.

Website:
http://ipimar-iniap.ipimar.pt/pelagicos/index.html
System Types Studied:
Portuguese Coastal Waters

Target Organisms:
Small pelagic fish, e.g. Sardine (*Sardina pilchardus*) and Horse mackerel (*Trachurus trachurus*)

Physical Processes Examined:
Upwelling, buoyant plumes, poleward flows

Key Questions, Hypotheses and Issues:
- Understand the interactions among pelagic fish populations, environmental conditions and human harvesting,
- Evaluation of the state of pelagic fish resources and the level of their exploitation using current and alternative methodologies,
- Predict the future state of pelagic fish resources (short, medium and long term) and exploring management option scenarios with the associated implications for resources and their users.

Chief Scientist:
Yorgos Stratoudakis yorgos@ipimar.pt
INIAP-IPIMAR
Av. Brasilia s/n
1449-006 Lisboa
Portugal

Participating Institutions:
INIAP-IPIMAR
University Nova of Lisbon, Department of Sociology
FENACOOPESCAS (Purse-Seine Association)
University of Évora, Department of Mathematics
University of Algarve, Department of Marine Sciences
University of Aveiro

Duration:
48 months (Started: June 2001)

Budget:
499,000 Euro

Funding Agency:
Portuguese Foundation for Science and Technology
Country: Spain

Project Title:
GLOBEC Spain

Source of Information:
Celia Marrase, December 2003

National Representative/Contact:
Dr Fidel Echevarría
Universidad de Cádiz
Departamento de Biología
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Spanish GLOBEC Projects:
Details of all Spanish GLOBEC projects are included below, even where they are already completed as
details were not published in the previous edition of the GLOBEC Activities Report.

1. Development of a numerical model for predicting the dispersion of eggs and larvae
stages of fishing species of commercial interest in the Biscay Bay.

Source of Information:
Fundación AZTI

National Representative/Contact:
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Project Description:
The objective of this model is to develop a 3D transport model for the Bay of Biscay to simulate the
dispersion of eggs and larval stages of commercial fish species. The model will take into account the
combined effects of wind, tide, and freshwater runoff on the physical transport of the eggs and
larvae. The spatial and temporal evolution of the sea water temperature, salinity and chlorophyll are
variables which will be used for the biological part of the model, i.e. the growth and mortality of the
fish in its early stages of life.

Website:
http://www.azti.es

System Types Studied:
Oceanography and fishing resources

Target Organisms:
Bay of Biscay commercial fish species, particularly the anchovy
Physical Processes Examined:
Currents originated by the wind, tide and freshwater runoff to study the dispersion (advection-diffusion) of fish eggs and larvae. Historical records of sea water temperature, salinity and chlorophyll.

Key Questions, Hypotheses and Issues:
The biological behaviour of the each fishing species is the most important question to answer. The principal assumption is to consider a passive physical behaviour for the eggs and larvae stages because their possible swimming ability is minimum and unknown.

Number of scientists and fte: 60
Participating Institutions: Fundación AZTI
Duration: From 01/01/02 until 31/12/04
Budget: 30,000 Euros
Funding Agency: Departamento de Agricultura y Pesca del Gobierno Vasco

2. Mesopelagic (ref. Cicyt MAR97-1036)

Source of Information:
Universidad de Las Palmas de Gran Canaria

National Representative/ Contact:
Santiago Hernández-León (shernandez@dbio.ulpgc.es)

Project Description:
The project studied the effect of the physical structure of the water column and of the interzonal diel vertical migrants on the structure of the communities of the pelagic system of the subtropical gyre, from microplankton to micronekton. Such a study was carried out in the physical gradient which is observed from the upwelling area off West Africa to the well stratified waters west of the Canary Islands. The study of the deep scattering layer and on their associated diel vertical migrants was of special interest because they increase the amount of predators in the surface layers by night. This fact produced a top-down effect which structured the pelagic system in different ways depending on the mesopelagic biomass and faunistic composition observed in areas of different stratification. The effect of the different community structures on the so-called biological pump and on the active flux was also assessed. The project reached the following objectives: (1) Historical data review, (2) The development of a model to simulate the diel vertical migrations, (3) The study the vertical structure of biomass, size and faunistic composition of plankton and micronekton, and (4) The effect of biomass and community structure on the active flux.

Website:
http://www.ulpgc.es/webs/cbm

System Types Studied:
Oceanic

Target Organisms:
Zooplankton, diel vertical migrants

Physical Processes Examined:
Water column stratification

Key Questions, Hypotheses and Issues:
The importance of diel vertical migration in structuring the pelagic realm and in driving the active flux.

Number of scientists and fte: 15
Participating Institutions:
Facultad de Ciencias del Mar de la Universidad de Las Palmas de Gran Canaria
Instituto Canario de Ciencias Marinas
Facultad de Ciencias Biológicas de la Universidad de La Laguna
Museo de Ciencias Naturales de Tenerife
Instituto Español de Oceanografía

Duration: 1997-2000
Budget: EUR 124,271
Funding Agency: Comisión Interministerial de Ciencia y Tecnología, Spain


Source of Information:
Universidad de Las Palmas de Gran Canaria

National Representative/ Contact:
Santiago Hernández-León (shernandez@dbio.ulpgc.es)

Project Description:
Small and mid-sized fish are the link between the climatic conditions of the ocean and tuna fisheries, an important resource in the economy of the Canary Islands. The great variability in the stock of the small and mid-sized pelagic fish is one of the most common features of these resources. It is known that there is a close relationship between recruitment, stock size, climatic conditions, water mass dynamics and plankton productivity and there is an exhaustive knowledge of the hydrology around Gran Canaria Island. The flow of the Canary Current induces the formation of a wake of cyclonic and anticyclonic eddies and the phyto-, zoo- and ichthyoplankton distribution have been shown to be related to these structures. However, the small and mid-sized fish distribution and its relationship with the dynamics of the water masses around this oceanic island is, at present, poorly known. Water mass dynamics as well as plankton distribution must be of importance in the presence and distribution of those fishes around oceanic islands. This is the primary hypothesis of this proposal. In this sense, it seems clear that the knowledge of fish biomass as well as the factors governing its variation and distribution is crucial for the fisheries management of the Canary Islands. Therefore, this proposal is based on the objectives: (1) Historical data review, (2) Knowledge of fish biomass and distribution using acoustic methods and experimental trawls, (3) The relationship of phyto-, zoo- (including the deep scattering layer), and ichthyoplankton with the hydrology around the island, and (4) To assess the fish biomass and distribution during the three characteristic periods of the annual cycle in this archipelago: the late winter bloom, the Trade Wind and non-Trade Wind seasons.

Website:
http://www.ulpgc.es/webs/cbm

System Types Studied:
Island shelf, Oceanic

Target Organisms:
larval fish
zooplankton
diel vertical migrants

Physical Processes Examined:
Filaments of upwelling
Key Questions, Hypotheses and Issues:
The effect of filaments of upwelling on the transport of fish larvae from Northwest Africa to the Canary Islands.

Number of scientists and fte: 15

Participating Institutions:
Facultad de Ciencias del Mar de la Universidad de Las Palmas de Gran Canaria
Instituto Canario de Ciencias Marinas
Facultad de Ciencias Biológicas de la Universidad de La Laguna
Museo de Ciencias Naturales de Tenerife
Instituto Español de Oceanografía

Duration: 1998-2001

Budget: EUR 173,016

Funding Agency:
European Union (Feder)
Comisión Interministerial de Ciencia y Tecnología, Spain

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4. Mesoscale vortices/meanders in the central portion of the Bransfield Strait: identification and physical–biological coupling. (BREDDIES)

Source of Information:
Universidad de Las Palmas de Gran Canaria

National Representative/ Contact:
Pablo Sangrà psangra@dfis.ulpgc.es
Universidad de Las Palmas de Gran Canaria
Edificio de Ciencias Básicas
Campus de Tafira
35017 Las Palmas de Gran Canaria
Spain

Project Description:
Historical observations suggest the presence of mesoscale vortices/meanders in the central portion of the Bransfield Strait. The general objective of this project is their identification and the study of the coupling between the underlying physical processes and the plankton community. With this aim an interdisciplinary sampling was conducted in the region, with a greater spatial resolution and a degree of interdisciplinary interaction than previously seen. Through these observations we aim at gaining a better physical and biological characterization of these structures as well as understanding the adjustment mechanisms between the physical processes (water column stability, diapycnal mixing, advection) and the planktonic community (abundance and structure). Additionally we will develop a physical-biological model that allows us to understand and diagnose the nature of such coupling. In this way the results of this project could contribute to the identification of mesoscale structures not previously described and to a better understanding of the adjustment between the planktonic community and the physical environment in the marine antarctic system at the mesoscale range.

System Types Studied:
Central part of the Bransfield Strait

Target Organisms:
Bacteria, phytoplankton and zooplankton

Physical Processes Examined:
Fronts, eddies, vertical stability, diapycnal mixing
Key Questions, Hypotheses and Issues:
Mesoscale activity influence planktonic community distribution/structure through water column stability, diapycnal mixing and advectives processes.

Participating Institutions:
Universidad de Las Palmas de Gran Canaria
Instituto de Ciencias Marinas de Andalucía (CSIC)
Universidad de Vigo

Duration: 3 years
Budget: EUR 145,144
Funding Agency:
Ministerio de Ciencia y Tecnologia (Spain)
FEDER (UE)

5. Estudio de series temporales de datos oceanográficos (RADIALES) / Oceanographic time-series studies

Source of Information:
Instituto Español de Oceanografía
Universidad de Oviedo

National Representative/ Contact:
J. Luis Valdés Santurio (luis.valdes@gi.ieo.es)

Project Description:
The objective of the project is to "Understand and parameterise the response of the ecosystem to the different sources of temporal variability, both regarding the oceanographic processes and the planktonic populations, and with particular focus on the factors and processes that affect biological production and can have an impact on the ecosystems". The project is based on a systematic and prolonged sampling making interdisciplinary (physical, chemical, biological) observations in the ocean. The frequency of sampling is set to depict the oceanographic events occurring at different seasonal and interannual scales in order to distinguish between the different sources of temporal variability and to characterize the main patterns.

As part of the in situ sampling programme, regular observations are performed on a monthly basis along transects located offshore Santander (sampled since 1991), and on a seasonal basis along transects located off Málaga (since 1992) and Murcia (1996). In the La Coruña ria, the benthic community has also been sampled on a seasonal basis since 1982. At each location sampling is carried out following similar methodologies and the results are stored in the data base of the IEO (SIRENO) from where data is available to all the researchers in the programme.

Website:
http://www.seriestemporales.net

System Types Studied:
Shelf seas

Target Organisms:
Plankton

Physical Processes Examined:
Mesoscale processes (i.e. upwelling events, fronts, etc)

Number of scientists and fte: 15 scientists
**Participating Institutions:**
Instituto Español de Oceanografía
Universidad de Oviedo.

**Duration:** 1991- present (IEO Core Strategic Project)

**Budget:** EUR 100,000/year

**Funding Agency:**
Instituto Español de Oceanografía
Various funds from CICYT, Fundación Marcelino Botín y Fundación Pro-Vigo proposals.

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6. **Variabilidad temporal de las comunidades planctónicas en el Cantábrico central (VARIPLACA) / Temporal variability of the planktonic community in the central Cantabrian Sea.**

**Source of Information:**
Instituto Español de Oceanografía.

**National Representative/ Contact:**
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**Project Description:**
The objective of VARIPLACA is to study the trophic structure of the planktonic community in the central Cantabrian Sea and how the temporal variability is related to the different oceanographic processes occurring in a temperate sea such as the Cantabrian Sea. This study of the trophic structure is based on the hypothesis that physical forcing determines the size structure of planktonic producers and the circulation of organic matter through the classical (herbivorous) and microbial food webs. In order to achieve this objective the distribution of different size classes of primary producers (picoplankton, nanoplankton and microplankton) will be analysed and their physiological state will be estimated (through flow cytometry and cell sorting). The size structure of the zooplankton community will also be studied as well as the trophic preferences of the main zooplankton constituents through the analysis of the stable nitrogen isotope ratios ($^{14}$N/$^{15}$N) in order to determine the adaptive strategies to the oceanographic conditions characteristic of temperate seas (stratification periods, fronts, upwelling events, oligotrophic phases, etc.). The project also involves sardine larvae growth studies and the relationship of growth to food availability (sardine was selected as the target species due to the existing knowledge on the otolith methodology and on the fact that there is sufficient amount of information in other regions to use for comparative purposes). The project takes advantage of the logistical resources available through the RADIALES project; it is based on monthly sampling of a transect off Gijón and intensive sampling periods during the spawning period of the sardine. Data will be included in the oceanographic database of the IEO.

**Website:**
http://www.seriestemporales.net

**System Types Studied:**
Shelf Seas  
Central Cantabrian Sea (Bay of Biscay)  
Transect from the Asturian coast to shelf break
Target Organisms:
Plankton

Physical Processes Examined:
Mesoscale processes (i.e. upwelling events, fronts, etc)

Number of scientists and fte: 6 scientists, 5 technicians

Participating Institutions:
Instituto Español de Oceanografía.

Duration: 2002 – 2004

Budget: EUR 100000 / 3 years

Funding Agency:
Instituto Español de Oceanografía, Plan Nacional 2000-2003

7. Análisis de series temporales, biología y ecología del zooplankton / Time-series analysis, zooplankton biology and ecology.

Source of Information:
Instituto Español de Oceanografía.

National Representative/ Contact:
J. Luis Valdés Santurio (luis.valdes@gi.ieo.es)

Project Description:
The main objective of the project is to study the seasonal and interannual variability of zooplankton abundance in the Cantabrian Sea and Bay of Biscay. The changes in abundance, diversity and size structure observed by long term monitoring studies will be analysed at different spatial and temporal scales to develop models that describe and predict the main patterns in the seasonal succession of the planktonic community. The specific objectives of the project are:

• Parameterise the ecological realized niche of several target zooplankton species using empirical statistical models and combine them with geographical information systems to predict the habitat distribution of each species.

• Validate and improve current theoretical models which attempt to explain the effect of temperature and body size on the development time and metabolism of different groups of zooplankton. Make use of the models developed to predict the succession and the changes in community size structure observed by the RADIALES project and use them as a baseline to detect anomalous conditions.

• Analyse the seasonal and long-term trends of zooplankton abundance using a comparative approach where the data collected by the RADIALES programme will be analysed in combination with data from monitoring programs maintained by other European and US institutions in the North Atlantic.

Website:
http://www.seriestemporales.net

System Types Studied:
Shelf seas

Target Organisms:
Plankton

Physical Processes Examined:
Mesoscale processes (i.e. upwelling events, fronts, etc)
**Number of scientists and fte:** 4 scientists

**Participating Institutions:**
Instituto Español de Oceanografía.

**Duration:** 3 years

**Budget:** EUR 27100/ year

**Funding Agency:**
Plan de Investigación Desarrollo Tecnológico e Innovación de Asturias 2001-2004
Instituto Español de Oceanografía

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8. **Role of Microphagous Zooplankton in Marine Microbial Communities: Trophic Impact and Carbon Transfer (ZOOTRANSFER) REN 2001-1693**

**Source of Information:**
Institut de Ciències del Mar (CSIC)

**National Representative/ Contact:**
Dr. Enric Saiz (enric@icm.csic.es)

**Project Description:**
Marine stratified waters are often characterized by high abundance of two groups of mesozooplankton, cladocerans and small copepods. Little is known, however, on the functional roles of these groups and their importance in biogeochemical fluxes. Here, by combining field studies and laboratory work, we will attempt to determine the trophic impact of these groups of zooplankton on the different components of microbial food webs, and quantify the carbon fluxes mediated by them. Furthermore, other aspects of the ecology and ecophysiology of these organisms, like trophic niche overlapping, threshold and critical food concentrations for growth, and the effects of small-scale turbulence in their ingestion rates, will be studied.

**Website:**
http://www.icm.csic.es/bio/projects/zootransfer

**System Types Studied:**
Mediterranean coastal waters

**Target Organisms:**

**Physical Processes Examined:**
Small-scale turbulence

**Number of scientists and fte:** 5

**Participating Institutions:**
Institut de Ciències del Mar (CSIC)

**Duration:** 28/12/2001 to 27/12/2004

**Funding Agency:**
Spanish Ministerio de Ciencia y Tecnología
9. Effects of polluting hydrocarbons on marine zooplanktonic communities (PETROZOO)
VEM2003-20037

Source of Information:
Institut de Ciències del Mar (CSIC)

National Representative/ Contact:
Dr. Albert Calbet (acalbet@icm.csic.es)

Project Description:
The catastrophe of the Prestige has revealed our lack of knowledge concerning the consequences of crude oil spills on the dynamics and functioning of marine planktonic food webs, specifically zooplankton, which constitute the most important food source for fish. The goal of this project is to study the ecological consequences associated with fuel discharges on the zooplanktonic community, and to identify related responses including energy transfer through the marine planktonic food web. This will be done by using functional toxicity bioassays and experimental mesocosms developed in the laboratory with autochthonous organisms. More specifically it is intended to identify ecological risks of polycyclic aromatic hydrocarbons (PAHs) associated with fuel-oil spills.

System Types Studied:
Mediterranean coastal waters

Target Organisms:
Oithona spp., Acartia spp.

Key Questions, Hypotheses and Issues:
• To determine the effects of polycyclic aromatic hydrocarbons (PAH), present in oil slicks, on the local species of marine planktonic copepods.
• To study the transfer of contaminants (PAH) through the marine planktonic food web.
• To evaluate the changes in structure and function in the natural planktonic communities produced by hydrocarbon contaminants.

Number of scientists and fte: 3

Participating Institutions:
Institut de Ciències del Mar (CSIC),
Universitat Politècnica de Catalunya

Duration: November 2003 to November 2006

Budget: 88000 Euro

Funding Agency:
Spanish Ministerio de Ciencia y Tecnología

10. Estuarine and coastal quality network of the Basque Country

Source of Information:
AZTI

National Representative/ Contact:
Angel Borja (aborja@pas.azti.es)

Project Description:
The study and surveillance of the different biological elements contained in the Water Framework Directive, relating its evolution with the physico-chemical and pollution elements of the system, including water, sediment and biota analysis.
System Types Studied:
Estuaries and coastal waters (up to 40m water depth)

Target Organisms:
phytoplankton, macroalgae, soft-bottom benthos and fishes

Key Questions, Hypotheses and Issues:
Development of methodologies in establishing the ecological status.

Number of scientists and fte: 12

Participating Institutions:
AZTI
Insub
University of the Basque Country
Labein

Duration: 1994 to date

Budget: EUR 412000 /year

Funding Agency:
Departamento de Ordenación del Territorio y Medio Ambiente, Gobierno Vasco.

11. Efecto de los procesos hidrograficos sobre la distribución y la alimentación de las larvas de Sardina pilchardus y sus consecuencias sobre el crecimiento, en la costa asturiana (SARDINA)

Source of Information:
Universidad de Oviedo

National Representative/ Contact:
Ricardo Anadón (ranadon@correo.uniovi.es)

Project Description:
The stock of Iberian sardine has suffered a significant decrease in recent years. The coast of Asturias (Bay of Biscay) is an important spawning area where the fleets from Asturias and Cantabria develop an important fishing activity on this resource. Recruitment, which is closely related to population size, is determined by the dynamics during the early life history of fish. The general objective of this project has been to determine the influence that mesoscale hydrographic processes have on the dynamics of the early life history of the Iberian sardine. Both, the direct effect of these processes on the distribution of eggs and larvae, and through the effect that these processes have on the dynamics of the ecosystem and therefore the availability of food for larval fish. The effect that feeding has on growth will be analysed because of the role that growth has on recruitment variability. A retrospective analysis on abundance of sardine eggs and larvae of the Cantabrian Sea, combined with satellite imagery data, would allow to link the role of mesoscale processes with larger spatial and temporal hydrographical and climatic processes.

System Types Studied:
Coastal pelagic ecosystem in relation to sardine larvae.

Target Organisms:
Sardina pilchardus

Physical Processes Examined:
Portuguese Coastal Counter Current
Interannual variability
Key Questions, Hypotheses and Issues:

- Spawning areas in relation with hydrographic structure.
- Retrospective analysis on abundance of sardine eggs combined with satellite imaginary data.
- Effects of coastal mesoscale processes on egg and larvae distribution.
- Growth and survival related with ecosystem food web structure.
- Feeding of sardine larvae.

Number of scientists and fte: 8 and 4 doctoral students

Participating Institutions:
Universidad de Oviedo
Instituto Español de Oceanografía

Duration: 30 months

Budget: EUR 220000

Funding Agency: CICYT – FEDER

12. TEMPANO. Temperature effect on structure and metabolism of planktonic communities of Antarctic waters (REN-2001-0588ANT)

Source of Information:
Institut de Ciències del Mar

National Representative/ Contact:
Dr. Dolors Vaqué (dolors@icm.csic.es)

Project Description:
Temperature is considered to be one of the main environmental factors responsible for the control of plankton metabolism. In general, in mid-latitude areas, the metabolic changes on poikilotherms in relation to temperature can be adequately described by means of well known equations (i.e. Arrhenius). However, when temperature conditions are extreme, the effects can be quite different. In Antarctica, for instance, with extreme temperatures and yearly water temperature ranges restricted to less than 5ºC, thermal laws can be different. If the different metabolic processes (i.e. respiration, excretion, feeding, production, etc.) follow different patterns and non-linear functional responses for a similar temperature rise, the consequences in terms of the fate of biogenic carbon can be extremely important. Carbon flow between the different trophic compartments of the system can be altered, as well as the equilibrium between the proportion of sequestered, particulate C, and CO₂ returned to the atmosphere by respiration. This possible change in the role of the Southern Ocean as a source or sink of CO₂ is of paramount importance (greenhouse gas effects), and its consequences for the parameterisation of integrated climatic models is out of question. This project focuses in these problems, and will try to quantify the effects of slight temperature rises in the Antarctic Ocean, similar to the climatic tendencies observed the last decade, for the ocean-atmosphere CO₂ exchange. The objective of the project is to experimentally determine how temperature changes, in a short variability range, can affect the regulation of the different metabolic processes of auto- and heterotrophic communities (phytoplankton, bacteria, protozoa and zooplankton).

System Types Studied:
Antarctic waters (Bransfield strait, Gerlache Strait and Bellingshausen Sea)

Target Organisms:
Prokaryotes, protists, phytoplankton and zooplankton

Physical Processes Examined:
Temperature, irradiance
Key Questions, Hypotheses and Issues:
We hypothesize that an increase of temperature will i) increase bacterial production because, on one hand DOC would be more available for bacteria, on the other hand bacteria would increase the release of ectoenzymes that participate in the organic compounds break-down; ii) will favour changes of bacterial diversity. Thus in areas where the temperature would be the coldest (~2°C), the prokaryotic activity should be dominated by communities of strict psychrophilic microorganisms. Once temperature increases we should observe changes to tolerant psychrophilic communities; iii) the fate that Archaea communities were abundant during the winter season, will suggest that an increase of temperature would provoke a decrease of abundance and activity iv) It will increase bacterivory ingestion rates by protists and their growth; v) It will modify the daily pattern of optic characteristics related with the increase of cell activity, as well as with changes of autotrophic pico-nanoplankton community structure; vi) It will increase the ingestion rate and respiration of copepods. All of that would be converted in an increase of excretion of CO$_2$, which part of it would be used again by phytoplankton, and in the worse of cases the left CO$_2$ would go to the atmosphere and it would contribute to the global warming.

Number of scientists and fte: 21

Participating Institutions:
Institut de Ciències del Mar-CMIMA (CSIC)
Spanish Institut of Oceanography of Xixon and Malaga (IEO)
University of Barcelona (UB)
University of Jaen (UJ)
University of Málaga (UMA)

Duration: 2 years

Budget: EUR 168000

Funding Agency: MCyT

13 Bay of Biscay microzooplankton

Source of Information:
Xabier Irigoien (xirigoien@pas.azti.es)

National Representative/ Contact:
Xabier Irigoien (xirigoien@pas.azti.es)

Project Description:
The objective of the project is to investigate the microzooplankton distribution in the Bay of Biscay during the spring period and to model the distribution through ecological niche factor analysis.

System Types Studied:
Bay of Biscay

Target Organisms:
Microzooplankton

Physical Processes Examined:
River plume and shelf break front.

Key Questions, Hypotheses and Issues:
Bottom up vs top down control of the microzooplankton distribution.
Number of scientists and fte: 2
Participating Institutions: AZTI
Duration: 4 Years
Budget: EUR 36 000 €
Funding Agency: Basque Government

14. Effects of the Prestige Oil spill on the zooplankton and ichthyoplankton

Source of Information:
Xabier Irigoien (xirigoien@pas.azti.es)

National Representative/ Contact:
Xabier Irigoien (xirigoien@pas.azti.es)

Project Description:
The objective of the project is to develop a GAM model of the zooplankton and ichthyoplankton distribution in the Cantabrian Sea to evaluate the impact of the Prestige Oil spill.

System Types Studied:
Cantabrian Sea, Bay of Biscay

Target Organisms:
Mesozooplankton and ichthyoplankton.

Physical Processes Examined:
River plumes, eddies and shelf break front.

Key Questions, Hypotheses and Issues:
Impact of oil spill vs natural variability

Number of scientists and fte: 4
Participating Institutions: AZTI, IEO
Duration: 3 Years
Budget: EUR 80 000 €
Funding Agency: MCYT

15. Biological effects of mixing processes in the Strait of Gibraltar (REN2001-2733-C02-02)

Source of Information:
Universidad de Cádiz (carlos.garcia@uca.es)

National Representative/ Contact:
Carlos M García (carlos.garcia@uca.es)

Project Description:
The project will try to characterize the mixing processes in the Strait of Gibraltar and its effects on biological productivity in both, the channel area and the adjacent areas within Alborán Sea. The project will focus on the variability of internal wave generation processes occurring in Camarinal Sill at a fortnightly scale, as a key mechanism for mixing, either as internal bore release during higher amplitude tides or due to the existence of arrested waves in neap tides or during the transition from
neap to spring phases. These mixing episodes represent a rich deep water intrusion on the eastward flowing surface layers. This fact, together with the shallower position of the Atlantic-Mediterranean Interface (AMI) toward east, enhances the magnitude of phytoplankton blooms in the eastern sector. The study of mixing processes will allow us to detail better the magnitude of the water masses, gases and nutrient exchanges through the AMI. Another aspect to study will be the propagation to the Mediterranean of internal waves and the transport of surface water so enriched and, finally, the resulting biological and chemical patterns in the eastern sector, hypothetically derived from diverse mixing processes produced in the different tidal cycles. As objectives, we will try to understand the mechanism producing the internal undulatory processes and the associated mixing phenomena on the sill, aiming to develop future suitable predictive models. Furthermore, we will try to describe the effects of these mixing processes on nutrients and seston patterns in both the Gibraltar and Western Alboran Sea, identifying sources for space and time variability. The synthesis will include mixing intensity estimations as well as its consequences on production and the typical response patterns that could be related to tidal cycles or to weather or climatic variability in the area.

**Website:**
http://www2.uca.es/grup-invest/ecosist-acuaticos/Oceanogr/Estrecho/Gibraltar_Pr.htm

**System Types Studied:**
Pelagic, coastal, strait

**Target Organisms:**
Plankton (wide sense)

**Physical Processes Examined:**
Mixing induced by tides

**Key Questions, Hypotheses and Issues:**
Tides in the Strait of Gibraltar induce mixing processes and transport of enriched surface waters to the NW Alboran Sea, the project will study variability of mixing events, particularly on a fortnightly scale. The basic hypothesis is that enrichment so generated exists and is higher in spring tides than neap tides.

**Number of scientists and fte:**
2 senior scientists (fulltime), 2 senior scientists (part-time), 1 fellowship researcher

**Participating Institutions:**
University of Cadiz

**Duration:** 3 yr

**Budget:** EUR 94418

**Funding Agency:**
Comision Interministerial de Ciencia y Tecnología (Ministry of Science and Technology, Spain)

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16. **Study of the effects of global change on marine communities in the western Mediterranean. REN 2002-01339**

**Source of Information:**
Institut de Ciències del Mar (CSIC)

**National Representative/ Contact:**
Ana Sabatés (anas@icm.csic.es)
**Project Description:**
The overall objective of the project is to relate the likely climate changes in the western Mediterranean to relevant changes in the composition, distribution and abundance of plankton communities (fish larvae and gelatinous zooplankton), and fish communities. To this end, time series of data (physical and biological) collected by systematic samplings performed in the last 20-25 years will be analysed.

**System Types Studied:**
NW Mediterranean continental shelf

**Target Organisms:**
Fishes, gelatinous zooplankton

**Physical Processes Examined:**
Study of the interannual variability in climatic conditions and physical characteristics of sea water in the Catalan Sea (NW Mediterranean), to determine the magnitude of environmental changes during the last decades.

**Key Questions, Hypotheses and Issues:**
The study aims to ascertain whether the eventually observed changes in the species distribution and biology are indicators of a trend in the long term, consequence of the global change or, on the contrary, they are a response to the interannual variability in the physical characteristics.

**Number of scientists and fte:** 8

**Participating Institutions:**
Institut de Ciències del Mar (CSIC)

**Duration:** November 2002- October 2005

**Budget:** EUR 81,380

**Funding Agency:**
MCYT (Spanish Ministry of Science and Technology)

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**17. Nutrient dynamics mediated through Turbulence And Plankton interactions (NTAP)**

**Source of Information:**
Institut de Ciències del Mar (CSIC)

**National Representative/ Contact:**
Cèlia Marrasé (celia@icm.csic.es)

**Project Description:**
Turbulence effects on plankton can strongly modulate nutrient and organic matter dynamics in coastal areas. However, data at present show that effects may be non-linear, depend on initial environmental conditions, and/or may be specific to certain sizes of organisms or specific taxa. In models of marine systems, turbulence is accounted for as affecting the transport of chemicals and organisms, but rarely as affecting biological processes, since biological effects appear complex and little is known about their dynamics. The overall objective of the project is to provide a unified conceptual framework for nutrient dynamics as modulated by the interaction of turbulence and plankton and to use this information to aid in implementing and modifying legislation on coastal water quality and management. The specific objectives are a) to build a database on turbulence effects by gathering existing scattered data, b) to produce experimental data on key organisms, interactions and mass transfer rates, c) to develop a sensor for laboratory measurement of small-scale turbulence, and d) to produce a dynamical model at community level with exploratory and predictive capabilities. The research strategy for fulfilling the specific objectives as well as building the overall framework consists
of using multi-level approaches and levels of observation. Existing data from both experiments and field observations is analysed to guide the design of new experiments and preliminary modelling efforts. New experimental data on the effects of turbulence on plankton, ranging from organism to net community responses, is produced. A microsensor to measure flow in small containers is developed to overcome current size constraints. Modelling efforts are conducted to incorporate small-scale turbulence effects into a microbial food web model.

Website:
http://www.icm.csic.es/bio/projects/ntap/

System Types Studied:
Coastal communities enclosed in micro and mesocosms

Target Organisms:
Pico-, nano-, microplankton and meso-zooplankton

Physical Processes Examined:
Small scale turbulence

Key Questions, Hypotheses and Issues:
Turbulence influence trophic interactions and nutrient fluxes in marine ecosystems

Number of scientists and fte: 20

Participating Institutions:
Institut de Ciències del Mar (CSIC), Spain
University of Bergen, Norway
Laboratoire d’Oceanographie de Villefranche, France
University of Cambridge, United Kingdom
Marine Biological Laboratory, Denmark
Nortek AS, Norway

Duration: 01/04/2001- 31/03/2004

Budget: EUR 1,494,000

Funding Agency:
European Commission

18. DINAPROFIT- DINÂmica de PROliferaciones de Fi Toplancton de Primavera en el Cantábrico Central (Dynamics of Spring Phytoplankton Blooms in the Central Cantabrian Sea). Project ID#: REN2003-09549-CO3-01

Source of Information:
Spanish Ministry of Science and Technology

National Representative/ Contact:
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Project Description:
Bursts of microphytoplankton (or net phytoplankton), of which the Spring Phytoplankton Bloom (SPB) in mid and high latitudes is the most conspicuous and best known example, represent the main contribution to atmospheric CO₂ sequestration in ocean sediments and to fish production, because large particles sink fast and are readily consumed by large predators. The SPB does not proceed as an isolated, sudden event, but as trains of small blooms, or microsuccessional (MS) events which are a consequence of successive “windows of opportunity”. DINAPROFIT aims at identifying the conditions that determine the initiation, dynamics and fate of MS events during the SPB in the Cantabrian Sea, and to develop tools for their prediction from meteorological and hydrographic data. To this end, DINAPROFIT will follow 3 complementary approaches: 1) Retrospective analysis of satellite imagery, time-series data and stored samples, that will allow the statistical characterisation (initiation, frequency, intensity and species composition) of MS events, their empirical modelling using meteorological and hydrographic variables and the identification of optimal periods for the development of subsequent DINAPROFIT cruises; 2) A meso-scale cruise using automated probes calibrated against manual methods and repeated at very short (3 days) intervals during the month of maximal variability of chlorophyll distributions. The high temporal resolution of this cruise, in combination with the low average residual current velocity in this area should allow close control of horizontal advection and clear resolution of the relative role of different factors on the initiation of MS events and their propagation to upper trophic levels. A further cruise along time series transects at weekly intervals during the following year will give an indication of interannual variability of the observed patterns; 3) Microcosm experiments to determine the role of upper trophic levels in determining the dynamics and fate of the SPB.

Website:
http://www.uniovi.es/dinaprofit

System Types Studied:
Winter, temperate shelf system with circulation patterns dominated by the Portuguese Coastal Counter Current.

Target Organisms:
Phytoplankton, microzooplankton, copepods, appendicularians, fish larvae

Physical Processes Examined:
Portuguese Coastal Counter Current, changes in vertical structure (mixing depth, turbulence), coastal haline stratification

Key Questions, Hypotheses and Issues:
Hypothesis 1: Generation: the Sverdrup mechanism suffices to explain the generation of production pulses (vs. other mechanisms have to be invoked).

Hypothesis 2: Propagation: production pulses can be immediately detected in upper trophic levels (vs. there is a delay).

Hypothesis 3: Control: the species composition of the community of consumers affects the fate and dynamics of production pulses (vs. control of fate and dynamics is bottom-up).

Number of scientists and fte:
14 scientists, 9 EDP (work power units meaning one person, full-time job per EDP)

Participating Institutions:
Universidad de Oviedo
Instituto Español de Oceanografía
**Duration:** 3 years 2004-2007

**Budget:** EUR 110000 (ship costs not included)

**Funding Agency:**
Spanish Ministry of Science and Technology

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**19. Seasonal and interannual zooplankton variability in relation to environmental physicochemical variables in the Balearic Sea (HERCULE and ECOBALEARES).**

**Source of Information:**
Spanish Oceanographic Institute

**National Representative/ Contact:**
Mª Luz Fernández de Puelles Martinez (mluz.fernandez@ba.ieo.es)

**Project Description:**
The main goal of both projects is to describe the pattern and variability of zooplankton in relation to environmental and oceanographic variables to give a better understanding the pelagic system of the Balearic Sea.

**Website:**
http://www.seriestemporales.net

**System Types Studied:**
Pelagic and neritic waters (0-200m)

**Target Organisms:**
Cladocera (*Evadne spinifera*, *E. Tergestina* and *Penilia avirostris*)  
Copepods (*Calanus helgolandicus*, *Centropages typicus*, *Acartia clausi*, *Temora stylifera*, *Diaixis hibernica*, *Ctenocalanus vanus*, etc.)

**Physical Processes Examined:**
Interannual variability in relation to climatic change and some mesoscale processes (fronts and eddies in the area).

**Key Questions, Hypotheses and Issues:**
- To describe the seasonal and interannual dynamics of the main species of zooplankton in the Balearic Sea waters, and to study the main environmental factors involved in the zooplankton variability.
- How are the main species changing in relation to ‘warming’ or ‘cooling’ years?
- Are the zooplankton changes in the area related to local and/or global climate changes?

**Number of scientists and fte:** 2 scientists and 4 technicians

**Participating Institutions:**
Spanish Oceanographic Institute (Baleares Center)

**Duration:** From 1994 to 2004

**Budget: Yearly:** EUR 25000 (Hercule) and EUR 50000 (Radial Balear)

**Funding Agency:**
Spanish Oceanographic Institute
20. Estudio de los recursos pesqueros del Golfo de Cádiz / Study of the Fishery Resources from the Gulf of Cádiz

National Representative/ Contact:
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Project Description:
The project aims at describing temporal and spatial changes in environmental parameters including currents, water quality, pelagic productivity and zooplankton, and their relationship with early life stages, recruitment and fishery dynamics of six species of economic interest in the southern Iberian Peninsula. Physical and biological data are collected from surveys during 26 months (2002-2004) on board Regina-Maris managed by Junta de Andalucía.

Physical data: Monthly survey of hydrology in discrete stations (vertical profiles) and in continuum along the Gulf of Cádiz complemented with data from moorings, meteorological and riverine-discharge data. Study of fluorescence and main nutrient concentrations are also addressed.

Biological data: Monthly surveys of ichthyoplankton are conducted in ca. 30 stations and trawling data is collected from 7 strategic areas. Main biological variables are monthly abundance and distribution of planktonic phases for the target species, total zooplankton abundance, as well as biometry, reproductive status and population dynamics of the six species under study. Community structure is also studied. Current fishery data is complemented with previous monthly (1997-2004) and annual (from the 70's or 80's, depending on the species, to present) data from the main ports of the Gulf of Cádiz.

Anthropogenic factors: are also considered, including fishery dynamics (landings, dredging, etc.). The study has an integrative nature that may enable the establishment of ecosystem-based indicators to predict fishery variability of certain species.

System Types Studied:
Shelf waters (over the continental shelf, from 10m down to 90m depth) with highly riverine-influenced areas. Particular attention is placed onto the planktonic community (fish and crustaceans) and demersal communities of fish and crustaceans.

Target Organisms:
The species under study are four fish and two crustaceans of commercial interest in the Gulf of Cádiz. Fish species studied are anchovy Engraulis encrasicolus, pilchard Sardina pilchardus, meagre Argyrosomus regius and wedge sole Dicoglossa cuneata. Crustaceans are mantis shrimp Squilla mantis and the penaeid shrimp Melicertus kerathurus.

Physical Processes Examined:
Hydrology and hydrodynamics is explored on a monthly basis, as well as its relationship with meteorological forcing or annual variations in environmental indices like the North Atlantic Oscillation.

Key Questions Hypotheses and Issues:
Ecosystem functioning and its variability in the Gulf of Cádiz. Special attention is given to the build-up of a model linking physical forcing, early life stages, recruitment and fisheries of the main species studied. The fishery of the Gulf of Cádiz is particularly important at national level with respect to anchovy. The fluctuations in landings are caused both by fishing pressure (with strong political forcing due to historical dependence of Moroccan fishery grounds) and by environmental fluctuations, which probably act synergistically to determine the final biomass. Therefore, it is a key issue to understand both biology and population dynamics and their links with the environment in order to build future ecosystem-based indicators that help the modelling and prediction of the fishery.
Number of scientists and fte: 11

Participating Institutions:
Consejería de Agricultura y Pesca (Junta de Andalucía)
Instituto de Ciencias Marinas de Andalucía (ICMAN-CSIC)
Instituto Español de Oceanografía (IEO)

Duration: 2002-2005

Budget: EUR 848 042

Funding Agency: Junta de Andalucía


Source of Information:
Universidad de Vigo

National Representative/ Contact:
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Spain

Project Description:
An active scientific debate has been held on the metabolic balance of the oligotrophic ocean during the past years. Briefly, this debate arises from the discrepancy between two statements: respiration exceeds production in the oligotrophic ocean versus the open ocean is in metabolic balance.

The principal objective of CARPOS is to quantify the net metabolic carbon balance of the planktonic communities in the central and marginal regions of the subtropical NE Atlantic by adopting a lagrangian approach. This main aim splits into 4 particular objectives: 1) To verify that the net metabolism of the planktonic communities in the central region of the North Atlantic subtropical gyre is balanced or autotrophic, 2) to build up and compare in situ versus in vitro net metabolic balances for two contrasting oligotrophic environments, 3) To quantify the effect of short-scale physical variability on primary production rates and to infer its potential effect upon the net metabolic balance of the region and 4) to evaluate the effect of methodological limitations associated to in vitro experiments on the metabolic balance of this oceanic region.

These objectives will be accomplished through the development of a working plan organised in 4 modules which includes the completion of two oceanographic cruises. The first of these cruises (CARPOS-I), consists of a lagrangian experiment in the central region of the North Atlantic Subtropical Gyre, where a balanced net metabolism is expected.

The second cruise, CARPOS-II, will be centered on the marginal NE area of the subtropical North Atlantic, where the metabolic balance is known to be net heterotrophic. In this region, a new lagrangian study lasting 20 days will be conducted.

System Types Studied:
Subtropical NE Atlantic

Target Organisms:
Phytoplankton, bacteria, microzooplankton, mesozooplankton

Physical Processes Examined:
Short-scale vertical displacements of the seasonal thermocline
Key Questions, Hypotheses and Issues:

Hypothesis 1: The central region of the subtropical Atlantic gyre is characterized by balanced net community production rates (i.e. primary production equals community respiration)

Hypothesis 2: The lack of consideration of short-scale physical variability associated to internal wave activity leads to significant biases in the estimates of organic matter production and consumption in the region.

Hypothesis 3: The heterotrophic net metabolic balance of the subtropical NE Atlantic is, at least partly, the result of methodological artefacts related to the confinement of microbial populations in experimental bottles

Number of scientists and fte: 23 scientists

Participating Institutions:
Universidad de Vigo
Instituto Español de Oceananografía
Universidad de Oviedo

Duration: 2004-2006

Budget: EUR 330970 (ship costs not included)

Funding Agency: Spanish Ministry of Science and Technology

**Source of Information:**
Fundación AZTI

**National Representative/ Contact:**
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**Project Description:**
The objective of this project is to estimate the daily egg production, the spawning area and the adult parameters of the Bay of Biscay anchovy (*Engraulis encrasicolus, L.*) in 2003. The spawning stock biomass is calculated as the relation between the daily egg production and the daily fecundity of the adult population applying the daily egg production method (DEPM). This estimate is presented to the ICES working group on the assessment of this species.

These results were presented in the ad hoc working group on 'In season assessment of anchovy in the Bay of Biscay' to provide the Commission with scientific background for management.

**Website:**
http://www.azti.es

**System Types Studied:**
Fishing resources

**Target Organisms:**
*Engraulis encrasicolus*

**Physical Processes Examined:**
Physical parameters including: temperature, salinity, chlorophyll, currents, and wind in the study area to analyse the relationship between anchovy and the environment. Water column stratification.

**Number of scientists and fte:** 5

**Participating Institutions:**
AZTI Foundation

**Duration:** From 01/01/03 until 31/12/03

**Budget:** EUR 275,448

**Funding Agency:**
Partly funded by the Spanish National Programme for fishery monitoring and the Department of Agriculture and Fisheries of the Basque Government.
24. Physical and Biological Structures and Biogeochemical Fluxes in the Northwestern Mediterranean (EFLUBIO) (REN2002-04151-C02-01/ MAR)

Source of Information:
Institut de Ciències del Mar

National Representative/ Contact:
Mikel Latasa (latasa@icm.csic.es)

Project Description:
Hydrographic and biological processes play a fundamental role in the distribution and fluxes of the biogeochemical elements in marine ecosystems, with a clear importance for the interests of our society (climate, fisheries, pollution, tourism, etc.). The northwestern Mediterranean is the most productive area of the whole Mediterranean Sea because the intensity and extension of its processes of fertilization. In spite of such an importance, most studies have been restricted to the coastal margins, with a limited geographical extension. Meanwhile, the open sea comprising the area of influence of the Nor-Balearic Front and the two boundary water masses, is basically unknown, especially from a multidisciplinary point of view. Therefore, the goal of this project is to identify, quantify and establish relationships between the physical and chemical conditions, the structures of the planktonic communities and the biogeochemical fluxes in that area. An intensive study is proposed during the bloom period in April, when strong physical and biological contrasts exist north and south of the Nor-Balearic front. A reference study, reduced in time and effort, is proposed during the summer stratification, the most extended situation in time and the one with the strongest contrasts with the April situation.

System Types Studied:
Nor-Balearic Front: open ocean spring bloom

Target Organisms:
Bacteria, phyto and zooplankton

Physical Processes Examined:
Spring stratification, Nor-Balearic front, mesoscale instabilities.

Key Questions, Hypotheses and Issues:
• Which organisms are key players in the spring phytoplankton bloom of the NW Mediterranean?
• Which ones are responsible for the phytoplankton bloom?
• Which ones are associated to different water masses?
• Which ones are associated to the biogeochemical behaviour of the system?
• Which ones are associated to sedimentation of organic matter?

Number of scientists and fte: 5

Participating Institutions:
Institut de Ciències del Mar (CSIC)
Instituto Oceanográfico de Palma de Mallorca

Duration: 2003-2005

Budget: EUR 133000

Funding Agency:
Comisión Interministerial de Ciencia y Tecnología, Spain
COUNTRY: TURKEY

Project:
Black Sea GLOBEC

Source of Information:
Temal Oguz, November 2003

National Representative/ Contact:
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System Types Studied:
Semi enclosed, marginal seas with buoyancy and wind driven circulation dominated by mesoscale dynamics and intense meandering boundary current structure.

Projects:

1. Regulation of the Black Sea ecosystem by decadal-scale climatic variations and anthropogenic forcing

Project Description:
This research is aimed to study the prominent role of climate-induced decadal-scale variability in different trophic levels of the Black Sea ecosystem, and interprets the ecosystem changes as an integrated response of the climatic variability and various anthropogenic and human-induced perturbations. Firstly, all available long-term biogeochemical data are analyzed to determine the robust anthropogenic signal during the 1970s and 1980s. Secondly, climatic fluctuations and their linkages to major hemispherical climatic oscillations (such as the NAO) are identified both in the biogeochemical and hydro-meteorological data.

Website:
http://www.ims.metu.edu.tr/cv/oguz/bs_res.html

System Types Studied:
Black Sea

Target Organisms:
Plankton, pelagic fish

Physical Processes Examined:
Climatic decadal scale oscillations and accompanying local processes in the physical structure of the surface layer

Key Questions, Hypotheses and Issues:
It is hypothesized that the North Atlantic Oscillation (NAO) play a prevailing role on the Black Sea hydro-meteorological structure and controls decadal structure of biogeochemical processes, plankton biomass, pelagic fish stocks.

Number of scientists: 2

Participating Institutions:
Institute of Marine Sciences, Middle East Technical University.
2. Effects of physical and biogeochemical variabilities on the spatial heterogeneity of the zooplankton distribution in the Black Sea

Project Description:
This research aimed to study the physical and biogeochemical processes determining the hydrodynamic impact on the distribution of zooplankton. The study contains both observational and modelling components.

The large scale upper layer circulation over the deep portion of the basin is generally cyclonic with a system of anticyclonic eddies evolving in its periphery. The edge of the cyclonic circulation is dominated by an internal anticyclonic jet: the Rim Current. The Rim Current carries nutrient rich river waters originated from the northwestern region and the biological production is high on this waters. Zooplankton were mainly advected to the region with the Rim Current. The presence of the anticyclonic eddies between the Rim current and the coast was entrapping the zooplankton as well as the other biogeochemical variables.

System Types Studied:
Black Sea coastal and open waters ecosystem dynamics

Target Organisms:
Zooplankton

Physical Processes Examined:
Shelf and open sea processes

Key Questions, Hypotheses and Issues:
The main goal of this study is to understand how physical and biogeochemical processes influence zooplankton abundance and distribution in order to predict the response of the ecosystem.

Number of scientists and fte: 2 + 3

Participating Institutions:
Institute of Marine Sciences, Middle East Technical University

Duration: 2 years

Budget: 40,000 USD

Funding Agency:
Turkish Scientific and Technical Research Council (TUBITAK), NATO

3. Egg production and growth of copepods in NE Mediterranean Sea

Project Description:
This study considers the nutritional environment and its relationship to egg production by copepods in NE Mediterranean Sea. Virtually no information exists about the nutritional quality (protein and lipid concentrations, and carbon: nitrogen ratio) of the seston in NE Mediterranean Sea. Seasonal variations in copepod abundance, egg production and growth rates were determined and they were correlated with food quality and quantity.

System Types Studied:
Coastal and open ocean ecosystems in the Mediterranean Sea
Target Organisms:
Temora stylifera
Acartia clausi

Key Questions, Hypotheses and Issues:
In this study, we intended to enhance our understanding of numerical response of copepods in food availability and quality in an oligotrophic environment.

Number of scientists and fte: 2+1

Participating Institutions:
Institute of Marine Sciences, Middle East Technical University

Duration: 1 year

Budget: 10,000 USD

Funding Agency:
Turkish Scientific and Technical Research Council (TUBITAK)
Middle East Technical University


Project Description:
Monthly acoustical data collected within the past decade were examined to discriminate and identify the layers of densely populated Calanus euxinus and Sagitta setosa in the Black Sea. Acoustical data were collected with the echosounder BioSonics Model 120 at 120kHz and 200kHz and an acoustic Doppler current profiler (ADCP, RD broadband) at 150kHz. This method allows in situ monitoring of the species; estimation of biomass and spatio-temporal distributional patterns.

System Types Studied:
Offshore pelagic, the Black Sea

Target Organisms:
Calanus euxinus
Sagitta setosa

Physical Processes Examined:
Volume backscattering strength
Dissolved oxygen
Basic physical parameters (temperature, salinity, density, current)

Key Questions, Hypotheses and Issues:
Calanus euxinus have distinct patterns of vertical migration and time spent swimming, depending on the DO concentration of the water column. Time spent swimming (T, %) does not depend on water temperature. Under normoxic conditions, T varied widely from 15–20% to 90–95%. When oxygen concentration declines to the values characterizing C. euxinus’ daytime habitat at depth (0.8–1.15mg O₂ l⁻¹), T of all investigated animals increases to 80–100%. The concentration layer of Sagitta setosa can acoustically be identified by observing their diel migrational pattern during different months in the Black Sea. Sagitta setosa shows different temporal patterns depending on their generation time and stage composition. During the cold-water season when their population consists mainly of adult individuals, their daytime concentration layer coexists with that of C. euxinus in the Oxygen Minimum Zone whereas in warm-water season when the immature individuals (juveniles) comprise more 60% of the population, the concentration layer stays in the oxycline. In July and September, individuals of new generation do not migrate during the day and stay in subsurface water. Calanus euxinus starts accelerating upon entering the oxycline while S. setosa accelerates after entering well-oxygenated subsurface water. S. setosa completes its migration within 4 hrs at an average swimming speed. In
contrast to the pattern observed during downward migration, \textit{C. euxinus} lags behind \textit{S. setosa} during upward vertical migration.

This ability would allow in situ monitoring of the species; estimation of biomass and spatio-temporal distributional patterns during the day could then be considered in past and future works.

**Number of scientists and fte:** 1

**Participating Institutions:**
Institute of Marine Sciences, Turkey

**Duration:** 2002-2005

**Funding Agency:**
The Scientific and Technical Research Council of Turkey (TUBITAK)

5. \textit{Mnemiopsis} predatory impact on the pelagic community of the Black Sea.

**Project Description:**
The objective of the proposed research is to assess the food supply and predatory effect of the ctenophore \textit{Mnemiopsis} population on mesozooplankton and fish larvae stocks and to quantify its role in energy transformation within the pelagic community.

The proposed study will promote the identification of the relative contribution of \textit{M. leidyi} predation to the observed decrease in the plankton community biomass.

Results obtained may be used to improve the ecological model of the Black Sea pelagic ecosystem functioning and to gain a better understanding of ctenophore population dynamics for future.

**Target Organisms:**
Zooplankton

**Key Questions, Hypotheses and Issues:**
- Determination of ingestion, respiration and growth rates of \textit{Mnemiopsis} and the effects of food concentration, body weight and temperature on these parameters.
- Study of annual dynamics of abundance, biomass and population structure of \textit{M. leidyi} in the Black Sea.
- Determination of the chemical composition (protein, lipids, carbohydrates, glycogen, mono- and polysaccharides) and evaluation of the ctenophore's condition in the Black Sea.

**Number of scientists and fte:** 10

**Participating Institutions:**
Mayıs University, Faculty of Aquatic Products, Sinop, Turkey,
Institute of Marine Sciences, Middle East Technical University,
Institute of Biology of the Southern Seas, National Academy of Sciences of Ukraine.

**Duration:** 2 years

**Budget:** 25,000 USD

**Funding Agency:** NATO
COUNTRY: UKRAINE

For details of the Ukrainian GLOBEC programme, please see the Report on the GLOBEC National, Multi-national and Regional Programme Activities, GLOBEC Special Contribution No.4, p.51-55, 2001.
**COUNTRY: UNITED KINGDOM**

**Source of Information:**
Phillip Williamson, September 2004 and NERC Marine Productivity website (March 2004)

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**Title of National Programme:**
Marine Productivity: physical controls on ecosystem dynamics (Natural Environment Research Council directed programme)

**Programme Description:**
The overall aim of the Marine Productivity (MarProd) programme is to investigate the population dynamics of marine zooplankton and the way physical factors, such as temperature and water movements, influence those dynamics. This information will be used to develop coupled modelling and observational systems for the pelagic ecosystem that will help address the questions:

- How are basin-scale structures in zooplankton species maintained?
- How do zooplankton species respond to basin-scale forcing? and
- What are the impacts of basin-scale physical changes on secondary production in shelf seas?

Programme-wide science objectives are:

- To identify the dominant spatial and temporal scales of physical parameters and zooplankton population dynamics, by observation, modelling and retrospective analysis.
- To parameterise the critical processes governing zooplankton dynamics by observations and experiments.
- To construct and validate spatially explicit models of zooplankton and their food and predators, capable of resolving short term changes in population structure.
- To provide data for model validation by developing and applying new interdisciplinary techniques to a wide spectrum of biological and physical parameters.
- To develop a database and information system for historic and new data and models.

Marine Productivity activities are guided by a Steering Committee (Chair: Dr Martin Angel) and have been implemented through four major research cruises and more than 30 component projects (as research grants). Most projects are multi-institute, involving up to six research groups; each has its own project-specific science objectives.

**Websites:**
www.nerc.ac.uk/funding/thematics/marprod/ (general programme information)  
www.bodc.ac.uk/projects/marprod (research cruise data, cruise reports)

**Participating Institutions:**
Aberdeen University  
British Antarctic Survey (BAS)  
British Oceanographic Data Centre  
Department of Agriculture & Rural Development, Northern Ireland (DARD)  
Fisheries Research Services, Aberdeen (FRS)  
Heriot-Watt University  
National Museums of Scotland, Edinburgh  
Plymouth Marine Laboratory (PML)  
Proudman Oceanographic Laboratory (POL)
Queen’s University Belfast  
Scottish Association for Marine Science/Dunstaffnage Marine Laboratory (SAMS)  
Sir Alister Hardy Foundation for Ocean Science (SAHFOS)  
Southampton Oceanography Centre/University of Southampton (SOC)  
Stirling University  
University of Exeter  
University of Leeds  
University of Liverpool  
University of St. Andrews  
University of Strathclyde  
University of Wales, Swansea

**Duration:**  
5 yr for main activities, 2000-2005

**Budget:**  
£6.1m

**Funding Agency:**  
Natural Environmental Research Council (NERC)

### Initial MarProd Studies - Focus on Shelf Seas

The laboratory-based Phase 1 of Marine Productivity (2000-2002, £1.5m) involved 57 researchers at 17 institutions. Effort was focussed on the assembly and analysis of relevant historical databases; testing existing biological models in a variety of physical settings; and developing the technology needed to provide new field data for hypothesis testing. Results included:

- New insights into the effects of food quality (nitrogen-poor versus nitrogen-rich foods) on copepod growth rates
- Analyses of the role of microzooplankton in energy flows within shelf seas
- Conversion of historical zooplankton abundance data (from the Continuous Plankton Recorder survey, since 1948) into numbers per cubic metre, confirming the validity of systematic trends and climatic correlations.
- Assembly and publication of a 30 yr time series for zooplankton and associated data in the western English Channel
- Development of zooplankton population models which combine knowledge of spatial distributions with information on developmental stage and physiological status. Additional details on the 15 Phase 1 projects were given in GLOBEC Special Contribution No.4.

### Field-based MarProd Studies - Focus on Open Ocean

The main, field-based phase of the MarProd programme (2001-2005, £4.5m) has been directed at the northern North Atlantic, particularly the Irminger Sea. Emphasis has been on large-scale patterns, dynamics and influences, to test the assumption that climatically-driven physical processes, operating on the regional scale, are the main factors determining the distribution and abundance of marine zooplankton.

A limited number of key species were selected for detailed study of their life cycle dynamics and demography. Most effort was focussed on the copepod *Calanus finmarchicus*, since:

- it is the favoured food for many commercially-important fish;
- it occurs in high numbers over large areas (depth-integrated densities of up to 60,000 per m$^2$, estimated to comprise 70-80% of zooplankton biomass in the northern North Atlantic);
- it has been identified by the UK government as a candidate indicator for climate change
there is a good background of previous work, including EU projects (ICOS and TASC) and national studies (by Canada, Iceland, Norway, USA and others).

Other species given particular attention in Marine Productivity include the euphausiids *Meganyctiphanes norvegica* and *Thysanoessa longicaudata* (predators on *Calanus*); and *Oithona* copepods (potential prey for *Calanus* adults, and/or predators on their eggs). Their biological-physical interactions were investigated by high-resolution measurements and modelling of hydrodynamics in the Irminger Sea and Iceland Basin, together with the application of molecular, genetic and biochemical approaches for taxonomic and population analyses.

Seasonal factors affecting zooplankton survival were studied by fieldwork in early winter (November - December 2001 and 2002), spring (April-May 2002) and summer (July-August 2002). Full analyses of the collected datasets should make it possible to quantify the importance of biological factors (changes in food timing, quality or quantity; changes in predation) and physical factors (changes in overwinter conditions and deep transport; changes in surface advection and on-off shelf transport) on species’ interannual variability and long-term population trends.

Eleven Phase 2 projects received support, involving 72 researchers at 18 institutions (with links to laboratories in Canada, Spain, Iceland, Norway and USA). Summary descriptions of these projects follow:

1. **Recruitment and mortality of *Calanus* eggs and nauplii**
   *Andrew Hirst (BAS Cambridge, aghi@bas.ac.uk), Steve Hay (FRS Aberdeen) and Roger Harris (PML)*

   Mortality in marine copepods can be more important than fecundity and growth in determining spatio-temporal patterns of abundance, biomass and secondary productivity. As the mortality of egg and nauplius is most variable, least understood, and yet by far the greatest, we place most emphasis on these stages. We will measure early mortality and its variability in *Calanus*, assess underlying causes, with the aim of understanding the consequences of changing physical and biological forces in the natural environment. We will perform detailed experimental work in the laboratory, make appropriate measures in the North Atlantic, and work at the L4 station off Plymouth, and Stonehaven off Aberdeen. The study will target fecundity and hatch success as recruitment terms, and the effects of food, starvation, and temperature on early nauplii development, growth and survival/mortality in *C. finmarchicus* and *C. helgolandicus*. Rates of cannibalistic predation and their control will be investigated, as well as determining which predators are most important at the North Atlantic stations.

2. **Data-driven, basin-scale, modelling of the abundance and demography of *Calanus finmarchicus* in the North Atlantic**
   *William Gurney (Univ of Strathclyde, bill@stams.strath.ac.uk), Simon Wood (St Andrews), Michael Heath (FRS Aberdeen); Michael Fasham, Yanli Jia and Kelvin Richards (SOC)*

   This study is designed to elucidate the relationship between oceanic circulation and the abundance of *Calanus finmarchicus* over its whole North Atlantic range. Capitalising and extending on our successful Phase 1 MarProd project, we shall use automatic optimisation to fit a series of process-based demographic models to existing and projected abundance data. Formal statistical methods will be used to evaluate the relative goodness of fit generated by models embodying competing hypotheses, thus allowing us to distinguish between them.

3. **Zooplankton demography and trophic interactions in the sub-arctic North Atlantic, and their coupling to physical oceanography: 40 years on from the NAO minimum**
   *Michael Heath (FRS Aberdeen, heathrmr@marlab.ac.uk); Kelvin Richards, Raymond Pollard, Denise Smythe-Wright & David Hydes (SOC); Colin Moffat & Steve Hay (FRS Aberdeen); Gary Smerdon (PML); Chris Reid (SAHFOS); Andrew Brierley (St Andrews); Peter Boyle (Aberdeen)*

   This project will conduct a campaign of seagoing measurements in the Irminger Sea and adjacent areas to discover the relationships between oceanic circulation, the life cycle dynamics and demography of three key crustacean zooplankton (*Calanus finmarchicus*, *Thysanoessa longicaudata* and *Meganyctiphanes norvegica*) and the structure and productivity of the pelagic food web. The impact of climate variability on these relationships will be examined by means of a comparative analysis of the data collected during the campaign with comparable measurements made in 1963 during the NORWESTLANT surveys, and with data from the Continuous Plankton Recorder surveys.
4. The role of *Oithona* spp. in the marine productivity of the North Atlantic basin

Richard Lampitt (SOC, rsl@soc.soton.ac.uk) and Roger Harris (PML); in collaboration with Xabier Irigoien (AZTI, Spain)

*Oithona* spp. is the most abundant copepod in many marine ecosystems including the North Atlantic. However, because of its small size, its ecology is not well known and its role in the ecosystem undetermined. In addition, there are strong indications of predation by *Calanus* on *Oithona* nauplii with the potential for the nauplii to be an important prey during periods before the spring bloom. The objectives of this proposal are: i) to increase our knowledge in the ecology of *Oithona* by assessing its diet, productivity, total biomass and production; and ii) to investigate the link between *Oithona* and *Calanus* with special emphasis on the possible consequences of a climatic shift on the size structure of the zooplankton population.

5. Nutritional regulation of egg production of *Calanus finmarchicus* in the North Atlantic

Thomas Anderson (SOC, tra@soc.soton.ac.uk); Michael Bell (Stirling); David Pond (SOC/BAS) and John Williams (SOC)

The proposed work is a combination of two projects: 1) An examination of the role of food quality (C, N, fatty acids) in influencing egg production of *Calanus finmarchicus*, using ship-board experiments in which copepods are fed in situ food. Experiments will be undertaken on MarProd cruises in spring and autumn. 2) Complementary ship-board experiments in which copepods are fed labelled tracers in food to examine the extent to which *Calanus* can synthesise de novo "essential" fatty acids. Analysis of results will be underpinned by the quantitative stoichiometry theory proposed by Anderson and Pond (2000).

6. Determining ciliate parameters for intra and inter-basin scale models: abundance, biomass, cell size structure, biodiversity and production

David Montagnes (Liverpool, dmontag@liv.ac.uk) and Michael Heath (FRS Aberdeen)

We consider microzooplankton in two main roles: as competitors with, and as food for, mesozooplankton. We will parameterise the abundance, size structure, biomass, biodiversity and production of ciliates. These parameters will be examined at inter and intra basin-scale levels to test hypotheses concerning ciliate production and its fate. The project will also provide a service to other components of the MarProd programme by producing useful data for model parameterisation.

7. Automated identification of *Calanus* to species level at any developmental stage

Gary Smerdon (PML, grs@pml.ac.uk)

Identification of *Calanus* individuals to species level is problematic and normally impossible with early developmental stages (nauplii and early copepodites). This programme will develop an automated system for identification based on a modified method of Lindeque et al. (1999). The system requires a robotic workstation with integral thermal cycler, and will provide underpinning identification (>20 000 individuals) for the Heath et al. and Hirst et al. MarProd projects.

8. Trophic interactions of copepods - application of natural abundance of stable isotopes

Kevin Flynn (Univ of Wales: Swansea, k.j.flynn@swansea.ac.uk) and Nicholas Owens (PML)

Natural abundance isotope ratio (NAIR) signatures will be determined for components of the zooplankton food chain collected during Phase 2 Marine Productivity cruises in the North Atlantic. This will enable the detection of shifts in trophic level and diet for individual species over geographic and temporal transects, and the detection of differences in diet between different species inhabiting the same water column. We shall also attempt to determine corrective algorithms for the determination of NAIR signatures in preserved zooplankton enabling a future interpretation of CPR records. The approach is core to the MarProd hypotheses concerning the trophic activity of zooplankton and the only method covering meaningful periods of time between cruises.
9. Effects of current systems in the North Atlantic Ocean and Norwegian Sea on the genetic structure of *Calanus finmarchicus* populations
Graham Savidge (Queen’s University Belfast, g.savidge@qub.ac.uk); Christine Maggs and Jim Provan (QUB)

Samples of *Calanus finmarchicus* will be collected during spring and summer from approximately 18 stations located across the North Atlantic and from the Norwegian Sea. Microsatellite primers for *C. finmarchicus* will be developed and used to analyse levels and patterns of diversity within and between samples. The data obtained will be used to establish the presence of sub-populations of the species together with associated gene flow and will be interpreted in relation to the current structure of the area using historical data and, if possible, data to be generated elsewhere in the MarProd programme. Complementary data will be obtained from a limited number of winter samples and from a time series of samples from the eastern American seaboard.

10. Environmental, nutritional and endocrine regulation of diapause in the calanoid copepod, *Calanus finmarchicus*
David Pond (SOC/BAS, dwpo@bas.ac.uk); Gary Smerdon (PML), Laurence Dinan (Exeter)

Diapause is a key feature of the life-cycle of many marine copepods and is thought to be regulated by a number of interacting factors that range from broad scale environmental cues, through to the action of specific hormonal messengers acting at the cellular level. The proposed studentship aims to study the interaction between the environment, nutrition, the levels of specific endocrine hormones and their receptors in marine calanoid copepods. In particular, this research aims to develop a predictive capability of the behaviour and life-cycle of *C. finmarchicus* in the North Atlantic, thereby providing crucial information for researchers developing population dynamic models for this key species.

11. Use of satellite remote sensing to determine phytoplankton abundance and production
Stephen Groom (PML, s.groom@pml.ac.uk), Ian Joint and Jim Aiken (PML)

Satellite remote sensing will be used to provide support for the North Atlantic study in the Marine Productivity programme, in particular for seagoing activities.

**Concluding MarProd Studies**

In early 2004, NERC approved funding of £110k for 9 additional ‘small grant’ awards, to assist in the interpretation, integration and exploitation of results from the MarProd programme. It is expected that most of these will be completed by March 2005. Titles and contact information for these projects follow:

12. Determining microzooplankton parameters for spatial and seasonal modelling of the Irminger Basin
David Montagnes (Liverpool, dmontag@liv.ac.uk) and Mike Lucas (SOC)

13. Assessment of *Calanus finmarchicus* field growth and dormancy based on enzyme activity
Andrew Hirst (BAS, aghi@bas.ac.uk) and Lidia Yebra Mora (PML)

14. Size structures of *Calanus finmarchicus* populations and of planktonic predators in the Irminger Basin
Christopher Secombes (Aberdeen, c.secombes@abdn.ac.uk), Anna Ingvarsdottir (Aberdeen), Stephen Hay (FRS Aberdeen) and Andrew Brierley (St Andrews)

15. An assessment of bottom-up control of *Calanus finmarchicus* production based on measured phytoplankton production and satellite-based estimates of new production
Mike Lucas (SOC, mike.i.lucas@soc.soton.ac.uk), Stephen Groom & Gavin Tilstone (PML), Richard Sanders (SOC)
16. Plankton size structure in the Irminger Sea: setting the Marine Productivity cruises in the basin-scale context of the Atlantic Ocean
Roger Harris (PML, rph@pml.ac.uk)

17. A trans-Atlantic comparison of the relative overwintering depths of Calanus and its predators: setting the Irminger Sea in a wider geographic context
Andrew Brierley (St Andrews, asb4@st-and.ac.uk), Michael Heath (FRS Aberdeen)

18. Practical bench manual for North Atlantic marine zooplankton identification
Graham Pierce (Aberdeen, g.j.pierce@abdn.ac.uk) and Anna Ingvardsdottir (Aberdeen)

19. Analysis of Continuous Plankton Recorder samples collected in the Irminger Sea during summer 2002
Martin Edwards (SAHFOS, maed@mail.pml.ac.uk)

20. Ultrastructure of the digestive epithelium in Calanus finmarchicus: a marker for imminent diapause?
Roger Harris (PML, rph@pml.ac.uk) and Gary Smerdon (PML)

Other GLOBEC-related UK research (excluding marine productivity and involvement in EU-funded programmes):

1. The Continuous Plankton Recorder (CPR) Survey
Dr P C Reid (SAHFOS, Plymouth, pcre@nerc.ac.uk)

The CPR survey provides cost-effective monitoring of large-scale changes in near-surface plankton of marine pelagic ecosystems, from coastal to open ocean, using merchant ships to tow self-contained, automatic plankton recorders of standard design. Main geographic coverage: NW European shelf and the North Atlantic (since 1931/1946), the North Pacific and Southern Ocean (since 2000). All zooplankton larger than 2mm are identified and sub-samples taken for analysis of small zooplankton and phytoplankton. Around 450 taxa (phyto- and zooplankton) are routinely counted, and over 200,000 samples have been analysed to date. Current research topics include: seasonal to decadal variability and large-scale biogeography associated with environmental variability and physical structures; distinguishing between anthropogenic and natural plankton variability; monitoring changes in pelagic communities and diversity in relation to marine management issues (e.g. global change, biodiversity, eutrophication and fisheries); and relationship between CPR data and remote sensing of ocean colour.

Funding: Defra (Department for Environment, Food and Rural Affairs; MF0430), NERC and international funding.
Budget: c £700k pa
Duration: Ongoing (survey started in 1931)

2. Development of models of plaice population dynamics incorporating biological processes for use in risk assessment
Clive Fox (Centre for Environment, Fisheries & Aquaculture Science, Lowestoft; c.j.fox@cefas.co.uk); Richard Nash (Port Erin Marine Laboratory/Univ of Liverpool); and Richard Hillary (Imperial College London).

This project is constructing population models for plaice which explicitly incorporate processes such as maturation, spawning, egg and larval drift and growth and mortality on the nursery grounds. Fieldwork is focused on the Irish Sea, with sampling in 2001 and 2002 (building on data collections made in 2000). The aim is to develop models initially for the Irish Sea, and then examine their applicability to the North Sea.

Funding: Defra (MF0423)
Duration: 2000 - 2005
3. Population dynamic models of European cod stocks
Carl O’Brien (Centre for Environment, Fisheries & Aquaculture Science, Lowestoft; c.m.obrien@cefas.co.uk) and Bill Gurney (Univ of Strathclyde)

The objective is to build models of the important UK cod stocks, incorporating the accumulated knowledge of the biology and environmental influences on recruitment and survival, in order to improve the basis for defining sustainable harvesting strategies.

Funding: Defra (MF0427)
Budget: £534k (total)
Duration: 2001-2005

4. Impacts of environmental change on the recruitment of commercial fish stocks: an examination of potential mechanistic linkages through temperature and prey
Clive Fox (Centre for Environment, Fisheries & Aquaculture Science, Lowestoft; c.j.fox@cefas.co.uk) in collaboration with SAHFOS

This project examines effects of sea temperature change on egg and larval growth and survival, maturation and fecundity of adult fish, and changes in prey abundance and distribution in order to determine their impact on the recruitment success of cod and plaice around the UK.

Funding: Defra (MF0431)
Duration: 2002-2007

5. Biological oceanography of western Irish Sea
Richard Gowen (DARD Belfast; richard.gowen@dardni.gov.uk)

Long-term studies of nutrients and plankton dynamics are being undertaken at two sites in the western Irish Sea (near-coastal site and in the stratified region). Moored instruments at these stations support CTDs, fluorometers, water samplers (nutrients and phytoplankton) and sub-surface light sensors. Shipboard sampling is carried out at least monthly for collection of zooplankton samples.

Funding: DARD (Department of Agriculture and Rural Development, Northern Ireland)
Duration: ongoing

6. Fisheries of western Irish Sea
Richard Gowen (DARD Belfast; richard.gowen@dardni.gov.uk)

The overall objective of DARD research on pre-recruitment processes is to determine the level of interannual variation in recruitment to commercial Irish Sea stocks, with a view to improving the precision of stock assessment and appraising the likely effects of long-term environmental change. Effort is focussed on production and distribution of fish larvae; trends in the production of young fish; interactions between species; and factors affecting recruitment success, and the abundance and distribution of juvenile fish. Surveys are carried out to investigate the distribution and abundance of zooplankton, fish larvae and juveniles in the western Irish Sea (three 5-7 day cruises between April - June, using Gulf VII high speed plankton sampler with coarse and fine nets). Samples also collected for growth studies of larval fish and their relation to environmental conditions.

Funding: DARD
Duration: ongoing

7. Marine ecosystems
Michael Heath (FRS Marine Laboratory, Aberdeen; heathmr@marlab.ac.uk)

This programme includes studies of fish population biology (recruitment, population structure, stock identity; environmental time series); multispecies interactions (effects of fishing on marine ecosystems; resource partitioning; marine foodweb energy flow); and habitats and species (ecology of zooplankton and early life stages of fish; environmental effects on pelagic productivity and fish recruitment; simulation modelling of ecological processes and population dynamics). Geographic focus on northern North Sea and northeastern Atlantic.

Funding: SEERAD (Scottish Executive: Environment and Rural Affairs Department)
Duration: ongoing
8. Fisheries management
Robin Cook (FRS Marine Laboratory, Aberdeen; cookr@marlab.ac.uk)
This programme includes acoustic surveys for pelagic fish, and the assessment, modelling and
management of pelagic fish stocks (emphasis on herring and mackerel). Also stock assessments for
demersal and inshore fisheries.
Funding: SEERAD (Scottish Executive: Environment and Rural Affairs Department)
Duration: ongoing

9. The aquatic environment
Colin Moffat (FRS Marine Laboratory, Aberdeen; moffatc@marlab.ac.uk)
This programme includes studies of ocean climate variability, decadal climate change, and interactions
between physical processes and fish stocks. Also data management and quality assurance,
environmental protection, ecotoxicology, and marine biotoxins.
Funding: SEERAD (Scottish Executive: Environment and Rural Affairs Department)
Duration: ongoing

10. Southern Ocean ecosystem dynamics
Eugene Murphy (British Antarctic Survey; e.murphy@bas.ac.uk)
The programme will generate a Southern Ocean view of ecosystem operation through analyses of a
relatively simple and tractable marine food web with krill as a key component. Two component
projects: Variability of Southern Ocean Ecosystems (VSOE) and Spatial Structure in the Southern
Ocean Ecosystem (SSSOE).
Funding: NERC (core strategic)

11. Ocean processes
Raymond Pollard (Southampton Oceanography Centre, rtp@soc.soton.ac.uk)
Multidisciplinary research directed at defining and modelling upper ocean processes; export and fluxes
to the deep-sea floor; and the biology of pelagic and benthic deep-sea fauna. Hydrobiological goals
include the development of bioacoustic techniques, and the linking of ocean physics and chemistry to
biological distributions and biogeochemical fluxes. Biological modelling goals include the development
and validation of simple, realistic models of marine ecosystem dynamics, and the development of 3D
models of the ocean carbon cycle for studies of future climate. Most work focuses on the NE Atlantic,
also interest in the Southern Ocean, Indian Ocean (Arabian Sea, Gulf of Oman) and elsewhere.
Funding: NERC (core strategic)

12. Upper ocean processes and biogeochemistry
Patrick Holligan (Southampton Oceanography Centre; pmh1@soc.soton.ac.uk)
Multidisciplinary research directed at physical mixing in the surface ocean (ocean eddies and fronts,
tidal and shelf break fronts, remote sensing of surface ocean, dynamics of marine boundary layer);
 system modelling (phytoplankton and global nutrient cycles, thermocline dynamics); plankton
productivity and ecology (microbiology, phytoplankton and zooplankton ecophysiology); and trace
metal and nutrient biogeochemistry.
Funding: NERC and others
COUNTRY: USA

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A) Project Title: Georges Bank

Source of Information:

Contact:
US GLOBEC Georges Bank Program Office
Woods Hole Oceanographic Institution
Woods Hole, MA 02543-1050
USA

Project Description:
The U.S. GLOBEC Georges Bank Program is a large multi-disciplinary multi-year oceanographic effort. The proximate goal is to understand the population dynamics of key species on the Bank - cod, haddock and two species of zooplankton (Calanus finmarchicus and Pseudocalanus) in terms of their coupling to the physical environment and in terms of their predators and prey. The ultimate goal is to be able to predict changes in the distribution and abundance of these species as a result of changes in their physical and biotic environment as well as to anticipate how their populations might respond to climate change. The effort is substantial, requiring broad-scale surveys of the entire Bank, and process studies which focus both on the links between the target species and their physical environment, and the determination of fundamental aspects of these species’ life history (birth rates, growth rates, death rates, etc). Equally important are the modelling efforts that are ongoing which seek to provide realistic predictions of the flow field and which utilise the life history information to produce an integrated view of the dynamics of the populations

System Types Studied:
NW Atlantic: Georges Bank

Target Organisms:
Gadus morhua
Calanus finmarchicus
Melanogrammus aeglefinus
Pseudocalanus spp.

Physical Processes Examined:
Stratification
Retention/Loss
Cross-Frontal-Exchange
Key Hypotheses and Issues:
• Retention and in situ growth are more important than lateral exchange processes
• Stratification results in prey aggregation and increased predator survival
• Variation in mixing and stratification affects phytoplankton production and food web dynamics
• Large episodic water mass exchanges contribute to population variability
• Stratification and turbulent mixing affects predator-prey encounter rates

Number of scientists and fte:
Phase No. Scientific Investigators
1 70
2 81
3 80

Participating Institutions:
Bedford Institute of Oceanography
Bigelow Laboratory for Ocean Sciences
Brookhaven National Laboratories
Cornell University
Dartmouth College
Florida State University
Institut Maurice-Lamontagne
Lamont Doherty Earth Observatory of Columbia University
Louisiana State University
Massachusetts Institute of Technology
Massachusetts Institute of Technology
National Marine Fisheries Service (Narragansett/ Sandy Hook/Woods Hole)
Ohio University
Oregon State University
Rutgers University
San Francisco State University
Scripps Institution of Oceanography
State University of New York
University of Alabama
University of Georgia
University of Maine
University of Massachusetts
University of Miami
University of New Hampshire
University of North Carolina
University of Rhode Island
University of Southern California
University of Washington
Woods Hole Oceanographic Institution

Funding Agency:
U.S. National Science Foundation Division of Ocean Sciences
U.S. National Oceanic and Atmospheric Administration Coastal Ocean Program Office

GEORGES BANK PHASE 4 Projects: Modelling and Synthesis (2002-2006)
For Georges Bank projects phases 1-3, please see the first edition of the GLOBEC Activities Report.

1. The Physical Oceanography of Georges Bank and Its Impact on Biology
Robert Beardsley (WHOI), Ken Brink (WHOI), Dick Limeburner (WHOI), Jim Churchill (WHOI), Jim Ledwell (WHOI), Changsheng Chen (UMassD), James J. Bisagni (UMassD), Charles Flagg (BNL), Peter Smith (BIO), Ron Schlitz (NEFSC), Jim Lerczak (WHOI)

The U.S. GLOBEC NW Atlantic/Georges Bank program was designed to investigate the underlying physical and biological processes that control the population dynamics of marine animals, with the specific target species being the pelagic early life stages of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) and the copepod zooplankton Calanus finmarchicus and Pseudocalanus spp. (GLOBEC, 1992). The resulting combination of broadscale, long-term and process-oriented field studies conducted between 1994-1999, together with numerical model studies, has produced unique data sets and new ideas with which to investigate specific processes and the integration of these processes into a new level of understanding of the physics and biology of the Bank. Developing this new paradigm for physical/biological processes that control the population dynamics of the target species is a central goal of the Phase IV synthesis effort.
The research proposed here has three primary objectives that all serve the broader Phase IV effort. First, we seek to more fairly understand the physical dynamics and interactions of several specific processes (e.g., those associated with the seasonal evolution of stratification on the Bank, the crucial flow field over the Northeast Peak, and cross-frontal exchange within the tidal mixing and northern flank fronts) that are thought to play critical roles in zooplankton and fish recruitment. Second, we propose to combine these observationally based process synthesis studies into model-based studies to provide our best descriptions of the Bank's physical environment and its variability on time scales from minutes to monthly to seasonal for the GLOBEC field years. These model studies will use the finite-volume coastal circulation model (FVCOM) developed by C. Chen for coupled physical/biological studies. The model solutions, generated by hindcast and data assimilation approaches, will be used to define and quantify key physical mechanisms and physical/biological interactions on the Bank. Third, we want to provide other Phase IV investigators with as complete a description and understanding of the basic physical processes affecting their observations as possible.

Our work has two long-term goals: (a) to refine and quantify the new physical paradigm and the physical/biological interactions that impact the target species, and (b) to develop with Franks, Chen et al. the FVCOM coupled physical/biological model system to understand the coupled physical/biological system on the Bank, including why one year might differ from another biologically. These goals are clearly related, since the proposed data synthesis work will guide model evaluation and refinement, and the model simulations (both process and seasonal prognostic) will provide process understanding and realistic property and flow fields that are essential for quantitative biological modelling.

2. Zooplankton population dynamics on Georges Bank: model and data synthesis

Peter J. S. Franks (SIO), James M. Pringle (UNH), Jeffrey A. Runge (UNH), Changsheng Chen (UMassD), Edward G. Durbin (URI), Wendy Gentleman (UW)

The goal of the proposed work is to gain a mechanistic understanding of the influences of climate variation on the population dynamics and production of target zooplankton species on Georges Bank (Calanus finmarchicus, Pseudocalanus moultoni, P. newmani, and Oithona similis) through its effects on advective transport, temperature, food availability, and predator fields. Using data analysis and models as tools, results acquired during the first three phases of GLOBEC will be incorporated into a new synthesis of the physical and biological processes regulating zooplankton abundance on the Bank.

Physical models will be forced with measured daily, interannually variable data, and coupled to biological models synthesizing the detailed observations collected during the GLOBEC program. To understand the role of advection, and to disentangle the effects of physical and biological processes, a hierarchy of physical and biological models is proposed. These include 1-, 2-, and 3-D physical models, ecosystem models, and individual-based models (IBMS) for the target species. The IBMs will be coupled to 1-D physical models designed to represent the characteristic environments of the different Gulf of Maine and Georges Bank subregions. Ultimately, the IBMs will be coupled to the full 3D physical/ecosystem model through particle tracking. This will provide a physical and biological milieu in which to develop and probe hypotheses regarding the combined influences of physical and biological factors on the copepod population dynamics.

Although the population dynamics in all broadscale survey years will be studied, initial investigations will concentrate on 1995, 1998 and 1999. The data sets are the most complete for these years, and SeaWiFS data are available for 1998 and 1999. These years also represent a wide range of environmental conditions: an extensive winter bloom in the Gulf of Maine in 1999 related to Scotian Shelf inflow and increased stratification; a slightly warmer year in 1995; and stronger storm activity in 1998 than 1999. In addition 1998, and to a lesser extent 1999, give indication of being strong years for haddock recruitment but apparently not for cod.

Specific issues to be investigated include: wind control of the advective supply of the target zooplankton species to Georges Bank during January-April; interannual and/or event-level variations in the advective flux of Calanus finmarchicus to Gulf of Maine basin diapausing populations during June-April; interannual and/or event-level variations in advective losses of copepods from Georges Bank and bank subregions; the influence of stratification on the planktonic ecosystem, and how this affects the population dynamics of the target zooplankton species through food and predation. As a link to Phase IV synthesis studies on target ichthyoplankton, our investigation will provide mechanistic insight into the factors determining production of ichthyoplankton prey for larval cod and haddock on the Bank.
The proposed work will educate a number of graduate students over the course of the Phase IV research. These students will represent the best of our ability to train broadly educated researchers adept at combining techniques from a variety of disciplines in their work. In addition, this will be the first major independent funding source since graduation for two young investigators (Pringle, Gentleman).

3. Patterns of energy flow and utilization on Georges Bank

D.J. Gifford (URI), James J. Bisagni (UMassD), J.S. Collie (URI), E. G. Durbin (URI), Michael Fogarty (NMFS), Jason Link (NMFS), Lawrence P. Madin (WHOI), David Mountain (NMFS), Debbie Palka (NMFS), Michael F. Sieracki (BLOS), John Steele (WHOI), and B.K. Sullivan (URI)

The overall objective of the research is to provide a broad ecosystem context for interpretation of the population dynamics of the Georges Bank GLOBEC target species. The proposed research will synthesize key aspects of production and energy flow, based on US-GLOBEC studies in the Northwest Atlantic, and augment the US-GLOBEC data with information from other sources on production processes at the lower and upper levels of the food web. The primary objectives are to examine several alternate model outcomes of GLOBEC and GLOBEC-related studies that will help to address a number of outstanding issues and to re-examine patterns of energy flow on Georges Bank. The proposed research will enhance and expand the findings of previous investigations, with explicit consideration of factors not addressed in earlier models of this system including:

- the microbial food web,
- consideration of new and recycled primary production,
- spatial heterogeneity of primary and secondary production on Georges Bank,
- changes in biomass and production at higher trophic levels, and
- the effects of environmental forcing on production processes.

Incorporation of these elements into the modelling effort will permit a more detailed understanding of production processes on the Bank. The first four elements will help provide the broader ecosystem context, while the last provides the link to one of the US-GLOBEC program's principal themes, climate change. The latter will be addressed by comparing several different decadal-scale time periods that reflect differing environmental and fish community regimes:

- the cold 1960s characterized by abundant groundfish stocks fished by distant water fleets;
- the 1970s, characterized by "average" water temperatures, increased domestic fishing effort and depletion of groundfish stocks;
- the 1980s, characterized by "average" water temperatures, overfishing of groundfish stocks, and increases in elasmobranchs; and
- the "average" temperature, lower salinity 1990s, characterized by reduced fishing mortality, rebuilding of groundfish stocks, and increases in elasmobranchs and pelagic fish.

Because of large-scale changes in the fish community structure as a result of over-exploitation, a full understanding of the population dynamics of the target species cannot be attained without consideration of changes in other ecosystem components. Individual model networks will be formulated initially to represent each of the above periods. Subsequently, dynamic modelling will be developed to describe the transformations or shifts between these regimes.

4. Tidal front mixing and exchange on Georges Bank: Controls on the production of phytoplankton, zooplankton and larval fishes

R. Houghton (LDEO), D. Townsend (UMe), C. Chen (UMassD), L. Incze (BLOS), G. Lough (NOAA/NMFS) Collaborating PI: C. Hannah (BIO)

Georges Bank supports a rich fishery because: (1) large portions of the bank are shallow enough that light-limitation of phytoplankton is usually not important; (2) deep waters rich in inorganic nutrients are available for mixing onto the bank; and (3) the Bank's clockwise circulation can retain the planktonic stages of important fish species.

The tidally mixed front (TMF) is central to the productivity of Georges Bank through the processes of nutrient injection in the north and retention of larvae on the south flank. These two regions are connected by a circulation pathway along the front in which nutrients lead to phytoplankton and
zooplankton growth, creating a donut-shaped region of high production surrounding the crest. We suggest that the productivity of this pathway is the result of northern edge nutrient injections and is susceptible to climatic influences on nutrient supply in that region.

The overall objective of this proposal is to understand the processes within the TMF that sustain the biological productivity of Georges Bank and the success of the target species, cod and haddock. This requires that we understand how mixing and circulation within the TMF supply new nutrients, support primary production, and retain larvae. GLOBEC dye tracer experiments have for the first time measured directly the near-bottom Lagrangian circulation and mixing in the TMF. Results show that vertical mixing in the front, and the on-bank flow through the base of the TMF, are dynamically connected. Our study examines the 3-dimensional dynamics of the TMF based on these measurements. Models will help us assess how the strength of the across- and along-isobath circulation sets time and space scales compatible with the development of cod and haddock larvae.

This project will consist of a mix of data analysis and modelling activities. First, dye dispersion data and simple shear dispersion models will be used to understand the link between cross-bank flow and vertical mixing. Second, a finite-volume coastal ocean model (FVCOM) will be used to calculate the temporal and spatial structure of nutrient flux into the TMF, contrasting northern and southern flank inputs. A coupled FVCOM-NPZ (nutrient-phytoplankton-zooplankton) model will be used to test the following hypotheses: (i) Nutrient injections in the north are advected around the crest of the bank and lead to a plume of elevated phytoplankton and zooplankton production. (ii) The plume enriches the area of larval entrainment on the south flank. If the above statements are true, then production in the plume, can be altered by the nutrient content of source waters in the Northeast Channel of the Gulf of Maine, and these changes will affect the feeding environment of larval cod and haddock. Finally, models incorporating the measured 3-D flow and turbulence fields will be used to examine spatial patterns of larval retention and define the kinds of environmental transitions that larvae experience during this process.

5. Integration and synthesis of the Georges Bank broad-scale survey results

Peter Wiebe, Carin Ashjian, Larry Madin, Dennis McGillicuddy (WHOI) Ann Bucklin, Jeff Runge (UNH), Steve Bollens (SFSU), Dave Mountain, John Green, Peter Berrien (NMFS), Ted Durbin, Barbara Sullivan-Watts, Robert Campbell (URI), Dave Townsend (UMaine)

The GLOBEC NW Atlantic/Georges Bank study identified the pelagic early life stages of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) and the copepod zooplankton, Calanus finmarchicus and Pseudocalanus spp. as target organisms (GLOBEC, 1992) for an extensive and intensive effort to understand the underlying physical and biological processes that control the population dynamics of key populations of marine animals in space and time. Over a six year period, broad-scale surveys of the Georges Bank and adjacent waters were conducted to collect samples for cohort and survivorship analysis of the target fish and zooplankton populations. These surveys included the collection of data on hydrography, acoustics, phytoplankton chlorophyll, competitors, and predators, as well as the target species, in order to provide a description of the biological and physical environment in which the target species resided. More than 30 surveys of the Bank were conducted between January and June/July over the period June 1994 to June 1999.

Phase IV of the US GLOBEC Georges Bank program will synthesize the results from the program's earlier phases to provide an integrated understanding of the population dynamics of key, target species and evaluate how a varying climate may influence these populations. Our intent in this proposal is to capitalize on the very comprehensive broad-scale survey data sets that now exist to address two overarching questions:

- What controls inter-annual variability in the abundance of the target species on Georges Bank (e.g., bottom up or top down biological processes, or physical advective processes)?
- How are these processes likely to be influenced by climate variability?

Under this proposal, a team of principal investigators will bring together the broad-scale data sets for integrative studies. Most of the analyses to date have been done on an individual or project basis and an integrative approach is needed now. Two general methods of analysis will be used to identify and investigate these patterns and relationships: statistical analysis and inverse modelling using the adjoint method of data assimilation.
The broad-scale data sets represent a unique opportunity to explore the spatial and temporal patterns and relationships between the various measured biological and physical fields as they relate to the population dynamics of the target organisms. These results will provide a fundamental foundation for a complete interdisciplinary synthesis involving all components of the GLOBEC Georges Bank program.

6. Phase IV support for the scientific investigators' data synthesis symposia
Peter H. Wiebe and Robert C. Groman (WHOI)

The U.S. GLOBEC (GLOBal ocean ECosystem dynamics) research program on Georges Bank, which was initiated in 1994, conducted a three-phase broad-scale and process-oriented field study for a six year period ending in December 1999. During the same period, modelling and retrospective/synthesis analyses were also taking place. The field program has now been completed and many scientific papers describing the results of specific experiments and events have been published. However, a directed effort now is needed to enable investigators who participated in the program and other investigators to collectively bring about an integration and synthesis of the data sets in order to reach a new level of understanding about the physical and biological processes controlling the abundance of target species in the Georges Bank region and more generally of their predators and prey. Phase IV of the US GLOBEC Georges Bank program is thus focused on the synthesis of the results from the program's earlier phases. Each year a series of related workshops will be held to focus on a particular step in the synthesis. Each workshop will focus on a specific topic with a set of specific objectives. At the end of each year a symposium will be held to present the products of these integrated analyses. The last year of the synthesis will be dedicated to the production of a book that will present the overall results of the program and address the original programmatic goals articulated in the Implementation Plan (GLOBEC Report 6).

This proposal requests the funds to support the yearly workshops and the symposia. These funds will defray the costs of the meeting facilities and pay partial or full travel support for those investigators whose presence at one or more of these meetings are deemed important by the Executive Committee and yet may not have sufficient funds to attend the meetings on their own. The funds will also be used to assist in the documentation of the symposia through the preparation of reports, which will be published both in hard copy and on the Program's web site (http://GLOBEC.whoi.edu/), as has been done in the past. During the fourth year of the project, funds will be used to assist in the planning and development of the book showing the results of the analysis and synthesis of the GLOBEC Georges Bank program data sets and modelling efforts.

B. Project Title: Northeast Pacific

Source of Information:
US GLOBEC Webpages http://GLOBEC.oce.orst.edu/groups/nep/projs.html and Ted Strub, May 2004

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Project Description:
US GLOBEC Northeast Pacific aims to study the effects of past and present climate variability on the population ecology and population dynamics of marine biota and living marine resources, and to use this information as a proxy for how the ecosystems of the eastern North Pacific may respond to future global climate change. The strong temporal variability in the physical and biological signals of the NEP will be used to examine the biophysical mechanisms through which zooplankton and salmon populations respond to physical forcing and biological interactions in the coastal regions of the two gyres. Annual and interannual variability will be studied directly through long-term observations and detailed process studies; variability at longer time scales will be examined through retrospective
analysis of directly measured and proxy data. Coupled biophysical models of the ecosystems of these regions will be developed and tested using the process studies and data collected from the long-term observation programs, then further tested and improved by hindcasting selected retrospective data series.

The US GLOBEC Northeast Pacific Program has five specific goals:

1. To determine how changing climate, especially its impacts on local wind and buoyancy forcing and basin-scale currents, affect spatial and temporal variability in mesoscale circulation and water column structure.
2. To quantify how physical features in the California Current System and variability related to climate change impact zooplankton biomass, production, distribution, and the retention and loss of zooplankton from coastal regions. There is particular emphasis on the euphausiids Euphausia pacifica and Thysanoessa spinifera and calanoid copepods, and how these, in turn, influence the distributions of higher trophic levels, such as forage fish, coho and chinook salmon, and marine birds and mammals.
3. To quantify the impacts of key coastal physical and biological processes, including (i) primary and secondary production, (ii) intensity and effectiveness of upwelling, (iii) cross-shelf transport associated with wind-driven upwelling, and (iv) variability in the timing of the spring transition, on controlling juvenile salmon growth and survival in the coastal zone of the CCS.
4. To determine the extent to which high and variable mortality of juvenile coho and chinook salmon in the coastal region of the California Current is responsible for large interannual variation in adult salmon populations. To determine whether and how the proximate mortality causes (e.g. predation, parasites, starvation, loss by advection) are affected by climate variability.
5. To compare the impacts of climate variability and change (such as El Niño-La Niña cycles and regime shifts) on similar marine animal populations (euphausiids, salmon) of the CCS and CGOA.

**System Types Studied:**
- NE Pacific California Current
- Eastern Boundary Current
- NE Pacific Coastal Gulf of Alaska, buoyancy-driven flow

**Target Organisms:**
- Oncorhyncus kisutch
- Oncorhyncus tshawytscha
- Euphausia pacifica
- Thysanoessa spinifera
- Calanus spp.
- Oncorhyncus gorbuscha
- Euphausia pacifica
- Thysanoessa spinifera
- Neocalanus spp.

**Physical Processes Examined:**
- Stratification,
- Alongshore-transport
- Cross-shelf-transport
- Upwelling

**Key Questions, Hypotheses and Issues:**
To understand the effects of climate variability and climate change on the distribution, abundance and production of marine animals (including commercially important living marine resources) in the eastern North Pacific. To embody this understanding in diagnostic and prognostic ecosystem models, capable of capturing the ecosystem response to major climatic fluctuations.
- Predation is dominant source of mortality
- Local wind forcing and basin-scale currents affect spatial and temporal variability
• Mesoscale features impact zooplankton biomass, production, and distribution and retention and loss of zooplankton
• Variation in the intensity of cross shelf transport and the levels of primary and secondary production control juvenile coho and chinook salmon growth.
• High and variable predation mortality on juvenile coho and chinook salmon is responsible for population variation

Participating Institutions:

Biological Resources Division, USGS
Canadian Wildlife Service
Co-operative Institute for Marine Resource Studies
H. T. Harvey & Associates
Hatfield Marine Science Center
Lawrence Livermore National Lab.
National Marine Fisheries Service
Naval Postgraduate School
NOAA Alaska Fisheries Science Center
NOAA Pacific Marine Environmental Laboratory
NOAA Southwest Fisheries Science Center
North Carolina State University
Ocean Imaging Inc.
Old Dominion University
Oregon State University
Pacific Fisheries Environmental Laboratory
Rutgers University
Scripps Institute of Oceanography
University of Alaska, Fairbanks
University of California, Berkeley
University of California, Davis
University of Hawaii
University of Maine
University of Maryland
University of Minnesota
University of Texas
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Western Washington University

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NE Pacific GLOBEC: Projects Funded in Fall 2000

For NE Pacific GLOBEC projects funded in 1997 and 1999 please see the first edition of the GLOBEC Activities Report.

1. Factors Affecting the Distribution of Juvenile Salmon in the Gulf of Alaska

J. Helle (NMFS/AFSC, Auke Bay Laboratory), E. D. Cokelet (Pacific Marine Environmental Laboratory), E. V. Farley, Jr. (NMFS/AFSC, Auke Bay Laboratory), A. B. Hollowed (NMFS/AFSC), P. J. Stabeno (Pacific Marine Environmental Laboratory)

Remarkable changes in atmospheric, oceanic and biological conditions have occurred in recent decades in the North Pacific Ocean including declines in the marine survival of some salmon stocks. Fishery scientists generally agree that in the first few months after leaving freshwater, salmon survival and growth are linked to oceanic variability. The purpose of this research is to focus National Marine Fisheries Service studies on the GLOBEC region, augment oceanographic measurements and determine what biological and physical factors influence the distribution of juvenile salmon. Three general hypotheses are explored in this proposal: (1) juvenile salmon prefer the buoyancy-driven Alaska Coastal Current (ACC) at the head of the Gulf of Alaska, (2) they associate with oceanic temperature, salinity, current and prey fields, and (3) they migrate landward of Kodiak Island in the ACC rather than seaward in the Alaskan Stream. Annual, summer cruises aboard a chartered fishing vessel will catch juvenile salmon on 10 transects between Yakutat Bay and Kodiak Island. The vessel will be outfitted with a thermosalinograph to measure sea-surface temperature and salinity, and with an Acoustic Doppler Current Profiler (ADCP) - each operating continuously for fine-scale resolution. Modelled tidal currents will be removed from ADCP measurements to reveal the mean flow fields. At each trawl site, temperature and salinity profiles will provide water-column properties, and bongo-net hauls will give zooplankton distributions. Stomach samples from juvenile salmonids will be analyzed in the laboratory for diet composition and compared with zooplankton distributions. Analysis of salmon otoliths for hatchery thermal marks and Genetic Stock Identification techniques will be used to determine the home stream of hatchery and wild stocks in the Gulf of Alaska and their distribution with respect to oceanographic regimes. Retrospective analysis of catch per unit effort versus
oceanographic and prey factors will reveal what affects the distribution of pink, chum, coho and sockeye salmon in the study region. Proxies for bio-physical factors will be developed and compared with salmon-run size.

2. Nested interdisciplinary models for the Gulf of Alaska

D. Haidvogel (Rutgers University), A. Hermann (Pacific Marine Environmental Laboratory), S. Hinckley (Alaska Fisheries Science Center), P. Stabeno (Pacific Marine Environmental Laboratory)

The proposed work will significantly augment an ongoing GLOBEC-funded interdisciplinary modelling effort for the Coastal Gulf of Alaska. Technical objectives include: higher spatial resolution and nested grid capabilities for regional circulation modelling, nested mesoscale atmospheric modelling for regional wind and buoyancy forcing, and a deep-ocean NPZ model to provide boundary conditions for an existing coastal NPZ model. Present single-year simulations of these models will be expanded to continuous multi-decadal integrations, designed to provide circulation and prey fields to an individual-based model of juvenile salmon, proposed under this AO by Dr. Peter Rand. Together, these coupled models will be used to explore the mechanisms by which interannual/interdecadal variability of physical fields affect the production of GLOBEC target zooplankton species and the feeding of juvenile salmon in the CGOA. The ecosystem dynamics of these models will be compared with those developed under GLOBEC for the California Current System. This comparison will help elucidate the observed (inverse) covariance of salmon in the two systems on decadal time scales.

Central scientific issues include the following:

• The "optimal stability window" hypothesis: Gargett (1997) has suggested that variations in the Aleutian Low affect salmon through their impact on water column stability in the CGOA and CCS systems. Typically, high nutrient but low light conditions are observed in the subarctic gyre adjacent to the CGOA, in contrast to low nutrient but high light conditions in the subtropical gyre adjacent to the CCS. In Gargett's hypothesis, there exists an "optimal window" of stability for each area, which yields greatest primary production with optimal levels of both nutrients and light. Shifts in the Aleutian Low, with associated changes in coastal runoff and winds, yield greater/lesser production in the two areas, producing the observed covariance between northern and southern stocks. The links in this chain of causality will be probed directly through continuous, multi-decadal simulations with a suite of coupled models (circulation- NPZ-salmon) of the CGOA, and contrasted with parallel GLOBEC-funded efforts in the CCS.

• The source of nutrients to the CGOA: The Coastal Gulf Alaska is a downwelling system for nearly all of the year. The adverse pressure gradient so produced should work against the supply of deep nutrients to the shelf, whether that shelf is smooth and straight or (as is the case in the CGOA) punctuated by submarine canyons. At the same time, a coastal NPZ model, calibrated with CGOA data and run in 1-D mode, suggests a severe depletion of nutrients without some lateral supply. It is suggested that surface Ekman flux from the adjacent subarctic gyre may account for much of the required nutrient flux. This hypothesis will be tested by diagnosing the output from the multi-decadal runs.

3. Feeding, growth, condition and energetics of juvenile pink salmon

L. Haldorson [University of Alaska], D. Beauchamp (University of Washington), K. Myers (University of Washington)

The goal of this project is to determine how pink salmon in the northern Gulf of Alaska are affected by variation in the plankton production system during their first months at sea. This will be accomplished through an integrated project that includes field sampling, laboratory analyses and modelling. Pink salmon occupy surface waters of the continental shelf in the summer and fall after entering marine waters in the spring. In that period they grow rapidly and their feeding changes from small zooplankton in the summer to large zooplankton in the fall. This project will document temporal and spatial variation in prey use and availability, it will assess the effects of the shelf environment by measuring growth and condition of pink salmon, and it will use spatially-explicit foraging/bioenergetic modelling to understand observed patterns in feeding, growth and condition. Fish of hatchery origin, identified by thermal otolith marks, will be of particular interest, as the marine survival of each hatchery cohort will be available a year after those fish enter the marine environment.
Spatial and temporal variation in pink salmon diets and surface zooplankton will be described through laboratory analyses of field samples, and the basis for diet shifts to larger prey will be determined by calculations of prey selectivity. Standard length/weight condition measures will be calculated, and the energy content of salmon will be measured by calorimetry. Growth will be measured by size at age for hatchery fish and by scale analyses for all fish. The relationship between condition, growth and the environment will be examined. Habitat quality over the continental shelf will be assessed with spatially-explicit models with foraging and bioenergetic components that produce weight-specific estimates of growth potential. Bioenergetic modelling will also be used to estimate daily ration and seasonal consumption by pink salmon. The relationship between diets of pink salmon and other planktivorous fishes will be assessed.

This research will contribute directly to accomplishment of the GLOBEC program goal of understanding how production of upper trophic level species is linked to variation in oceanographic conditions. It is widely accepted that production of salmon in the GOA is determined by planktonic production. Detailed descriptions of spatial and temporal variation in diet, prey availability, temperature, growth and fish condition will substantially enhance our understanding of the connections between the marine environment and salmon production.

4. Relationship of growth and survival of coho salmon utilizing the coastal Gulf of Alaska
W.R. Heard, J. Taylor, J. Orsi (all at NMFS/AFSC, Auke Bay Laboratory), and M. Adkison (Juneau Center of Fisheries and Ocean Sciences, University of Alaska, Fairbanks)

The U.S. GLOBEC effort in the Northeast Pacific is directed at an overall goal of improving predictability of living marine resources of the region through improved understanding of ecosystem interaction and the coupling between the physical environment and the living resources. Salmon (Oncorhynchus spp.) are keystone species for the research effort because of their economic and ecological importance and because of the linkage of regional abundance of salmon stocks to climatic shifts in the North Pacific. Salmon from different regions of the North Pacific have responded differently to the recent warming that has occurred in the North Pacific. For example, coho salmon in the Pacific Northwest have declined precipitously, precipitating wide-spread listings of coho salmon populations in that region under the Endangered Species Act. In contrast, coho salmon catch from populations adjacent to the Gulf of Alaska have been at historically high levels in the 1990's. The major hypotheses of the North Pacific Climate Changes and Carrying Capacity Science Plan are that: (1) Ocean survival of Pacific salmon is determined primarily by survival of juvenile salmon in coastal regions, and is affected by interannual and interdecadal changes in Gulf of Alaska physical forcing; and (2) Variation in size-at-age of returning salmon is determined largely by interdecadal and interannual variation in physical conditions and productivity of the oceanic realm of the subarctic Pacific, and may show density dependence. This project will use retrospective analyses of archived coho salmon scales from an Alaska stock and on-going marine collections of juvenile coho salmon to directly address these hypotheses, and to develop a forecasting model for year-class strength of coho salmon returning to Southeast Alaska.

The retrospective analysis will be of archived scales collected from juvenile and adult coho by two long-term monitoring programs supported by the NOAA Auke Bay Laboratory. At Auke Creek, coho salmon scales have been collected from adults returning to Auke Creek from 1971-1999. All coho salmon smolts leaving Auke Creek since have been coded-wire tagged since 1976, all returning adults have been examined for tags, and Alaska Department of Fish and Game samples the commercial and sport fisheries to estimate harvest, so accurate and precise marine survival data have been compiled for this stock. Scales will be digitized, and marine growth will be broken into three phases: juvenile nearshore/coastal; juvenile Gulf of Alaska; and adult. These growth data will be analyzed for correlation with size at return, stock-specific marine survival, abundance of coho in Southeast Alaska fisheries, and measured biophysical characteristics of the Gulf of Alaska environment, including air and sea surface temperature records and climatic indices such as the Aleutian low pressure index. These data will be used to create a hindcast model relating phase-specific growth and environmental variants to survival and year-class strength.

Scales from juvenile coho salmon captured in the marine environment by the Auke Bay Laboratory's Southeast Alaska Coastal Monitoring (SECM) program will also be digitized and analyzed. Scales are available from archived samples since 1997, and sampling will continue through 2005. These scales will provide information to estimate circuli growth at the time of migration from inside waters into the coastal gyre and the Gulf of Alaska. Scale growth data from the juvenile collections will be used to
test the hindcast model for forecasting accuracy, and size, condition, and relative abundance data from the SECM will be evaluated as auxiliary variables for explaining interannual variation in year-class strength and stock-specific marine survival.

5. Gulf of Alaska copepod growth and reproduction
R. R. Hopcroft, K. Coyle & R. Gradingerb [all at University of Alaska]

Over the last few decades our knowledge of the zooplankton communities in the subarctic Pacific has improved considerably. We now appear to know the important players in the communities and their overall life histories. Nonetheless, our knowledge of copepod population dynamics is largely inferential through the examination of preserved collections (i.e. natural cohort analysis). There are few direct measurements of birth, growth or development for the dominant copepod species in the Gulf of Alaska (GoA). This is true not only for the region, but also for those species over their entire geographic range. A fundamental goal of the GLOBEC program is to understand the secondary production of the GoA and how the success of higher trophic levels, specifically salmon, are affected by the variability in the magnitude of secondary production seasonally, inter-annually, and at the decadal scale. Furthermore, because of the highly advective nature of the GoA, it will be necessary to establish the relative importance of local versus imported production. We cannot begin to address these questions without direct knowledge of the rates of development, growth and egg production, and how each is related to the environment.

This proposal seeks to undertake a comprehensive determination of rates of development, growth and egg production for the dominant copepod species in the GoA. It will determine the in situ rates inshore and offshore on LTOP cruises scheduled for 2000-2004 by incubation techniques employing artificial cohorts and individual females. Incubation techniques are the only appropriate methods for this region due to its highly advective nature. The proposed research will put the in situ rates in perspective by determining their maximal rates under food-saturated conditions in the laboratory. It will estimate the extent to which secondary production is food-limited in the field. It will determine the functional relationships of development, growth and egg production to body size, temperature and food regimes. Food regimes will be assessed in terms of chlorophyll and particulate organic carbon, plus the abundance and biomass of autotrophic and heterotrophic protists. It will estimate the rates of local copepod production, along with their temporal and spatial variability.

Thus, this proposal will provide half of the required information directed to the question of local versus advected production. At this point, it would be prohibitive to address the entire question in a single proposal. Other proposals address the other half of the question; establishing the rates of advection in this ecosystem. Still other proposals seek to understand the feeding or production of other groups. When all are complete, through synthesis it will be possible to establish the relative importance of each, and how their importance varies over space and time. The implications of these physical versus biological processes on the success of salmon recruitment can then be established and predicted.

6. A long-term observation program using natural stable isotope abundance for detecting coastal Gulf of Alaska zooplankton source fluctuations in fishes
T. Kline (Prince William Sound Science Center)

Decadal-scale changes in the production cycles of the subarctic Pacific Ocean have been conjectured to effect population changes in fishes via their zooplankton forage base. Zooplankton occurring near the Gulf of Alaska continental shelf break appear to undergo dramatic oscillations in abundance over decadal time scales. Interzonal zooplankton stocks are driven onto the shelf providing the ecosystem with an important forage base. Natural stable isotope data suggested that the transport of zooplankton from the Gulf of Alaska into Prince William Sound may provide significant quantities of forage for food webs and may be a good method for detecting changes in biophysical coupling in the greater Coastal Gulf of Alaska region. This project will augment and complement existing and continuing core LTOP observations being made along the Seward Line transect (GAK1 to GAK13). 3080 samples that were acquired by the P.I. from fall 1997 through summer 2000 on pilot LTOP project (Weingartner, P.I.) cruises will be isotopically analyzed as part of this project during FY2001 and FY2002. From fall 2000 to summer 2005, 2450 samples per year will be collected and isotopically analyzed as part of this project. The data arising from these samples will enable the assessment of
seasonal and inter-annual $^{15}$N/$^{14}$N and $^{13}$C/$^{12}$C variability of large-bodied zooplankton across the Gulf of Alaska continental shelf during their peak occurrence in spring and summer each year that will be matched to analogous measurements for juvenile pink salmon and other fishes. These data will be used to characterize isotopically coastal oceanic organic carbon sources and their utilization by fishes, which are expected to vary proportionately with the intensity of cross-shelf transport, thus affecting a relationship between intensity of cross-shelf transport and success of coastal fish populations. These data will also be used to validate the tacit assumption in NEP GLOBEC retrospective studies that $^{15}$N/$^{14}$N values of lower food chain biota are constant so that so that changing values can be interpreted to reflect varying food chain length or salmon run size.

7. Mesoscale surveys in the Gulf of Alaska: microplankton

*E. Lessard (University of Washington)*

This is one of three collaborative GLOBEC proposals for mesoscale surveys to study the physical and biological processes controlling the growth and survival of juvenile pink salmon on the Gulf of Alaska shelf. A central objective of the mesoscale studies is to determine how physical forcing affects the availability and production of zooplankton prey for juvenile pink salmon. Juvenile salmon prey (copepods, euphausiids, pteropods, amphipods) depend directly or indirectly on diverse microplanktonic prey, including microzooplankton (flagellates and ciliates) which have recently been recognized to be a significant dietary component of zooplankton. The size-structure, taxonomic composition and growth dynamics of the lower trophic food web are expected to be highly responsive to physical forcing and, in turn, exert strong influences on zooplankton growth, fecundity, community composition and nutritional state. The focus of this proposal is to describe quantitatively the abundance, biomass and size-structure of the microplankton (phytoplankton and microzooplankton <200m) prey fields. Group-specific phytoplankton growth and microzooplankton grazing rates will also be measured to identify trophic pathways and responses to changing physical regimes. This study will provide critical mechanistic insight and validation for coupled biological-physical models of the Gulf of Alaska shelf ecosystem.

8. Coastal Gulf of Alaska Copepod Egg Production and Viability - Do Interactions Between Climate and Microplankton Assemblages Produce Variability in Prey for Forage Fish and Salmon?

*J. Napp and C. Baier (NOAA-Alaska Fisheries Science Center), S. Strom (Western Washington University)*

Climate variability affects the productivity and food web dynamics of ecosystems. The Northeast Pacific Ocean (NEP) ecosystem is particularly sensitive to climate-driven change. The mechanisms, however, by which biological production are affected are unknown. Process studies, as part of GLOBEC's NEP program for the coastal Gulf of Alaska (CGOA), will: 1) document spatial and temporal variability in key biological rate processes and compare these to variability in physical processes affected by climate, and 2) test competing hypotheses of what controls productivity in the CGOA.

The CGOA is a highly productive ecosystem that provides a nursery area for many commercially exploited fish (e.g. salmon, walleye pollock, and halibut). Copepods are important prey for both early juveniles of these fish species, and for the forage fish (herring, capelin, and sandlance) that later replace zooplankton in the diets of juvenile fish. Recruitment by copepods, the dominant biomass component of CGOA zooplankton, depends on the quantity and viability of egg produced by females. Together, they are a "vital rate" (i.e. birth rate). Recent laboratory and field studies have demonstrated that food quality is an important determinant of egg production and viability. To our knowledge no one has simultaneously measured egg production and viability in the CGOA.

The investigators propose to quantify copepod egg production and viability of three numerically abundant copepod genera (*Calanus*, *Metridia*, and *Pseudocalanus*), and compare these to physical, chemical and biological attributes of the water column directly affected by weather and climate. These results will be linked to concurrent studies of the microplankton community (Strom and Dagg), and copepod grazing (this proposal). Shipboard incubations to determine egg production and viability will be accomplished on GLOBEC process cruises in March/April, May, and July/August, of 2001 and 2003, in four different hydrographic regimes. In addition, methods that do not require shipboard incubations will be developed to estimate egg production. Data emerging from the experiments will: 1) provide the first in situ reproduction data for important copepod species in the CGOA, 2) allow a
test of the hypothesis that (in nature) egg production or viability is reduced from physiological maximum levels, 3) determine if diet is the causative factor, 4) allow prediction of how mesoscale transport of organisms from one regime to another affects vital rates, and 5) provide key data to GLOBEC ecosystem modellers to parameterize mechanistic models to investigate how copepod recruitment in the CGOA will respond to changes in climate.

Specific measurements:

- Abundance and distribution of female copepods.
- Egg production rates of *Calanus* spp., *Pseudocalanus* spp. and *Metridia pacifica* feeding on different natural microplankton assemblages.
- Egg viability for *Calanus* spp., *Pseudocalanus* spp. and *Metridia pacifica* as a function of the microplankton community.
- Feeding rates and prey selectivity of female *Calanus* spp., *Pseudocalanus* spp. and *Metridia pacifica* grazing on natural microplankton assemblages.

9. Long-Term Changes in California Current Zooplankton Assemblages.

M. Ohman, E. Brinton, B. Lavaniegos (all at the University of California, San Diego), G. Rau (University California, Santa Cruz), R. Harvey (University of Maryland)

Marine zooplankton are one of the primary pathways through which physical climate signals propagate to marine fish populations. Evidence now shows geographically extensive changes of zooplankton biomass in concert with variations in the atmospheric and oceanic circulation in the NE Pacific. However, such analyses of bulk zooplankton biomass do not distinguish among taxa with diverse life histories, some of which are important trophic links to planktivorous fishes and others of which are not. The species composition of the zooplankton can strongly influence the intensity of zooplankton–fish linkages, and consequently alter recruitment success. Mechanistic understanding—and quantitative modelling—of climate linkages to planktivorous fishes will depend upon specific knowledge of the zooplankton fauna and the differential responses of different zooplankton taxa to variations in circulation and productivity of the NE Pacific.

We propose a retrospective analysis of the past 4 1/2 decades of the California Current System (CCS). We will use the high quality CalCOFI zooplankton collection, together with associated hydrographic data and indices of atmospheric forcing, to understand the causes of changes in the zooplankton from 1951 to the present. Three aspects of the zooplankton composition will be investigated: changes in the high-level taxonomic composition of all holozooplankton taxa, including gelatinous and crustacean forms; changes in the species composition of copepods and selected other taxa; and changes in trophic structure and nitrogen economy as inferred from the N stable isotope composition of two species of particle grazing copepods.

We hypothesize that there have been differential, taxon-specific responses to: (1) decadal-scale changes in the climate of the NE Pacific, including the 1976-77 warming event; (2) El Niño and other interannual variations in flow from the equatorial region and from the Subarctic Pacific; (3) regional differences in the intensity of coastal upwelling and cross-shore transport.

Our studies will provide, for the first time, an understanding of multi-decadal zooplankton species changes in the Pacific. We will uncover the taxa responsible for the long-term 70% decline in CCS zooplankton biomass. We will establish the temporal coherence of population changes in the central and southern sectors of the CCS, with which to analyze the co-variation with related zooplankton species in the Subarctic Pacific. These studies will form the foundation for the design of new GLOBEC field studies and the development of NE Pacific pelagic ecosystem models.

10. Spatial and Interannual Variation of Microzooplankton: an Ancillary Retrospective Analysis and Sampling Component of the Long Term Observation Program in the Northern California Current System.

B. F. Sherr and E. B. Sherr (both at Oregon State University)

Microzooplankton, grazing organisms <200µm in size, have a central role in marine pelagic food webs, and have been identified as a missing component of the GLOBEC Northeast Pacific (NEP) program. The microzooplankton size class is dominated by phagotrophic protists: ciliates, heterotrophic dinoflagellates, and other flagellates, which are significant consumers of
phytoplankton and are a major food resource for larger zooplankton. We propose to provide detailed information on microzooplankton stocks in the GLOBEC California Current System (CCS), in the context of physical, chemical, and biological data collected in the CCS Long Term Observation Program (LTOP). We will document temporal (seasonal and interannual) and spatial (along-shore and from coast to offshore) variability in distribution of microzooplanktonic protists in the CCS. Specific objectives of our research are: 1) Retrospective analysis of microzooplankton stocks in the CCS from samples collected along the Newport (NH) line off Oregon in September 1997 during a strong El Niño, and in September 1998 after relaxation of the El Niño event. 2) Seasonal/regional sampling of microzooplankton stocks in the CCS as part of the LTOP program through September 2003. 3) Analysis of spatial and interannual variability in microzooplankton stocks with respect to environmental parameters collected as part of the LTOP cruises, and 4) Estimating potential rates of herbivory by microzooplankton, and their significance as a food resource to mesozooplankton, for use in CCS food web models.

To facilitate comparison of our results with other microzooplankton data collected in the NEP region, we will process two types of samples: sample sets preserved with a high concentration of Lugol’s solution and inspected via inverted microscopy (optimal for enumeration of ciliates), and samples sets preserved with aldehyde fixative, stained with the fluorochrome DAPI, settled onto filters, and inspected via epifluorescence microscopy (optimal for enumeration of heterotrophic dinoflagellates, other flagellates, and mixotrophic ciliates). Data will include abundance and carbon biomass of general taxonomic groups of microzooplankton, and observations of ingested prey in protist food vacuoles and of the abundance of mixotrophic ciliates. Results from the retrospective analysis of microzooplankton standing stocks, and from our sampling program during the LTOP cruises in 2000-2003 will be processed, archived and disseminated to other GLOBEC investigators as the data become available. The results of this study will provide valuable data on the response of microplankton in upwelling systems to El Niño events, in the context of other data already collected in the CCS during the 1997-1998 El Niño. Our study will also provide important information for CCS ecosystem modellers, and will add to comparisons of CCS and Coastal Gulf of Alaska (CGOA) ecosystem dynamics.

11. Variability in Shelf Transports in the Gulf of Alaska

P. Stabeno (NOAA/PMEL), N. Bond (NOAA/PMEL), C. Mordy (NOAA/PMEL), J. Overland (NOAA/PMEL), J. Napp (NMFS/AFSC), D. V. Holliday (BAE Systems)

The proposal study tests the hypothesis that interannual variations in atmospheric forcing result in variations of on-shelf flow of nutrient- and zooplankton-rich slope water and of along shelf transport. The along shore transport is dominated by the Alaska Coastal Current (ACC). This westward flow is interrupted by cross shelf events that result from instabilities in the slope flow, eddies, interaction of currents with bathymetric features, and wind-driven downwelling. Changes in the large scale atmospheric forcing can modify on-shelf fluxes of nutrients and zooplankton through eddy formation and Ekman drift. Our results will support salmon studies, since it is hypothesized that salmon survival is dependent upon prey availability during the critical period when they first enter the ocean. Prey availability is likely related to bottom-up processes associated with the introduction of nutrient- and zooplankton-rich slope waters.

These hypotheses will be addressed through a combination of atmospheric modelling, observations and retrospective studies (Overland and Bond); biophysical moorings (Stabeno, Holliday, Mordy and Napp); and satellite-tracked drifters (Stabeno). The atmospheric modelling and observational studies will document and elucidate the downscale effects of coastal terrain on the local atmospheric forcing (along-shore winds and runoff) of the ACC. The retrospective study will describe how the local and basin wide forcing have varied over the last half century. Ten biophysical moorings will be deployed in years I and III, and five moorings in years II and IV. These moorings will measure temperature, salinity, fluorescence, and currents, and, at selected sites, nitrate. A surface mooring will be deployed each year and in addition to standard oceanographic variables will measure wind, barometric pressure, air temperature, and radiation, which will provide local observations for downscaling studies. A bioacoustics instrument to measure zooplankton will be used in years I and III to examine zooplankton and community size structure. Twenty-four (32 in years I and III), satellite-tracked drifters together with current measurements at the moorings will be used to study the currents. We will examine timescales from events to interdecadal. This proposal will address the effect of onshelf
12. Responses of the Neocalanus spp. - microplankton community to physical forcing in the coastal Gulf of Alaska.

S. Strom (Western Washington University), M. Dagg (Louisiana Universities Marine Consortium)

Ocean and atmospheric conditions in the coastal Gulf of Alaska vary widely over daily, seasonal, and interannual time scales. The abundance of dominant upper trophic level species, including salmon, has been shown vary in concert with this environmental change, most notably on decadal time scales. The mechanisms linking these large-scale population shifts with climate are not clear, but may involve lower trophic level responses (i.e. bottom-up effects). Although lower trophic level species are less well studied in the CGOA, preliminary data indicates that the abundance and activity of microplankton populations also respond strongly at least to short-term changes in CGOA physical regimes. Additionally, microzooplankton are likely the dominant consumers of phytoplankton on the shelf, thus constituting a key link between physical forcing of primary production and higher trophic levels. We propose to examine the processes structuring microplankton communities and linking them with populations of Neocalanus spp., the dominant particle-grazing copepods in the coastal Gulf of Alaska. Collectively, 3 species of Neocalanus (N. flemingeri, N. plumchrus, N. cristatus) contribute substantially to total spring and summer mesozooplankton biomass in the CGOA. Neocalanus are capable of consuming both phytoplankton and microzooplankton, though the factors dictating this diet partitioning are not well understood. Furthermore, these copepods have been shown to alter individual body size, population biomass, and life cycle timing in response to variations in ocean conditions. Finally, the size and abundance of Neocalanus make them an important potential prey for pink salmon fry and other coastal fish species. Thus the microplankton - Neocalanus food web is a potential locus for the translation of environmental variation into higher trophic level responses.

Specific measurements to be made are:

- Microplankton abundance and composition (phytoplankton size structure, microzooplankton species and size composition);
- Rates of microzooplankton herbivory; and
- Rates of Neocalanus spp. grazing on microzooplankton and phytoplankton.

A novel element of the work is the use of the FlowCAM (Flow Cytometer and Microscope) to characterize microplankton abundance and community composition during feeding experiments. This new imaging-in-flow technology should allow us to conduct many more copepod grazing experiments than would be possible with complete reliance on conventional microscopy. The proposed study comprises six separate cruises to the CGOA, sampling three seasons (early spring, mid-spring, mid-summer) each field year. Four core sites are proposed, encompassing a broad range of conditions across the shelf. In addition, a nested Lagrangian study is proposed to examine how water mass properties, community structure and biological processes are influenced by the strongly advective environment of the Alaska Coastal Current. By sampling across a range of coastal physical regimes and seasons, our proposed work will test the hypothesis that variation in the physical environment dictates production levels and food web structure in the CGOA, altering the timing, amount and quality of resources available to Neocalanus and ultimately to other higher trophic level species.

13. Gulf of Alaska Long-Term Observation Program

T. Weingartner, L. Haldorsen, R. Hopcroft, K. Coyle, T. E. Whitledige (all at University of Alaska, Fairbanks), T. Royer (Old Dominion University)

This project is to conduct the Gulf of Alaska Long-Term Observation Program (GOA-LTOP) as part of Phase II of the Northeast Pacific (NEP) GLOBEC program. The GOA shelf supports a rich ecosystem that includes many commercially important fisheries. The basis for this productivity is enigmatic for the GOA shelf is deep, forced by downwelling-favourable winds, and fed by a massive nutrient-poor coastal freshwater discharge. Both the winds and the freshwater discharge are intimately linked to the strength and position of the Aleutian Low. The GOA ecosystem experiences substantial physical and biological changes on decadal and interannual time scales. Although some of these changes are correlated with various climatic indices a mechanistic understanding of climate change and ecosystem response is unavailable. The generic goal of this LTOP is to understand and quantify temporal
(seasonal and interannual) and spatial (cross- and along-shelf) variations in the thermohaline, chemical, and biological properties and relationships of this shelf. Our proposal supports GLOBEC goals that will help: 1) retrospective studies interpret historical data, 2) design a cost-effective long-term monitoring program, 3) provide the seasonal and interannual context for concurrent mesoscale and process studies, and 4) provide boundary conditions and data sets for model evaluation. This 5-year project entails 4 field years and a fifth year for data analyses and synthesis. The field effort involves seven, 9-day interdisciplinary cruises/year in the northern GOA. The study area encompasses the 220-km long, Seward Line (sampled in the 1970s) that extends across the shelf and slope and high resolution sampling of the Alaska Coastal Current (ACC), upstream, downstream, and within Prince William Sound. The ACC is an important shelf habitat for YOY salmon migrating from nursery areas in the sound and into the GAO. The sampling effort (Table A) is year-round and motivated by seasonally significant physical and biological events affecting young of year pink salmon.

14. Seasonal and Interannual Variability of the Alaska Coastal Current: Long-Term, Three-dimensional Observations using a Telemetering, Autonomous Vehicle
Craig Lee and Charles Eriksen (both at University of Washington)

A five-year program of physical and biological measurements is proposed to study the seasonal and interannual variability of the Alaska Coastal Current (ACC). The dynamics of the ACC govern stratification and circulation over the inner portion of the Alaska continental shelf, a region that plays a critical role in the early life history of several commercially important fish species, including juvenile salmon. The system responds strongly to large seasonal and interannual changes in freshwater discharge and wind-forcing. Moreover, seasonal shifts in dynamics likely exert strong influences on the seasonal and spatial structure of stratification, on the spring phytoplankton bloom and on the advective transport of zooplankton and fish. Seasonal cycles in dynamics may also play a key role in explaining how nutrients are replenished in this downwelling-favorable system that is inundated by nutrient-deplete freshwater discharge. Thus, variability in wind-forcing and freshwater discharge produce significant changes in ACC dynamics which can influence the recruitment success of zooplankton and fish through a number of different pathways. The proposed study will focus on understanding:

- Seasonal and interannual variability in ACC freshwater content and transport
- The ACC's role in governing springtime mixed layer evolution over the shelf
- Processes controlling temporal and spatial variability in the spring bloom
- Processes that may produce onshore nutrient flux

These processes are inherently three-dimensional and exhibit a wide range of temporal scales. To address these sampling requirements, this program will exploit the capabilities of new, autonomous, telemetering vehicles (Seagliders) to make continuous, high-resolution sections of the ACC. Seagliders measure temperature, conductivity, pressure, chlorophyll fluorescence, dissolved oxygen and backscatter, profiling from the surface to within 10 m of the shelf bottom with 2 km horizontal resolution. A Seaglider will be operated year-round, repeating a sampling pattern designed to provide five sections across the ACC every twenty days. The sampling strategy was designed in co-ordination with other Long Term Observation Program (LTOP) investigators to augment existing and proposed LTOP components. The temporal and spatial resolution provided by Seaglider surveys will resolve processes such as springtime restratification and phytoplankton blooms, while the multi-year extent of these observations will explore the system's response to long timescale perturbations in forcing.

Projects Funded in Fall 2002

1. GLOBEC-NEP: Topographic Control of Mesoscale Variability in the Gulf of Alaska
D. L. Musgrave and T. E. Whitledge (both at Oregon State University) and S. Pegau (Kachemak Bay Estuarine Research Reserve)

This proposal addresses studies of the physical and biological distributions and processes and their effect on juvenile salmon recruitment on the Gulf of Alaska shelf. The spatial scope of the study is from Montague Strait to west of the Chiswell Ridge. The overriding theme of the proposal is that along-shelf and cross-shelf mesoscale structures are due to bathymetric control of the currents. Physical and biological oceanographic characteristics associated with the Alaska Coastal Current, its
offshore excursions in the Seward Eddy and Seward Counter Eddy, the shelfbreak front, slope eddies and meanders and the deep flow. These features affect the transport and distribution of deep-water zooplankton that are alleged to be an important food source for juvenile salmon and may determine their survival. An undulating, underwater, towed vehicle (SeaSoar) will be used to continuously map salinity, temperature, depth (CTD), and biooptical parameters. Surface samples of the above (minus depth), nutrients, and chlorophyll fluorescence will be measured continuously using similar sensors. We will use an Acoustic Doppler Current Profiler (ADCP) to measure along- and cross-track velocities to 150 m. In May and July, 2003, we will conduct two to three synoptic surveys (5 days each) of cross-shelf transects spaced every 10 km alongshelf.

The broader impacts of this study include the training of two PhD students in multidisciplinary oceanography and a better understanding of the effects of oceanographic effects on salmon variability in the Gulf of Alaska.

Projects Funded in 2004

Phase IIIa of the US GLOBEC Northeast Pacific Program will concentrate on synthesis of data from the California Current System and comparative analyses of this system with other appropriate ocean regions. There will be an emphasis on a number of topic areas, including:

1. Synthesis of data sets:
Integration of long term observation program (LTOP), process, and survey components of the program, and of remote sensing data, retrospective data sets, and modelling analyses are critical in the development of the synthesis research efforts. Topics under this initiative include, but are not limited to:

   a) Abundance and distribution of target species:
   The emphasis is on the determination of the distribution and abundance of the target organisms (calanoid copepods, euphausiids, juvenile salmon, salmon forage) in relation to their physical environment during the spring-fall, when juvenile salmon enter the coastal ocean, and when it is believed that mortality is both high and variable. What constitutes favourable habitat for juvenile salmon entering the coastal ocean, and where and when does such habitat occur both seasonally, and between years? How does interannual and long-term environmental variability impact this ecosystem? Creation of integrated data sets that can be used for inter-annual comparisons of population processes and their coupling to the physical structure and variability of the environment to answer the key questions listed above is of fundamental importance.

   b) Processes that regulate the abundance and distribution of target species:
   How often and where do planktonic populations and salmon encounter retentive regions near or on the west coast shelf? How important are topographically controlled recirculations in producing or maintaining highly productive and predictable regions that favour secondary production and salmon growth and survival? How important is the episodic upwelling (intermingled with periods of low or downwelling winds) off of central Oregon and Northern California in establishing productive regions nearshore for juvenile salmon? What are the mechanisms through which climate variability affects these processes? Answering these and similar questions will require a concerted effort to integrate the results of physical observations, estimates of in situ animal abundances, the condition and reproductive rates of plankton, and the distributions of predators.

   2. Physical/biological modelling:
   The development and use of conceptual and quantitative models to investigate physical and coupled physical/biological processes have been emphasized throughout the US GLOBEC Northeast Pacific program. Circulation models have been used to examine the effects of episodic upwelling on nearshore retention of plankton populations, and to explore the influence of wind forcing on alongshore and cross-shelf flow near a shelf bank and coastal headland using both idealized and realistic regional bathymetry and forcing. These studies have mostly involved diagnostic models. In Phase IIIa, these and other model approaches (including prognostic and data assimilation) will be encouraged, with the following multiple aims: (a) to improve understanding of the key physical and biological processes that affect the distributions and local productivities of the target species in the CCS; (b) to understand how climate variability and potential longer-term changes (e.g. regime shifts) modify these processes; (c) to help integrate and synthesize the various physical and biological data
collected during the field program; and (d) to begin coupling the lower and upper trophic level models of the NEP ecosystem.

3. Broader Scale Effects Influenced by Climate Change and Comparative Regional Studies:

Waters from the Subarctic and transition ocean regions that are advected eastward (West Wind Drift) split into two limbs (currents) as they approach the west coast of North America: to the south, the water enters and becomes a major contributor to the California Current; to the north, the water enters and becomes important to the Alaska Current. Nutrients and seed populations of plankton from the West Wind drift are important to these coastal ecosystems. Moreover, recent responses of the zooplankton fauna of the Pacific Northwest region suggest that there may be significant transport of subarctic species from the Gulf of Alaska to west coast regions. It has been hypothesized that the contributions of the West Wind Drift to these two downstream regions are out-of-phase and primarily controlled by longer-term large-scale fluctuations in North Pacific climate—particularly, by the positions and strengths of the atmospheric pressure systems in the region. These longer term changes in ocean basin scale atmospheric forcings have had well documented impacts on biological populations in both coastal and oceanic regions of the northeast Pacific Ocean. A well documented environmental shift ("regime shift") occurred in 1976-77, and, relevant to US GLOBEC, another may have occurred in 1998. Plankton abundance and salmon survival have increased in the Pacific Northwest since 1998, corresponding to a change in the sign of the Pacific Decadal Oscillation.

In the Phase IIIa synthesis activities, emphasis will be placed on the inter-regional comparison and coupling of target species populations through the larger scale current systems. This initiative will provide an opportunity for evaluation of large-scale environmental influences. Integration and collective analysis of data sets from throughout the Northeast Pacific (including both GLOBEC CCS and CGOA programs as well as other research from the region) are encouraged. Together with historical data sets, recent observations made during earlier GLOBEC NEP phases can be used to evaluate the effects of environment on zooplankton populations and survival of juvenile salmon at multiple spatial and temporal scales.

4. Development of indices to characterize environmental and ecosystem status and change.

A more complete understanding of the NEP-CCS ecosystem gained through the US GLOBEC program should allow for the design of better, more efficient, and more informative, monitoring programs in the region. Achieving this improvement will involve determining indices for the physical and lower trophic level system components that best characterize the status of the ecosystem, particularly in relation to potential higher trophic level production. An important goal is for the indices to identify the environmental influence on juvenile salmon survival variability that can be incorporated into the assessment of the fish stocks in the region. Indices may be derived from directly measured parameters (from field observations), remotely sensed parameters, or from output of specific configurations of coupled physical-biological models.

C. Project Title: US Southern Ocean GLOBEC

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The US Southern Ocean Programme is described in the Regional Programmes Section under Southern Ocean GLOBEC.
GLOBEC Multi-national Activities

GLOBEC has a very broad scope from small scale National Activities to Regional Programmes covering ocean basins. Some GLOBEC programmes are not solely national activities but do not cover sufficient geographical area to be considered regional Programmes. Multi-national programmes consist of several countries working together on a specific aim or area. These jointly funded multi-national programmes are a vital part of GLOBEC. At present there are five active multi-national GLOBEC programmes and three programmes which have been already completed.

BENEFIT draws on the work of scientists in Namibia, Angola and South Africa and from co-sponsor countries (Germany and Norway) to answer questions about the Benguela Current Ecosystem.

ENVIFISH conducted a retrospective analysis of environmental and fisheries records from 1982 to 1999 and involved scientists from Italy, Angola, Namibia, South Africa, Germany, England, Norway and Portugal. ENVIFISH was completed in 2001.

IDYLE aims to understand how the adaptive strategies of fish are structured by the presence of inshore upwelling and the resulting ecosystemic patterns. IDYLE is based in the Benguela and involves scientists from France, Namibia, Angola and South Africa.

LIFECO was an EU funded programme enabling scientists from Denmark, Germany, Norway and the UK to work together to establish the links between frontal activity and ecosystem dynamics in the North Sea and Skagerrak and their importance to fish stock recruitment. The LIFECO programme was completed in 2003.

NATFISH aims to analyse and quantify the influence of the natural variability of the Northwest African upwelling system on the abundance and distribution of small pelagics. NATFISH involves scientists from Italy, Norway, Morocco, Mauritania and Senegal.

OFCCP will investigate the effect of climate change on the productivity and distribution of oceanic tuna stocks and fisheries in the Pacific Ocean with the goal of predicting short- to long-term changes and impacts related to climate variability and global warming.

SARDYN investigates the stock structure and dynamics of the sardine population in the north-east Atlantic and involves scientists from Portugal, Spain, Greece, England, Norway and France.

TASC involved scientists from Denmark, The Faroe Islands, France, Germany, Iceland, Norway and the UK in a study of Calanus finmarchicus in the Atlantic, the study was completed in 2001.
**PROGRAMME: BENEFIT**

**Project Title:**
Benguela Environment and Fisheries Interactions and Training Programme (BENEFIT)

**Source of Information:**
Neville Sweijd, (September 2004) and BENEFIT webpage: http://www.benefit.org.na (March 2004)

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**Research Focus 1: Fisheries Resources**

**Project Descriptions:**
Benefit projects are investigating six key research themes that represent the primary resource questions, while recognising that priorities will shift annually based on evolving needs. Commercial fisheries to be targeted by BENEFIT include the hakes, horse mackerels and small pelagic species such as sardine, sardinellas, and anchovy and their competitors including seabirds and seals, jellyfish and non-exploited mesopelagic species. It is recognised that the research agenda should be sufficiently flexible to consider new or developing stocks, and species of ecological importance, but not identified as a fishery per se.

**System Types Studied:**
Benguela Current Ecosystem

**Target Organisms:**
- *Sardinops ocellata*
- *Engraulis capensis*
- *Merluccius paradoxus*
- *Euphausia luceus*
- *Calanus agulhensis*
- *Trachurus capensis*
- *Merluccius capensis*
- *Nyctiphanes capensis*
- *Calanoides carinatus*
- *Dentex macrothalmus*

**Key Questions, Hypotheses and Issues:**

The following is a broad outline of the scope of the programme.

1. **What are the biological characteristics of the commercial stocks and competitors/food sources?**
   This question deals with basic biological characteristics such as growth, natural mortality, fecundity and reproductive strategies, recruitment strength and variability, and the age structure of the population, all of which are important inputs to population dynamic models. The work will be based on analysis of length, age, and reproductive state of fish sampled from commercial and research catches. Where possible and appropriate, survey information will be used to estimate natural mortality directly and the strength and variability of recruitment. A crucial aspect in all these studies will be the improvement and verification of ageing techniques through validation of otolith readings based on length distributions in commercial and research catches, and growth studies on captive fish.
2. How are the resources and their competitors and food sources distributed throughout the region, and how are different stocks or sub-stocks linked?
This question covers such topics as stock identity and definition, stock separation mechanisms, and large-scale migrations and distributional shifts. It leads to the better definition of unit stocks for management purposes. The question will be addressed through large-scale collaborative surveys at different times of the year, extending across national boundaries in the case of shared stocks. ADCP studies of large-scale circulation patterns, which could influence fish movement and migration, would form an important part of such cruises. Retrospective analysis of both survey and commercial catch data would be used to elucidate broad distributional patterns and changes in these with time. Genetic and/or morphometric studies would be undertaken to identify separate stocks or sub-stocks within the region. Where appropriate and practicable, tagging would be attempted to study migrations and interchange between stocks.

3. What is the biomass of the resource and competitors in absolute or relative terms?
This key question is central to the entire programme. Absolute estimates are of particular value for resource management, while relative estimates revealing trends in biomass are both of value for management and essential in studies aimed at understanding resource dynamics. Biomass estimates of national resources will be made by the Fisheries Research Institutes of the region from surveys and catch information as part of their statutory function, and will not be a BENEFIT activity per se. The BENEFIT Resources Programme will however contribute indirectly to these assessments by developing, improving and promoting the standardization of resource assessment methods used in the region (Key Question 4).

4. How can estimates of biomass be improved?
This is the main thrust of the Programme, and deals with the reduction of bias and variance in biomass estimates, particularly those derived from surveys and Virtual Population Analysis (VPA). It includes such topics as survey design and strategy, development and standardization of analytical techniques, equipment calibration and inter-calibration, gear performance studies, studies on aspects of fish behaviour affecting survey estimates, target strength estimation (acoustic surveys), and biological studies relevant to improving biomass estimates.
The problems will be addressed through a wide variety of approaches, including:

- Survey designs will be improved based on theoretical and simulation models;
- Target strength estimates will be improved through *in situ* estimation techniques;
- Sonar techniques will be developed to supplement echo-integrator surveys of near-surface fish;
- A combination of acoustic observations, trawling and photographic observations will be used, together with environmental sampling, to understand fish behaviour in relation to sampling gear performance;
- Virtual Population Analysis (VPA) estimates will be improved through the use of better ageing techniques and age and distributional information from surveys;
- Variance in egg-production surveys will be reduced through the use of continuous underway egg-sampling methods.

5. What are the major factors affecting stock dynamics?
This question is aimed at improving understanding of the key environmental and human factors which determine the distribution, abundance and productivity of the stock, primarily to assist in predicting changes in the stock far enough in advance to be useful to management.
The question will be addressed *inter alia* by:

- Relating fish distribution patterns to environmental information obtained during the surveys or from satellite imagery;
- Dedicated meso-scale studies in frontal areas; and
- Retrospective analyses aimed at relating previous fluctuations in distribution, stock size, fish condition, growth and mortality to large-scale local and global environmental fluctuations.
6. **How productive are the exploited stocks and their competitors and food sources?**

This key question is aimed at improving understanding of the dynamics of the population in terms of recruitment strength and variability, growth, reproduction, and mortality, to assess the population's sustainability as an exploited resource. The effect of the environment on stock production also needs to be considered. The question needs to be addressed through the development of existing and new single-species population dynamics models in conjunction with resource modellers already active in the region. Multi-species models also need to be developed for strongly interacting species, as well as ecosystem models to develop a holistic understanding of changes in stock production and productivity. Essential inputs in the population models are survey-based estimates of absolute abundance of different year-classes, biomass trends from surveys and other indicators, growth estimates, and estimates of both natural and fishing mortality. Key questions 1 to 4 are all therefore directly relevant to population modelling and key question 5 to ecological modelling.

**Participating Countries and Institutions:**

Namibia, Angola, South Africa

**Duration:**

Annual

**Budget:**

$2.1M for 2003 (including ship time and administration)

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**Fisheries Resource Research agenda for 2004**

While the following questions form a broad scope of the programme, investigators elect research projects according to their research needs, within the framework of the programme.


   The main objective of this study has been to investigate the patterns of horse mackerel diel vertical migrations and their possible links to hydrographical factors and feeding behaviour, and thereby improve survey methodology and ultimately biomass estimates. A retrospective analysis of environmental, acoustic, and trawl data from Namibian horse mackerel surveys between 1990 and 1998 will be conducted. Several research cruises have been conducted to address these issues. The study will include environmental sampling (oxygen, salinity, temperature, light intensity and surface illumination), current measurements by ADCP, acoustic measurements, bottom and midwater trawling, and stratified sampling of prey items with a multi-sampler net. The project is near termination and several publications are expected.

2. **Identification of horse mackerel acoustic targets in Angola/ northern Namibia (Vaz-Velho, de Barros, D'Almeida)**

   This project has been running for almost five years and is in the final stages of analysis and publication. It has focussed on the need to identify horse mackerel targets in acoustic surveys in the northern Benguela (primarily Angola), through the identification of characteristic aggregating patterns of horse mackerel, and of common types of mixed aggregation in the area (horse mackerel/ sardinella, horse mackerel/ *Dentex* etc.). The project is related to the existing BENEFIT Target Identification project, but differs in that it is totally retrospective, and does not use multi-frequency methods.

   Echograms and trawl data collected since 1985 have been examined by regression and discriminant analysis techniques to develop descriptors of the various aggregation types in different parts of the region (e.g. north and south of the Angola/Benguela front). Several workshops have been held with collaboration among regional, Norwegian and French scientists to exchange echograms, standardize interpretation methods, and discuss criteria for the discriminant analysis.
3. Abundance and distribution of jellyfish in the northern Benguela. (Mark Gibbons, Andrew Brierly)
This project focuses on the use of multi-frequency techniques to estimate the abundance and elucidate the distribution of jellyfish (Aequorea aequorea and Chrysaora hysoscella) in regional waters. The project has seen several dedicated cruises on the Dr Fridtjof Nansen between 2001 and 2004 to complement work done on a similar BENEFIT cruise in 1999. The primary objective is to estimate target strengths of jellyfish at a number of frequencies, so as to be able to use acoustics to map jellyfish distribution in key areas, estimate abundance and study behaviour. Other objectives are to collect information on the biometry, biology and trophic ecology of jellyfish, and to study population size structure.

4. Performance of research bottom trawls (Titus Illende, Arill Engås)
This project started as a BENEFIT project in 1999. Several gear performance experiments on Dr Fridtjof Nansen have been performed. Acoustic and underwater video techniques have been used to study the reaction of demersal species to the trawl. The current phase of the project has been focussed on heading and escapement and the final phase will focus on environmental effects and correlations.

5. Coordinated demersal surveys of Namibian and South African coasts (Lipinski, Iilende, de Barros, Strømme)
This 3-year project for planning of coordinated, quasi-synoptic trawl surveys of demersal fish (mainly hake) between Port Alfred on the South African south coast and the northern border of Namibia, using 3 vessels (probably Dr Fridtjof Nansen, R.V. Africana and a Namibian commercial trawler). The primary intention is to produce an integrated assessment of all M. capensis and M. paradoxus stocks in Namibian and South African waters, using comparable methodologies throughout. The project has progressed to a stage where some focussed activity on the transboundary area around the Orange River has been conducted with special focus on the movement of M. paradoxus in relation to the hydrography and bathymetry of the region. The activities have been conducted on a seasonal basis with around 60 days ships time being dedicated to the project in 2004 funded by the Nansen Programme and the BCLME. This project has also incorporated several intercalibration activities with the RV Africana.

6. Biology and ecology of the pelagic goby (Gibbons, A Gro-Vea Salvanes)
This study into the distributional ecology and general biology (feeding, growth, reproduction etc.) of the pelagic goby Suffliogobius bibarbatus off the coast of Namibia is motivated by the species' ecological significance in the region. The project has investigated changes in distribution through time, relationships between distribution and environmental features, diet in relation to habitat (benthic or pelagic), geographical trends in size, age and growth, and the seasonality of reproduction. The distributional study has been based on a retrospective analysis of survey and commercial data collected in Namibia and South Africa, and on Namibian and South African information on the occurrence of gobies in the diets of seals, seabirds and demersal fish (especially hake) in the region. The biological studies have been conducted in cruises of opportunity and on several dedicated cruises with a 12-day cruise planned for early 2005.

7. Monitoring distribution of seals at sea, and potential for interaction with commercial fishing operations (Oosthuizen, Roux, Tolley, Bjørge)
This project has been ongoing for almost 5 years and is set to consolidate and produce its final report in 2005. The project has been a collaborative international study into the distribution of Cape fur seals at sea off Namibia and South Africa using satellite tracking, primarily to assess the degree of geographical overlap with commercial fishing operations which seals are known to disrupt. Dispersal and migratory habits at sea have been elucidated by satellite tracking of tagged animals, extending the work of this nature previously done by MCM in South Africa on animals tagged at the Kleinzee and Seal Island (False Bay) colonies. The distributional analyses have been done using GIS-based spatial analysis methods, in which MCM and NatMIRC staff were instructed, adding a training component to the project. In 2001, animals were tagged at one of the major colonies and tracked for approximately 100 days. Training in GIS techniques was given to regional staff. The tagging/tracking was extended in 2002, and the GIS analysis will be carried out to completion in the final year of the project (2005). The Geography Department of the University of Bergen (Dr Anne Lucas), will be involved in all aspects of the GIS work.
8. Activity NORAD 2001/005.- Investigations on recruitment of pelagic species in the Northern Benguela during a potential regime shift (A. Kreiner, R. Cloete, C. V.D. Lingen; E. Stenevik)

Ichthyoplankton surveys targeting pelagic species have been conducted on board the research vessel "Dr. Fridtjof Nansen" since 2000. Since 2003 these surveys have been conducted during January/February, the main spawning season for the commercially important species sardine, horse mackerel and anchovy. During the surveys, data on the horizontal and vertical distribution of eggs and larvae have been collected and related to environmental conditions. In addition, onboard measurements of egg buoyancy of different species have been conducted. Modelling experiments have been done to simulate both the vertical mixing of the eggs and horizontal drift routes of larvae. The results have shown that the vertical behaviour the larvae is adapted to the flow field in a way that promotes retention of the offspring in nearshore nursery areas and therefore advective loss of larvae is not a major factor limiting recruitment of these species in the Northern Benguela. The results have been presented at international symposia both in the region and elsewhere, and are also published in cruise reports and in international journals such as South African Journal of Marine Science and Fisheries Oceanography. The final year of data collection on the project will involve a cruise that will consolidate data on the goals. These are to investigate the spatial distribution of eggs and larvae of sardine and anchovy in relation to frontal systems and other environmental variables (temperature, oxygen), investigate what influence different environmental conditions have on recruitment success and investigate the main spawning areas of sardine and anchovy in order to compare these with historic observations. Eggs and larvae will be collected during a cruise with a multinet and environmental data with a CTD.

9. Activity NORAD 2002/001.- Characterization and comparison of the spawning habitats of sardine and anchovy in the Northern and Southern Benguela. (van der Lingen, Kreiner, Maartens)

The objective of this project is to characterize the spawning habitats of sardine and anchovy populations in the Northern and Southern Benguela in terms of space, time, and the physical and biological attributes of the waters in which the eggs of these fish are collected. Once characterized, the spawning habitats will be compared for the two species within each subsystem (i.e. sardine and anchovy in the Northern Benguela), and for each species between each subsystem (i.e. sardine in the Northern and Southern Benguela). This work has already been initiated for the Southern Benguela. The present project report refers specifically to the characterization and comparison of the spawning habitats of sardine and anchovy in the Northern Benguela subsystem. Once complete, subsequent comparisons between spawning habitat of populations in the Northern and Southern Benguela will be conducted. Three key questions have been examined through a retrospective analysis of egg abundance and distribution data collected during research surveys made off Namibia. Surveys include the SWAPELS cruises (monthly ichthyoplankton surveys conducted from Hollams Bird Island to Cape Frio over the periods 1972-74 and 1978-85), collaborative Namibian/Spanish (SNEC) surveys made during the 1980s, and more recent ichthyoplankton surveys conducted by the Dr. Fritjof Nansen. The key questions are:

- Do (did) sardine and anchovy in the Northern Benguela show a temporal separation in the time of peak spawning?
- Do (did) sardine and anchovy in the Northern Benguela show a spatial separation in the time of peak spawning?
- Can sardine and anchovy spawning habitats in the Northern Benguela be characterized in terms of physical and biological parameters, and if so, are their characteristics different?

10. Reproductive biology of the big-eye dentex (Dentex macrophthalmus) in the Benguela current (Moustapha Diedhiou; Stephen Brouwer; Paul Kainge).

This new project is aiming to investigate the reproductive biology of *D. macrophthalmus* using data collected from both research surveys carried out by the *RV Dr. Fridtjof Nansen* and GOA, as well as monthly samples collected from the commercial fishery using the Angolan National Sampling Program. Big-eye dentex, *Dentex macrophthalmus*, is a demersal sparid typical of the northern part of the Benguela ecosystem. This species is distributed from northern Angola (5°S) to northern Namibia (24°S), but are most abundant between 11-12°S and 17-18°S. It is one of the most important commercial species in Angola, but it is currently not targeted in Namibia. Given the high commercial importance of this species in the area, it has been a major target of fisheries research in Angola, and several surveys have been directed at estimating its abundance and stock structure. However, no
information is available on this species from Namibian waters. The results of a recent BENEFIT project on distribution and movement patterns of *D. macrophthalmus* concluded that during spring/summer (September to March) this species aggregates in the central Angolan waters, which was thought to be associated with spawning activities (Kilongo et al., 2001). During autumn/winter (April to August), the species is widely dispersed, which is thought to be related to feeding and favourable environmental conditions (Kilongo et al., 2001). The main reproductive area was speculated to be between 17 and 18°S. Although previous studies have investigated some aspects of the biology of *D. macrophthalmus*, little is known about the reproductive biology in Angolan waters.

11. Population relationship between southern right whales off Namibia and South Africa (Best; Braby; Roux)
The relationship between the right whales occurring off Namibia and South Africa is unknown. Richards and Du Pasquier (1989) speculated that the extended 19th century whaling season at the Cape reflected two stocks, one calving there and not proceeding further north, and a second stock continuing north to calve at Walvis Bay and returning later in the season. Certainly the historical catching season off Namibia (May to August) strongly overlapped the current seasonality of right whales off the southern Cape, suggesting that it was unlikely that animals moved between the two grounds in the same year (although individuals could of course have utilised the two grounds in different years). Establishing the relationship between right whales in these two regions is important to understanding the process of stock depletion and recovery in large whales. Does the current concentration of right whales at the tip of southern Africa represent range contraction of a single stock following depletion, or was the Namibian population a separate entity that underwent far greater depletion than the South African?

Right whales are individually recognisable from the pattern of wart-like callosities on their head (Payne et al., 1983). These are most easily documented through aerial photography, and in a series of annual aerial surveys since 1979, a catalogue of some 700 individual adults has been compiled for the South African region. Over 90% of these are adult females, for which average re-sighting rates each year are as high as 60-65%. Re-sightings of adult females first photographed as calves also indicate very high philopatry (>93%). This project has initiated a similar programme of aerial photography of right whales off Namibia, the results of which are compared with the South African catalogue to determine how many individuals (if any) have been photographed previously off South Africa. If a sufficiently large number of adult females can be sampled off Namibia, it should also be possible to estimate the degree of mixing with South Africa. For this reason a three-year survey programme is proposed, as this will increase the sample size and cover all three cohorts of calving females (as most right whales have a three-year calving interval).

12. Migratory behaviour, ageing and assessment of the shortfin mako shark (*Isurus Oxyrinchus*) and blue shark (*Prionace Glauca*) (H. Skrypzeck; C. Smith)
Concerns over the impact of fishing on chondrichthyan stocks around the world are currently being raised at an international level e.g. CITES, ICCAT, FAO and the Species Survival Commission of IUNC. These concerns about chondrichthians were raised due to the following facts (Bonfil, 1994; Stevens et al., 2000): vulnerability to over-exploitation, increased fishing effort; lack of regional management plan; oceanic and highly migratory nature. Both these species swim and feed together and thus are caught simultaneously by the longline vessels in a ratio of about one mako to four blue sharks. These are an increasingly targeted resource and a bicatch resource in the Benguela region. As the planned tagging cruises would be onboard vessels of the industry while on their normal fishing cruises, the optimum use of research possibilities should be made.

Although many studies related to age, biology and migration were conducted on these two species (Pratt and Casey, 1983; Heist et al., 1996; Mollet et al., 2000; Henderson et al., 2001; Kohler et al., 2002; Skomal and Natanson, 2002; Natanson, 2002); no research has been done on them in the Benguela system. According to Compagno (pers. comm.) to date there is very little known of the biology and distribution of the blue and shortfin mako sharks in the Benguela system, and he cannot recall any dedicated biological studies of these species in this area. Therefore, it is currently not possible to predict the migration, age and growth of these sharks in this area, thus constraining the assessment of these two shark stocks. The objectives are to collect and analyse data on the life history and population dynamics of the blue and mako shark; to assess the blue and mako shark stocks using population parameters derived from (1) in stock assessment models. The results would
form the basis of a co-management plan for shared sustainable harvesting of the blue and shortfin mako sharks between countries sharing this resource.

13. Hake and Dentex otolith reading validation and training. (M Wilhelm; D. Durholtz; H. Lituba)
The broad objective of this project would be to facilitate the development of regional, standardized otolith age estimation procedures for hake (*Merluccius capensis* and *M. paradoxus*) and Dentex (*Dentex angolensis* and *D. macrophthalmus*). These procedures should be appropriate for producing age information that is comparable within the region, and suitable for stock assessment purposes. The specific objectives are to develop appropriate otolith preparation methods and to train researchers in the implementation of the appropriate otolith preparation methods for the four species, to standardize and stabilize otolith interpretation criteria in order to ensure generation of comparable ageing data across the region and to generate otolith reference collections for each species.

14. Annual Stock Assessment Workshop
This is an annual event whereby stocks are selected for international peer reviewed assessments of modelling approaches and research needs of key stocks. In the past the workshops have focussed on abalone, seals, rock lobster and hake. This year the focus will be on hake and horse mackerel.

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**Research Focus 2: Environmental Studies**

**Project Descriptions:**
Environmental research in the BENEFIT programme aims to understand
- The natural environmental variability within the Benguela system
- The role of variability on the living resources of the system
- How those resources respond in space and time to the variability, thus leading to the ability to forecast shifts in stock resources and facilitate resource management

**System Types Studied:**
Benguela Current Ecosystem

**Key Questions, Hypotheses and Issues:**
- Satellite derived SST data
- SST (coastal sites)
- Sea level (coastal)
- Wind (coastal)
- Oxygen levels (cruises)
- Oxygen (moorings)
- H₂S
- Phytoplankton productivity
- Currents (ADCP)
- Currents (drifters)
- Estuaries
- Seabird breeding
- Ocean colour
- SST anomalies
- Weather model
- Nutrients
- Zooplankton productivity (cruises)
- Zooplankton productivity (moorings)
- Harmful algae blooms
- Currents (moorings)
- Thermohaline structure
- Role and dynamics of estuaries
- Seabird diet

**Participating Countries and Institutions:**
Namibia, Angola, South Africa

**Duration:**
Annual

**Budget:**
±$N2 Million (2004)
Environmental Research Agenda for 2004

1. **Implementation of effective ADCP data collection and management for oceanographic and fisheries research in the SE Atlantic (Duncombe Rae, Iita)**
   
   This project terminated in 2003, but is currently being written up for publication. In South Africa much has been learned about prevailing currents over the shelf from the systematic use of ADCP data collected on MCM research vessels. The data have been useful in interpreting fisheries data collected during these cruises, and have already been used in biophysical advection models of pelagic fish recruitment and the use of ADCP will be necessary to support 3D - physical circulation models in the future. ADCP data were collected in the region and have been incorporated into a regional ADCP database for use by participants in the BENEFIT programme. Key items addressed by the research include data management issues and an investigation of how the flow patterns influence the distribution, availability, and abundance of the key stocks in the region?

2. **Continuity and Mesoscale patterns of circulation in the Benguela Upwelling System: Phase II: (Largier, Iita, Bartholomae).**
   
   The surface circulation of the Benguela system is a critical component of the fishery environment, transporting both planktonic larvae and planktonic food for fish. Much needed in fishery and environment management in the Benguela are (i) direct observations of the surface circulation, (ii) understanding of the processes controlling surface circulation, and (iii) quantification of the dispersion of plankton transported by the surface circulation. The aim of this study has been to describe and quantify surface circulation in the Benguela ecosystem. Specific objectives are to

   - describe transport pathways;
   - address the continuity of the surface circulation;
   - identify locations of preferred onshore or offshore transport;
   - identify areas of limited exchange;
   - describe mesoscale circulation features;
   - quantify dispersion;
   - make transport data available for other environment and resource studies; and
   - provide training and collaboration opportunities in lagrangian methods.

   The project has concentrated on the Southern and Northern Benguela and will now turn its attention to areas further north beyond the Angola / Benguela currents front.

3. **Ground truthing of remotely sensed ocean colour (Barlow; Bartholomae)**
   
   This project will terminate in 2004 and will produce indices for utilization in retrospective studies. Implementation of the MODIS satellites will require further development of this project. The project goal is to use remotely sensed observations of ocean colour to explore seasonal and inter-annual variability in the Benguela ecosystem. The data has been used to build predictive models that will allow us to examine the biogeochemical responses of phytoplankton in this region to environmental change. A necessary first step in using the remotely sensed ocean colour observations is to ground-truth the data by making in-situ pigment and ocean colour measurements. This has allowed the accuracy of the pigment data derived from ocean-colour observations to be confirmed and improved. The specific objectives are to

   - Map the distribution of pigment biomarkers for ground-truthing remotely sensed ocean colour satellite data;
   - Profile pigment and in situ bio-optical properties of the water column across the SW African shelf and shelf break;
   - Integrate bio-optical and pigment data to verify and appropriately modify the ocean colour algorithms for use in the Benguela region;
   - Investigate the seasonal, interannual and spatial variation in phytoplankton biomass and composition; and
   - Investigate phytoplankton biomass dynamics at particular frontal systems and upwelling cells.
4. Application of remote sensing in the Benguela ecosystem (Barlow, Shillington, Roy, Weeks, Bartholomae)

The goal of this proposal is to utilize high resolution, 1 km, satellite data for sea surface temperature (AVHRR SST) and ocean colour (SeaWiFS) to study mesoscale upwelling events and consequent phytoplankton response in the Benguela ecosystem. Implementation of the MODIS satellites will require further development of this project. Satellite imagery now offers the opportunity of investigating the dynamic variations in upwelling and primary production that occur in the Benguela and it may be possible to derive quantitative indexes that would serve as a measure of ecosystem function for comparison with fluctuations in recruitment of exploited marine resources. If such links can be firmly established, then the use of satellite data in operational management of resources may be more widely used. The specific objectives are to

- Investigate and implement suitable algorithms for generating ocean colour products applicable to the Benguela;
- Develop indices of upwelling and phytoplankton chlorophyll distribution from AVHRR sea surface temperature and SeaWiFS ocean colour data;
- Investigate the intra-seasonal variations in SST and upwelling indexes for various biogeographic provinces of the Benguela;
- Investigate the intra-seasonal variations in pigment distribution and phytoplankton indices for various biogeographic provinces of the Benguela;
- Investigate the mesoscale dynamics of physical processes and upwelling (SST) and the phytoplankton response (ocean colour) at particular frontal systems and upwelling cells.

5. Inshore monitoring of environmental variability in the Benguela system: (Bailey, Currie, Noli-Peared)

Long-term monitoring of key environmental variables such as temperature, dissolved oxygen and products of anaerobic decomposition like hydrogen sulphide is essential in inshore areas of the Benguela upwelling system. Events such as mass mortalities of hake recruits off Walvis Bay in 1994/95 and rocklobster mortalities in the vicinity of Elands Bay in 1994 and 1997 have borne this out. The key questions for this programme are:

- What are the spatial and temporal trends in wind forcing and nearshore temperature and dissolved oxygen in the Benguela upwelling system?
- How do these parameters change during onset of ENSO or Benguela Nino conditions?
- How do these and associated environmental parameters differ between upwelling centres near Palgrave Point, Walvis Bay, Luderitz, Cape Columbine, St Helena Bay, and Elands Bay?
- What are the changes in the wind and hydrological regime at Namibe during southward passage of the Angola/Benguela front and how do these changes impact on resources?
- What are the conditions leading up to large-scale oxygen depletion in bottom waters of the Benguela upwelling system?
- What is the abundance and distribution of hydrogen sulphide in the nearshore between Walvis Bay and Swakopmund and how does this relate to other parameters being monitored?

6. Activity GTZ 2001/005.- A Namibian modelling-based case study on the biogeochemistry and dynamics of hypoxic environments in the Benguela system and their linkage to fisheries habitat suitability. (Monteiro, vd Plas, Bailey, Emeis)

This new project for FY 2002 is an outgrowth of a programme in FY 2000-2001, entitled ‘The coupling of benthic boundary layer (BBL) dynamics and biogeochemical processes in recent sediments on the Namibian Shelf in order to understand their impact on the variability of fisheries habitat suitability’, which may be construed as Phase 1 of the FY 2002 activity. This proposal has close links with NAMIBGAS, a project designed to investigate the role and source of sedimentary gases in the Namibian upwelling system. NamibGas is a component of the German-Namibian bilateral programme. The over arching hypothesis remains consistent with Phase 1 of this project: "Persistent low oxygen conditions which develop on the Namibian shelf as a result of unique physical and biogeochemical dynamics are the key constraint in habitat suitability for pelagic and demersal fish and benthic biota of the region. This hypothesis imposes an upper boundary on fish production potential along the Namibian coastline. Therefore, the fishery is not food limited but, through water quality..."
characteristics, it is environmentally constrained." This activity in FY 2002 will investigate the validity of the hypothesis using a combined modelling - measurement approach that may also serve as the mechanism to integrate the outputs from the suite of process-oriented projects that make up the H_2S initiative within Benefit 2002 - 2004. The modelling framework in this project will be based on coupled hydrodynamic (ROMS / MOM and Delft3D) and biogeochemical (Delft3D-WAQ) platforms to resolve detailed dynamics of the inner shelf with inputs (boundary conditions) from a coarser scale regional model.

7. Activity GTZ 2002/001.- Seasonal oceanography and fisheries in the Benguela current region. (Hutchings, Paim, Klingelhoefifer)

This project aims to develop comparable ship-based monitoring programs in the Benguela from the Agulhas Bank to southern Angola, in the form of routine monitoring of selected transects. These transects will be sampled on a regular basis, preferably once per month, but varying from once per three months to once per week or even once per day, depending on the nature of any detected environmental perturbations. It aims to (i) build up regional longer-term time-series, (ii) improve such monitoring by pooling the resources available in the three participating BENEFIT countries and exchanging expertise among them, and (iii) interpret environmental variability within a fisheries context by linking observed temporal and spatial changes in the environment with shorter- (seasonal) and longer-term (interannual to interdecadal) fluctuations in the respective fisheries of the region.

The key research questions are:

- What are the seasonal and interannual variations in oceanographic conditions, which are likely to affect fish recruitment strength?
- What are the likely mechanisms causing these variations?
- Are these variations likely to increase or decrease survivorship of larvae and recruits? and
- How do seasonal variations compare with historic data?

8. Activity GTZ 2002/003.- The influence hydrogen sulphide on early life-stages of commercially important marine resources (Currie, Kreiner)

The overall objective of this activity is to study the impacts of sulfide, anoxia and hypoxia on the eggs, larval and pre-recruit stages of the commercially important resources (sardine, hake, monk, horse mackerel and rock lobster). Remarkable features of the near-coastal shelf environment of the middle and northern Benguela regions are seasonally reoccurring outbreaks of sulphide. The H_2S outbreaks are suspected to have a major influence on coastal and pelagic habitats in the shelf ecosystem, because H_2S is not only a potent respiratory toxin but also leads to anoxia and hypoxia in the water column. In conjunction with experimental work, information on behaviour and distribution of the young stages will be collected. Correlations between recruitment success and the incidence and severity of hydrogen sulphide/hypoxia in the water column will be tested. The key questions to be addressed are

- What concentrations of hydrogen sulfide can eggs, larval and post-larval stages of the commercially important species tolerate?
- How does hydrogen sulfide influence hatching time, hatching success (=survival), and the formation of morphological abnormalities/deformities of the eggs?
- What are the lower limits of hypoxia that eggs, larval and post-larval stages of the commercially important species can tolerate?
- What is the critical time period for exposure of larval, post-larval and pre-recruit stages to hypoxia, anoxia and/or hydrogen sulfide? and
- To what extent, temporally and spatially, do H2S outbreaks and spawning of commercially important species overlap?

9. Activity GTZ 2002/004.- Biogeochemical dynamics of hydrogen sulfide and methane in Namibian inner shelf sediments, with implications to the living marine resources (Currie, Goosen, Buechert)

This study aims to achieve a quantification of hydrogen sulphide fluxes into the water column on an annual and interannual basis. To date no study has systematically investigated the exact mechanism and the episodic nature of the hydrogen sulphide effluxes from the inner shelf sediments. As a
consequence, it is not presently possible to predict the time of their occurrence and their spatial extent. Thus, although recognized as a potentially important mechanism for the regulation of fish stocks, hydrogen sulphide can not be included as a variable in ecological models.

To understand the role of sulphide in the regulation of marine resources an understanding of the annual and interannual variability flux regulation is required, including:

- An account of the interannual variation of bacterial sulphate reduction rates,
- The quantification of the annual sulphide fluxes across the sediment/water interface,
- The quantification and the assessment of the annual variation in methane fluxes across the sediment/water interface,
- The identification of the hydrogen sulphide sources, i.e., the depth of origin, from deep within the sediment, from the near-sediment surface, or from the water column, and
- The quantification of the sulphide-oxidizing efficiency by sulphide-oxidizing bacteria.

A dedicated cruise leg for this project took place on the RV Alexander Von Humboldt in 2004 and a PhD student has been assigned to this project based at the Max Planck Institute in Bremen, Germany.


The Orange and Kunene estuaries are wetlands of major significance along the west coast of Southern Africa. They interrupt an otherwise severely arid coastal strip, which is itself the interface between land and sea. They are in contrasting stages of development: the Orange River Mouth, despite its valuable biodiversity, requires rehabilitation as a consequence of mining and “old-style” development, whilst the Kunene Estuary is at a stage where development will be able to benefit from research and informed management. And both sites also contain the political boundaries between the countries of the region, making co-operative governance not only an option, but a necessity. The BENEFIT and BCLME programmes are well placed to assist in achieving the optimal management of these key estuaries, with sustainable benefits to all three countries served by these programmes. There are many issues that need research, in support of conservation and sustainable development, and the review and prioritisation of these should be a valuable first step. This in turn should lead on to a number of sub-projects and culminate in co-operatively derived management plans and support for their implementation.

The key questions are:

- What is our current state of knowledge and understanding of the Orange and Kunene River estuaries with regard to the following:
  - biodiversity and ecosystem functioning
  - threats to biodiversity and ecosystem functioning
  - economic activities
  - economic opportunities
- Social and legal issues
- What studies/research are needed to address the most urgent issues addressed above, ie. where is a lack of knowledge hindering our ability to understand the systems and thus our ability to make informed management proposals?
- What actions/proposals are necessary to ensure conservation of biodiversity and development of compatible economic activities?
- How can these be put into practice, either as new sub-projects or as incremental support for key ongoing initiatives?

11. The impact of the seasonal variations of the poleward undercurrent and of the cross shelf circulation on the environmental conditions of the Benguela upwelling system (Johnson, Morholtz, Da Silva).

This project is in its first year of operation and has the main goal to investigate and quantify the poleward transport of oxygen depleted but nutrient rich South Atlantic Central Water (SACW) by the undercurrent into the northern Benguela on a seasonal scale in relation to: 1. the impact of physical
forcing on the environmental conditions for the marine ecosystem, and 2. the development of harmful hydrogen sulphide outbreaks at the shelf.

Specific objectives are:

- to identify the seasonal changes in poleward transport of oxygen deficient SACW,
- to quantify the SACW content on the water masses at the shelf
- to identify the local and remote forcing of the poleward undercurrent
- to investigate the interaction between the poleward undercurrent and the wind driven cross shelf Ekman circulation.
- to investigate vertical and temporal distribution of zooplankton in relation to the environmental conditions.
- to estimate the habitat size of zooplankton at the shelf
- to provide collaboration and training opportunities in operating oceanographic moorings
PROGRAMME: ENVIFISH

Project Title:
Environmental conditions and fluctuations in recruitment and distribution of small pelagic fish stocks (ENVIFISH)

Source of Information:
Progress in Oceanography 59(2-3), 2003, ENVIFISH website, March 2004 and Leo Nykjaer, April 2004

National Representative/ Contact:
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Project Description:
Although the ENVIFISH programme was completed in 2001, it is included in this volume as it was not covered in the original GLOBEC Report on National, Multinational and Regional Programme Activities, 2001.

ENVIFISH conducted a retrospective analysis of environmental and fisheries records from 1982 to 1999. It produced a consistent and quality-controlled database of satellite products: 18 years of sea surface temperature data; 7 years of sea surface height data and 3 years of ocean colour data. These remote sensing products were augmented by the regional databases of in-situ data from ships and buoys, enhancing the spatial and temporal coverage on environmental information. Extracting relevant patterns from this vast amount of environmental data and relating it to fisheries problems necessitated a substantial degree of innovative analyses, and it is this area that ENVIFISH has made real progress.

Website:
http://www.me.sai.jrc.it/me-website/contents/contract_projects/inprogress/envifish/

System Types Studied:
Benguela marine ecosystem (encompassing the coastlines of Angola, Namibia and the west coast of South Africa).

Target Organisms:
Economically and socially important small pelagic fish

Physical Processes Examined:
Coastal upwelling

Key Questions, Hypotheses and Issues:
The main objective of ENVIFISH was to develop appropriate methodologies for improving the sustainable management of small pelagic fish based on the identification and quantification of key environmental conditions that influence fluctuations in their recruitment and distribution in the Benguela and Angolan systems.

Specific objectives of ENVIFISH were:
- To develop a consistent and quality controlled database of satellite, oceanographic and fisheries data, together with tools for analysing the data;
- To identify and quantify the key environmental features associated with, and possibly causing, the significant variability in abundance in small pelagic fish stocks in the last 15 years;
To evaluate the impact of key environmental features, such as areas of spawning and recruitment habitat, as well as processes such as concentration, enrichment and retention, on recruitment success;

To relate environmental conditions to the spatial distribution of small pelagic fish stocks;

To develop adequate training and capacity building to allow these scientific findings to be transferred to management and decision making in the African countries.

**Number of scientists and fte:**
30 scientists (15 fte)

**Participating Institutions:**
Joint Research Centre (JRC), Ispra, Italy
Instituto de Investigacao Pesqueira (IIP), Luanda, Angola
National Marine Management and Research Centre (NatMIRC), Swakopmund, Namibia
Sea Fisheries Research Institute (now Marine and Coastal Management, MCM), Cape Town, South Africa
University of Cape Town (UCT), Cape Town, South Africa
Baltic Sea Research Institute (IOW), Warnemünde, Germany
Plymouth Marine Laboratory, Plymouth, UK
Institute of Marine Research (IMR), Bergen, Norway
Food and Agriculture Organisation (FAO), Rome, Italy
Instituto de Investigacao das Pescas e do Mar (IPIMAR), Lisboa, Portugal

**Duration:**
1998-2001

**Budget:**
1 M EURO of which 750k EURO from the funding agency and 250k EURO of own funds

**Funding Agency:**
European Commission International Co-operation Developing Countries programme
**PROGRAMME: IDYLE**

**Project Title:**
Interactions and Spatial Dynamics of renewable resources in upwelling Ecosystems

**Source of Information:**
Dr Pierre Freon, April 2004 and IDYLE website, January 2004

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**Project Description:**
The scientific focus of the programme is to understand how the adaptive strategies of the different species of fishes and their dynamics are structured by the presence of inshore upwelling and the resulting ecosystem patterns. We focus on the meso-scale dynamics of the environment, reproductive strategies, spatial strategies (macroscale) and on pelagic fish aggregation, as well as on trophic strategies within the framework of ecosystem dynamics. The knowledge of these adaptive strategies has natural applications to the sustained development and viability of fisheries.

The programme is based and developed in the Benguela ecosystem where important knowledge has been accumulated. It makes use of generic tools in order to allow the fast transfer of the methodology and results to other areas. It is a follow-up of the VIBES project (Viability of exploited pelagic fish resources in the Benguela Ecosystems in relation to the environment and Spatial aspects, 1997-2000), primarily directed towards coastal pelagic resources and their management. Training constitutes a major aspect of this programme at both bilateral (France / RSA) and regional scales.

IDYLE is a collaborative programme between IRD (Institut de Recherche pour le Développement), M&CM (Marine and Coastal Management; Department of Environmental Affairs and Tourism), UCT (University of Cape Town) and other universities / institutes in the region. IDYLE is funded by those institutions and additional French funding. IDYLE is closely associated with the Benguela Ecology Programme (BEP-V) and affiliated to the BENEFIT and BCLME regional programmes.

**Website:**
http://sea.uct.ac.za/idyle/index.html

**System Types Studied:**
Benguela current ecosystem

**Target Organisms:**
Pelagic fish

**Physical Processes Examined:**
In-shore upwelling

**Key Questions, Hypotheses and Issues:**
As a result of the multi disciplinary focus of IDYLE, we implemented different models of dynamic representation of an ecosystem in order to better understand the impact of: (1) the spatial structuring of the environment on the dynamics of populations; (2) interspecific relationships within the ecosystem; (3) the spatio-temporal structuring on the management of exploited resources. The IDYLE programme is subdivided into five scientific projects:

- 3D-hydrodynamic modelling of the physical processes related to the transportation and the retention of eggs and larvae
• IBM modelling of the coupling between the recruiting processes and the dynamics of the environment (in collaboration with the GEODES programme)
• Trophic modelling of the spatio-temporal dynamics of populations and definition of ecosystem indices
• GIS approach of interactions in an exploited pelagic ecosystem
• Retrospective analysis of the determinism of the recruitment and the spatial dynamics

**Number of scientists and fte:**
11 French scientists (9 from IRD full time and 2 from LPO part-time) and 12 South African scientists and 1 Namibian scientist.

**Participating Institutions:**

**Links with partners from the southern hemisphere**
The main partners of this programme are:
- Research component of Marine & Coastal Management
- Oceanography Department of the University of Cape Town
A specific agreement was signed between those different institutes at the end of 1997 and renewed end of 2002. The secondary partners are:
- Zoology Department of the University of Cape Town
- Geography Department of the University of the Western Cape
- NatMIRC Laboratory of the Ministry of Fisheries and Marine Resources of Namibia
- Institute of Marine Research of Angola
The Research Unit is affiliated to the BENEFIT and BCLME Programmes, which integrate research from the three countries of the Benguela region.

Other partners from southern regions, outside of the study area, have lately shown a particular interest in this programme and some collaborative work has been undertaken:
- University of Concepción and the Fisheries Institute (IFOP), Chile
- University of Concepción, Chile
- Peruvian Institute of the Sea (IMARPE), Peru
- Other laboratories from tropical upwelling regions through the SPACC network of GLOBEC;
  School of Aquatic Sciences of Chile, National Institute on Fisheries Research of Morocco (INRH)

**Links with partners from the northern hemisphere (except those related to our establishments)**
- IFREMER, University of Brittany (LPO) and other French laboratories through the PNEC
- University of British Columbia
- FAO
- ENSAR (National School of Agronomic of Rennes), Fisheries Department
- Biomathematical Laboratory of the Universities Paris VI and VII
- Centre for Biological Studies of Chize
- Institute of Marine Research of Bergen (Norway)
- Laboratories of northern countries with upwelling areas through the SPACC network of GLOBEC
  (to which IDYLE is affiliated): USA, Spain
- Joint Research Centre (JRC) of the European Union, and more specifically the Space Application Institute of Ispra (Italy), with which we have close connections through our now official collaboration with the European Programme ENVIFISH
- Several projects within the Large Marine Ecosystems of the East Atlantic Ocean
- Ecology Laboratory of the University of Paris VI
Duration:
2001-2004 for the first phase. A second phase (2005-2008) proposal has been submitted which will give more emphasis to the comparative approach between upwelling ecosystems (mainly the Benguela Current, the Humboldt Current and the Canary Current).

Budget:
Around 100 k€ per year excluding salaries and routine data collection.

Funding Agency:
IRD (Institut de Recherche pour le Développement)
M&CM (Marine and Coastal Management; Department of Environmental Affairs and Tourism), UCT (University of Cape Town)
PNEC (French national project)
FSP (special fund of the French Ministère des Affaires Etrangères)
SCOR/IOC
The LIFECO programme was completed in 2003, for further details please see the Report of the GLOBEC National, Multinational and Regional Programme Activities, 2001. GLOBEC Special Contribution No.4, p.98-102.
Programme: NATFISH

Project Title:
Natural variability of a coastal upwelling system and small pelagic fish stocks (NATFISH)

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Project Description:
The objective is to analyse and quantify the influence of the natural variability of the Northwest African upwelling system on the abundance and distribution of small pelagics. The study will:

- compile relevant environmental, biological, and fisheries data into a distributed database together with tools for analysing the data;
- identify and quantify environmental variability relating to significant changes in abundance and distribution in small pelagic fish stocks;
- model different environmental situations and their consequences on key processes influencing successful recruitment and fish distribution;
- investigate the potential of using models as a tool for suggesting precautionary measures to be incorporated into responsible fisheries management strategies;
- develop adequate training and capacity building for African scientists and managers to properly understand natural environmental variability and its significance for fisheries management.

The project is carried out as a retrospective analysis of environmental, biological and fisheries data with focus on the decade 1990 to 2000. The different activities consist of:

- A documentation of the environmental variability associated with the major changes in fish population for three case studies;
- An investigation of upper ocean dynamics through application of an existing hydro-dynamic model;
- An examination of the influence of oceanographic key parameters on the distribution and biology of small pelagics;
- To establish to what extent some of the environmental changes can effectively be monitored and how their effect on the fishery resources can be forecasted.

System Types Studied:
Coastal upwelling system

Target Organisms:
Sardines, sardinella, chub and horse mackerel

Physical Processes:
Coastal upwelling

Participating Institutions:
Joint Research Centre (JRC), Ispra, Italy
Institute of Marine Research (IMR), Bergen, Norway
Institut National de Recherche Halieutique (INRH), Casablanca, Morocco
Institut Mauritanien de Recherches Oceanographiques et des Peches (IMROP), Nouadhibou, Mauritania
Centre de Recherches Oceanographiques de Dakar-Thiaroye, (CRODT), Dakar, Senegal
Number of Scientists:
15 – 20

Duration:
01.01. 2002 – 31.12.2004

Funding Agency:
European Commission INCO-DEV programme

Budget:
590000 EURO
**PROGRAMME: OFCCP**

**Project Title:**
Oceanic Fisheries and Climate Change Project

**Source of Information:**
Patrick Lehodey, November 2003

**Representative/ Contact:**
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**Project Description:**
The Oceanic Fisheries and Climate Change Project (OFCCP GLOBEC) will investigate the effects of climate change on the productivity and distribution of oceanic tuna stocks and fisheries in the Pacific Ocean with the goal of predicting short- to long-term changes and impacts related to climate variability and global warming. The project should lead to the first tentative understanding how greenhouse warming will affect, at the ocean and global scales, the abundance and productivity of marine populations in the pelagic ecosystem, focusing on the major exploited species and fisheries, by a real coupling between atmospheric, oceanic, chemical and biological processes. Potential feedbacks from the changes in the pelagic ecosystem, and socio-economical consequences will be investigated to propose adaptation measures for the future.

However, analyses of simulations based on retrospective series of oceanic and fishing data sets (hindcast simulations) are necessary intermediate steps to increase the reliability in the predictive capacity of the models. In particular, realistic prediction by the models of changes and fluctuations observed at short (e.g. ENSO) and decadal (e.g. Pacific Decadal Oscillation, PDO) time scales in the ocean ecosystem and the tuna populations are necessary before prediction based on the global warming projection are incorporated. In addition, diverse studies are needed to improve the parameterization (e.g. energy transfer from primary to secondary production), the modelling of key processes (e.g. recruitment, movements, and feeding), and to validate the results of the simulations. Four major components have been identified to achieve these objectives: (i) monitoring the upper trophic levels of the pelagic ecosystem, (ii) food web structure in pelagic ecosystems, (iii) modelling from ocean basin to individual scale, and (iv) socio-economical impacts.

**Website:**
http://www.spc.int/OceanFish/Html/GLOBEC/index.asp

**System Types Studied:**
Tropical to sub-temperate pelagic ecosystems of the Pacific Ocean

**Target Organisms:**
*Tuna and associated species.*

Tunas are highly migratory pelagic fishes inhabiting all the world’s oceans from temperate to equatorial regions. Although most tunas are spawned in tropical waters, general biological characteristics and habitat ranges of the adults vary among species. It is convenient to classify tuna species as tropical tunas (skipjack and yellowfin), subtropical tunas (bigeye and albacore) and temperate tunas (northern and southern bluefin). High fecundity is characteristic of all tunas, with females spawning millions of eggs per year in multiple batches. Tropical tunas spawn over wide areas, while the temperate bluefin tunas have relatively discrete spawning grounds. As adults, tunas are high-level predators, a trophic position that may have important implications on ecosystem stability.
Physical Processes Examined:
Basin-scale circulation and oceanographic features
Meso- to small scale physical processes (e.g. eddies, fronts, vertical structures) affecting the dynamics of individuals and schools of tuna

Key Questions, Hypotheses and Issues:

1. Monitoring the upper trophic levels of the pelagic ecosystem
The past decade has generated significant progress in understanding ocean processes and the coupling of ocean and atmosphere in regulating Earth’s climate. These accomplishments were made possible by the concurrent development of new technology and instrumentation, as well as substantial progress in numerical modelling (ocean general circulation models and new conceptual models of lower trophic level food webs). Despite the increase complexity when considering all the pelagic ecosystem, a similar approach, closely associating observation and modelling, seems the most appropriate to investigate the dynamics of upper trophic levels (from macroplankton to higher predators). However, while there has been substantial progress in acoustical technology or individual electronic tracking devices, the instrumentation allowing large-scale and long-term recording of key upper trophic components is still missing. One of these key components is the micronekton for which there is relatively little information. Comparatively, there is much more information on large pelagics (the predators of the micronekton) that are usually valuable exploited species. The fisheries for these species provide key information (catch, size) allowing population dynamics models to predict the population biomass, and eventually their spatial distribution, especially where large scale tagging programmes have been carried out for these valuable species. Therefore, while climate change concerns as well as recent ecosystem-based management requirements necessitate rapid development of numerical ecosystem models, we have only a very preliminary idea of the biology, ecology and dynamics of the intermediate key components of the pelagic food web. Indeed, there are not even enough observations to produce a mean spatial distribution of the micronekton biomass at the scale of ocean basins.

It is proposed to use existing technologies, and also to develop new instrumentation for monitoring the upper trophic levels of the pelagic ecosystem. Observation will combine both extensive studies at ocean basin-scale and intensive studies in some sub-areas and key sites. Extensive studies aim at building ocean data sets for micronekton biomass and large pelagics biomass or individual records, using acoustic (micronekton biomass), sonar (tuna biomass), and electronic tracking (individuals) devices. Intensive studies will focus on important processes and behaviour (e.g. prey-predator interaction, habitat, schooling and aggregation of tunas, reproduction, composition and dynamics of micronekton, etc). In addition, at each scale of observation there will be a corresponding modelling development, e.g. large-scale ecosystem, population models or individual-based models. Observations will be used to parameterize and improve the models. Eventually, models could provide real-time prediction for operational activities at sea, and help in the validation of dynamic processes or hypotheses arising from model simulations.

2. Food web structure in pelagic ecosystems
Production at higher trophic levels (usually exploited species) depends on the production at lower levels (bottom-up control) and may be modulated by the physical forcing and the structure of the marine food webs. Ecological concepts suggest for instance that the structure of the food web can be controlled by the biodiversity within the system and/or by higher predators (top-down control). However, concerning pelagic ecosystems, there is very little observation to illustrate such controls. In association with the data collected by the monitoring component of this project, it is essential for modelling the pelagic ecosystem to identify the functional groups, how energy and matter flow through these groups and how they are affected by physical and biological changes as well as by human activities (fisheries).

Two kinds of analyses will be helpful in this task. A classical approach based on the study of stomach contents to establish the prey-predator interactions, and the more recent isotope-ratio approach, that appears a promising way for describing the energy transfer through the food web. The success of these approaches also relies on the multiplicity of studies in different regions of the ocean(s) and in different periods of time. The comparative study necessitates developing standardized protocols, reference databases and controlled laboratory experiments. Retrospective analyses based on the
numerous diet studies published or still in archives of many institutes should be also encouraged. Information obtained from these studies and from the monitoring will be used in individual energetics models (IBM), mass-balance models (ECOPATH-ECOSIM) and spatial ecosystem models (SEPODYM).

3. Modelling from ocean basin to individual scale
Close association between observation and modelling has been a permanent guide in conceptualization of this project. Recognizing the diversity of space-time scales processes overlapping in pelagic ecosystem dynamics, a second key idea is that a general framework is needed to integrate studies at different time and space scales with potential connections between them. There is a large range of models represented in the project covering global to individual scales. At global or basin scales, predictions from three different coupled physical-biogeochemical models will be used over the period 1950-present. The global model will also provide predictions for the next century using a scenario of greenhouse warming. These predictions will be used to run the ecosystem models of upper trophic levels on which the economical and social analyses rely. At least one of the physical-biogeochemical models should provide prediction at high resolution in one or a few identified sub-regions (first step for a nested model approach) where intensive process studies are conducted. A similar approach will be investigated for the spatial ecosystem models. This would allow connections between large and small scales (low and high frequencies) processes and testing the mechanisms that control the system when moving from one scale (frequency) to the other.

4. Socio-economical impacts
The interannual climate variability due to ENSO events has important socio-economic impacts on tuna fishery and industry at the global scale, which in turn may affect the tuna populations (e.g. higher/lower catch) and the pelagic ecosystem (by-catch, interaction between species, top-down effects). Several causes drive the fluctuations of tuna stocks and catches. While economic rather than biological reasons limit (today) the catch increase of the most productive tuna species (skipjack) in the Pacific, the intense fishing effort on the highly valuable bluefin tuna, perhaps combined with environmental forcing, has led to a decline in this population from the 1960’s to the eighties. Interactions amongst species and between the multiple and diverse fisheries, as well as potential cascade effects in the ecosystem raise important questions for management with potential strong socio-economic repercussions. Based on spatial model developed for investigating optimal spatial allocation of fishing effort, new studies will include climate variability to obtain information on alternative scenarios regarding the interannual as well as spatial variability of fish stocks. A key issue will be in classifying alternative scenarios of climate change that could be translated into the spatial and temporal distribution of fish species, as well as their movement. Other issues that will need to be modelled include multiple fleets with different efficiency characteristics, and the presence of fishing vessels from multiple political jurisdictions, that will imply different costs of fishing through differences in material and labour costs. The presence of multiple countries will allow the use of strategic behavioural models. For instance, Nash Equilibria could be calculated for regions that are subject to fishing by multiple countries. These results could be compared to optimal outcomes under single ownership of the fishery and the impacts of feasible management measures could be simulated.

Investigations of these interactions and effects occurring with ENSO would help to assess the vulnerability and impacts in a scenario of global warming, and to eventually propose adaptations and/or mitigation measures for the future.

Number of scientists and fte:
On-going or planned studies currently involve scientists from two international bodies (SPC and IATTC) and from institutions listed below.

Participating Institutions:
Two regional organisations are involved in OFCCP: the Secretariat of the Pacific Community (SPC) that is an international development organisation serving the Pacific Islands, and the Inter-American Tropical Tuna Commission (IATTC).

SPC has 27 member countries: 22 Pacific Island countries and territories (American Samoa, Cook Islands, Federated States of Micronesia, Fiji Islands, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn
Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Wallis and Futuna) and 5 funding countries (Australia, France, New Zealand, the United Kingdom and the United States of America).

IATTC has 12 member countries: Costa Rica, Guatemala, Panama, Ecuador, Japan, United States of America, El Salvador, Mexico, Vanuatu, France, Nicaragua, Venezuela.

In addition, scientists from the following institutions are involved or have shown strong interest in developing collaboration through OFCCP: CSIRO (Australia), Institut Pierre Simon Laplace (France), NIWA (New Zealand), National Fisheries Research and Development Institute of Philippines, Institute of Oceanography of National Taiwan University (Taiwan ROC), University of Hawaii, the Pelagic Fisheries Research Program of the University of Hawaii, University of Maine, University of Maryland, NOAA National Marine Fisheries Service (USA), the Ocean Research Institute University of Tokyo (Japan), the National Research Institute of Far Seas Fisheries (Japan), and Hanoi University of Science (Vietnam).

Duration:
Not fixed, though limited by the termination of GLOBEC (2009).

Budget:
No estimation available as the project is relying on many different existing self-funded programmes.

Funding Agency:
Studies are funded through collaborations with the institutions involved and by developing new funding proposals. In 2002, the Pelagic Fisheries Research Program of the University of Hawaii has funded three new studies directly relevant to OFCCP.
**PROGRAMME: SARDYN**

**Project Title:**
SARDine DYNamics and stock structure in the North-east Atlantic (SARDYN)

**Source of Information:**
Instituto Español de Oceanografía (IEO)

**National Representative/ Contact:**
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**Project Description:**
The principal objective of this project is a comprehensive study of the life history and structural dynamics of the sardine (*Sardina pilchardus*) in Atlantic European waters with an emphasis on the factors required for improvement of the assessment and management of this species. The study will lead to the modification/extension of existing assessment models or to the development of a new model based on biologically defensible definitions of the stock boundaries and an adequate description of the sardine dynamics within the stock area. The objective will be achieved by establishing a multi-disciplinary team to study the stock structure of sardine in the North-East Atlantic, to describe the sardine dynamics in relation to the environment and finally to integrate the above results in appropriate analytical assessment methods.

**System Types Studied:**
Oceanography and fishing resources

**Target Organisms:**
*Sardina pilchardus*

**Physical Processes Examined:**
Upwelling, buoyant plumes, poleward flows

**Key Questions, Hypotheses and Issues:**
- Identification of current spawning grounds and seasons of the sardine in the North East Atlantic.
- Description of sardine spawning dynamics by the comparison of historical and recent information.
- Description of sardine morphometric and genetic variability of sardine in Atlantic waters of continental Europe and comparison with the extremes of the species distribution (Azores, Morocco, Celtic Sea, Aegean Sea).
- Analysis of evidence of seasonal and inter-annual fish movements from historical catch, survey and tagging data, with an emphasis on the current stock unit area and its boundaries.
- Testing hypotheses on the mechanisms relating sardine spawning/adult distribution to environmental conditions.
- Development of analytical assessment model specific for the NE Atlantic sardine, throughout the analysis of models that provides estimates of population parameters by area, as well as for the entire distribution of the population, and that could take into account migration and more than one distinct stock.
Number of scientists and fte: 39

Participating Institutions:
Instituto Nacional de Investigação Agrária e das Pescas (INIAP-IPIMAR), Portugal
Instituto Espagnol de Oceanografia (IEO), Spain
Institute of Marine Biology of Crete (IMBC), Greece
Marine Biological Association (MBA), UK
Institute of Marine Research (IMR), Norway
Centre National de la Recherche Scientifique (CNRS), France
Instituto Tecnológico Pesquero y Alimentario (AZTI), Spain
Centre for Environment, Fisheries and Aquaculture (CEFAS), UK

Duration:
36 months (Started: December 2002)

Budget:
1,209,726 Euro (Portugal), 748,762 Euros (Spain)

Funding Agency:
European Commission
PROGRAMME: TASC

The TASC programme ended in 1999, for details of past projects see Report of the GLOBEC National, Multinational and Regional Programme Activities, 2001. GLOBEC Special Contribution No.4, p.41-44.
The Regional Programmes address basin scale research that could not be carried out by a single country. At present GLOBEC has six active regional programmes: Cod and Climate Change (CCC), coordinated through ICES, Climate Change and Carrying Capacity (CCCC), driven by PICES, Southern Ocean GLOBEC (SO-GLOBEC), Small Pelagic Fish and Climate Change (SPACC), Ecosystem Studies of Sub-Arctic Seas (ESSAS) and Climate Impacts on Oceanic Top Predators (CLIOTOP). Each of the programmes has a different structure and the format of the entries reflects this.

The general objective of CLIOTOP is to organize a large-scale worldwide comparative effort aimed at identifying and elucidating the key processes involved in open ocean ecosystem functioning. In particular, CLIOTOP aims at determining the impact of both climate variability at various scales and fishing on the structure and function of open ocean pelagic ecosystems and their top predator species. Ultimately, the aim is to develop a reliable predictive capability of the dynamics of top predator populations and ecosystems that combine both fishing and environmental effects.

The Ecosystem Studies of Sub-Arctic Seas (ESSAS) program addresses the need to understand how climate change will affect the marine ecosystems of the Sub-Arctic Seas and their sustainability. ESSAS will investigate the connection between climate-forced changes in physical aspects of the marine environment and the responses of the biota in the Sub-Arctic Seas.

The central question being investigated by the ICES/GLOBEC Cod and Climate Change program is the effect of climate variability on cod stock fluctuations. The programme is designed to advance the understanding and prediction of variability in fish stock recruitment, both in the short term (annual forecasts) and in the long term (“climate effects”).

PICES/GLOBEC Climate Change and Carrying Capacity programme addresses how climate change affects ecosystem structure and the productivity of key biological species at all trophic levels in the open ocean and coastal North Pacific ecosystems. There is a strong emphasis on the coupling between atmospheric and oceanic processes, their impacts on the production of major living marine resources, and how they respond to climate change on time scales of seasons to centuries.

The SO GLOBEC programme is focused on understanding how physical forces influence population dynamics and predator-prey interactions between key species. Special efforts will be made to study the little-known over-wintering strategies of zooplankton and top predators. In this report an overview of the Southern Ocean programme is given and the field activities of the United States, Germany and the International Whaling Commission are detailed. Australia, Japan, Korea and the United Kingdom are each planning their participation in the SO GLOBEC programme but details of their activities have not yet been finalised.

The SPACC programme aims to understand and ultimately predict climate-induced changes in the fish production of marine ecosystems. In this report, the aims of SPACC and its research are
described. Details of national contributions to SPACC can be found in the National Programmes Section.

Further information on all of the programmes can be found in the GLOBEC Implementation Plan and from the GLOBEC website, www.globec.org.
**PROGRAMME: CLIOTOP**

**Project Title:**
CLimate Impacts on Oceanic TOp Predators

**Source of Information:**

**National Representative/ Contact:**
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**Project Description and Objectives:**
The general objective of CLIOTOP is to organize a large-scale worldwide comparative effort aimed at identifying the impact of both climate variability (at various scales) and fishing on the structure and function of open ocean pelagic ecosystems and their top predator species by elucidating the key processes involved in open ocean ecosystem functioning. The ultimate objective is the development of a reliable predictive capacity for the dynamics of top predator populations and oceanic ecosystems that combines both fishing and climate (i.e. environmental) effects.

These objectives require an approach involving research teams currently working in process-oriented projects which address the mechanisms linking physical forcing, zooplankton production, prey abundance and distribution, and top predator physiological, behavioural and population ecology. The work will therefore require cross-disciplinary studies by modellers involved in climate, physical and biogeochemical oceanography, and individual, population and ecosystem dynamics.

To be able to conduct standardized worldwide comparative analysis, homogeneous comprehensive records of climate variability, ocean and atmospheric circulation changes and related regional and local environmental changes will be used. Parts of such records are already available in several research centres and are being used by various scientists. CLIOTOP should serve to improve the availability of these data sets to the ocean and fisheries sciences communities, and to encourage incorporation of historical archived data. This should provide a unique opportunity to synthesize long-term fisheries data over the last 50 years (i.e. the industrial fishing era) and yield an unprecedented framework for comparative studies.

Integrative process-oriented studies (including retrospective analysis, field experiments, survey and monitoring) in a comparative framework are a key objective. In this respect, a strong modelling component is also fundamental for CLIOTOP. This will include a range of models of different complexity from simple box models, through more detailed energy budget and behavioural models to spatially explicit ecosystem models driven by OGCMs. The validation of ongoing ocean modelling and the development of more realistic models is a prime objective.

CLIOTOP is aimed at improving understanding of ocean top predators in their ecosystem. However, its successful implementation might have a significant impact on the management of the very important fisheries that exploit tunas and tuna-like species. These fisheries are managed by international organizations, which rely on international scientific consensus in understand the dynamics of the
populations they exploit. A comparative project such as CLIOTOP, by improving understanding will provide the basis for a better fisheries management.

CLIOTOP should develop strong interactions with the already existing multi-national GLOBEC project OFCCP (Oceanic Fisheries and Climate Change Project) that shares common general objectives, but is limited to the Pacific Ocean. It is believed that the CLIOTOP comparative approach between the three oceans will bring a major additional value to the research developed in each ocean separately. In addition, given the complex nature of its foci, the CLIOTOP program strongly encourages co-operation and exchange with other IGBP programs such as SOLAS, GAIM and IMBER as well as WCRP programs such as CLIVAR, the SCOR affiliated CoML project (CMarZ, TOPP, SEAMAP, MAR-ECO and FMAP), and the International Human Dimensions Programme on Global Environmental Change (IHDP). Being able to make use of the tools and expertise provided by those international programs will be crucial for an effective “open sea” project.

**Duration:**
2004-2009 (first phase)

**Key Questions, Hypotheses and Issues:**
Many scientific questions are relevant to CLIOTOP objectives. They can be classified according to the following three general foci:

1. **Processes**
   a) How are the adaptive strategies of the different species structured at the different time-space scales of environmental variability?
   b) How do adaptive processes interact? Can we predict their changes in relation to climate forcing?

2. **Responses**
   a) What are the respective impacts of climate variability and fishing on the structure and functioning of high-sea pelagic ecosystems?
   b) Are ecosystem dynamics well defined, i.e. abilities of ecosystems to respond to continuously changing forcing, from climate and fisheries, particularly regime shifts and global synchronies? What is predictable, what is not?
   c) What should be measured and monitored to maintain “status information” on individual species, and the larger ecosystem(s)?

3. **Management of top predator species and ecosystems in a context of climate variability**
   a) How might both socio-economic strategies/behaviours and ecosystem dynamics be addressed by management within the context of climate variability and change?

To answer these questions, two main integrated program thrusts are envisioned:

1. to evaluate the impact of both fishing and climate variations on marine ecosystems inhabited by open ocean top predators by analyzing and comparing long-term data series, ocean/atmosphere and biogeochemical reanalyses, field observations, *in situ* and laboratory experiments and measurements;

2. to use modelling and extensive simulations in a comparative framework to deduce and understand the dynamics of the ecosystem and its dependent resource populations, leading toward development of next-generation models which embody a high degree of realism and predictive skill. Models will help in identifying the main processes of the system (those indispensable for realistic predictions) and how they interact together.

Comparing various species, regions and ecosystems by searching for regularities and differences is of fundamental importance because universal patterns would reveal common principles underlying the organization of ecosystems and their response to climate forcing.
**Organisation and Working Groups**

CLIOTOP is organized around five flexible “easy-to-manage” working groups focused on key processes and scales to be studied (Fig.1):

- WG 1 Top predators larval ecology and biology
- WG 2 Physiology, behaviour and distribution of top predators (including spawning grounds)
- WG 3 Trophic pathways in the open ocean pelagic ecosystem
- WG 4 Integration (physic and biology) and prediction of ecosystem states
- WG 5 Socio-economics

Working groups are related by crosscutting issues and forcings.

Each working group will organize workshops and meetings focussed on precisely defined aspects, and more general meetings and symposia will bring together all the working groups. Typically, each working group is expected to have at least one workshop for implementation and one for the synthesis work. Intermediate workshops will be organized as necessary and according to opportunities and funding availability.

![Figure 1. Organization of CLIOTOP working groups, cross-cutting issues and forcings](image)

Each working group is organized around a set of key questions relevant to CLIOTOP’s objectives, and a set of strategic approaches to address those questions:

**WG 1 Early life history**

**Key scientific questions:**

- What environmental characteristics define spawning areas and the timing and intensity of reproduction?
- What environmental and biological characteristics most influence larval survival?

**Approaches:**

Laboratory experiments  
Field studies  
Comparative analysis  
Modelling
WG 2 Physiology, behaviour and distribution

Key scientific questions:
- To what extent does spatial dynamics result from proximate cues?
- How does school size, fidelity and species migration vary in relation to climate variability and change?
- What determine the time and place of reproductive and feeding-related behaviour?
- How do anthropogenic forces such as fishing interact with environmental impacts on the distribution and population structure?

Approaches:
Laboratory experiments (physiology) Field studies: archival tagging, acoustic tracking, direct census...
Retrospective and comparative analyses
Biophysical analyses (e.g. use of oceanographic information) and integration with behaviour Modelling

WG 3 Trophic pathways in open ocean ecosystems

Key scientific questions:
- What are the main trophic pathways of oceanic top predators and how do they differ among and within oceans?
- Is there evidence of change in trophic pathways over time and space consistent with climate variability – can seasonal and spatial variability be used to explore the impacts of climate variability?
- What is the spatial distribution of forage organisms and how does hydrodynamics drive this from small to large scales? What is the impact of climate variability on this distribution?
- Is it possible to identify indicators, such as prey species or size spectra, that would highlight significant changes in trophic pathways?

Approaches:
Diet analysis, Stable isotope analyses
Automated acoustical methods
Data recovery, retrospective and comparative analyses
Modelling

WG 4 Synthesis and modelling

Key scientific questions:
- What is the relative importance of fisheries exploitation and the dynamic environment in structuring pelagic ecosystems?
- Does any one mechanism (e.g. match/mismatch) explain observed variation across species, trophic pathways, regions, etc.? Do alternative mechanisms have equally good explanatory power? Which mechanism(s) provide the greatest predictive capabilities?
- What alternative states occur in historical pelagic ecosystem records, how might they be characterised (e.g. can they be described by indicators), how might they be caused, what are their consequences, and are they reversible, given that the climate changes continuously?
- Does knowledge about environmental forcing and the nature of fisheries (e.g. the species composition of the catch, growth variability, egg production rates by size/age) suggest an optimum allocation of fishing activities?

Approaches:
Use of existing observational databases in conventional models and development of new models.
Comparative analyses of models (several models for one case study/one model for several case studies)
Wide range of models from very simple models to large scale ecosystem models coupled to OGCM and biogeochemical models.
Retrospective analyses.
WG 5 Socio-economics; management strategies

Key scientific questions:

- What are the socio-economic pressures on, and context of, tuna fisheries?
- How have fisheries organizations (whether local, national, regional, or international) addressed climate change issues?
- What are the flows in capital and knowledge among the World’s large fisheries and how do they respond to variability?
- Can we evaluate how useful are the fisheries management decision support tools developed by WG4?

Approaches:
Surveys and interviews of diverse cultural fishing groups
Case studies, local, regional, and basin wide
Retrospective and comparative analyses, i.e. product usage, market changes, technology changes, etc.
Modelling

Website:
http://www.pml.ac.uk/GLOBEC/Structure/RegProgs/cliotop/cliotop.htm

System Types Studied:
Open ocean pelagic ecosystems

Target Organisms:
Open Ocean apex predators

Participating Institutions/ Projects at present:

APCP-EA, contact James F. Kitchell, Univ. of Wisconsin, Madison USA;
- APCP-EA: Apex Predators in the Central Pacific: An Ecosystem Approach
- Trophic interactions in the central north Pacific ecosystem.
- Modelling analyses at three scales: bioenergetics of individual fish species, predator-prey interactions and ecosystem models.
- Experimental Approach to Modelling.
- Modelling to Include Environmental Drivers.
- Bycatch and Ecological Interactions.

AZTI tuna section, contact Haritz Arrizabalaga, AZTI Fundazioa, Sukarrieta, Spain
- New environment dependent stock-recruitment relationships for albacore (in collaboration with ULPGC).
- Relationship between bluefin tuna catch rates and environmental conditions in the Bay of Biscay.
- Relationships between albacore recruitment and oceanographic conditions in the spawning areas and migration paths.

CCORS, contact Gary D. Sharp, Monterey, USA.

CSIRO, contact John Gunn, CSIRO, Australia.

ERL-NEA, contact Molly Lutcavage, Boston, USA.
- Movements and behaviour of large pelagics in relation to their environment.
- Large scale deployment of popup archival sat tags on BFT.
- Regional and Atlantic-wide BFT movements in relation to SST, primary productivity, and ocean frontal systems.
- Movements of whale sharks in relation to prey/and frontal systems in the Indian Ocean.
ESSIC, contact Raghu Murtugudde, ESSIC, USA
- OGCM models, process study.
- Bio-geochemical numerical models.

IATTC, contacts Robin Allen, Rick Deriso, Martin Hall, IATTC, USA

IPSL, contact Patrick Monfray CNRS, France

IFREMER-CLS, contact Jean-Marc Fromentin, IFREMER, Sète, France.
- Description of the spatial dynamics of Atlantic bluefin tuna population in relation to environmental variations (especially to the mesoscale hydrological structures).
- Confrontation of the outputs of an individual based model (IBM) of bluefin tuna behaviour with pop-up archival information.

IRD-ACTIVE, contact Pascal Bach, IRD Sète France.
- Vertical behaviours of large pelagic fishes, occupation of the pelagic habitat.
- Aggregative behaviour of tropical tunas.

IRD-THETIS, contact Francis Marsac IRD la Réunion, France.
- Leading mechanisms in the ecosystems controlling the distribution of a highly migratory resource.
- Joint effects of the environment and the exploitation on the structure and dynamics of high seas pelagic ecosystems.
- Trophodynamics of the high seas pelagic ecosystems.
- Effects of the aggregation around drifting floating objects on tropical tuna biology.
- Modelling environmental variability effects on spatial dynamics of tuna populations.

LODYC, contact Olivier Aumont, LODYC, Paris, France.
- OGCM models (OPA), process study.
- Bio-geochemical (N-P-Z-D-DOM) numerical models.

NMFS-Honolulu Laboratory, contact Jeffrey Polovina, NMFS, Hawaii, USA.
- Impacts of interannual and decadal climate variation on marine fisheries and ecosystems.
- Applications of satellite remote sensing and ocean circulation models to fisheries and protected species research.

NMFS-Miami, contact William J. Richards, NMFS, Miami, USA.
- Analyze long term data sets to relate ocean climate events to fish population fluctuations.
- Focus on early life history stages that precede any fishing mortality.

NMFS-Pacific Fisheries Environmental Laboratory, contact George Watters, USA.
- Data products and services (oceanography, fisheries, environment)
- How ocean conditions influence the production of marine resources?
- Modelling ecosystems taking into account environmental forcing on population dynamic.
- Describing and understanding the processes driving environmental variability on a variety of scales.

NRIFSF, contact Ziro Suzuki, Shimizu, Japan.
- Interactions between recruitment of major tunas and oceanographic and/or climate changes.
- Relation between migratory patterns of tunas and environmental conditions.

OFP-SPC, contact John Hampton, SPC, Nouméa, New Caledonia.

OFCCP, contact: Patrick Lehodey, SPC, Nouméa, New Caledonia.
- Monitoring the upper trophic levels of the pelagic ecosystem.
- Food web structure in the pelagic ecosystem.
- Modelling from ocean basin to individual scale.
- Socio-economic impacts.

**PFRP**, contact John Sibert, University of Hawaii, Honolulu, USA.
- Models which integrate individual and population scale variability.
- Incorporation of tagging and tracking information into population models.

**RSMAS-CSF**, contact: Robert K. Cowen, Miami, USA.
- Billfish spawning, early life history dynamics and nursery habitats.
- Environmental conditions required for spawning and early survival.
- Seasonally-resolved understanding of the annual cycle of billfish spawning, larval growth, feeding, and transport within the complex environment of the Straits of Florida (Atlantic Ocean).

**SCRIPPS**, contact Arthur J. Miller, USA.

**TUNIBAL**, Contact Alberto Garcia, Spain.
- Determine the abundance and spatial distribution of tuna larvae
- Determine larval daily growth and condition for the main target species and their relationship with environmental parameters.
- Analyse the influence of mesoscale phenomena and frontal systems in the distribution of phytoplankton, zooplankton and ichthyoplankton.

### Distribution of the participating projects main focus in term of Ocean and species.

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PROGRAMME: ESSAS

Project Title:
Ecosystem Studies of Sub-Arctic Seas

Source of Information:
ESSAS proposal and ESSAS Science Plan, March 2004 and
George Hunt, July 2004.

National Representative/ Contact:
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Fax: +1 949 824 2181

Project Description:
The goal of the ESSAS program is to compare, quantify and predict the impact of climate variability on
the productivity and sustainability of Sub-Arctic marine ecosystems.

The Ecosystem Studies of Sub-Arctic Seas (ESSAS) program addresses the need to understand how
climate change will affect the marine ecosystems of the Sub-Arctic Seas and their sustainability. The
Sub-Arctic Seas support stocks of commercial fish that generate a major portion of the fish landings of
the nations bordering them. They also support subsistence fishers along their coasts, and vast
numbers of marine birds and mammals. Climate-forced changes in these systems will have major
economic and societal impact.

In recent decades, components of Sub-Arctic Sea ecosystems have shown unexpected changes in
abundance or distribution that, in many cases, correlate with physical variability. The high spatial and
inter-annual variability of the Sub-Arctic Seas provide the opportunity to use short-term variability at
longer time scales. Understanding the underlying processes responsible for ecosystem responses is
the basis for providing good stewardship as these dynamic regions evolve.

ESSAS will investigate the connections between external forcing mechanisms and the hydrographic
structure and physical processes in the Sub-Arctic Seas, atmospheric forcing (solar insulation and
winds) and transport of water between the temperate regions of the North Pacific and North Atlantic
and the Arctic. Variability in these forcing mechanisms occurs on all spatial and temporal scales,
including local episodic events (storms), interannual variability at the scale of basins, and decadal- and
climatic-scale events at North Pacific/Atlantic- and global-scales. Issues of particular importance
include re-supply of nutrients to the continental shelves, fluxes through the Sub-Arctic Seas to the
Arctic Ocean, and how the location, timing, and intensity of storms affect shelf ecosystems. Flows
through the Sub-Arctic Seas to the Arctic appear to be changing, but the effects of these changes on
the heat balance, nutrient flux, and ecosystem structure of the Sub-Arctic Seas remain unknown.

ESSAS will investigate the connection between climate-forced changes in physical aspects of the
marine environment and the responses of the biota in the Sub-Arctic Seas. Factors affecting
interaction that are important in these regions include:

- Stratification of the water column – affect the availability of light and nutrients needed to support
  primary production, as well as the vertical distribution of many of the smaller plankton organisms;
- Sea ice – affects light, water temperature, and the availability of substrate;
- Water temperature – affects the rates of physiological processes, and directly influences behaviour
  of top predators

Seasonal sea ice cover is a dominant feature of the Sub-Arctic Seas, and ESSAS will provide a
comparative framework for investigating how changes in sea ice cover impacts Sub-Arctic marine
ecosystems. Sea ice is pivotal to structuring the physical environment and in some areas affects...
timing and fate of the spring bloom and hence changes in the mechanisms controlling fish populations would have important implications for fisheries management.

On the continental shelves, pools of cold subsurface water are a signature feature of sea ice during spring. ESSAS will investigate how changes in the size, duration and distribution of cold pools affect the circulation and ecology on the shelves. If warming of bottom waters allows expansion of the ranges of epibenthos-feeding fish, severe competitive pressures could impact other benthic-foraging populations.

ESSAS will also develop tools for integrating the effects of climate change across spatial and temporal scales. The goal will be to provide forecasts of how the Sub-Arctic marine ecosystems might be expected to behave under different climate scenarios. Although there are models that address regional climate variability and others that address large-scale circulation, there are presently no models that provide links from global climate forcing through physical oceanography to the impact on individual organisms and then back up to the ecosystem consequences of the responses of the organisms to forcing. A series of linked models would have the prospect of providing not only intellectually exciting opportunities to investigate the ways in which the ecosystems might respond to climate change, it would also be a valuable tool for management of fisheries in the Sub-Arctic Seas. Development of a model that would facilitate inclusion of ecosystem considerations in management models would be an important contribution toward sustainable management of the ecosystems of the Sub-Arctic Seas.

The ESSAS Program will leverage knowledge and resources from three important areas: 1) recently completed studies of the Sub-Arctic Seas, 2) ongoing national and international programs, and 3) international programs addressing global change. The results of prior research in the Sub-Arctic Seas provide a strong foundation on which to build. Important within ESSAS will be the comparative approach through which insights can be gained that would not be possible by examining a single Sub-Arctic region alone. It is vital to the future economic and social well being of the people who depend upon the Sub-Arctic Seas that we understand how processes controlled by climate influence their productivity. The ESSAS program will develop the information necessary to facilitate the wise use and stewardship of these most important marine ecosystems.

Website:
http://www.pml.ac.uk/globec/structure/regional/essas/essas.htm

System Types Studied:
Sub-Arctic Seas, including the Bering Sea, the Barents Sea, the Newfoundland/Labrador Shelf, Sea of Okhotsk, Greenland waters, Iceland waters and the Oyashio Current.

Target Organisms:
- Demersal species (particularly cod, capelin and walleye Pollack)
- Zooplankton (particularly copepods)
- Phytoplankton

Physical Processes Examined:
- Arctic Oscillation
- North Atlantic Oscillation
- Pacific North American Pattern
- Pacific Decadal Oscillation

Key Questions, Hypotheses and Issues:
ESSAS will address three major areas of inquiry:

- What are the external forcing functions that link global and regional climate processes the physical oceanography of the Sub-Arctic seas?
- How does variability in the physical aspects of the marine systems affects ecosystem processes and structure?
- How can we integrate across spatial and temporal scales to permit forecasting how changes in climate will affect the productivity and sustainability of the marine ecosystems of the Sub-Arctic Seas?
**Participating Institutions:**
Alaska Fisheries Science Center, USA
Alfred-Wegener-Institut Für Polar- und Meeresforschung, Germany
Bedford Institute of Oceanography, Canada
CNRS/Université Bordeaux, France
Hokkaido University, Japan
Institute of Marine Research, Norway
Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Russia
Marine Institute of Iceland, Iceland
Memorial University, Canada
National Marine Fisheries Service, USA
National Marine Mammal Laboratory, USA
Plymouth Marine Laboratory, UK
University of Arhus, Denmark
University of California, Irvine, USA
University of Tromsø, Norway

**Duration:**
2005-2015
PROGRAMME: ICES/GLOBEC CCC

Project Title:
Cod and Climate Change

Source of Information:
Keith Brander (ICES-GLOBEC CCC co-ordinator) and Geir Ottersen, August 2003

Representative/Contact:
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University of Oslo
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NORWAY

Project Description:
The International Council for the Exploration of the Sea (ICES) and GLOBEC began an innovative programme on the relationship between cod stock fluctuations and climate change in 1989. The aim was to develop co-operative, pan-Atlantic research in two fields: a) fish recruitment processes and b) the relationship between ocean physics (on basin and regional scales) and fish stocks. Cod was chosen as the principal target species because its biology is well known and supported by ample databases, it has a pan-Atlantic distribution, and its abundance and distribution have been shown to be sensitive to environmental variability.

The key question for the Cod and Climate Change (CCC) programme is “how does climate variability affect the productivity and distribution of cod stocks?” Cod (Gadus morhua) was chosen as the principal target species because its biology is well known and it is a major component of most North Atlantic ecosystems. Its abundance and distribution have been shown to be sensitive to environmental variability. A range of scientific disciplines and scales of investigation is applied, from the effects of small-scale turbulence on encounter between fish larvae and their prey, to large-scale effects of interdecadal changes in wind fields on circulation and transport of heat, plankton and young fish.

The processes by which physical forcing affects cod stocks are complex, but the effects of climatic variability can nevertheless be detected. For example, periods of low temperature are observed to result in stock declines at the northern limits of cod distribution (Barents Sea, Greenland); particular hydrographic and wind conditions result in unusual transport of eggs and larvae (Iceland-Greenland) or flush out deoxygenated basins where cod spawn (Baltic). These examples combine empiricism, a growing understanding of ocean/climate variability and detailed knowledge of processes during the life history of cod (especially the early life history). They give grounds for believing that the question posed is not intractable and that it will be possible to predict major changes in cod distribution and productivity under different physical regimes. An obvious subject of concern is the likely impact of the rise in ocean temperature, which has occurred over the past fifteen years, on cod stocks close to their upper thermal limit.

The GLOBEC approach provides a framework for nesting studies at different scales. In 1993 the CCC working group (GLOBEC Report No.4) identified common themes and methods which have since been applied in programmes at national and individual levels. It proposed and initiated comparative studies and cooperative research which has been carried at regional or international level, by workshops co-ordinated by ICES and GLOBEC.
Key Questions, Hypotheses and Issues:

In 1998 the CCC Working Group adopted a strategic plan with seven main objectives related to the key question posed above:

*Fisheries Management:* To incorporate environmental information in a quantitative manner into fisheries management strategies and planning.

*Retrospective Analyses:* To examine past events or periods as a means of better understanding the links between changes in the environment and fisheries.

*Zooplankton-Cod Linkages:* To understand the relative importance of zooplankton in determining the variability in cod abundance and production.

*Comparative Analyses:* To undertake comparative studies of life history strategies and interannual variability in growth, distribution, and abundance between cod stocks around the North Atlantic.

*Climate and Atmosphere-Ocean Interactions:* To understand and predict climate variability and its associated ecosystem response.

*Data Availability and Management:* To ensure that environmental and fisheries data are easily and widely available.

*Synthesis:* To provide a synthesis of the research information obtained on cod stocks.

The strategic plan is reviewed annually and a series of action plans proposed and carried out. The most recent review and action plan (ICES CM 2003/C:11) proposes a series of six workshops between 2005 and 2009 (details set out under Future Plans). Progress in achieving the objectives of the strategic plan is reviewed under Results and Achievements.

One of the principal issues which will continue to be addressed over the period to 2009 is how new understanding gained from detailed scientific studies can be applied to used to improve the management of fisheries and of the marine ecosystem.

Achievements and Results:

Cod stocks have generally declined over the past twenty years and landings fell from about 1.6 million tons in 1980 to just over half that in 2000. Climate change probably played a part in this decline for some stocks, but the overwhelming cause was excessive levels of fishing. Productivity and distribution of cod has been affected by environmental variability, with major consequences for recovery rates of depleted stocks.

The decline in cod stocks was steepest in the NW Atlantic, where landings in 2000 were 10% of their 1980 level and most fisheries remain closed. In many of these stocks individual growth rates declined from the early 1980s onward and condition of individual fish was also poor, so that mean weights at age fell by 50% or more. Poor condition contributed to lowering of recruitment rates, while natural mortality increased. The consequence of these changes, which are due in part to environmental variability and climate change, is that the productivity of some stocks has declined to the point where they are unlikely to recover even if the ban on fishing continues.

In the NE Atlantic the changes are less adverse. From 1980 to 2000 landings dropped by 50%, but in NEAFC Region 1 the decline was only 28%. Recruitment rates have fallen at the warm end of the species range, around the British Isles, but growth rates remain high and there is no evidence to date of increased natural mortality, such as has been observed in the NW Atlantic.

Information about the effects of climate on the processes which govern production (growth, maturation, egg production, transport during early life, survival and natural mortality) can be used in appraising the management options for sustainable fisheries. The development of methods for doing so has been an ongoing theme of the programme. Most of the processes have been the subject of workshops and theme sessions over the past few years, for example a workshop on Transport Processes in 2002 evaluated the effects of variations in transport during early life on subsequent recruitment and examined the coupling of circulation models with early life history models to determine the physical and biological processes responsible for the transport or retention of cod larvae. Cod eggs and larvae travel up to 1600 km during the pelagic stage, but greater distance does not lead to greater variability in survival and recruitment. The workshop is being followed up with a
Theme Session in 2003 which will hear about further coupled modelling to explore survival and the transport between stocks. The results will be published as an ICES Cooperative Research Report.

Talks at the Session on Comparative studies of North Atlantic ecosystems at the 2nd Open Science meeting in Qingdao dealt with the response of plankton and fish to climate forcing and the effects of food and environmental limitations on growth production of cod. An ICES Workshop and Theme Session on cod growth provided much new information about the role of size selective fishing, food availability, environment and genetics in determining the changing growth patterns. (ICES Cooperative Research Report 252).

Future Plans:
The Cod and Climate Change programme is currently in a synthesis phase, with three major activities dominating the timetable until the end of 2004:

1. **Publication of a book in the IGBP series on the current state of knowledge about cod and its response to climate change**
   The biological and life history processes underlying climate driven changes in cod include recruitment (i.e. the number of young fish produced), growth, maturation, natural mortality and migration. Thanks to its commercial importance, a long history of research and a dedicated programme within ICES on Cod and Climate Change over the past decade, much has been learned about these processes and about their interaction with each other and with the food chain, predators and other components of the marine ecosystem. Cod is probably the most comprehensively studied marine fish species, occupying a key role in several North Atlantic ecosystems. An understanding of its dynamics is of direct and indirect relevance to other species and to gaining insight into the response of the marine ecosystem to climate change and variability. Chapters of the book will review many aspects of our knowledge of cod, but will also report new results and analyses. They will use a comparative approach to draw conclusions from differences and similarities between the many stocks, which occupy a range of different physical and biological situations.

2. **A Symposium on the Influence of Climate Change on North Atlantic Fish Stocks in Bergen in May 2004**
   This will be an opportunity to measure progress against the 1993 Cod and Climate Change Symposium, held in Reykjavik. Invited talks will include Climate variability in the North Atlantic: past, present and future (J. Hurrell), The impact of climate on the distribution and migration of fish populations (G. Rose), The effect of climate variability on growth, maturity and recruitment (G. Marteinsdottir), Zooplankton and the link between climate variability and fish (M. Heath), Taking account of climate in the evaluation of the state of fish stocks (C. O’Brien) and Managing fish stocks under future climate scenarios and in the face of climatic uncertainty (L. Richards).

3. **An update of Cooperative Research Report 205 on life history information for cod stocks**
   This is a detailed compilation of information for all major cod stocks, based on a checklists which has been circulated to experts on each stock. It is intended as a comprehensive data source for those studying cod and will update the material and references contained in the previous report. The scope will be somewhat wider than the earlier report and will include information on migration and adult growth.

_The above synthesis activities will be completed in 2004, but a plan for continuing work within the Cod and Climate Change programme has been put forward for the period to 2009, when the GLOBEC programme as a whole is due to end. The work will be drawn together in a series of workshops:_

1. **Workshop on the Impact of Zooplankton on Cod Abundance and Production (in 2005)**
   Early stages of zooplankton are important prey for larval and early juvenile stages of cod. For most cod stocks Calanus species are the main prey, while in some areas, e.g. the Baltic, other species dominate. Survival and growth through these early stages have been shown to be critical for establishing a strong cod year class in some cod stocks. A better understanding of zooplankton-cod linkages should therefore be an important step towards better early estimates of year-class strength.
and thus recruitment to the cod stocks. The workshop would therefore examine relations between
temporal and spatial dynamics of zooplankton and early stages of cod. Issues to be addressed would
include how timing of zooplankton production and spatial dynamics of nauplii relates to the spawning
and distribution patterns of early stages of cod and ultimately cod recruitment. Links between later
stages of cod and zooplankton will also be addressed. A combination of statistical data analyses,
process studies and a variety of modelling approaches will be applied. The workshop will build on the
results of the 2002 workshop and the 2003 theme session on transport of cod eggs and larvae as well
as output from the ICES 2003 Zooplankton Symposium. The WG felt that this should be undertaken
together with the ICES Working Group on Zooplankton Ecology (WGZE). The co-chairs were
requested to contact the chair of the WGZE to ask their interest in co-sponsoring and participating in
such a workshop.

2. Workshop on the Decline (and Recovery) of Cod Stocks throughout the North Atlantic
(in 2006)
During the presentations on the update of the cod stocks around the North Atlantic, the WG was
struck by the similarity in the abundance trends of many of the stocks, from high values in the 1960s
that in some cases persisted through into the 1970s and 1980s, followed by a decline to relatively low
levels. In addition, there were often declines in size-at-age and age of maturity. The cause of these
decreases and the potential for recovery are among the most important issues for cod fisheries today.
The Workshop will compare the changes that have occurred in all of the cod stocks around the
Atlantic and address the relative importance of fishing and climate induced ecosystem changes.

3. Workshop on the Influence of Climate on Tropho-Dynamics of Cod Ecosystems (in
2006)
This Workshop also addresses the observed changes in size-at-age and maturity, but from a tropho-
dynamic and bioenergetic perspective. It can therefore be regarded as complementary to the
previous Workshop and could be linked to it. The workshop will consider both observations and
theory, including mass balance and scaling from individual based modelling. The role of forage
species will be reviewed, particularly capelin in the Barents Sea and at Iceland and sprat in the Baltic.
To what extent are observed changes cod stocks due to climate induced variability in their principal
prey species? What is the role of climate change on predators of cod (e.g. harp seals)?

Over the last decade, concern over the impacts of global change in climate have increased. New
evidence documents the ecological impacts of rising temperature in northern high latitudes. Scenario
studies from GCMs indicate substantial climate change over the next 50 years therefore further
investigation into the impacts on cod are warranted. The Workshop will assess how abundance,
distribution, and production of cod may respond to future climate scenarios. Results from statistical
and dynamic downscaling will be applied together with relations established through retrospective
analyses. The WG felt that this topic, which gave the programme its name, should be addressed
directly before GLOBEC ends. Scientists working on statistical or dynamical downscaling from GCMs,
especially in marine settings (e.g. in Norway the RegClim project), should be invited. K. Drinkwater
was willing to be one of the co-chairs.

5. Workshop on Implications of Results from CCC for Fisheries Management (in 2008)
As recognized at the CCC meeting in 2002, more work is need on the application of the results from
the CCC to fisheries management. The WG reconfirmed this by agreeing upon a workshop on the
subject. Its aims were not well developed, but should be discussed at all Workshops during the
intervening period, in order to ensure that they are addressed. The aim will be to develop techniques
and methods for incorporating environment into fisheries and ecosystem management and to provide
examples.

The WG felt that if the CCC program ends in 2009 when GLOBEC is scheduled to finish, a second
Synthesis Workshop should be held to highlight the results of the CCC program. The subjects to be
addressed by the Workshop will depend on results and issues that arise during the next 5 years.
References
Project Title:
Climate Change and Carrying Capacity

Source of Information:
Hal Batchelder, April 2004

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Project Description:
Remarkable changes have been observed in the North Pacific and adjacent seas in recent decades. Concurrent changes in atmospheric pressure and ocean temperatures indicate that in 1976-1977 the North Pacific shifted from one climate state, or regime, to another that persisted through the 1980s. Analysis of records of North Pacific sea surface temperature and atmospheric conditions show a pattern of regime shifts lasting several years to decades. The most recent change in North Pacific ocean conditions occurred in 1998 following a strong El Niño and La Niña pairing. The spatial pattern of atmospheric forcing (sea level pressure anomaly [SLPA]) and sea surface temperature anomaly (SSTA) during 1999-2002 differs from that observed during either the pre-1977 and post-1977 Pacific Decadal Oscillation (PDO) patterns (Bond et al., Geophysical Research Letters 2003, 30, 2183-2186). Since about 1989 there has been a shift in North Pacific anomaly fields: before then there was a predominant E-W pattern (PDO dominant), since then the spatial pattern has shifted to one having a dominant N-S pattern (Victoria Pattern). Although the important linkages are poorly understood, there is growing evidence that biological productivity in the North Pacific responds to these decadal-scale shifts in atmospheric and oceanic conditions. Initially, before the recognition that there was more than one kind of pan-Pacific ocean/climate change, it was thought that the response would be an alternation between periods of high and low productivity. Salmon survival in the Eastern North Pacific (both in Alaska and the Pacific Northwest) was clearly impacted by the 1976-77 change in ocean conditions. Ecosystem responses to the 1998 change in sign of the Victoria pattern are more striking in the California Current than in the northern Gulf of Alaska and Bering Sea. Zooplankton populations in the south have responded markedly, in both biomass and species composition. Similarly, salmon survival in the Pacific Northwest has improved. Conversely, there is scant, if any, evidence for major shifts in the planktonic community or salmon survival in the coastal Gulf of Alaska. The CCCC Program addresses how climate change affects ecosystem structure and the productivity of key biological species at all trophic levels in the open ocean and coastal North Pacific ecosystems. There is a strong emphasis on the coupling between atmospheric and oceanic processes, their impacts on the production of major living marine resources, and how they respond to climate change on time scales of seasons to centuries.
Activities in the CCCC Program focus on two spatial scales:

- Basin-scale studies to determine how plankton productivity and the carrying capacity for high trophic level, pelagic carnivores in the North Pacific change in response to climate variations.
- Regional-scale, ecosystem studies comparing how variations in ocean climate affect species dominance and fish populations in the coastal margins of the Pacific Rim, from China to California.

In distinguishing between regional and basin scales, the former is understood to mean studies in coastal waters, generally conducted by scientists of a single country; some of these are identified as national GLOBEC programs. Basin scale refers to studies in the open ocean, generally requiring international co-operation for their conduct. The term subarctic Pacific includes the adjacent seas of the region, in accordance with terms of the PICES Convention.

On the regional scale, comparative studies of ecosystems along the continental margins of the subarctic Pacific will be of particular importance in the CCCC Program. The following regional (1-10) and basin scale (11-12) components have been identified.

1. California Current System, south
2. California Current System, Oregon to Vancouver Island
3. Southeast, Central Alaska
4. Eastern Bering Sea
5. Western Bering Sea/Kamchatka
6. Okhotsk Sea
7. Oyashio/Kuroshio
8. Japan Sea/East Sea
9. Bohai, Yellow Sea
10. East China Sea
11. Western subarctic gyre
12. Eastern subarctic gyre

The ultimate goal of the CCCC Program is to forecast the consequences of climate variability on the ecosystems of the subarctic Pacific. To achieve this goal, CCCC must, first, document North Pacific climate variability and its impacts on marine ecosystems, and second, develop a mechanistic understanding of how the observed climate variability promulgates to all levels of the ecosystem, and whether it occurs through bottom-up, top-down or a balance of processes.

Websites:
http://www.pices.int/ and http://www.pices.int/members/scientific_programs/cccc.aspx

Key Questions, Hypotheses and Issues:

**Physical Forcing:**

- What are the characteristics of climate variability, can interdecadal patterns be identified, how and when do they arise?
- Establish the pattern in space and time of atmospheric variations that have driven the interannual and decadal variations in ocean conditions.
- Establish the pattern in space and time of the interannual and decadal variations in ocean conditions, as it relates to circulation and mixing, structure, and content of heat and dissolved substances.
- Determine what measures of climate variations are most indicative of regime shifts and which criteria can be used to establish the occurrence and early detection of regime shifts.
- Construct time series of the selected measures and compare those from east and west.
- Determine available measures of the strengths of the Alaska and California Currents, assemble time series of these measures, and make comparison.
- Determine available measures of the strengths of the Kuroshio and Oyashio, assemble time series of these measures, and compare with each other and with variations in the Alaska and California Currents.
- Construct plausible hypotheses to account for observed relationships.
Lower trophic level response:

- How do primary and secondary producers respond in productivity, and in species and size composition, to climate variability in different ecosystems of the subarctic Pacific?
- Determine available measures of productivity of Pacific Rim coastal ecosystems, assemble time series of these measures, and determine patterns of their variations as far back as possible.
- Determine average level of primary production before and after regime shifts and identify environmental conditions that might account for any observed differences.
- Establish what changes in species dominance, biomass, and productivity of key zooplankton species have taken place.
- Conduct retrospective studies of the relation between variations in ocean conditions and in zooplankton populations.

Higher trophic level response:

- How do life history patterns, distributions, vital rates, and population dynamics of higher trophic level species respond directly and indirectly to climate variability?
- Establish what changes in species dominance, biomass, and productivity of key fish species have taken place.
- Conduct retrospective studies of the relation between variations in ocean conditions and in fish populations.
- Establish what changes have occurred in growth, size and age at maturity, ocean distribution, survival, and abundance of salmonids and other key species of the region.
- Relate these changes to (1) changes in environmental conditions, and (2) exploitation patterns, and develop and test plausible hypotheses for the observed relationships.
- For potential dominant species, assemble existing information on abundances, migration patterns, and stock recruitment relationships before and after the recent shifts (1977, 1989, 1998) in ocean climate.
- Identify differences in these responses among the compared species. Determine what spatial shifts have occurred in pelagic ecosystems.
- Relate these shifts to environmental changes and fishing patterns.
- Determine changes in ecosystem structure that accompanied these spatial shifts.

Ecosystem interactions:

- How are subarctic Pacific ecosystems structured? Do higher trophic levels respond to climate variability solely as a consequence of bottom up forcing? Are there significant intra-trophic level and top down effects on lower trophic level production and on energy transfer efficiencies?
- Determine the criteria to be used in defining the structure of coastal and oceanic ecosystems. Make tentative descriptions of present coastal and oceanic ecosystem structures based on available information.
- Compare current ecosystem structures with those present prior to the mid-1970s.
- Evaluate methods for monitoring key elements of these ecosystems in order to detect future structural changes. Develop indices of ecosystem condition, and provide recommendations on how to most efficiently monitor variation in the ocean environment.
- Determine working definition of "carrying capacity" and identify measures by which its magnitude for key species can be determined.
- Evaluate evidence for changes in carrying capacity for salmonids and other key upper trophic level species.
- Identify possible causes of these changes, e.g. in underlying productivity and in species dominance.
- Examine the role of seasonally migrating species, such as pomfret, neon flying squid, and saury, as competitors with salmonids for food.
- Establish relationships between circulation and ecosystem changes and develop plausible hypotheses to explain these relationships.
- Develop coupled atmosphere-ocean-ecosystem models for testing, analysis, and prediction of the relationships that appear from these studies.
Participating Institutions:
Cooperation between CCCC and other international activities has several facets:

- CCCC is part of GLOBEC International, a program sponsored by the Scientific Committee on Oceanic Research (SCOR), the Intergovernmental Oceanographic Commission (IOC), the International Council for the Exploration of the Sea (ICES) and the North Pacific Marine Science Organization (PICES), and a core scientific program of the International Geosphere-Biosphere Program (IGBP).

- Cooperation is envisaged with several existing international organizations in the region, including the North Pacific Anadromous Fish Commission (NPAFC), the International Pacific Halibut Commission (IPHC), and new organizations concerned with fisheries in the international area of the Bering Sea and with tuna in the North Pacific. PICES and NPAFC have agreed to examine jointly (i) the factors affecting current trends in the productivity of the North Pacific Ocean and their impacts on salmonid carrying capacity, and (ii) the factors affecting changes in biological characteristics of Pacific salmon. In order to promote this joint effort, a representative of the NPAFC is serving on the Implementation Panel Executive Committee.

- Other international programs concerned with climate and ocean changes, including ocean fluxes (JGOFS), ocean circulation (WOCE), and monitoring systems (GOOS) can make important contributions to meeting the goals of CCCC, and close liaison, exchange of information, joint workshops, and invited participation will be sought.

- PICES CCCC also anticipates cooperating with the Ecosystem Studies of Sub-Arctic Seas (ESSAS) program, which is being developed under the auspices of GLOBEC International.

Research efforts to be carried out under PICES auspices are funded nationally rather than by the organization. As noted earlier, the role of PICES is to stimulate and facilitate action; to coordinate planning and, as appropriate, implementation; and to improve communication among participants.

Elements of support for the CCCC Program include the following:

- PICES provides funds for coordinating activities, workshops, symposia,
- National GLOBEC programs related to CCCC and involving international cooperation,
- Institutional programs related to CCCC and involving international cooperation,
- National research programs related to CCCC (many of which are GLOBEC) and capable of providing ship time and data,
- International science exchange and cooperation programs with funds and other resources.

Duration:
Phase 1. Planning and Retrospective Data Analysis (1995-1996)
Phase 2. Observing, Process Studies, and Modelling (Started 1997)
Phase 3. Model Integration and Testing (Started 2000)
Phase 4. CCCC Synthesis and Integration (Started ca. 2003)

Activities:
As with other components of GLOBEC, research activities within CCCC fall into major categories: retrospective analyses, development of numerical models, ecosystem process studies, the development of observation systems and data management. The Programme is organised into four Task Teams to accomplish its goals. It was recognised that the comparative approach would be an important ingredient to the study of the central scientific issues. Particularly, comparative studies of the ecosystems along the continental margins of the subarctic Pacific and east/west comparisons of the subarctic gyres. Two task teams of the programme were formed to provide that key ingredient: REX, to consider regional experiments to compare findings of coastal GLOBEC and GLOBEC-like programmes, and BASS, to consider development of comparative research studies in the open ocean subarctic gyres. As of early 2004, the BASS and REX task teams are undergoing a merger. In recent years there has been increased recognition that the linkages between the coastal regions (REX) and open ocean (BASS) are important to both systems. The CCCC program supports the merger of these two task teams, and has requested that the leadership of REX and BASS develop TOR for a new merged team called Climate Forcing and Marine Ecosystems (CFAME). An additional advantage of CFAME will be to ensure better national participation at workshops, and to provide a clearer focus for examining climate change impacts on ecosystems. Two other teams were tasked to identify
requirements and simulate improved models (MODEL), and to review and coordinate sustained North Pacific monitoring activities (MONITOR).

In 2002, PICES-CCCC established a Working Group NEXT (for Nemuro Experimental Planning Team, whose goal was to develop a scientific strategy for achieving a broad-scale synthesis and integration of the past decade of activities of the CCCC program. Recommendations for a road-map to CCCC synthesis were finalized at the annual PICES meeting in 2003. In brief, the major recommendations of NEXT are that CCCC 1) convene a major symposium in April 2006 to present CCCC synthesis findings from national programs, and to foster international synthesis of the connections between climate variability and ecosystem structure and function, 2) conduct detailed model-data comparisons and validation of the NEMURO lower trophic level model using data from many different coastal regions, 3) implement a two-tiered approach for further development of ecosystem and coupled physical-ecosystem models in the North Pacific, with Tier I lead by MODEL to develop further theory and implementation of the basic model frameworks, and Tier II, which is model-data validation, being done in a distributed mode by individual scientists and programs, and 4) improve collaborations between model developers and data collectors through dedicated training workshops and better centralized web page support for distributing model code, documentation and products. In addition, the NEXT team developed a suite of core hypothesis that could (and should) be addressed using NEMURO, ECOPATH/ECOSIM, and similar modelling approaches.

MODEL
Task Team Co-Chairs: Dr. Francisco Werner and Dr. Shin-ichi Ito

Model has reviewed the roles and limitations of modelling for the CCCC Programme, proposed the level of modelling required, and provided a plan for how to promote these modelling activities (PICES Press, vol. 4 No 2; PICES Scientific Report No. 7, 1997). The Task team recognised that many modelling activities are already taking place regarding North Pacific physics and biology. Therefore, the primary role of MODEL has been identified as:

- Facilitate communication among modelling studies and with field programmes
- Identify and stimulate areas of modelling that are significant to the CCCC's Programme but which are not presently addressed
- Assist field programmes of CCCC (e.g. REX, BASS) with model-related needs.

In these regards, the MODEL Task Team has developed a prototype lower trophic level model (code-named NEMURO) to simulate physical forcing of lower trophic level dynamics in the North Pacific (PICES Scientific Report No. 15, 2000). To provide input data for the model, physical data sets and parameter files were constructed for three locations in the North Pacific: off Hokkaido, Ocean Station PAPA, and the Eastern Bering Sea. Workshops to develop and expand the model in several aspects, e.g. a bioenergetic fish model (for herring and saury) has been coupled to NEMURO, and NEMURO has been coupled to physical circulation codes. Further integration of modelling work with the other PICES Task Teams is planned for 2001. Publication of these models is planned for 2004.

REX
Task Team Co-Chairs: Dr. Yoshiro Watanabe and Dr. Douglas Hay

The Regional Experiment (REX) Task Team was established to encourage the development of regional experiments in coastal regions of the North Pacific, and to provide co-ordination among various marine science research programs (GLOBEC, PICES, federal, etc.) located in the North Pacific. REX began by reviewing the status of national research programmes in order to identify areas for cooperative research experiments in support of the CCCC's.

- PICES member nations should compile a catalogue of historical samples and data sets that are not yet analysed or readily available
- Issues of standardisation of sampling and analysis methods for comparative studies should be addressed
- A series of symposiums and workshops should be held to examine the impact of climate effects on small pelagic species
- A scientific session that highlights research findings of GLOBEC and GLOBEC-like programmes in the North Pacific should be convened frequently as part of the PICES annual meetings.
REX has held four workshops that have focused on 1) commonalities among key small pelagic stock in the North Pacific, 2) herring and euphausiid population dynamics, 3) trends in herring populations and trophodynamics, and 4) long-term trends in size-at-age among key species of fishes around the North Pacific.

BASS
Task Team Co-chairs: Dr. Akihiko Yatsu and Dr. Kerim Aydin

BASS began work in 1997 with five primary objectives:

- to undertake retrospective comparison of lower trophic level dynamics in the eastern and western subarctic gyres
- to provide guidance for standardizing the sampling and analysis methods for zooplankton
- to develop time-series measurements of primary productivity and zooplankton stocks in the subarctic gyres
- to develop an inventory of higher trophic species inhabiting the subarctic gyres in the North Pacific
- to acquire and collate the work or science plans of all agencies/programs conducting research in the eastern and western gyres

Several BASS workshops have resulted in substantial progress on several of these objectives - all but standardizing zooplankton sampling and developing time-series. Information on higher trophic species in the gyres was collated, incorporated into ECOPATH/ECOSIM type models, and used to explore potential consequences of both harvesting and climate change on the ecosystems of the eastern and western gyres. These model activities identified data gaps in our knowledge of the oceanic basins, and suggested priorities for future research.

An Iron Fertilization Experiment Advisory Panel (IFEP) formed as a subgroup of BASS has provided oversight and co-ordination for several iron experiments that have been conducted in the North Pacific. These experimental manipulations provided insight on the responses of lower trophic levels to enhanced iron availability, in traditionally iron-poor oceanic environments. Experiments have been conducted in both the eastern (by Canada) and western gyre (by Japan).

MONITOR
Task Team Co-Chairs: Dr. Phillip Mundy and Prof. Sei-ichi Saitoh

The terms of reference for the MONITOR Task team are:

- Review existing activities of PICES member nations and suggest improvements in the monitoring of the Subarctic Pacific to further the goals of the CCCC Programme.
- Consult with REX, BASS and MODEL Task Teams and TCODE on the scientific basis for designing the PICES monitoring system. Questions of standardisation and intercalibration of measurements, particularly in the area of biological collections, should be addressed.
- Assist in the development of a co-ordinated monitoring programme to detect and describe events, such as El Niño, that strongly affect the Subarctic.
- Report to CCCC IP/EC on the monitoring in the Subarctic to be implemented in the international GOOS or other related activities.

MONITOR has made excellent progress in addressing the above goals. Major North Pacific time series observation programs were catalogued in PICES Report No.18. However, closer links to TCODE and regional programs are needed to enhance data availability. Progress has been made on specifying performance standards of what a program should measure and how well, but instituting standardized sampling and analysis protocols has not happened. A significant new Continuous Plankton recorder (CPR) program in the North Pacific has been instituted under the leadership of MONITOR, and its CPR Advisory Panel. A north-south CPR route from Alaska to Southern California, which transits the subarctic, transitional and subtropical regions is run several times per year, and an east-west route which traverses both subarctic gyres is occupied 1-2 times per year. These routes, which have been supported by diverse funding sources, will begin to provide large scale distributional and abundance data on zooplankton in a very undersampled region of the North Pacific.
## NATIONAL AND INTERNATIONAL PROGRAMS IN REGIONS

### SUMMARY TABLES

#### 1. California Current System, South U.S.A.

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#### 2. California Current System, Oregon to Vancouver Island Canada

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#### 3. Southeast, Central Alaska U.S.A.

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**U.S.A**

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**China**

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### 10. East China Sea

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**Korea**

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### 11. Western Subarctic Gyre

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### 12. Eastern Subarctic Gyre

#### Canada

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**PROGRAMME: SOUTHERN OCEAN GLOBEC**

**Co-ordinator:**
Eileen Hofmann (chair)  
hofmann@ccpo.odu.edu  
Center for Coastal Physical Oceanography  
Old Dominion University  
Crittenton Hall  
768 52nd Street  
Norfolk VA 23529  
USA

**Project Description:**
Although the Antarctic food web is diverse, it is characterized by short trophic linkages that are dominated by fewer than four to six species. These short trophic connections arise because the basic prey types available to predators are limited, with Antarctic krill (*Euphausia superba*) serving as the primary prey. As a result, predators concentrate on a single prey, such as Antarctic krill, or on a core group of species, such as other euphausiids and some fish. Thus, environmental or biological perturbations can potentially affect all components of the Antarctic marine ecosystem irrespective of their initial impact. The knowledge base on which predictions about potential trophic changes that might be expected from climate and population variations is very limited. In particular, little is known about how marine animal populations adapt to austral winter, which is a critical part of many life cycles.

It is the strong linkage to climate and close coupling between trophic levels that resulted in the choice of the Southern Ocean as one of the first study sites for the Global Ocean Ecosystem Dynamics (GLOBEC) program, which has the goal of understanding marine population variability in response to environmental change. The primary objective of the Southern Ocean GLOBEC (SO GLOBEC) program is to understand the physical and biological factors that contribute to enhanced Antarctic krill growth, reproduction, recruitment, and survivorship throughout the year. This objective also includes the predators and competitors of Antarctic krill, such as penguins, seals, cetaceans, fish and other zooplankton. The emphasis by SO GLOBEC on habitat and top predators, as well as Antarctic krill, is a first in international interdisciplinary Antarctic science and reflects the lessons learned from prior multidisciplinary Antarctic research programs, such as the Biological Investigations of Marine Antarctic Systems and Stocks (BIOMASS), the Antarctic Marine Ecosystem Research at the Ice-Edge Zone (AMERIEZ), and the Research on Antarctic Coastal Ecosystem Rates (RACER).

The science questions developed for SO GLOBEC, as a result of four international workshops (U.S. GLOBEC Report No. 5; International GLOBEC Report Nos. 5, 7, 7A), reflect the broadening in scope to take a holistic view of the Antarctic marine ecosystem. As a result, the SO GLOBEC science programs include studies of the habitat, prey, predators and competitors of Antarctic krill, as well as studies specifically focused on Antarctic krill biology and physiology. Moreover, the year-round focus, with an emphasis on winter processes by the U.S. and German SO GLOBEC programs, provides a new and different direction in international Antarctic research.

Southern Ocean GLOBEC includes studies of:
- Regional differences in over-wintering strategies of Antarctic krill in relation to the physical environment;
- Population dynamics of selected zooplankton species, both sea-ice related and pelagic species;
- Population dynamics of major krill predators, both ice-based and pelagic species;
- Hydrographic, circulation and sea ice distributions; and
- Modelling of circulation, sea ice, and biological processes.

Several multidisciplinary field projects have been undertaken as part of SO GLOBEC and others are planned (see listing below). The completed field studies were focused around Marguerite Bay along the western Antarctic Peninsula and at 70°E. The field studies included survey and process-oriented cruises, deployment of surface drifters and moored current meter arrays, deployment of passive acoustic moored arrays for cetacean sampling, surveys of the distribution and abundance of penguins, seabirds, seals and cetaceans (via collaboration with the International Whaling Commission),
deployment of satellite transmitters on seals and penguins, and numerous approaches and methods for studying Antarctic krill physiology and ecology.

Programme Objectives:
The primary science questions that are the focus for Southern Ocean GLOBEC are:

- What key factors affect the successful reproduction of krill between seasons?
- What key physical processes influence krill larval survival and subsequent recruitment to the adult population between seasons?
- What are krill’s seasonal food requirements in respect to energetic needs and distribution and type of food?
- What are the geographical variations in krill distribution in relation to the between- and within-season variability in the physical environment?
- How does the winter distribution and foraging ecology of krill-dependent predators relate to the characteristics of the physical environment and the distribution of their prey?
- How does summer breeding season foraging ecology relate to the abundance and distribution of the available krill population?
- How does year-to-year variability in predator population size and breeding success relate to sea ice extent and its possible effects on krill recruitment, availability and distribution?

Achievements and Results:


The first special volume of Deep-Sea Research II that is devoted to the results of the Southern Ocean GLOBEC program is scheduled for publication in late 2004. The titles, author listing, and abstracts for the papers that are included in the volume are available at: http://www.cccpo.odu.edu/Research/GLOBEC_menu.html.

SO GLOBEC Field Activities:

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<td>2001</td>
<td>Jan-Feb</td>
<td>Australian Fine Scale Krill Survey - 70°E</td>
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<tr>
<td></td>
<td>March-April</td>
<td>U.S. SO GLOBEC mooring deployment cruise – west Antarctic Peninsula</td>
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<tr>
<td></td>
<td>April-May</td>
<td>German SO GLOBEC cruise to west Antarctic Peninsula</td>
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<td></td>
<td>April-June</td>
<td>U.S. SO GLOBEC survey and process cruises to west Antarctic Peninsula</td>
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<td></td>
<td>July-Sept</td>
<td>U.S. SO GLOBEC survey and process cruises to west Antarctic Peninsula</td>
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<td>2002</td>
<td>February</td>
<td>U.S. SO GLOBEC mooring recovery/deployment cruise to west Antarctic Peninsula</td>
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<td>April-May</td>
<td>U.S. SO GLOBEC survey and process cruises to west Antarctic Peninsula</td>
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<td>U.S. SO GLOBEC survey and process cruises to west Antarctic Peninsula</td>
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<td>2003</td>
<td>Feb-March</td>
<td>U.S. SO GLOBEC mooring recovery cruise – west Antarctic Peninsula</td>
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<td>2005</td>
<td>August-Sep</td>
<td>German SO GLOBEC cruise to Lazarev Sea</td>
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<tr>
<td>2006/7</td>
<td>Jan-Feb</td>
<td>German SO GLOBEC cruise to Lazarev Sea (tentative)</td>
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</table>

Website:
http://www.cccpo.odu.edu/Research/GLOBEC_menu.html
**PROGRAMME:** SO GLOBEC - USA

**Source of Information:**
Eileen Hofmann and NSF Awards Abstracts Database, April 2004

**Contact:**
Eileen Hofmann     hofmann@ccpo.odu.edu
Center for Coastal Physical Oceanography
Old Dominion University
Crittenton Hall
768 52nd Street
Norfolk VA 23529
USA

**Project Title:**
US Southern Ocean GLOBEC

**Project Description:**
The focus of the U.S. Southern Ocean GLOBEC program is on the biology and physics of a region of the continental shelf to the west of the Antarctic Peninsula extending from the northern tip of Adelaide Island to the southern portion of Alexander Island and including Marguerite Bay. The primary goals of the program are:

- To elucidate shelf circulation processes and their effect on sea ice formation and Antarctic krill (Euphausia superba) distribution; and
- To examine the factors that govern Antarctic krill survivorship and availability to higher trophic levels, including seals, penguins and whales.

The U.S. Southern Ocean GLOBEC field studies consist of mooring deployment/recovery cruises, process-oriented cruises and survey cruises. During the first mooring cruise, which took place on the ARSV Laurence M. Gould, a current meter array was placed along a line extending off Adelaide Island and along a line across the opening of Marguerite Bay. This mooring array remained in place for one year. A second cruise in early 2002 retrieved the first array and redeployed a second current meter array that consisted of three moorings aligned across the opening to Marguerite Bay. These mooring were retrieved in March 2003. The current meter arrays deployed as part of the U.S. SO GLOBEC program provide the first long-term measurements of the current structure on the WAP continental shelf.

Other activities on the mooring cruises consisted of deploying arrays of passive acoustic moorings to obtain information on cetacean distribution and deploying surface velocity drifters. The IWC observers aboard the RV L.M. Gould also completed cetacean surveys that established a baseline for cetacean abundance along the Antarctic Peninsula at the start of the austral fall. The cetacean surveys provide observations from regions and seasons that have not been previously sampled and, as such, are important information for the IWC, which has responsibility for management of cetacean resources in this region of the Southern Ocean. Details of the mooring cruises and some preliminary results are given in U.S. SO GLOBEC Report Numbers 1, 4 and 9 (see report listing below).

The U.S. Southern Ocean GLOBEC field program consisted of joint survey and process cruises on board the RVIB Nathaniel B. Palmer and ARSV Laurence M. Gould, respectively. The region covered by the U.S. cruises overlaps with the region covered by the German SO GLOBEC cruise. The U.S. Southern Ocean GLOBEC cruises provided information from mid to late austral fall and during the austral winter for two years. The German program sampled during late summer to early fall. Thus, the sequence of cruises in the WAP region will provide essentially good coverage for the austral fall, the set-up for austral winter, and the austral winter.

Studies on the RVIB Nathaniel B. Palmer survey cruises are based upon data collected from conductivity-temperature-depth (CTD) casts, an Acoustic Doppler Current Profiler (ADCP), a Multiple Opening/Closing Net and Environmental Sampling Sensing System (MOCNESS) with nine 1m² nets, and a Bio-Optical Multifrequency Acoustical and Physical Environmental Recorder (BIOMAPER-II). These data sets provide repeated realizations of hydrographic structure, upper water column currents,
nutrients, phytoplankton, micro-zooplankton and mesozooplankton, and Antarctic krill distributions. Seabird and cetacean surveys were done during the relatively short daylight periods and buoys are deployed for listening to cetacean sounds. Other activities consisted of Remotely-Operated Vehicle (ROV) operations and deployment of surface drifters. The first survey cruise also deployed two Automatic Weather Stations on the Kirkland Islands and the Faure Islands inside of Marguerite Bay. These stations are now providing the first continuous meteorological observations from this region of the Antarctic (data available at http://amrc.ssec.wisc.edu). Detailed accounts of the 2001 survey cruises and some preliminary results are given in U.S. SO GLOBEC Report Numbers 2 and 3. Results for the 2002 survey cruises area given in U.S. SO GLOBEC Report Numbers 6 and 8.

The process cruises are based on focused studies of several days duration at specific sites in and around the Marguerite Bay region. The objectives of the process studies were to understand the factors that govern Antarctic krill survivorship, overwintering strategies, and availability to higher trophic levels. Studies on the process cruises consisted of ship-based laboratory experiments of zooplankton and Antarctic krill physiology; under-ice diving to characterize the sea ice habitat, sea ice biota, and to collect animals for experiments; and focused 1m² and 10m² MOCNESS net tows to characterize community assemblages in the water column. In addition ADCP and hydroacoustic measurements were made to complement observations on the survey vessel. Detailed accounts of the 2001 and 2002 process cruises and some preliminary results are given in U.S. SO GLOBEC Reports Numbers 1, 3, 5 and 7.

As part of the process cruise activities Adélie penguins and crabeater seals (*Lobodon carcinophagus*) were instrumented with satellite transmitters. Additional satellite transmitters were placed on Adélie penguins in the colonies near Palmer Station on Anvers Island (64 46ºS, 64 04ºW) in the early austral fall preceding the cruises. The animal tagging provides insight to where predators go during austral winter, which is still largely unknown. Also, the combination of the tagging studies with the *in situ* and survey data provides a unique opportunity to better understand the foraging strategies used by marine predators in the face of meso- and fine-scale ecological variability.

The sites at which Adélie penguins and seals were tagged during the 2001 and 2002 U.S. SO GLOBEC process cruises ranged from Adelaide Island to the northern part of Alexander Island. As a result, a range of habitats are included in the animal tagging studies. The returned trajectories show that like crabeater seals penguins are moving over large areas and are suggestive that the animals are concentrating in areas that are characterized by fronts where availability of Antarctic krill may be greatest. Therefore, the information on penguin and seal movement will contribute to understanding how these animals select their foraging locations and prey, and how alterations in environmental conditions and Antarctic krill abundance may impact top predator populations. Further details of the crabeater seal tagging program and updates on the seal trajectories can be found at: http://cwolf.uaa.alaska.edu/~afjmb4/GLOBEC/Crab.htm.

The first special volume of *Deep-Sea Research II* that is devoted to the results of the Southern Ocean GLOBEC program is scheduled for publication in late 2004. The titles, author listing, and abstracts for the papers that are included in the volume are available at: http://www.ccpo.odu.edu/Research/GLOBEC_menu.html.

**System Types Studied:**
Marguerite Bay, Western Antarctic Peninsula, Southern Ocean

**Target Organisms:**
*Euphausia superba* (Antarctic krill)

**Physical Processes Examined:**
Shelf circulation processes
Annual formation and destruction of sea ice
Key Questions, Hypotheses and Issues:

The specific objectives of the U.S. Southern Ocean GLOBEC survey cruises were:

- To conduct a broad-scale survey of the SO GLOBEC study site to determine the abundance and distribution of the target species, *Euphausia superba* and its associated flora and fauna;
- To conduct a hydrographic survey of the region;
- To collect chlorophyll data, nutrient data, and to make primary production measurements to characterize the primary production of the region;
- To collect zooplankton samples with nets at selected locations throughout the broad-scale sampling area;
- To survey the sea birds throughout the broad-scale sampling area and determine their feeding patterns;
- To survey the marine mammals throughout the broad-scale sampling area both by visual sightings and by passive listening techniques;
- To map the bank-wide velocity field using an Acoustic Doppler Current Profiler;
- To collect acoustic, video, and environmental data along the tracklines between stations using a suite of sensors mounted in a towed boy (BIOMAPER-II);
- To collect meteorological data;
- To determine the abundance and distribution of micronektonic krill predators, primarily fishes within the study area;
- To determine rates of metabolism and excretion of all life stages of Antarctic krill;
- To assess the numerical abundances of krill larvae underneath sea ice using SCUBA and videography;
- To capture krill larvae underneath sea ice using SCUBA and hand nets for experimental manipulation;
- To take samples of the surface layer under the sea ice to assess food concentrations;
- To freeze krill of all life stages to assess composition and biochemical indicators of conditions;
- To evaluate the behavioural and physiological overwintering strategies used by different life history stages of the Antarctic krill; and
- To assess the sexual maturity stages of female krill during winter in relation to environmental parameters.

The specific objectives of the process cruises were:

- To measure the optical properties of the predominant sea ice types in the Marguerite Bay area. Quantify what the sea ice types are and measure their physical characteristics, which have direct effect on the optical properties. Deploy drifting ice platforms to measure a long-term mass balance history of the sea ice cover over a 1-2 month period.
- To assess the distribution and activity of the sea ice microbial communities in order to determine the stocks and dynamics of the food reserves for krill over wintering in association with sea ice.
- To link the variability in the biological and physical characteristics of the sea ice habitat with the distribution and abundance of larval krill, and the diet and growth of larval and juvenile krill in winter.
- To apply recently developed biochemical approaches to determine the age of structure of *Euphausia superba* in field populations.
- To investigate specific lipids in *E. superba* as molecular markers of diet history and their potential as markers of trophic transfer.
- To use ARGOS-based satellite transmitters to determine the distribution and movement of important krill predators, Adélie penguins and crabeater seals, relative to features such as bathymetry and sea ice.
- To employ a variety of diet sampling techniques to determine the winter foraging ecology of these predators, and particularly their impacts on krill life history stages and size classes.
Listing of U.S. Southern Ocean GLOBEC Cruise Reports
Reports available from: Southern Ocean GLOBEC Planning Office, Center for Coastal Physical Oceanography, Crittenton Hall, Old Dominion University, Norfolk, VA 23529 USA.

- U.S. Southern Ocean GLOBEC Report No. 3. Reports of RVIB Nathaniel B. Palmer Cruise NBP01-04 and R/V Lawrence M. Gould Cruise LMG01-6 to the Western Antarctic Peninsula, 24 July to 31 August 2001 and 21 July to 1 September 2001.

Participating Institutions:
Woods Hole Ocean Institute
University of Wisconsin
Earth and Space Research
University of Maryland
University of Tennessee, Knoxville
University of California, Santa Barbara
University of Alaska, Anchorage
Columbia University
University of California, Berkeley
University of South Florida, Tampa
Old Dominion University
University of Nevada
University of Minnesota
Scripps Institution of Oceanography
University of California, Santa Cruz
USACRREL
Massachussetts Institute of Technology

Funding Agency:
U. S. National Science Foundation Division of Ocean Sciences

Budget:
Approx. $8.5 million
Funded Projects:

1. **Zooplankton Distribution and Abundance**  
   *Peter H. Wiebe, pwiebe@whoi.edu, Cabell S. Davis, Carin J. Ashjian, Scott M. Gallager*  
   Woods Hole Oceanographic Institution, Woods Hole, MA

   This component will focus on juvenile and adult krill and mesozooplankton prey distribution and abundance using a sophisticated instrument package, BIOMAPPER II, which is equipped with an acoustic backscatter sonar system, a video plankton recorder and an environmental sensor system. The system is used in large-scale studies. Additionally, a remotely operated vehicle will be used to map the distribution and behaviour of krill under ice.

   Duration: October 1, 2000 - September 30, 2003 (Estimated)

   Budget: $1,203,118 (Estimated)

2. **Krill Physiology and Fish Ecology**  
   *Joseph J. Torres, Kent A. Fanning, U of South Florida, Tampa, FL*

   This component will focus on krill physiology, using measures of respiration, excretion, and proximate analysis. Additionally, the distribution and abundance of fishes and squid, which are krill predators, will be investigated using acoustic and net tow methods. This research will be co-ordinated with components studying krill in both the water column and under the ice.

   Duration: September 15, 2000 - September 30, 2003 (Estimated)

   Budget: $634,898 (Estimated)

3. **Seabird Distribution and Abundance**  
   *Christine Ribic, U of Wisconsin*

   This component will focus on the large-scale distribution, abundance and habitat of seabirds. This will be accomplished using strip-transect surveys and spatial analysis software and models to examine the large-scale data. This research will be co-ordinated with seabird studies that focus on seabird diet composition and small-scale foraging behaviour.

   Duration: September 15, 2000 - August 31, 2003 (Estimated)

   Budget: $164,473 (Estimated)

4. **Hydrography and Bio-physical Modelling**  
   *Eileen Hofmann (hofmann@ccpo.odu.edu), John Klinck, Ricardo Locarnini, Old Dominion University*

   There are two aspects to this project: the characterisation of the regional hydrography, and the development of a hierarchy of models to organise and integrate the physical and biological observations. The water masses on the continental shelf off Marguerite Bay consist of inflowing Upper Circumpolar Deep Water, which is relatively warm, salty, oxygen-poor, and nutrient-rich. In winter atmospheric processes cool and freshen this water, and recharge it with oxygen to produce Antarctic Surface Water which is diffused seaward, and supports both a sea ice cover and a productive krill-based food web. This project will define these water masses with repeated regional temperature, salinity, nutrients, and oxygen surveys, supplemented by a moored current meter and temperature array, and by acoustic surveys to observe the upper ocean current structure. The modelling effort will provide a mechanism to link water column and sea ice processes with the biology of krill and its predators. It will further help to link these winter observations to similar observations made in summer and elsewhere around Antarctic in the international context of the GLOBEC program. Three major types of models will be used to order the various observations:

   - time-dependent biological models - e.g. species interaction models
   - depth-time models of both physical and biological characteristics - e.g. effect of snow, ice, and water turbidity on the distribution of light
   - three-dimensional and time-dependent models synthesising physical and biological models over the continental shelf.
The specific objective is to develop a comprehensive ecosystem in order to test our understanding of the system, determine its sensitivities, and to provide an organising mechanism for integrating the Southern Ocean GLOBEC observations.

Duration: September 15, 2000 - September 30, 2003 (Estimated)
Budget: $305,471 (Estimated)

5. Mesoscale Circulation, Tides and Mixing on the Western Antarctic Peninsula Shelf
Laurence Padman, padman@esr.org, Earth and Space Research, Robin Muench, NSF

There are several aspects to this project: One is the collection, analysis, and archiving of Acoustic Doppler Current Profiler (ADCP), and Conductivity-Temperature-Depth (CTD) data in order to characterise mesoscale circulation features and the regional hydrography. Another is to develop an accurate and fully validated model of tidal currents in Marguerite Bay. A third is to provide a data set of small-scale processes such as shear instabilities, tidal stirring, mesoscale eddies, and double diffusion, that are required for the effective parameterisation of the vertical diffusivities of heat, salt, and nutrients. The results of this project will provide a unified data set that satisfies the data requirement of the co-ordinated chemical and biological studies which will link water column and sea ice processes with the biology of krill and its predators. The results further will help to link these winter observations to similar observations made in summer and elsewhere around Antarctic in the international context of the GLOBEC program. The overall objective is to develop a comprehensive ecosystem model that will test our understanding of the system, determine its sensitivities, and to provide an organising mechanism for integrating the Southern Ocean GLOBEC observations.

Duration: November 1, 2000 - November 30, 2003 (Estimated)
Budget: $369,293 (Estimated)

6. Sea Ice Microbial Communities
Christian H. Fritsen, cfritsen@dri.edu, U of Nevada

This component will focus on the distribution and activities of sea ice microbial communities. This will be accomplished using an integrated combination of sampling (vertical profiles, horizontal surveys, and under-ice surveys) and observational protocols. Experiments will be designed to estimate microbial activity within the sea ice and at the ice-seawater interface. The research will be co-ordinated with components studying the water column productivity and the sea ice habitat.

Duration: September 15, 2000 - September 30, 2003 (Estimated)
Budget: $301,485 (Estimated)

7. Biochemical Determination of Age and Dietary History in the Krill Euphausia superba
H. R. Harvey, Harvey@cbl.umces.edu, U of Maryland

This component will apply new biochemical approaches to determine the population age structure of krill in field populations over seasonal and interannual time scales. Lipids specific to different food resources will be used in parallel with the intent of establishing markers for dietary history. This research will be co-ordinated with components studying krill feeding and growth.

Duration: September 1, 2000 - September 30, 2003 (Estimated)
Budget: $262,356 (Estimated)

8. Krill Distribution and Abundance in Winter
Meng Zhou, mzhou@d.umn.edu, U of Minnesota

This component will focus on juvenile and adult krill and mesozooplankton prey distribution, using acoustic techniques. Studies will be conducted and krill shrinkage and mortality rates as well as krill aggregation behaviour. The results will be analysed in co-ordination with components involved in physical and biological models.

Duration: September 15, 2000 - September 30, 2003 (Estimated)
Budget: $251,717 (Estimated)
9. Krill Distribution, Physiology and Predation  
*Thomas G. Hallam, hallam@tiem.utk.edu, U of Tennessee, Knoxville*

Duration: September 1, 2000 - September 30, 2003 (Estimated)  
Budget: $300,000 (Estimated)

10. Winter Ecology of Larval Krill: Quantifying their Interaction with the Pack Ice Habitat  
*María Vernet, U of Cal SD, Scripps Institute, La Jolla*

This component will focus on water-column primary production using direct experimental estimates, modelling results from a fast repetition rate fluorometer and modelling of primary production from both optical as well as biophysical models. This research will be co-ordinated with components focused on sea ice production and sea ice habitat.  
Duration: September 1, 2000 - September 30, 2003 (Estimated)  
Budget: $300,000 (Estimated)

11. Winter Ecology of Larval Krill: Quantifying their Interaction with the Pack Ice Habitat  
*Robin M. Ross, Langdon B. Quetin, U of Cal Santa Barbara*

This component will focus on the under-ice distribution and abundance of larval and juvenile krill. The physiological condition of the krill associated with sea ice of differing food quality and quantity will be assessed. This research will be co-ordinated with the krill components that focus on adults in the water column, with the goal of understanding the overall age-specific dynamics of krill in winter.  
Duration: September 1, 2000 - September 30, 2003 (Estimated)  
Budget: $518,000 (Estimated)

12. Foraging Ecology of Crabeater Seals (*Lobodon Carcinophagus)*  
*Daniel Costa, costa@biology.ucsc.edu, Daniel Crocker, U of Cal Santa Cruz*

This component will focus on the distribution and foraging behaviour of adult female crabeater seals, using a combination of satellite-linked tracking, specialised diver recorders, and stable isotopic tracers. This research will be co-ordinated with components focused on prey (krill) distribution and the physical environment. The results will be analysed using an optimality model.  
Duration: September 15, 2000 - September 30, 2003 (Estimated)  
Budget: $183,933 (Estimated)

Jennifer Burns, burns@biology.ucsc.edu, U of Alaska, Anchorage  
Duration: September 15, 2000 - January 31, 2004 (Estimated)  
Budget: $116,067 (Estimated)

13. Optical Environment of the Western Antarctic Peninsula (WAP) Region  
This project is a contribution to a co-ordinated attempt to understand the interactions of biological and physical dynamics by developing mechanistic links between the evolution of the Antarctic winter ice and snow cover, and biological habitat variability, through modelling the optical properties of the environment. The optical properties of snow and sea ice evolve through the winter and vary greatly both spectrally and spatially. These properties are an important element of the physical environment that strongly influences both the distribution of and the resources available to Antarctic krill. The intensity of incident radiant energy and its distribution within the snow, ice, and water column environment, and the linked physical, optical, chemical, and biological processes that modulate its distribution are generally known but poorly quantified. The optical properties of snow and ice also influence snow algae, ice algae, and water column productivity, as well as visibility for both predator and prey. Furthermore, optical properties play an essential role in satellite observations, as proxy indicators of geophysical sea ice parameters, which permit local observations to be more accurately extrapolated in space and time, thus providing regional coverage that would otherwise not be possible. What is proposed is the deployment of an array of instrumented ice beacons, augmented by periodic ship-based and satellite observations, along with theoretical studies to create improved quantitative models with which to follow the temporal and spatial evolution of this snow and ice marine ecosystem. The specific objective is to develop a
thermodynamic sea ice/ecosystem model through coupling of existing components in order to test our understanding of the system, determine its sensitivities, and to provide an organising mechanism for integrating the Southern Ocean GLOBEC observations.

Raymond Smith, ray@icess.ucsb.edu, U of Cal Santa Barbara
Duration: September 1, 2000 - September 30, 2003 (Estimated)
Budget: $157,457 (Estimated)

Donald K. Perovich, perovich@crrel.usace.army.mil, USACRREL
Duration: September 1, 2000 - August 31, 2001 (Estimated)
Budget: $46,056 (Estimated)

Douglas Martinson, dgm@ldeo.columbia.edu, Columbia University
Duration: September 1, 2000 - September 30, 2003 (Estimated)
Budget: $167,278 (Estimated)

14. Modelling the Effects of Eddies and Mean Flows on Southern Ocean Biology
Glenn Flierl, MIT
This project is an attempt to understand the interactions of biological and physical dynamics by modelling the spatial distribution of Antarctic krill, a small crustacean that forms dense aggregations or patches on the small scale. The spatial distribution of these patches appear to depend on the advance and retreat of the sea ice, the three dimensional movement of water masses from small scale turbulence to the dynamics of the Antarctic Circumpolar Current, as well as on food supply and predation pressure. Prior work has shown that physical processes dominate on the larger scale, while biological processes dominate on the smaller scale, but the relative importance of the two as a function of scale has not been investigated systemically. This work will be carried out in the context of the Southern Ocean Experiment of the Global Ocean Ecosystem Dynamics Study (GLOBEC), a large, multi-investigator study of the winter survival strategy of krill under the Antarctic sea ice. The problem of accurately representing patchiness in a circum-Antarctic model is that of properly representing effects that occur on a scale that is not resolved in the model. The approach that will be used here is to first study a detailed model that can resolve the scale of krill patches and can help to analyse and understand the observations that will be made in the Experiment. These results will allow us not only to make a more quantitative estimation of the errors involved, but also to improve the parameterisation of krill distributions in meso-scale and basin-scale models of the Southern Ocean.
Duration: July 15, 2000 - June 30, 2001 (Estimated)
Budget: $334,870 (Estimated)

15. Small Scale Mixing and Krill Behaviour
Thomas M. Powell, zackp@socrates.berkeley.edu, U of Cal Berkeley
The objective of this project is to make a quantitative assessment of the small scale temperature and salinity structure of the oceanic surface layer in order to study the effect of stratification and turbulence on the biochemical and biological processes under the winter sea ice. The water masses on the continental shelf off Marguerite Bay consist of inflowing Upper Circumpolar Deep Water, which is relatively warm, salty, oxygen-poor, and nutrient-rich. In winter atmospheric processes cool and freshen this water, and recharge it with oxygen to produce Antarctic Surface Water which is diffused seaward, and supports both a sea ice cover and a productive krill-based food web. The modification processes work through mixing associated with shear instabilities of the internal wave field, double diffusion of salt and heat, and mixing driven by surface stress and convection. These processes will be quantified with two microstructure profilers, capable of resolving the small but crucial vertical variations that drive these processes.
Duration: September 15, 2000 - September 30, 2003 (Estimated)
Budget: $227,683 (Estimated)
16. Circulation and Water Property Evolution  
Robert C. Beardsley, rbeardsley@whoi.edu, Richard Limeburner, Woods Hole Ocean Institute
The objective of this project is to develop and deploy a series of moorings on the continental shelf off Marguerite Bay. These will include current meters, salinity and temperature sensors, zooplankton concentration, upward-looking acoustic sounders to track ice motion, and Acoustic Doppler Current Profilers. The proposed mooring design will quantify and characterise the inflowing and outflowing water masses, and provide the physical component for the integrated modelling effort. Instrumented drifters that track surface flow will supplement the mooring data. The water masses on the continental shelf off Marguerite Bay consist of inflowing Upper Circumpolar Deep Water, which is relatively warm, salty, oxygen-poor, and nutrient-rich. In winter atmospheric processes cool and freshen this water, and recharge it with oxygen to produce Antarctic Surface Water which is diffused seaward, and supports both a sea ice cover and a productive krill-based food web. The observations produced by this project will quantify the spatial and temporal variability of the presumed clockwise flow through the bay, and define the tidal and transient flows driven by storms and southward meanders of the Antarctic Circumpolar Current.
Duration: September 15, 2000 - September 30, 2003 (Estimated)
Budget: $2,082,652 (Estimated)

17. Mysticete Whale Acoustic Census
John A. Hildebrand, jah@mpl.ucsd.edu, Sue Moore, Mark A. McDonald
U of Cal SD Scripps Inst La Jolla, CA
This component will focus on determining minimum population estimates, distribution and seasonality for mysticete whales, especially blue whales. This will be accomplished using passive acoustic recorders deployed on the seafloor for a period of one to two years. The deployment of a large aperture autonomous hydrophone array in the Antarctic will incorporate the use of passive acoustics as a tool for mysticete whale detection and census.
Duration: September 1, 2000 - August 31, 2003 (Estimated)
Budget: $388,045 (Estimated)
**Project Title:** Seasonal population dynamics and ecophysiology of Antarctic krill *Euphausia superba* in the Lazarev Sea

**Source of Information:**
Dr. Uli Bathmann, November 2003

**Chief Scientist:**
Dr. Uli Bathmann  
ubathmann@awi-bremerhaven.de

**AWI for Polar and Marine Research**  
Am Handelshafen 12  
Postfach 120161  
D-27515 Bremerhaven  
Germany

**Project Description:**
The Antarctic krill (*Euphausia superba*), is a species with increasing commercial interest. It is a key individual in the Antarctic ecosystem, being a major food item for a large number of top predators such as whales, mammals and sea birds. Even their faecal pellets are incorporated in the food web through ingestion by copepods. *E. superba* is very successful in the extreme environment of the Southern Ocean because it is capable of exploiting a food supply that is both patchy and seasonal. However, despite several decades of intensive research the understanding of its life strategy is incomplete. Up to now, most of the information available is based on investigation during the Antarctic summer on adult *E. superba*, and only little is known about its larval ecology. The winter distribution and behaviour of the stocks of Antarctic krill developed during summer months are still unresolved. There is a comparative lack of data on the winter energy budget, particularly for krill larvae. And there is a lack of data from regions around Antarctica especially from the area east of the Weddell Sea (i.e. Lazarev Sea). These data are essential, for developing a model for population dynamics and for a better estimation of krill production.

Therefore the question of increasing interest is how do krill survive during winter, when most of the Southern Ocean is covered by ice and primary production is low?

The study will be carried out in cooperation with our partners during expeditions into the Lazarev Sea. We will focus on early and late winter studies from board the research vessel "Polarstern" (April, May 2004; August, September 2005; January, February 2006 (tentative)) in the area 0°E to 25°E, 64° to 70°S. In addition, in February to July 2005 laboratory experiments are planned in the AAD in cooperation with Dr. Steve Nicol, to investigate regulating mechanisms for metabolic reduction in krill during winter.

**Website:**
http://www.awi-bremerhaven.de/Biomeer/zooplankton-top02-e.html

**System Types Studied:**
The Atlantic and Indian Sector of the Southern Ocean.  
Overwintering regions of krill (pelagial, sea-ice, others).

**Target Organisms**
*Euphausia superba* (Antarctic krill)
Structure of the Project:

Co-ordination: U. Bathmann, B. Meyer (AWI)

<table>
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<tr>
<th>Populations Dynamics</th>
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<th>Krill Distribution</th>
<th>U. Bathmann</th>
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<td>AWI-Acoustic</td>
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<th>Larval Physiology</th>
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<th>Krill Lipids</th>
<th>W. Hagen</th>
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<td>Univ. Bremen</td>
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Funding: BMBF, DFG, AWI, others

Partners: S. Nicol AAD, A. Atkinson BAS, D. Thiele IWC

Outreach: ACE-CRC, CCMLR, ICCED, IPY, IMBER (IGBP), MARCOPOLI, SCAR

Key Questions, Hypotheses and Issues:
The main objectives of this research project are to establish:

- If, when and what do larvae and adult krill feed on during late autumn and winter in the Lazarev Sea
- What is krill abundance in the area and do we have one or more populations present?
- What are the available food sources and to quantify specific ingestion and assimilation rates for single developmental stages of E. superba present during the time of investigation.

These objectives are essential for a better understanding of the reproduction success and therefore for stock assessment.

To achieve the research objectives for larval and adult krill the project contains the following working steps:

- determination of hydrographic conditions in the Lazarev Sea relevant for krill
- determination the krill abundances in space and time
- determination of quantity and quality of food sources present
- determination of elemental and biochemical composition of larvae and adult krill
- determination of feeding rates on the phytoplankton stock in general and on different autotrophic groups and heterotrophic micro- and mesozooplankton in particular

Number of scientists and fte:
9 senior scientists/post-docs, 5 PhD students, 2 technicians

Participating Institutions:
Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI), Germany
Marine Zoology, University of Bremen, Germany
Environmental Physics, University of Bremen, Germany
Bundesamt für Fischerei (BfF), Hamburg, Germany

Co-operation:
British Antarctic Survey (BAS), Cambridge, UK
Antarctic Cooperative Research Center (ACE-CRC), Tasmania, Australia
ALTERRA, Marine and Coastal Zone Research, Netherlands
International Whaling Commission (IWC), Australia
Laboratory of Aquatic Ecologie (LAE), Leuven, Belgium

**Duration:**
2004-2007

**Funding Agency:**
Bundesministerium für Bildung und Forschung (BMBF)
Deutsche Forschungsgemeinschaft (DFG)
Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI)

**AWI Future Plans:**
Draft Ship Schedule: from 2004:

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Institution</th>
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<tr>
<td>2004</td>
<td>April - May</td>
<td>AWI (Alfred Wegener Institute), Germany</td>
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<td>2005</td>
<td>August - September</td>
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<td>2006/07</td>
<td>January-February</td>
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**PROGRAMME: SO GLOBEC - INTERNATIONAL WHALING COMMISSION**

**Project Title:**

**Source of Information:**
Deborah Thiele, November 2003

**National Representative/ Contact:**
Deborah Thiele
dthiele@deakin.edu.au
Chair, IWC Scientific Committee Working Group on IWC-Southern Ocean Collaboration
Whale Ecology Group – Southern Ocean (WEG-SO),
School of Ecology and Environment,
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Australia

**Project Description:**
The initial collaboration in the Southern Ocean for the IWC under the then IWC - SOWER programme involved research with GLOBEC and CCAMLR. The IWC participated in German and US SO GLOBEC programs in the Western Antarctic Peninsula during 2001 – 2003. On those cruises, visual surveys were run to collect cetacean sightings simultaneous with krill and other physical and biological data. Standard IWC methodology for multidisciplinary studies was used. Data were recorded on a laptop based tracking program, and photo and video records were also obtained for species identification, group size verification, feeding (and other behaviour), ice habitat use and individual identification where possible. Ship and helicopter time were provided to the IWC teams on some cruises to facilitate this work. During these surveys, work was done in partnership with cetacean passive acoustic studies, and this led to the development of a refined project approach for ongoing collaboration in this region.

The development of the AAA/IWC collaborative program is an important component in a circum-Antarctic approach to investigating the connections between whale ecology and the variability and dynamics of Antarctic ecosystems. The main objective of the IWC/AAA is implementing a circum-Antarctic continuous acoustic monitoring system for cetaceans, to investigate connections between cetaceans and variability in ecosystem processes at local, regional and circum-Antarctic scales. The AAA program has been structured to include a variety of novel and historical cetacean research methods whilst simultaneously developing the potential of the new year-round acoustic recording packages (ARP's). While methodologically powerful, passive acoustic technology can currently provide data on call frequency, but cannot, when used remotely in the Antarctic, provide a reliable measure of relative abundance on any temporal or spatial scale, and does not allow an assessment of the number of individual whales calling at any one time, both critical elements in determining seasonal abundance. In order that this tool reaches its potential for application to cetacean conservation and management issues it is essential that means be developed to overcome this limitation as far as possible. Additionally, acoustic research needs to be partnered by studies to develop an ecological context for the analysis of acoustic data. For example, calling rates or spectra may vary with behaviour in response to changes in habitat characteristics. This can only be determined by ship-based research simultaneous with acoustic recordings.

**Website:**
Full cruise reports, web diaries and images from all of the cruises can be found at:
http://www.ccpo.odu.edu:80/Research/GLOBEC/iwc_collab/menu.html

**Target Organisms:**
Cetaceans
**System Types Studied (current and planned):**
Marguerite Bay, Western Antarctic Peninsula, Southern Ocean (2001 – 2003 ongoing)
South Orkney Islands, Southern Ocean (2004 – ongoing)
Mawson and Casey, East Antarctica, Southern Ocean (2002 – 2004 ongoing)
Elephant Island, Antarctic Peninsula, Southern Ocean (2003-4)
Amundsen and Bellingshausen Seas (2006 – 2010)

**Physical Processes Examined:**
Sea ice cover and type

**Key Questions, Hypotheses and Issues:**

*Initial objectives*
The long term aim of the programme is to define how spatial and temporal variability in the physical and biological environment influence cetacean species in order to determine those processes in the marine ecosystem which best predict long-term changes in cetacean distribution, abundance, stock structure, extent and timing of migrations and fitness.

Three specific objectives have been identified under the framework of the overall objective:

- Characterise foraging behaviour and movements of individual baleen whales in relation to prey characteristics and physical environment.
- Relate distribution, abundance and biomass of baleen whale species to same for krill in a large area in a single season.
- Monitor interannual variability in whale distribution and abundance in relation to physical environment and prey characteristics.

*Expanded objectives with development of AAA program*

Our experience in the first two years of SO GLOBEC surveys has led to the development of an additional long-term objective: the development of a cost effective, useful cetacean monitoring system for the Southern Ocean. This system will be developed using year-round passive acoustic recording packages (ARP’s) and associated fine scale ecological studies across a number of oceanic regions in the Antarctic.

A major aim of this work is to develop a broad set of categories of association between behaviour, environmental conditions and calling rates for each species. These will be continuously refined until we have a tool that will allow the interpretation of ARP data with remotely sensed environmental data to predict, link and extrapolate whale distribution, and causes at local, regional and circum-Antarctic scales.

**Number of scientists and fte:**
Variable

**Participating Institutions:**
IWC
GLOBEC
CCAMLR
Various Institutions associated with Antarctic multidisciplinary research and national programs.
The AAA program is a joint research effort between J. Hildebrand (Scripps), Sue Moore (NOAA), and Deborah Thiele (IWC/WEGSO) and others, and is a core part of the IWC collaborative work in the Southern Ocean.

**Duration:**
Commenced 2001 and ongoing. Plans for collaborative work under the ICCED initiative beyond 2010

**Funding Agency:**
International Whaling Commission
Vessel, in kind and monetary support from national programs and other funding bodies
**PROGRAMME: SPACC**

**Project Title:**
SPACC – Small Pelagic Fish and Climate Change

**Source of Information:**
Claude Roy, December 2004

**Co-ordinators:**
Prof Dave Checkley Jr. (Co-chair)  
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USA

Dr Claude Roy (Co-chair)  
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**E-mail:** dcheckley@ucsd.edu  
clauderoy@ird.fr

**Project Description:**
The goal of the GLOBEC Small Pelagic Fish and Climate Change (SPACC) programme is to understand and predict climate-induced changes in the fish production of marine ecosystems. In addition to having broad economic and ecologic importance, this goal is especially pertinent today because of the expected changes in the earth climate over the next hundred years and their impact on the oceans and marine life. Small pelagic fishes are an ideal subject for the study of the effects of climate change on marine ecosystems because they are globally distributed and constitute over a third of the global marine fish catch. Moreover, by having a short life span and by feeding on the plankton-based food chains, they respond rapidly to changes in ocean forcing. Ocean-wide decadal swings in abundance have been identified and are thought to be environmentally driven. Lastly, time series of catches and abundance offer a rich data resource for retrospective data analyses.

The Small Pelagic Fish and Climate Change programme is a major component of the GLOBEC field research programme. An aim is to identify those physical forces that control the dynamics of small pelagic fish populations. Modelling is also a key issue for SPACC. By using a combination of retrospective data analyses, process studies and modelling experiments, the long-range goal of SPACC is to provide scenarios of the changes in the abundance and distribution of small pelagic fish populations caused by human- and naturally induced climate changes.

The approach of SPACC is to compare the characteristics and variability of the physical environment, zooplankton population dynamics, and fish population dynamics among ecosystems. SPACC involves:

- Retrospective studies, in which ecosystem histories are reconstructed by means of time series, paleoecological data, and genetic data.
- Process studies, in which cause-and-effect linkages between fish population dynamics and ocean climate are investigated and compared between ecosystems

The SPACC science and implementation plans were designed in the late 1990s (see GLOBEC Reports 8 and 11). They were revised in 2000 to increase focus and ensure maximum use of resources. SPACC is organised along four major scientific themes:

**Theme 1 – Long term Changes in Ecosystems: Retrospective Analyses**
*Theme representatives: J. Alheit, T. Baumgartner*

The focus of Theme 1 is to explore how fish populations respond to ocean climate over time spans of hundreds to thousands of years. Long time series of data and modelling are used to determine how variation in the coupled ocean-atmosphere climate system affects the ecosystems in which small pelagic fish are important. It has a global and atmospheric perspective because climatic
teleconnections are believed to be involved. The paleoecological component is driven by the fundamental discovery that anoxic sediments in regions with small, pelagic fish contain scales that can be used to reconstruct time series of abundance of those fish over thousands of years.

Three meetings related to Theme 1 were held over the last two years. "Major Turning Points in the Structure and Functioning of the Benguela Ecosystem" was the topic addressed by a GLOBEC-SPACC/IDYLE/BENEFIT meeting (Cape Town, South Africa, 12-16 February 2001). This meeting was the first of a series of similar workshops that will investigate turning points in other regions of the world that support large populations of sardine and anchovy. The Cape Town meeting was followed by a GLOBEC-SPACC/IAI workshop on "Comparative Studies of Long-Term Variability of Small Pelagic Fishes in the Humboldt and California Current Ecosystems" (Lima, Peru, 29 May -1 June 2001). Finally, a SPACC/GLOBEC Workshop on Paleoceanography (Munich, Germany, 10-13 October 2001) brought together research teams carrying out high resolution analyses of sediment cores from different anoxic sites in order to compare and cross-calibrate methodologies and co-ordinate future co-operation and comparisons. Overviews of the outputs of those three meetings were published in the April 2001 and April 2002 issues of the GLOBEC Newsletter.

A workshop, "SPACC in the Kuroshio System", was held 9-10 December 2003 at the Ocean Research Institute, University of Tokyo, Japan. This workshop included presentations of time series concerning anchovy, sardine, and herring in the North Pacific, as well as other regions, and possible mechanisms for the observed fluctuations.

### Theme 2 – Comparative Population Dynamics

**Theme representative: M. Barange**

Fish biomass per unit of stock is used to compute and compare quantitative estimates of small pelagic fish production and, most important, production of biomass or recruits per unit area of spawning and feeding habitats. This work provides a quantitative basis for comparing fish production between and within all systems in standard production units.

A review paper (Jacobson et al., 2001) emanated from the outcome of a workshop in Dartmouth, Canada. This paper is on surplus production and climate change in the great sardine and anchovy fisheries. Recent activities related to Theme 2 include an IOC/SPACC Study Group on "Use of Environmental information on the management of pelagic fish populations” (see GLOBEC Newsletter, April 2002). The group met for the first time in Cape Town (3-5 September 2001). Its second and final meeting was at IOC/UNESCO in Paris, November 2002 and resulted in GLOBEC Special Contribution No. 6.

### Theme 3 – Reproductive Habitat Dynamics
**(including WG7 – Spawning and Nursery Habitat Quality and Dynamics, WG8 – Spawning Habitat Dimensions and Location and WG6 – Daily Growth and Zooplankton)**

**Theme representatives: D. Checkley and C. Roy**

The focus of Theme 3 is comparisons between systems to identify how small pelagic fishes adapt their reproductive strategies to the various kinds of physical forcing and mesoscale features of their habitat, and how such systems constrain fish productivity. A central hypothesis is that changes in productivity are caused by changes in the temporal and spatial dimensions of the spawning habitat, as well as its location and quality. A major component of Theme 3 is based on the use of CUFES for mapping egg distributions and to achieve a quantitative description of the spatio-temporal dynamics of spawning. The use of hydrodynamic models coupled with NPZD and IBM models is also a central focus, in order to investigate the links between environment variability, spawning, and recruitment success. Ecosystems are compared to separate physical forcing from stock-dependent effects on spawning and recruitment selection and to examine the extent to which productivity is limited by space and time variation in spawning habitat.

Activities related to Theme 3 have a wide geographical range and cover the Humboldt, Benguela, and California Current Systems and the Bay of Biscay. A SPACC/IDYLE/ENVIFISH workshop held in Cape Town (September 2001) focused on spatial approaches of the dynamics of coastal pelagic resources and their environment in upwelling areas (see GLOBEC Newsletter, April 2002). The meeting aimed at synthesizing the state of the art concerning recent theoretical achievements, analysis techniques and
modelling tools used for the integration of spatial structures in the study of the dynamics of marine populations and their environments. The outcome was published in GLOBEC Report 16 (Van der Lingen et al., 2002). On-going CUFES sampling is currently taking place in California (16 cruises 1996-2002), Mexico (10 cruises 2000-2002), Peru (5 cruises 1999-2001) and Chile (4 cruises 1999-2001), thanks to IAI funding. CUFES is also used by South Africa (Benguela), Spain and France (Bay of Biscay), and Canada (East Coast). The automation of detection and counting of fish eggs in CUFES in real-time by use of machine vision is nearing completion.

A workshop and meeting on characterizing and comparing the spawning habitats of small, pelagic fish was held in Concepcion, Chile 12-16 January 2004. The meeting also addressed the use of daily egg production method to assess the spawning biomass of small, pelagic fish.

**Theme 4 - Economic Implications of Climate Change**

*(including WG10 – Economic Consequences and links to IGBP Food and Fibre and IHDP)*

*Theme representatives: J. Hunter (ex-officio)*

A workshop on the economics of small pelagics and climate change will take place in Portsmouth, UK, in September 2004. Some of the issues to be discussed at this workshop would be (a) effects of low- and high-frequency climatic events on fish productivity; (b) impacts of climate change on harvesting and processing capacity and fisheries investments; (c) economic benefits of cooperative management of transboundary stocks; (d) impacts of the international trade of small pelagic fish and their substitutes; and (e) the value of improved long-range climate prediction.

**SPACC Publications in GLOBEC report or special contribution:**


GLOBEC Report No. 11: Small Pelagic Fish and Climate Change Programme. Implementation Plan.


GLOBEC Report No. 16: Report of a GLOBEC-SPACC/IDYLE/ENVIFISH workshop on spatial approaches to the dynamics of coastal pelagic resources and their environment in upwelling areas. 6-8 September 2001, Cape Town, South Africa.

GLOBEC Special Contribution No. 5: Report of the 1st meeting of the SPACC/IOC study group on "Use of environmental indices in the management of pelagic fish populations". 3-5 September 2001, Cape Town, South Africa.


**National contributions to SPACC**

**Benefits and obligations of GLOBEC SPACC projects**

GLOBEC and SPACC provide a framework to encourage the fullest participation of national, multinational and regional scientific efforts. It does not impose a rigid template on the format and nature of these efforts, except the acceptance of the scientific principles outlined in the GLOBEC Science and Implementation Plans. The following provides some guidance on the benefits and responsibilities associated with involvement in GLOBEC and SPACC; they are not intended as a formal set of regulations.
Benefits
- Provides the opportunity for participation in the development, planning and implementation of a collaborative international science programme.
- Adds to the scientific value of planned work by providing complementary information; for example, by widening the range of studies and extending their spatial and temporal coverage.
- Promotes rapid communication of ideas and results, through meetings and publications.
- Connect and favour collaboration between scientists from different regions working on similar scientific themes (data and methodological exchanges).
- Develops and tests standard methods and protocols for measuring variables, thereby facilitating quality control and meaningful data sharing.
- Makes available metadata sets (inventories) collected in component studies and develops a common metadata management strategy.
- Enables close working links with other relevant international or regional programmes and studies.
- Facilitates process understanding of regional studies through comparisons with other ecosystems.

Responsibilities
- Acceptance of general principles and goals outlined in the GLOBEC and SPACC Science Plans.
- Carry out a programme in general accordance with relevant aspects of the GLOBEC and SPACC Implementation plans and strategies.
- Participation in the activities of the programme through its management bodies (GLOBEC SSC, SPACC Executive, etc.), by assisting in its planning and development as a whole.
- Make metadata collected within the programme available to the wider GLOBEC community, in accordance with GLOBEC protocols for international metadata exchange.
- Acknowledgement of the links with GLOBEC-SPACC in the products of the project (e.g. acknowledgement in scientific papers).
- Assist in programme co-ordination in the provision of central services; for example, data management.

All SPACC contributions are included even those that have been completed as they were not included in the last edition of the GLOBEC Activities Report.

SPACC Projects
Many National and Multinational GLOBEC projects also contribute to SPACC, details of the projects can be found under the relevant section with a cross reference below. National contributions to SPACC include: Japan, China, Chile, Brazil, Germany, Korea, Peru, Mexico and the Multinational projects: BENEFIT and IDYLE.

1. VARIPLACA - Temporal variability of planktonic communities in the Central Cantabrian Sea
Details of the VARIPLACA project can be found in the Spanish GLOBEC section on page 55.

2. PELAGICOS - Reinforcing the capacity of investigation in the area of oceanography and fishery biology applied to the management of pelagic marine resources
Details of the PELAGICOS project can be found in the Portuguese GLOBEC section on page 48.
3. Biological condition of Chilean jack mackerel in oceanic waters

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Instituto de Investigación Pesquera  
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Talcahuano  
Chile  

**E-mail:** lcubillos@inpesca.cl  
**Telephone:** +56 41 920410  
**Fax:** +56 41 920411

**Project Description:**
The aim of this research is to analyze the spawning of jack mackerel (Trachurus symmetricus murphyi), to analyze the feasibility of the daily egg production method for estimation of the spawning biomass. At present we have three years of data, and a repetition will be done in 2002. The main results of the research are: a) the persistence of the spawning of jack mackerel in oceanic waters off central-southern Chile, b) daily egg production and mortality estimates, c) fecundity, and spawning fraction of females.

**System Types Studied:**
Oceanic waters of central Chile

**Target Organisms:**
Trachurus symmetricus murphyi

**Participating Institutions:**
Instituto de Investigación Pesquera

**Funding Agency:**
Fondo de Investigación Pesquera, Chile

**Related Publications:**


4. Spawning biomass estimation for anchovy and common sardine in central south Chile

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Telephone: +56 41 920410
Fax: +56 41 920411

Project Description:
This research will provide an estimation of the spawning stock biomass of common sardine (*Strangomera bentincki*) and anchovy (*Engraulis ringens*) in 2002 by applying the daily egg production method.

Target Organisms:
*Strangomera bentincki* and *Engraulis ringens*

Participating Institutions:
Instituto de Investigación Pesquera

Funding Agency:
Fondo de Investigación Pesquera, Chile

Related Publications:


5. Daily egg production method applied to anchovy

Contact details:
Gabriel Claramunt Quiñónez  
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Universidad Arturo Prat  
Departamento de Ciencias del Mar  
Casilla 121  
Iquique  
Chile

Project Description:
Since 1992 the Daily Egg Production Method (DEPM) have been applied seven times to the northern stock of *Engraulis ringens* (1992, 95, 96, 97, 99, 2000 and 2001), which is aimed at estimating the spawning biomass. This fishery independent method is playing an increasing role in anchovy stock assessment, and is therefore included every year in the annual research program of the Fondo de Investigaciones Pesqueras (FIP; Fisheries Research Founds) in Chile. The area covered every year is between 18° 30' to 26° S.L. and from the coast to 60 nm offshore with 500 egg samples on average. Adult samples are obtained with purse seiners, with a minimum of 30 females and 40 hauls. Estimated biomass is ranged from 385.000 tons in 1996 to 754.000 tons in 2000. Lower spawning fraction was obtained in 1997, year with a El Niño event. Daily egg production in the sea goes from 23.8 to 66.9 eggs/0.05 m²/day for 1997 and 2001 respectively.

This year we are involved in the 8th application of the DEPM in northern Chile and the first in the southern Chile, then the populations comparison will be possible. In northern Chile, the DEPM time series will allow the examination of several population and biological responses, such as size and distribution of the spawning area, egg production and egg mortality rates, female size and partial fecundity and how these population features may have responded to environmental variability.

Target Organisms:
*Engraulis ringens*

Participating Institutions:
Universidad Arturo Prat

Funding Agency:
Fondo de Investigación Pesquera, Chile

Related Publications:


6. Fish reproduction

Contact details:
Gabriel Claramunt Quiñónez
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Casilla 121
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Chile

E-mail: gclaramu@cec.unap.cl

Project Description:
The reproduction studies in anchovy and sardine have been focused mainly on two interrelated topics. The first issue is related to the following question: How many eggs do stocks of fish with multiple spawnings and indeterminate fecundity produce on a given period, say a year? This question is highly relevant for population dynamics and fisheries biology since many fish stocks of commercial importance show indeterminate fecundity. For example, one of the major issues in the field is the existence and nature of a relationship between the abundance of spawners and recruitment. This issue can be clarified by considering total egg production, instead of spawning biomass, as best representing the true reproductive potential of a stock, and then search for its relationship with recruitment. This is not just a change of focus since spawning biomass and total egg production in fish with indeterminate fecundity are not expected to be proportional.

The second issue is the study of intra and interannual fluctuation of spawning frequency and batch fecundity. These variations can be caused by different factors, such as food availability, size structure of the population, temperature and stock size. Batch fecundity may vary during a season, between years, and between sub-populations. The controlling variables for these changes are probably energy supply, egg size and its relation to larval growth and survival, and duration of the plankton production cycle. Along with the fluctuations in fecundity, it is currently recognized that the reproductive energetic effort during spawning involves a compromise between fecundity and egg size and the amount of yolk to the eggs, and that these may also vary seasonally. The general pattern is larger eggs spawned during winter and smaller in summer. The egg size may be an important factor for the survival of early stages of development, as it affects the hatching size and growth rates of the young larvae. Egg size and fecundity are believed to usually vary inversely. However, Claramunt et al. (1994) reported that during the peak spawning they may vary in the same direction. According to them, the decrease in fecundity and egg yolk content (related to egg size) observed in 1992 might be associated to increases in temperature during the 91-92 El Niño as it had been also reported by Winters et al (1993) and Tanasichuk and Ware (1987) previously. These results suggest again, that the environmental conditions, may have an effect on the adult reproductive characteristics as well as on the quality of the spawned eggs.

Target Organisms:
*Engraulis ringens* and *Sardinops sagax*

Participating Institutions:
Universidad Arturo Prat

Related Publications:


7. IDYLE: Interactions and spatial dynamics of renewable resources in upwelling ecosystems
*Details of the IDYLE project can be found in the Multinational section on page 119.*

8. NATFISH: Natural variability of a coastal upwelling system and small pelagic fish stocks
*Details of the NATFISH project can be found in the Multinational section on page 123.*

9. FOREVAR: Meso-scale environmental forcing and variability of pelagic populations in the Bay of Biscay
*Details of the FOREVAR project can be found in the French GLOBEC section on page 15.*

10. Distribution, biology and biomass estimates of the Sicilian Channel Anchovy. Study project MED 96-052 (MAGO I).

**Contact details:**
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Angelo Bonanno (bonanno@irma.pa.cnr.it)  
Bernardo Patti (bpatti@irma.pa.cnr.it)

IAMC-CNR, Sezione di Mazara del Vallo  
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Italy

**Project Description:**
From the summary of the Final Report of the project:

“The objective of this project was to know the distribution, biology and abundance of the European Anchovy *Engraulis encrasicolus* in the Sicilian Channel, together with the analysis of the main hydrological factors affecting its different early life stages in order to explain the stock-environment relationship.

The objectives were accomplished by means of two oceanographic multidisciplinary surveys carried out during the anchovy peak spawning period. The plankton and hydrological survey (ANSIC-0797) was accomplished during July 19-August 8, 1997 on board the F/V Santa Anna; it covered from the northwestern Sicilian shelf and slope to the southern shelf which extends over Malta, and the surrounding Tunisian shelf/slope of Lampedusa. This survey defined the boundaries of the anchovy spawning grounds and acquired some environmental data related to the oceanographic regime of the study area and provided anchovy larval samples to do the daily growth and condition analysis. In 1998, two cruises (BANSIC-0698) were carried out simultaneously: a plankton, hydrological and the DEPM egg survey from June, 24th to July, 14th aboard the R/V Urania and an acoustic and the DEPM adult survey during June 11-30 on board the R/V Salvatore Lo Bianco. These surveys estimated the anchovy spawning biomass and characterised the main environmental features that influence the
distribution, abundance and survival of the early life stages of anchovy. In addition, the catch-effort fishery data collection and the biological sampling of anchovy were carried out at Sciacca, the most important anchovy base port in the study area.

Catch data revealed the socio-economic importance of anchovy and a high variability in their landings: 400 and 1,292 t in 1997 and 1998, respectively. The spawning stock and the fishery is mainly concentrated along the mid-part of the southern Sicilian coastline, particularly in the narrower region of the shelf. This area is under the direct influence of the incoming Atlantic current. The current describes two cyclonic gyres that favour upwelling at north-western and south-western ends of the study area. Moreover, intense wind-driven upwelling events occurring near shore and their associated off-shore Ekman transport, along with the circulation pattern of surface waters, can build up an effective along-shore transport of eggs and larvae displacing them to the southernmost end of the island. Here, the second gyre can act as a retention mechanism facilitating the recruitment of larvae into nursery and growth areas in the coastal waters off Cape Passero. This transport is evidenced by the decreasing trend in the anchovy egg abundance from the Sciacca spawning ground towards the south, and the higher larval concentrations in the vicinity of Cape Passero. Thus, the anchovy spawning strategy seems to be closely linked to the physical processes described in the region.

Higher anchovy larval growth rates are observed in comparison to the NW Mediterranean anchovy due to the higher surface temperatures. While comparatively lower RNA/DNA ratios (nutritional condition) are encountered, attributed to a more efficient and accelerated metabolism. Nevertheless, if feeding requirements are not met in these oligotrophic waters, match/mismatch phenomena can ultimately decide larval survival.

The DEPM and acoustic biomass estimates are in quite good agreement. The acoustic estimate in the area covered by the DEPM amount to about 7,800 t, while the DEPM estimate is 6,218 t. This spawning estimate takes into account the observed underestimation of the spawning fraction of mature females due to the extraordinary high incidence of atresic females.”.

**System Types Studied:**
Central Mediterranean (Strait of Sicily)  
Continental shelf and slope off the southern coast of Sicily

**Target Organisms:**
Anchovy (*Engraulis encrasicolus*), zooplankton, ichthyoplankton including anchovy larvae

**Physical Processes:**
Water column stratification and mixing  
Fronts  
Upwellings

**Participating Institutions:**
Istituto per l’Ambiente Marino Costiero, sez. di Mazara del Vallo (IAMC-CNR)  
Instituto Español de Oceanografía (IEO), Centro de Fuengirola, Málaga, Spain  
Departamento de Física Aplicada II, Universidad de Málaga, Málaga, Spain

**Number of Scientists:**
12 scientists, 8 technicians

**Duration:**
2 years: Jun 1997 – Jun 1999

**Funding Agency:**
European Commission, DG XIV

**Budget:**
1.167.682 €/ 2 yr
Related Publications:

11. The Sicilian channel anchovy fishery and the underlying oceanographic and biological processes conditioning their inter-annual fluctuations

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Italy

Project Description:
From the summary of the Final Report of the project:

“The general objective of this project was to investigate on the oceanographic and biological processes conditioning the inter-annual fluctuations of the European Anchovy Engraulis encrasicolus in the Sicilian Channel. In order to study of environmental conditions able to affect distribution of adults stages, their reproductive potential and ultimately the recruitment success, an interdisciplinary approach was adopted, which involved: 1) the collection and analysis of oceanographic, meteorological and satellite data to depict the main hydrological features of the study area, 2) the accomplishment of ichthyoplanktonic and hydro-acoustic surveys for the evaluation of the fish stock size, and 3) the analysis of retrospective Catch Per Unit Effort (heretofore CPUE) data in the main port (Sciacca) of the study area. Data analysis included information previously collected by the same research team within the former EU-funded project MED96-052. The spawning biomass of the anchovy population off the southern coast of Sicily in mainly composed by year class 1, so current stock size of this resource mainly depends on the recruitment success. Stock biomass evaluations and CPUE estimates indicated consistent and remarkable interannual fluctuations in the last 5 years (1997-2001) which were related to hydrological variability.

The main hydrographic feature off the southern Sicilian coasts is the Atlantic Ionian Stream (heretofore AIS), a meandering surface current inflowing towards the Ionian Sea. Its path and its year to year variability has consequences on the other predominant hydrological phenomena occurring in the region, such as, on the extension of upwelling and on the formation of frontal structures. All these hydrological features have shown their influence on the anchovy spawning strategy and the survival of the early life stages.
On one hand, the AIS acts as a transport mechanism for displacing eggs and larvae from the more important northern spawning grounds towards the southern limit of the region. If the AIS path is distant offshore, the northern coasts can show a greater upwelling extension, thereby, producing drastic changes in the temperature regime of the surface waters. If upwelling is intense, anchovy which has preference for warm waters, may refrain from spawning during the peak spawning season. On the other hand, by means of the AIS transport, larvae tend to aggregate in the southernmost region of the island’s tip, off Cape Passero. In this region, the AIS forms a cyclonic gyre which helps maintain the relative position of larvae in the area, thus retaining the larval population and reducing larval mortality linked to offshore advection. In addition, when the AIS trajectory meets water masses from the northern part of the Ionian Sea, a density front is formed that concentrates plankton, thus providing the feeding requirements for an adequate growth of larval stages. Data analysis indicates larval survival in the region off Cape Passero might have an important role on the recruitment success and consequently on the stock size of the Sicilian Channel population. The highest anchovy spawning biomass corresponded to year 1998. This stock suffered a sharp drop during 1999. Contrarily, the lowest anchovy spawning biomass estimated occurred during the year 2000. However, the CPUE of the year 2001 revealed the highest recuperation of the series. The intensity of the Cape Passero front was in these cases highly contrasting. During 1998, the frontal intensity was quite mild, while during the year 2000 it was the most pronounced of all the series.”.

**System Types Studied:**
Central Mediterranean (Strait of Sicily)
Continental shelf and slope off the southern coast of Sicily

**Target Organisms:**
Anchovy (*Engraulis encrasicolus*), zooplankton, ichthyoplankton including anchovy larvae

**Physical Processes:**
Water column stratification and mixing
Fronts
Upwellings

**Participating Institutions:**
Istituto per l’Ambiente Marino Costiero, sez. di Mazara del Vallo (IAMC-CNR)
Instituto Español de Oceanografía (IEO), Centro de Fuengirola, Málaga, Spain
Departamento de Física Aplicada II, Universidad de Málaga, Málaga, Spain

**Number of Scientists:**
16 scientists, 6 technicians

**Duration:**
2 years: June 1999 – January 2002

**Funding Agency:**
European Commission, DG XIV

**Budget:**
759,943 €/ 2 yr

**Related Publications:**


12. Application and development of hydro-acoustic technologies for the study of marine mobile organisms dynamics (ASTAMAR)

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Project Description:
Objectives:
- Design of acoustic transects and build up of a standard protocol for the realization of interdisciplinary oceanographic surveys, aimed at the contemporary collection of physical, chemical and biological parameters in the marine environment.
- Creation of abundance an distribution maps for small pelagic fish populations and ichthyoplanktonic biomass.
- Characterization and study of spatial-temporal variability in the main marine physical mesoscale structures.
- Determination, by means of biogeochemical techniques, of hydrographical variables useful for the definition of relationships between climate and small pelagic fish and plankton population dynamics.
- Study of coupling phenomena between physical and biological phenomena at sea governing inter-annual fluctuations in biomass and distribution of small pelagic fish species in the Strait of Sicily.

System Types Studied:
Central Mediterranean (Strait of Sicily)
Continental shelf off the southern coast of Sicily

Target Organisms:
Anchovy and sardine (adults), zooplankton, ichthyoplankton including anchovy larvae.

Physical Processes:
Water column stratification and mixing
Fronts
Upwellings

Participating Institutions:
Istituto per l’Ambiente Marino Costiero, sez. di Mazara del Vallo (IAMC-CNR)
Number of Scientists:
7 scientists, 5 technicians

Duration:
3 years: 2001 – 2003

Funding Agency:
Italian Ministry for Education, University and Scientific Research (MIUR)

Budget:
657,490,95 €/ 3 yr


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Project Description:
The main aim of this study is the evaluation of the distribution and biomass of small pelagic species in the Strait of Sicily by means of electro-acoustic devices, with special emphasis on the most economically important species, such as sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*).

System Types Studied:
Central Mediterranean (Strait of Sicily)
Continental shelf off the southern coast of Sicily

Target Organisms:
Anchovy and sardine.

Physical Processes:
Water column stratification and mixing
Upwellings

Participating Institutions:
Istituto sull’Ambiente Marino Costiero, sez. di Mazara del Vallo (IAMC-CNR)
Istituto di Scienze Marine, sez. di Ancona (ISMAR-CNR)

Number of Scientists:
6 scientists, 5 technicians

Duration:
3 years: November 1998 – November 2001

Funding Agency:
Italian Ministry for Agriculture and Forest Policy – Directorate for Fisheries
Budget:
175,595,35 €/ 3 yr

Related Publications:

Participants:
AZTI and Aquarium San Sebastian

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Summary:
The effect of environmental conditions on fish larval and juvenile growth it is one of the most relevant investigations topics on fish ecology. The current project is focused on the study of the changes in the width increments pattern of otoliths for two pelagic species of great commercial interest: the anchovy Engraulis encrasicolus and the mackerel Scomber scombrus. This work proposes two study lines: on one hand to carry out the experiments for the validation of daily growth either for mackerel larvae or for juvenile of mackerel and anchovy and in a second stage to determine the effect of environmental condition such as temperature and food availability on this growth structures. This experimental work takes implicit an improvement and optimisation of both larval culture systems and tanks for juveniles maintenance in order to guarantee the maximum quality of the results.

Project Status:

Funded By:
Basque Government

15. Valutazione acustica della biomassa, distribuzione e struttura delle popolazioni pelagiche in Adriatico, in relazione con i dati ambientali ricavati da satellite

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Participating Institutions:
IRPEM-CNR (now ISMAR-CNR)
MIPAF (Italian Ministry for Agriculture and Forestry Policies)
ADRIATICA Navigation Company
ISAO-CNR (now ISAC-CNR)
Project Description:
The aim of the research was to illustrate the spatial and temporal changes of the pelagic biomass in the
Adriatic Sea, as a whole and per species, to present the spatial distribution of the SST and chlorophyll
during the surveys and to attempt to find relationships between the biological and environmental
parameters. The acoustic data on the biomass of small pelagic fish and their spatial distribution in the
Adriatic Sea were acquired from eight surveys, carried out from July 1998 to November 2001. Four
surveys were conducted in South Adriatic, one every year, in the summer season (July-September).

The acoustic system used in the surveys was EK500, working at three frequencies contemporaneously
(38, 120 and 200 kHz) in the 2001 surveys, at two frequencies (38, 120 kHz) in the 1998 and 2000
surveys and at 38 kHz in the 1999 surveys. Before each survey the EK500 system was fully calibrated
by SIMRAD experts.

The biological data on fish size and biomass composition were acquired by a mid-water pelagic trawl
designed and built by I.R.P.E.M. team. The spatial position of the net in the water was monitored by
the ITI (SIMRAD's Integrated Trawl Instrumentation system) with the receiving sensors installed on a
towed body. During surveys, net samplings were carried out every 4-6 hours, depending on the
whether conditions.

The environmental data (SST and chlorophyll) were acquired by satellite. The “individual” images,
that show the temperature/chlorophyll distribution at the moment of the satellite pass, have been
composed in images covering a week, a month and, for SST only, a year.

The set of acoustic, biological and satellite data were processed using a software package, called
GFRDBS (Geographical Fishery Resources Data Base System), designed in the 1985 by I.R.P.E.M. team
and since then implemented, tested and adjusted. The GFRDBS processes the data in a geographical
context, converting Lat&Lon coordinates to X&Y coordinates. The Elementary Sampling Distance Unit
(ESDU) of the X&Y map is 1 nm. The Adriatic Sea monitored in this study is contained in two windows,
both with an extension of 100x180 ESDU. The first window includes the area called North Adriatic (from
Trieste to Giulianova, from Italian coast to the mid-line). The second window includes the area called
South Adriatic (from Giulianova to Brindisi, from Italian coast to the mid-line or the 250m bathymetric.

Project Status:
Completed (January 1998 – May 2001)

Funded By:
Italian Ministry for Agriculture and Forestry Policies (MIPAF)

16. The use of molecular genetic markers for the study of stock structure of anchovy
(Engraulis encrasicolus) in the Mediterranean and adjacent seas (FAIR CT 96 1899)

PI and Contact Information:
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Participating institutions:
Institute of Marine Biology of Crete
University of Padova
University of Algarve

Summary:
Marine species with high dispersal capabilities in the adult and /or premature stage usually exhibit very
little population structuring. European anchovy (Engraulis encrasicolus), is a small pelagic fish with
pelagic eggs and larvae, which in sharp contrast to the expected pattern was found to present strong
population structure. A previous study using RFLP analysis of mitochondrial DNA variation has revealed
that two distinct groups of haplotypes (phylads A and B) coexist but with proportions significantly
different among major basins. More samples from almost the whole distribution area of the species were
analysed and the results indicated a population structure even more complex than previously thought.
In the Black Sea phylad A is present almost exclusively. In northern Aegean Sea phylad A predominates
with a proportion of 0.85. In the Ionian Sea, the Tyrrhenian Sea, the Gulf of Lions and the Bay of Biscay
the proportions of this phylad drops to 0.40. In northern, central and southern Adriatic its proportion is
even less: 0.15. Quite unexpectedly, in samples taken from the seas intervening between the Gulf of
Lions and Bay of Biscay (that is between two areas dominated by phylad B) the proportions of phylad A
ranged between 0.85 and 0.95. Thus the population structure of this species is characterized by the co-
existence of the two clades, the long distance gene flow (as evidenced by the occurrence of the same
haplotypes over the whole distribution area of the species) and the large genetic differences between
the basins. A possible explanation for this pattern is that two subpopulations were isolated in the past,
subsequently extensive dispersal took place during some time period(s), while recently local genetic drift
occurred because of restrictions to gene flow due to hydrographic forces

**Project Status:**
Completed (December 1996 – December 1999)

**Funded By:**
EU

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17. The effect of abiotic and biotic factors on the distribution, abundance and the fish egg
and larval viability in exploited fish populations: Málaga transect

**Participants:**
IEO (Spain)

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**Summary:**
This project forms part of a national funded program that covers some areas of the Mediterranean
waters (Alborán Sea) and Atlantic waters (Galicia and Bay of Biscay). The general objective of the
program is to assess the effect of biotic and abiotic factors on the viability and survival of eggs and
larvae of the target species: anchovy, sardine and mackerel. Specifically, the Mediterranean subproject
focuses on the effect of environmental factors on the daily growth and condition of anchovy and sardine
larvae. The program is sustained by a quarterly monitoring program that collects information from a
series of transects off the coast of Málaga on the hydrographic conditions, the main variables of sea
water (oxygen content, chlorophyll, nutrients) and zooplankton biomass. Anchovy and sardine larvae
are collected from a nursery ground of these species in the Bay of Málaga.

In essence, this project continues the study carried out under an EU funded project on the "Precision
and Accuracy of Tools used in Recruitment Studies" (PARS) carried out from 1997-1999. The main
objective of this research project was to analyze the precision and accuracy of age and condition
(RNA/DNA) estimates in clupeoid larvae (sardine and herring).

Both of these projects provide a data series on daily growth and condition of winter and spring

**Project Status:**
Completed (January 2000 – December 2002)

**Funded By:**
CICYT (Spanish National Council)
18. Development of a numerical model for the study of larvae and eggs dispersion in the Bay of Biscay

Participants:
AZTI

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Summary:
The objective of this model is to develop a 3D transport model for the Biscay Bay, to be used in simulations of sardine and anchovy egg transport. The model will take into account the combined effects of tide, wind, and river discharges for knowing the physical transport of the eggs and larvae of the aforementioned species. The spatial and time evolution of the sea water temperature, salinity and abundance of food are the variables which will be used for modelling the biological part of the model, i.e. the growing and mortality of the eggs and larvae.

Project Status:

Funded By:
National

19. SARDYN (Sardine Dynamics and Stock Structure in the North-east Atlantic)

Details of the SARDYN project can be found in the Multinational section on page 129.

   Application of the Ecopath model.

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Participants:
ICM (CSIC)

Summary:
This project addresses the sustainability of a fishery from an area representative of the Iberian Mediterranean coast, through the systemic mass balance modelling approach, better known after the software which constitutes its operational tool, the program Ecopath. The use of this novel methodology, allowing for an integral ecological approach of the fishing system, is pioneering in the Mediterranean context. To this end, starting from the modelling of the central Catalan coastal ecosystem (also accounting for the fishery), the structure and functioning of the exploited ecosystem in the present time as well as the ecosystem effects of fishing will be thoroughly analysed. Finally, from the present time ecosystem model, taking the structural and functional features of the exploited model as arising from the past ecosystem model as a reference state, programs Ecosim and Ecospace will be used to define alternative management strategies implying a change in the present exploitation pattern, leading to the long term sustainability of fishing.
**Project Status:**
Completed (January 2000 – March 2003)

**Funded By:**
CICYT (National Spanish Research Commission)

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21. **SAVOR-Definition of the optimal environmental windows that limited egg and larval survival of pelagic fish species in spawning areas with highly contrasted habitat conditions.**

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Departamento de Ecología y Biología Animal
Facultad de Ciencias
Universidad de Vigo

**Participants:**
University of Vigo
University of the Basque Country
IEO-Malaga, IEO-Gijón
IEO-Palma Mallorca
AZTI
CMIMA-CSIC-Barcelona.

**Summary:**
Interannual variations in the recruitment success of pelagic fishes are mainly governed by the factors that affect their early stages (eggs and larvae). A high recruitment success will be achieved in those years that some specific abiotic and biotic factors combine within an optimal environmental window (OEW). The main aim of this project is to determine, in spawning areas with highly contrasted habitat conditions (Mediterráneo, Cantábrico and Atlántico) those factors that limit the OEW for the survival of the eggs and larvae of the anchovy (*Engraulis encrasicolus*) and the sardine (*Sardina pilchardus*). The proposal would be developed in several phases: 1) Identification of the spawning areas in those places that is unknown; 2) Egg and larval condition in the spawning areas; 3) Age estimation of class zero individuals obtained from landings in the ports to estimate those periods more favourable for recruitment and 4) Study of hydroclimatic series to see possible trends in the environmental conditions in the spawning areas. The possibility to estimate the OEW would allow to predict interannual variations in recruitment, and to determine whether global change is driving prevailing conditions in the spawning habitat of these pelagic fish species out of their OEW.

**Project Status:**
On-going (March 2003 – March 2006)

**Funded By:**
MCYT (Ministerio de Ciencia y Tecnología)