COUNTRY: USA

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A) Project Title: Georges Bank

Source of Information:
US GLOBEC Webpages http://globec.whoi.edu/globec-dir/list-of-all-projects.html, July 2004

Contact:
US GLOBEC Georges Bank Program Office
Woods Hole Oceanographic Institution
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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 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 Alaska 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

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GEORGES BANK PHASE 4 Projects: Modeling 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 modeling.

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

Funding Agency:

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

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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 Environmentla 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. Modeled 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 modeling effort for the Coastal Gulf of Alaska. Technical objectives include: higher spatial resolution and nested grid capabilities for regional circulation modeling, nested mesoscale atmospheric modeling 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 modeling. 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 modeling 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 modeling 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 variates 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 th e 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 15N/14N and 13C/12C 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 is expected to vary proportionately with the intensity of cross-shelf transport, thus effecting 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 15N/14N 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, 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 modelers 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 modeling--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 longterm 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 covariation 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 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 modelers, 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 modeling, observations and retrospective studies (Overland and Bond); biophysical moorings (Stabeno, Holliday, Mordy and Napp); and satellite-tracked drifters (Stabeno). The atmospheric modeling 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 fluxes of slope water and its associated nutrients and zooplankton as factors affecting the ecosystem, particularly the foraging success of young salmon.

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 consituting 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, emcompassing 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. Haldorson, R. Hopcroft, K. Coyle, T. E. Whitledge (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-favorable 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 GOA. 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 resonds strongly to large seasonal and interannual changes in freshwater discharge and wind-forcing. Moreover, seasonal shifts in dynamics likely exert strong infuences on the temporal 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 downelling-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
- Processess 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 them 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 modeling 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 favorable 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 favor 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 modeling:

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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