Report of the
U.S. GLOBEC Northeast Pacific
California Current
Scientific Investigator's Meeting
November 12 - 14, 2000

Edited by Harold P. Batchelder and P. Ted Strub

Acknowledgements

This meeting was organized by the U.S. GLOBEC Northeast Pacific Coordination Office. We gratefully acknowledge the contributions from the scientific investigators who attended the meeting and provided the summaries and figures for this report. A special thanks go to Linda Hunn for providing logistical support prior and throughout the meeting.

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Introduction

The U.S. GLOBEC Northeast Pacific (NEP) Program is a large multidisciplinary, multi-year oceanographic effort focusing on the biology and ecology of juvenile salmon, euphausiids, large copepods, and forage fish in coastal regions of the North Pacific, and how these populations are controlled by physical and biological processes at large- to meso-scales. Two specific regions have been targeted for intensive field studies and long-term observations: (1) the wind driven, coastal upwelling California Current System (CCS), especially the region extending from central Oregon south to Northern California, and, (2) a coastal Gulf of Alaska (CGOA) shelf region southwest of Prince William Sound. U.S. GLOBEC studies in the NEP have been phased in gradually. NEP research began in 1997 with integrated, multi-investigator, interdisciplinary programs of modeling, retrospective analysis, and long term observation programs (LTOPs). Focused process-oriented and field surveys of the CCS are planned for the summers of 2000 and 2002; these will alternate with intensive field studies in the CGOA in 2001 and 2003. The U.S. GLOBEC research effort in the NEP has an ultimate goal of improving the management of living marine resources in the region by developing better insights and understanding of ecosystem interactions and the coupling between the physical environment and the living resources at multiple temporal and spatial scales. The physical environment and biological populations of the eastern Pacific respond strongly to climate variability at several temporal scales: interannual changes like El Niño-La Niña oscillations; and, longer-term, lower frequency, probably atmospherically forced, changes like the regime shift that occurred in the winter of 1976-77, and perhaps more recently in the late 1990's. The U.S. GLOBEC research program is supported primarily by the U.S. National Science Foundation Division of Ocean Sciences, and by the U.S. National Oceanic and Atmospheric Administration's Coastal Ocean Program and National Marine Fisheries Service. Ancillary funding for some projects within the program is provided by the National Aeronautics and Space Administration. U.S. GLOBEC is a component of the U.S. Global Change Research Program.

This U.S. GLOBEC Northeast Pacific Scientific Investigator's workshop was held at the International Forum Room on the campus of Oregon State University in Corvallis, Oregon. The meeting goals were:

- To share mesoscale and process, LTOP, retrospective and modeling results
- To begin to integrate and synthesize findings
- To prepare for national and international meetings
- To interact with other investigators who might have insights into interesting, but unexplained, results
- To identify research nuggets of particular interest and broad appeal for early investigations
- To discuss future (2002) field (LTOP, mesoscale, process) research in light of observations/knowledge gained from the 2000 investigations. Specifically, what went well in 2000; what needs to be improved; and, to begin logistical planning for 2002.

There were four mechanisms for communicating results during the meeting:

- Short Oral Presentations
- Posters
- Structured Working Groups
- Informal Discussions/Unstructured Breakout Groups

Narrative

Sunday, 10 November 2000

The workshop began on Sunday, 12 November 2000. Ted Strub, chair of the NEP Executive Committee, began the meeting by reviewing the agenda and describing the objectives, goals and possible products of the workshop. Attendees were asked to think about potential future meetings at which GLOBEC NEP/CCS results could be highlighted in special sessions. We revisited discussion of special meetings and publications on the final day.

Each funded project was allotted ca. 10 minutes to describe the results and progress made during the past year. Prior to the meeting, the PI's were encouraged to provide the highlights of their results orally, and to provide the details in accompanying poster presentations. The response to this suggestion was heartening as the short oral presentations of most projects were supplemented by 1-2 posters. Appendix I provides an agenda of the speakers on day 1.

We concluded day one of the meeting by devoting about 20 minutes for brainstorming possible working group breakout sessions. Because time was short, and we did not want to cut into the scheduled poster session time from 1730-1900, we resolved to continue this discussion as the first topic for the following day.

The ca. 1.5 hour long poster session was well attended and led to many fruitful discussions among the scientific investigators. So much so, that we scheduled time for scientists to revisit posters on day two of the meeting.

The Northeast Pacific Executive Committee (NEPEXCO) met on Sunday evening from 1745 - 1930 to discuss the science that had recently been funded for the Coastal Gulf of Alaska region within the NEP program. All of the NEPEXCO members (Barth, Botsford, Brodeur, Peterson, Powell, Schwing, Strub, and Tynan) were in attendance, as was Hal Batchelder and Beth Turner. Strub summarized the very positive discussions that had occurred at the NEP/CGOA PI meeting on 8-9 November 2000 in Seattle. All but one of the CGOA projects were represented at the Seattle meeting, and the discussions were collegial and productive. Ted outlined the principal recommendations/changes that the CGOA PI's felt could be reasonably accomodated and which would improve the spatial context of the process oriented work. First, the PI's suggested reordering some of the LTOP and process cruises so that all process cruises are immediately preceeded by LTOP cruises. Second, it was recommended that 3-4 days of NOAA Vessel *Ron Brown* be used to survey "fine-scale" regions surrounding each of the three shelf process sites in May 2001. Third, it was suggested that each of the three *Alpha Helix* LTOP cruises that preceed the process-work be extended by two additional days, to permit sampling along a line extending offshore from Cape Cleare, parallel to the Seward Line. The modified Cape Cleare line is upstream of the process stations and would provide an opportunity to partition water, nutrients, plankton, etc., between along-shelf flow and flow exiting from Prince William Sound. We believe that some, but not all of the requested addition of 6 days may be recoved by reprogramming existing days allocated to December 2001 sampling (although this was not clear). There would need to be a request made to NSF and/or NOAA for additional ship days to permit the full extended sampling to be completed.

Following Ted's summary, the group discussed the CGOA sampling plan and developed several additional ideas that might improve the sampling design. The ideas of the NEPEXCO were forwarded after the meeting to all of the NEP/CGOA PI's for their consideration prior to their next planning meeting (11-12 January 2001).

Monday, 13 November 2000

On day 2, the meeting started with a plenary session (chaired by T. Strub) which continued brainstorming potential topics for working groups. Suggestions for working groups included: 1) providing the climate context to contemporary field observations and potential regime changes; 2) model-data comparison; 3) generation of salient questions about the comparison of regions north and south of Cape Blanco; 4) comparison of nearshore vs. offshore features and the importance of upwelling fronts and mesoscale structures to biological interactions; 5) comparison of 2000 with earlier years; 6) importance of Heceta Bank and other topographic features in creating regions with high retention; 7) trophic interactions; 8) zooplankton sampling in the CGOA and CCS, particularly for euphausiids; 9) linkages of scales from continuous to discrete patches, particularly for linking observations made on different spatial scales/resolutions; 10) connections to inner-shelf processes, particularly linkages to the PISCO program; and, 11) influence of the Columbia River in controlling ecosystem processes off Oregon.

After the brainstorming session, oral presentations were made on a number of other programs that are sampling off Oregon or that are making ancillary observations in conjunction with GLOBEC. These included the PISCO program of near-shore sampling (moorings inshore of 25 m and intertidal sampling of benthic invertebrates), the NSF funded COAST program, which will be sampling the Oregon shelf from Lincoln City, OR to Heceta Bank in May-June and August 2001; a NOPP West Coast Integrative Modeling effort that includes coastwide modeling and regional modeling focused on the shelf off Vancouver Island, Oregon-Washington, Monterey Bay, and Pt. Conception. The NSF funded WEST program off Point Reyes was described, as was the BPA program that has been sampling salmon off northern Oregon for several years and will continue for several more. Finally, we heard that the NMFS/NWFSC will undertake diet studies of fish from the OCC and GLOBEC sampling efforts (coordinated by Jack Helle) in the Gulf of Alaska, to compare with similar data being generated from GLOBEC studies in the CCS.

Bob Groman, data manager for the U.S. GLOBEC National Office, reviewed the GLOBEC data policy and currently supported methods for serving GLOBEC data to the oceanographic community. He emphasized that the PI's should make their data available to their colleagues when it first becomes useful to others. He encouraged the PI's to serve their own data locally, thus maintaining control over it if updates were needed, but did offer that a central data repository at Woods Hole was available for small-to-medium sized data sets. There is currently not sufficient data capacity at Woods Hole to handle large data sets like acoustics, OPC, or SeaSoar data.

After lunch on day 2, we reassembled for several hours into informal working groups around the following themes: 1) 2000 process cruise data and priorities for analysis (Barth/Tynan); 2) comparison of euphausiid research in the CGOA and CCS (Peterson/Hopcroft); 3) analysis of CCS MOCNESS samples, especially for euphausiids and copepods, but also considering gelatinous forms (Huntley/Peterson); 4) observations from the 2000 mooring program (Ramp/Kosro); 5) retrospective analysis of climate and ecosystem changes (Schwing/Berkeley); 6) salmon in the CCS issues (Botsford/Brodeur); 7) ecosystem modeling coupled to circulation models (Powell/Haidvogel/Hermann); and 8) microzooplankton studies in the CCS (Powell/Sherr).

Toward the end of the day, the attendees broke out into three formal working groups to discuss: 1) comparison of the CCS north and south of Cape Blanco (Barth); 2) trophic interactions (Wainright), and 3) possible recent regime changes (Murphree). We concluded day 2 in plenary with short reports of the discussions that occurred in the three formal working groups.

Tuesday, 14 November 2000

Day 3 (morning only) of the meeting was devoted to additional working group discussions and poster viewing. In addition, the day began in plenary with a discussion of future venues/opportunities for presenting GLOBEC NEP/CCS research at public meetings and in special publications. Greatest interest was expressed in having a special session (agreed to be co-chaired by Strub and Batchelder) highlighting "Biophysical Interactions in the Northeast Pacific" at the next Ocean Sciences Meeting of AGU (February 11-15, 2002 in Honolulu, HI). There was some interest also on having a session on shelf-coastal systems at the Fall 2002 AGU meeting in San Francisco, CA (December 6-10, 2002).

A number of specific options for special publications highlighting U.S. GLOBEC's research in the NEP were forwarded by the attendees, including 1) Topical Studies in Oceanography, 2) JGR-Oceans, 3) Progress in Oceanography, and 4) Fisheries Oceanography. There was some reluctance of the physical oceanographers to Fisheries Oceanography as a venue because it is not generally read by that community. Batchelder noted to the group that the National GLOBEC office, chaired by Mike Fogarty at the NEFSC of NOAA in Woods Hole, plans a sponsored issue of "Oceanography", the magazine of The Oceanography Society for late fall-winter of next year. One or two chapters, depending on the eventual organization of the issue, will be devoted to the NEP program of GLOBEC. Batchelder and Strub will take the lead on coordinating a team of authors in producing the articles for this issue.

The workshop concluded at noon on 14 November 2000.

Discussion Sessions

Informal Working Group Summaries

2000 Process Cruise Data and Priorities for Analysis

Jack Barth

A group of scientists (J. Barth, S. Pierce, H. Batchelder, T. Cowles, M. Zhou, M. Huntley, C. Tynan, D. Ainley) involved in the 2000 mesoscale survey and process studies met to discuss the status of data processing and to plan for joint analysis. The SeaSoar CTD, fluorescence, PAR and ac-9 data set processing is well underway. Preliminary maps and vertical sections of the data can be found at http://damp.oce.orst.edu/globec/nep. This site also points to vertical sections and maps of shipboard ADCP velocity data. A calibration of SeaSoar chlorophyll fluorescence with extracted chlorophylls from discrete 5-m flow-through samples (from R. Letelier) is planned for the near future. The OPC on SeaSoar data set is being processed by M. Zhou and data is being averaged into 4-m bins in the vertical.

The large bio-acoustics data set from the towed HTI four-frequency towed system is being processed by S. Pierce. A calibration of acoustic signals with data from MOCNESS samples was identified as a high priority. Bill Peterson's group will make counting the samples from when the Wecoma towed the HTI close to the New Horizon conducting MOCNESS profiling a high priority. S. Pierce is working on determining the presence of a diel migration pattern in the data and also on a non-negative least squares analysis of the volume scattering data.

D. Ainley and C. Tynan reported on the status of the bird and mammal observations data sets. They identified a number of environmental variables from the SeaSoar, HTI and other data sets that would be useful to combine with their observations. For example, SST, temperature at some specified depth, cross-shelf temperature and/or density gradients, depth/strength of pycnocline, depth/strength of subsurface chlorophyll maximum, depth/strength of maximum in 38-khz HTI signal, etc. They will work with the OSU SeaSoar group to create a grid of environmental variables to aid their analysis.

The group also identified the need to determine how the Wecoma and New Horizon were separated in time and space over the course of both cruises. It was suggested to make a set of daily (or half day?) maps showing the location of each vessel (Wecoma, New Horizon, Sea Eagle) and the type of sampling they were conducting. H. Batchelder volunteered to start on this by examining the navigation records from both the Wecoma and New Horizon for the July-August cruise.

Salmon in the CCS Issues

Loo Botsford, Rick Brodeur, Ed Casillas, Joe Fisher, Cathy Lawrence, and Tom Wainwright

The meeting was a discussion of the new field data, modeling efforts and retrospective data. We discussed the bioenergetically based ecosystem modelling approach being pursued by Wainwright and Brodeur. Their model will be a description of feeding relationships between the predators and prey of juvenile salmon. We also discussed the bioenergetic model of individual salmon that Lawrence and Botsford have developed, its comparison to data, and its eventual use in circulation models. There was extensive discussion of what data is being collected in the field program and how those data can be used in conjunction with the models.

Comparison of Euphausiid Research in the CGOA and CCS

Bill Peterson, Rodger Harvey, Se-jong Ju, Julie Keister, Leah Feinberg, Mark Ohman, Meng Zhou, Russ Hopcroft, Gordon Swartzmann, Jaime Gomez-Gutierrez

We discussed euphausiid experimental work as well as net sampling systems. Peterson, Keister and Feinberg explained how they run their incubations for egg productions and molting rates at sea — females with ripe-ovaries (i.e., females with purple-colored ovaries) are selected from plankton tows and sorted with a Chinese soup spoon into 1-L polycarbonate bottles previously filled with 200 µm filtered seawater. For molting rates, they spoon one furcilia or juvenile into a 500 ml plastic jar, with a total sample size of 40 jars. Both egg production and molting measurements incubate for 24 hours.

The group discussed problems with obtaining a sufficient number of *Thysanoessa spinifera* (they were relatively rare in samples collected in 2000). We also discussed Rodger and Se-jung's work on lipids — they reported that lipid composition of the *E. pacifica* and *T. spinifera* was quite different and we wondered if the difference was due to spatial variability in where the animals were collected or to a species-specific difference in feeding preferences.

We discussed the potential problem of comparing MOCNESS samples taken in the Gulf of Alaska vs. those taken in Oregon. The issue is that Oregon GLOBEC scientists use 333 µm mesh nets, whereas GOA scientists use 505 µm mesh nets. Differences in mesh size will prevent comparison of distributions and abundances of euphausiid eggs and early larvae (nauplii and calyptopis). We will not have a problem comparing furcilia, juvenile and adult densities. The two programs have different sampling strategies as well. GOA scientists sample only at night and only within the upper 100 m with five nets used to sample 5 equally spaced bins. Oregon scientists sample whenever they arrive at station, regardless of time of day, and sample the following depth strata (water depth permitting): 0-10 m, 10-20 m, 20-50 m, 50-100 m, 100-150 m, 150-200 m, 200-300 m and 300-350 m. In deep water, they have one extra net and that is used to sample one strata that has interesting sound scatterers. In shallow waters, often two or three nets are used to sample specific sound scattering layers. The chief reason for differences in sampling strategies between GOA and Oregon seems to be that GOA is focusing more of their attention on identifying acoustic targets whereas the Oregon group is more concerned with determining vertical distributions of eggs, larvae, juveniles and adults as a function of day and night and distance from shore.

Analysis of CCS MOCNESS Samples, Especially for Euphausiids and Copepods, but also Considering Gelatinous Forms

Bill Peterson, Jack Barth, Steve Pierce, Anders Roestad, Tim Cowles, Julie Keister, Mark Huntley, Hal Batchelder

We resolved to give MOCNESS samples from Newport line the highest priority. This will include samples from LTOP as well as MESOSCALE cruises. Second priority was to do the samples that were taken at the same time that acoustics data were gathered. This will include LTOP samples which have interesting acoustic signatures and MESOSCALE samples taken when the Wecoma “drove by” the New Horizon. Third priority was Heceta Bank and Bob Creek (Mesoscale Lines 3 and 4 and LTOP Line “HH”).

Retrospective Analysis of Climate and Ecosystem Changes

Frank Schwing, Steve Berkeley, Miriam Doyle, William Pinnix

The retrospective group first discussed climate indices that might be useful in understanding interannual and decadal scale fluctuations in abundance of several different species of larval fish caught in bongo net surveys in the Gulf of Alaska. Most of the collections are from the Kodiak Island and Shelikof Strait/Sea Valley region. The group then discussed statistical approaches that would be useful to begin exploring the coherence of multiple biological time series, and physical datasets. PCA was recommended as one approach to identify the time scales of variation for multiple fish species, and to help develop hypotheses of mechanistic relationships between biological and physical processes. Schwing agreed that his PFEL/NPS research group will assist and advise Doyle in obtaining environmental data sets and indices for comparison to fisheries data sets. A similar offer is available to other NEP investigators.

The group then identified several environmental indices that might be mechanistically linked to variations in year class strength and juvenile growth of sablefish and possibly early ocean entry salmon. It was pointed out that successful recruitment of larval fish required both good conditions for growth and early survival as well as delivery of larvae to suitable juvenile nursery areas. For sablefish and many other species, this presumably means delivery of larvae onto the slope and shelf. Circulation models for both the west coast and GOA, especially during late winter and spring (most marine fish along the west coast are winter spawners) would be very valuable in interpreting retrospective datasets on year class strength. Schwing noted that a basin scale wind driven model had been developed recently and another smaller scale model derived from drifter data was being developed (OSCURS) for the California Current System, and could be available soon if there was sufficient need.

Mixed layer depth was identified as a potentially important environmental parameter that might help interpret retrospective biological datasets. It was hypothesized that growth and mortality of neustonic larvae, such as sablefish, might be greatly impacted by the depth of the mixed layer since both predators and prey would be either concentrated or dispersed vertically depending on the depth of the mixed layer and the extent to which the temperature or density gradient provided a barrier to mixing. Although it wasn’t clear that there were enough data to resolve mixed layer depth on appropriate temporal and spatial scales, Schwing will be working with Berkeley and Pinnix to locate what data are available.

Comparison of the CCS North and South of Cape Blanco

Jack Barth and Loo Botsford

The north-south comparison point-of-view originated in the first GLOBEC west coast meeting in Bodega Bay during which it was noted that it was likely that physical and biological differences existed between the straight and the "bumpy" parts of the coast (Cape Blanco to the US-Canada border and Central California to Blanco, respectively). One approach to identifying differing responses in the north (e.g., Newport) and the south (e.g., Rogue River) would be to examine the seasonal progression in our data. This could be evident in the LTOP, the mesoscale studies, fish sampling, and models. We will look for the nature of differences in physics (wind forcing, thermohaline fields, circulation), nutrient supply, biology (phyto- and zooplankton) and salmon. It might be useful to plot data relative to depth coordinates because of the differences in shelf and slope width from north to south. Is there evidence for N-S differences in the moored array?

We noted that the representation of Newport as the straight part of the coast and Blanco as the bumpy is oversimplified. Heceta Bank, though sub-surface, is a significant topographical feature affecting circulation, as is Coquille Bank (Pt. Arago). Brian Grantham mentioned a break in species mix at Pt. Arago.

What could be the possible driving mechanism of N-S differences? Spatial differences in wind strength? The OSU mesoscale atmospheric model (R. Samelson) or QuikSCAT satellite winds could be used to drive models. Topography? Alongshore pressure gradients, which could be partially caused by salinity differences?

We must take care to note the biological response to N-S differences in physics. One obvious topographic feature is the Heceta Bank complex and the biological response (e.g., high chlorophyll biomass) it creates. What is the Bank's role in retention of organisms over the shelf? How does the circulation respond to the presence of the Bank even with spatially uniform wind forcing? This can be contrasted with larger spatial scale north-south differences due to north-south differences in wind strength.

Bill Peterson reported that in the LTOP zooplankton samples in 1998 and 1999, inshore and offshore samples are the same south of Blanco, while north of Blanco they are different. But there are different species north and south. In general there is a larger scale north/south zooplankton gradient along the coast.

Results shown at the meeting indicate that all salmon in the surveys were within the 200 m isobath. How do they maintain that position? Why are they found on the shelf both in the north and the south even though the physics and lower trophic fields seem to differ greatly in their offshore extent north to south? Other salmon N-S differences were noted (coho less abundant to south, but fatter to south; chinook fatter to north) and these can be quantified and related to environmental parameters. Drifters tend to leave the nearshore north of Blanco in July and August. Salmon are not swept offshore, though near surface. How? What would happen to them if swept offshore? They can swim at about 10-20 cm/s, slower than some drifter velocities.

There was some discussion of the importance of the alongshore pressure gradient. How does the wind set that up? What is the influence of the Columbia River? With regard to models, John Allen is beginning to put the Columbia River in his model. We need to investigate the N-S differences in riverine input and the biological response, e.g., chlorophyll structure. There was also a discussion of the role of alongshore differences in the strength of the cross-shelf density gradient, and potentially the strength of the alongshore jet since it is dynamically related to the cross-shelf pressure gradient.

Let us not forget the extremely important differences in response to daily scale fluctuations in the winds - 2D response to relaxation on straight coast versus responses with alongshore flow. Also need to consider the alongshore propagation of coastaly trapped waves, as driven by wind variability.

How should we distinguish differences? 1. Use models to vary conditions. 2. Track the cross-shelf position of the coastal jet at the north and the south ends of the GLOBEC region. In both the north and the south, the jet and front are close to shore early in the season, but are farther offshore in the south later in the season. This can be quantified using our data sets.

Decadal Events in the Northeast Pacific

Leah Feinberg, Tom Murphree, Frank Schwing, and Bob Smith

Introduction

Large scale, low frequency variations of the physical and biological environment of the northeast Pacific (NEP) have been identified in a number of studies (e.g., Simpson, 1992; Trenberth and Hurrell, 1994; Murphree and Reynolds, 1995; Mantua et al, 1997; Smith et al. 2001). These variations have time scales of from several months to several decades or more. Some of these variations are associated with processes that have been extensively described and analyzed, such as interannual fluctuations linked to El Niño (EN) and La Niña (LN) events in the tropical Pacific. In recent years, decadal variations have received an increasing amount of attention but still remain poorly understood. In this breakout discussion, we explored how NEP GLOBEC research efforts might be coordinated and focused to better determine the characteristics and origins of decadal events, and to better monitor and predict these events. In much of our thinking, we used the history of interannual variations (EN and LN events) in the tropical Pacific to guide our discussion of decadal variation in the NEP.

Recommendations

There are many terms that refer to north Pacific decadal events and their different phases, including: decadal variations, decadal regime shifts, interdecadal variations, Pacific decadal oscillations, decadal events, decadal regimes, etc. These terms are often used with little or no definition, and different users may use the same term to mean different things. We recommend that a glossary of decadal terms be developed. This would include a list of all relevant terms in use, with a clear operational definition for each term. These operational definitions would be directly linked to observed physical and biological quantities, if possible. Such definitions will need to be preliminary for at least the next several years, until a general understanding of decadal variations becomes more complete. Clear definitions will, of course, help clarify discussions between scientists, environmental managers, and the public. But more importantly, they will help focus environmental monitoring, prediction, and management efforts.

We also recommend that all NEP researchers coordinate their efforts to identify the key environmental variations that characterize decadal events. These are the variations that need to be observed and modeled in order to describe past and present events, and to predict future events. In particular, researchers should attempt to determine which features should be monitored in real time so that we can describe the state of on-going decadal variations. This is analogous to what was done a couple of decades ago in developing systems for real time monitoring of EN and LN events. In these systems, sea level pressures, surface winds, and upper ocean temperatures, and other quantities are monitored in critical regions of the tropical Pacific to characterize the state of EN and LN events and related phenomena, such as the Southern Oscillation.

However, before decadal events can be well characterized and defined, much more needs to be known about past decadal events. Unfortunately, there are very few regions within the NEP that have been well observed for several decades or more. For some regions of the NEP, long term observation records exist but are incomplete temporally, spatially, and/or in terms of the quantities observed. For example, observational records covering much of the last 40 years exist for several physical and biological quantities in the Oregon coastal environment. However, these records have large temporal gaps, and tend to emphasize either biological or physical quantities but not both. So we recommend that research be conducted to integrate different records, fill in temporal and spatial gaps, and develop physical and biological data sets that complement each other.

In addition, we recommend that composites of individual decadal events be developed at both large and small space scales, and for long and short time scales. That is, develop composite descriptions of the evolution of decadal events at basin to local (e.g., coastal) scales, and from monthly to interannual scales. This will help compensate for data gaps, while also enhancing the decadal signal to noise ratio. The composites for different regions should then be compared to characterize the spatial evolution of decadal events. Comparisons of different coastal regions with each other, and with the open ocean, are likely to be especially revealing.

For physical quantities, decadal variations are probably best understood on large spatial and temporal scales (larger than 1000 km and seasonal scales). This is because at these scales the observational record is relatively complete and the signal-noise ratio is relatively high. However, the relationships between these scales and the smaller scales that are of particular interest in NEP GLOBEC studies (e.g., coastal and intraseasonal scales) are not well known. We recommend that the relationships between these different scales be clarified, especially as a way of compensating for inadequate spatial and temporal coverage in local regions.

We recommend that the relationships between the decadal variations of physical and biological quantities be explored much further. Biological observations are relatively sparse compared to physical observations. But if strong relationships between biological and physical quantities can be identified, then physical variations may be used as a rough indicator of biological variations. Many of the strongest biological signals on decadal scales probably occur well after the strongest physical signals. So analyses of lag relationships between biological and physical quantities should be given special attention.

There is speculation that a new decadal event may have begun around 1998, with large physical and biological fluctuations already having shown up in the NEP (e.g., Schwing and Moore, 2000). If this speculation is correct, then the present situation in the NEP may be a decadal equivalent of what was going on in the summer of 1997 when a large EN event was developing. At that time, many rapid responses were initiated to monitor the impacts of the 1997-1998 EN event in the NEP. Obviously, if decadal events were better understood, it would be easier to determine if special decadal monitoring efforts should be mounted at this time. We recommend that NEP researchers and managers coordinate their on-going observations of the physical and biological environment to help determine if a new decadal event is in fact underway. Such a determination could help motivate interest in and increased funding for observational and modeling studies of the NEP.

In some locations, the impacts of EN and LN events are known well enough to allow environmental managers to alter their management as EN and LN events are identified and evolve. For example, in Ecuador and Peru, fishing regulations vary in response to present and predicted EN and LN conditions. A comparable situation may occur as decadal events and their impacts on human activities become better understood. So we recommend that scientists and managers begin anticipating how environmental management in the NEP might be affected by reliable monitoring and prediction of decadal events.

Summary

Our major recommendations for pursuing research on decadal events in the NEP are:

1. Develop operational and observationally based definitions of major terms related to decadal events.
2. Identify key quantities that characterize decadal events and that can be used to monitor these events.
3. Develop integrated and complementary physical and biological data sets.
4. Develop composite descriptions of decadal events for a range of space and time scales.
5. Identify relationships between decadal variations occurring at large and small space scales.
6. Identify relationships between decadal physical and biological variations.
7. Coordinate on-going observations to identify and describe the decadal event that may have begun about 1998.
8. Anticipate how environmental management will be affected by improved monitoring and prediction of decadal events.

The process of implementing these recommendations will need to be iterative. For example, developing preliminary definitions, descriptions, and monitoring programs for decadal events is an important first step in pursuing research, but the results of the research will lead to improved definitions, descriptions and monitoring. This iterative process is analogous to what has happened, and is happening, in the exploration of EN and LN events.

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Trophic Interactions/Integration Workgroup

Tom Wainwright, David Ainley, Hal Batchelder, Ric Brodeur, Bob Emmett, Al Hermann, Mark Huntley, Se-Jong Ju, Cathy Lawrence, Tom Powell, Anders Roestad, Gordie Swartzman, Laurie Weitkamp

Problem: How to integrate our work across trophic levels, including discussion of gaps in data/knowledge, differences in scale, and integration of models of physics, chemistry, NPZ, and upper trophic dynamics.

Gaps

Discussion started with identification of gaps in our information base. Particular areas of concern were:

- Microzooplankton. To date we have no measurements of microzooplankton (< 200 µm abundance) within the NEP program. Expect LTOP measurements beginning in 2001, but nothing else is planned for mesoscale surveys. Literature suggests that in some systems microzooplankton are primary controllers of primary production via interactions with small-celled organisms. We need to review existing literature on microzooplankton, especially the few local studies that have been done.

- Gelatinous zooplankton. These include a wide range of taxa, sizes, feeding modes, and life-histories. Sampling, preservation, and identification is problematic. Fish samplers have tried to quantify large jellies in trawl samples, but biomass estimates are not accurate. Plankton collections during the 2000 field season indicate that gelatinous zooplankton (primarily salps and ctenophores) make up a large fraction of the volume. These may be highly seasonal.

- Decadal or regime-shift time scales. Our sampling obviously does not cover these. We have some trophic information from off Oregon for the 1970s and early 1980s for comparison, but little information for the GLOBEC sampling area.

- Historic bird/mammal abundance. There is currently no effort to gather this type of information, which would be important for any comparisons with historic trophic structures. PNCERS may be developing some of this information.

- Near-surface feeding environment. Most of our physical and plankton sampling is not effective in the top few meters, where much of the pelagic fish feeding takes place.

- Small-scale patch structure. Small scale patches are important for understanding predator-prey interactions. It was suggested that we could do specific coordinated Seasoar/net tows to measure this.

- Pinniped feeding. Pinniped sampling is limited to visual surface observations, giving no information on feeding habits.

- Euphausiid and copepod diet analysis. There is no funded work in this area, which is critical to understanding lower trophic dynamics and transfers to higher trophic levels. We will have to rely on literature from other areas and possibly other species for our analyses.

Scale and Model Integrations

Due to time constraints, discussion of this topic was postponed until a later date. Wainwright will convene a meeting of interested parties, including Gulf of Alaska researchers.

Vital Questions

The following (in no particular order) are the major questions that need to be answered regarding trophic interactions in the CCS.

- What is the connection between fish and zooplankton?

- What is the role of gelatinous zooplankton in the trophic structure? Are large jellies predators or competitors of juvenile fish? Are large jellies displacing top predators? How do we sample all sizes of gelatinous zooplankton?

- Has there been a regime-shift switch between the dominance of pelagic and demersal fish?

- How does a shift in the position of the subarctic boundary affect food web structure off Oregon?

- Do jellies control populations of small zooplankton?

- What is the importance of diel migrations for trophic interactions?

- Is the shelf break an important area for concentrating zooplankton or phytoplankton?

- Do fish show patterns of cross-shelf zonation similar to that observed for birds and mammals?

- What is the importance of small-scale physical features in trophic structure and prey concentration?

ABSTRACTS OF PRESENTATIONS

Mesoscale and Finescale Mapping of Physical and Biological Fields in the Northern California Current System--Progress Report from the 2000 Field Season

Jack Barth, Tim Cowles, Steve Pierce and Bill Peterson

The primary measurement platform was the towed, undulating vehicle SeaSoar equipped with a CTD, two fluorometers, an ac-9 (multi-wavelength light absorption and attenuation), PAR and an Optical Plankton Counter. M. Zhou and M. Huntley are co-PIs on the OPC data. A shipboard ADCP measured water velocities and acoustic backscatter. A bio-acoustics instrument (HTI: 43, 120, 200, 420 kHz) was towed along the SeaSoar sampling grid. An ac-9, fluorometer and a Fast Repetition Rate Fluorometer (FRRF) were installed in the 5-m underway flow-through system. In addition, a large number of discrete 5-m samples for pigments and nutrients were collected. R. Letelier and M. Abbott are co-PIs on the FRRF and discrete sampling. Lastly, some high vertical resolution profiling was done with a bio-optics package near the location of the deployment of some bio-optical drifters.

Two cruises were carried out during spring-summer 2000 (29 May to 17 June; 29 July to 17 August) and a variety of wind forcing regimes were sampled. Survey tracks extended from Newport, Oregon in the north (44.6N) to Crescent City, California in the south (41.9N) and offshore for about 150km. The region covered (150 km by 300 km) is roughly the size of Georges Bank for comparison. Sampling was carried out from the R/V Wecoma in coordination with zooplankton net sampling and bird and mammal observations from the R/V New Horizon. A charter fishing vessel, F/V Sea Eagle, conducted surface trawling for juvenile salmon along a subset of the survey lines.

During the May-June cruise, the upwelling front and jet followed the bottom topography fairly well. There was cold water inshore of the shelfbreak (~200m) all along the coast with pockets of elevated biomass near the coast with maxima up to 4 mg/m^3. During early June, a strong downwelling favorable (northward) wind event occurred and SeaSoar sampling near Cape Blanco was successfully accomplished. The thermohaline, velocity and phytoplankton fields all show a strong downwelling response near the coast. Northward winds reached almost 40 knots, but sampling proceeded and will provide a nice data set for the downwelling event.

During the July-August cruise, the upwelling front and jet were much more convoluted including major meanders offshore associated with Heceta Bank and Cape Blanco. High levels of phytoplankton biomass (in excess of 10 mg/m^3) were found over Heceta Bank and near the coast south of Cape Blanco. The large offshore meander near Cape Blanco carried cold, nutrient-rich, high phytoplankton biomass (2-4 mg/m^3) away from the coast over 100 km offshore. Data from the underway FRRF and the MODIS satellite are being used by Letelier and Abbott to investigate photosynthetic capacity of phytoplankton in the study region.

Preliminary maps and vertical sections of the hydrography, chlorophyll fluorescence and velocity can be found at http://damp.oce.orst.edu/globec/nep.

In summary, we sampled physical-biological interactions over a wide range of time and space scales which can be categorized as follows. Time scales: weather band (2-5 days), seasonal evolution, interannual (this is a key GLOBEC goal). Space scales: finescale (100m to a few km horizontally; a few meters vertically), mesoscale (10-100 km), large area (150 by 300 km).
The data provide good examples of flow-topography interaction including the system's response to shelf-slope topography (inner shelf, mid-shelf, shelfbreak, slope), the influence of a major submarine bank complex (Stonewall and Heceta Banks) and a large coastal promontory (Cape Blanco). The three-dimensional data set will provide an excellent test bed for numerical modeling studies and can be used for model initialization, boundary conditions and verification. The data collected matches the model circulation and ecosystem fields including physical (T, S, density, particulates) and biological (phyto- and zooplankton, light) parameters. Jack Barth is working with Ken Johnson and Zanna Chase from MBARI to integrate their in situ nitrate sensor onto SeaSoar so that this key nutrient might be mapped during the 2002 GLOBEC NEP field work.

Trophic Relationships of Juvenile Salmon off Oregon and California

Richard Brodeur, Tom Wainwright, Robert Emmett, Kym Jacobson, and William Peterson (all at NMFS, Newport), Todd Miller, Cheryl Morgan, and Rebecca Baldwin (all at CIMRS, OSU, Newport).

For the first year of the trophic work, we proposed to participate in the collection of fish, including juvenile salmon, process these fish in the laboratory, and begin the analysis of stomach contents and parasite prevalence. We participated in all fish collection cruises and in the dissection of the fish for various body parts (Table 1). Stomach content analysis has begun for several species (herring, sardines, surf smelt) likely to be important competitors of juvenile salmon. Samples were also collected for stable isotope analysis of many of these fishes and their zooplankton prey.

Parasite-host interactions provide another tool to understand the role of juvenile salmon in the California Current System (CCS) trophic food web. Parasites commonly use predator-prey links in trophic food webs to find appropriate hosts. The body cavity, muscle, intestinal tract, stomach and gills will be examined for parasites. Approximately 300 salmon have already been assessed for the nematode *Anasakis simplex*. Prevalence for *A. simplex* in the body cavity ranged from 18 to 25%, with a decrease to about 10% in the muscle.

First year modeling work was proposed to consist of (1) describing food-web structure for the system from literature, (2) compiling existing data on standing biomass and bioenergetics for major food web components, then (3) incorporating this information into a trophic flux estimate, based on an ECOPATH-type model.

The literature review (tasks 1 & 2) has been substantially completed. This work focused on compiling all available literature on prey composition, bioenergetics, and growth of seven important *Oncorhynchus, Sardinops, Scomber, Trachurus*) in the northeast Pacific (NEP). Because there was limited information for several particular species, literature covering entire genera was included to provide analogous information when data for local species was lacking. Additional literature was obtained relating to prey of CCS invertebrates, birds and mammals; review for these groups was not extensive as they are covered largely by other GLOBEC projects. We have begun the task of entering predator-prey information from this literature into a NEP-wide predator-prey database that will be used to construct detailed food-web diagrams and models for the region.

Modeling work (task 3) began with an attempt to apply the ECOPATH model to the major components of the CCS pelagic food web. However, this model proved impossible to “tune” with reasonable parameters for this system, and it soon became obvious that the steady-state assumptions implicit in this model were substantially violated by the strong seasonal and inter-annual dynamics of the CCS. For this reason, we began early on work originally proposed for year 2: the development of a trophodynamic model for the system. An initial prototype of this model has been completed and tested with a simplified upper trophic web (Figure 1). This prototype model is a single spatial box model driven by seasonal upwelling, and incorporates information on sunlight, mixed-layer depth, and temperature to predict primary, secondary, and tertiary production, expressed as nitrogen content of biomass. It is a modification of the UBC model developed by Robinson and others. The lower trophic portion of our model is also similar in structure to the PICES CCCC NEMURO model.

Table 1. Collection information for fish available for stomach content, parasite and stable isotope analysis.

June Cruise

Order Common Name	Species	Number Collected	Number of Stations	Measured (length/wt.)	Stomachs Extracted	Stomachs Examined	Stable Isotope tissue taken
Salmoniformes							
Coho Salmon	*Oncorhynchus kisutch*	36	14	36	36	0	NA
Chinook Salmon	*O. tshawytscha*	55	18	55	55	0	NA
Cutthroat Trout	*O. clarki*	1	1	1	1	0	NA
Steelhead Trout	*O. mykiss*	20	6	20	20	0	NA
Whitebait Smelt	*Allosmerus elongatus*	129	6	55	55	0	10
Surf Smelt	*Hypomesius pretiosus*	183	6	183	183	8	5
Clupeiformes							
Pacific Herring	*Clupea pallasii*	188	9	35	35	33	15
Pacific Sardine	*Sardinops sagax*	7	2	7	7	7	7
Atheriniformes							
Pacific Saury	*Cololabis saira*	26	1	26	26	0	5
Mollusca (Teuthoida)							
Market Squid	*Loligo opalescens*	119	18	0	0	0	0

August Cruise

Order Common Name	Species	Number Collected	Number of Stations	Measured (length/wt.)	Stomachs Extracted	Stomachs Examined	Stable Isotope tissue taken
Carcharhiniformes							
Blue Shark	*Prionace glauca*	9	4	9	9	0	9
Salmoniformes							
Coho Salmon	*Oncorhynchus kisutch*	111	24	110	110	0	NA
Chinook Salmon	*O. tshawytscha*	251	26	251	251	0	NA
Cutthroat Trout	*O. clarki*	3	3	3	3	0	NA
Steelhead Trout	*O. mykiss*	36	12	36	36	0	NA
Whitebait Smelt	*Allosmerus elongatus*	69	3	0	0	0	0
Surf Smelt	*Hypomesius pretiosus*	72	4	0	0	0	0
Perciformes							
Jack Mackerel	*Trachurus symmetricus*	220	14	220	180	0	0
Pacific Mackerel	*Scomber japonicus*	54	6	19	0	0	19
Clupeiformes							
Pacific Sardine	*Sardinops sagax*	170	11	170	170	46	50
Nothern Anchovy	*Engraulis mordax*	7	4	0	0	0	0
Atheriniformes							
Pacific Saury	*Cololabis saira*	45	6	0	0	0	0
Mollusca (Teuthoida)							
Market Squid	*Loligo opalescens*	119	18	0	0	0	0

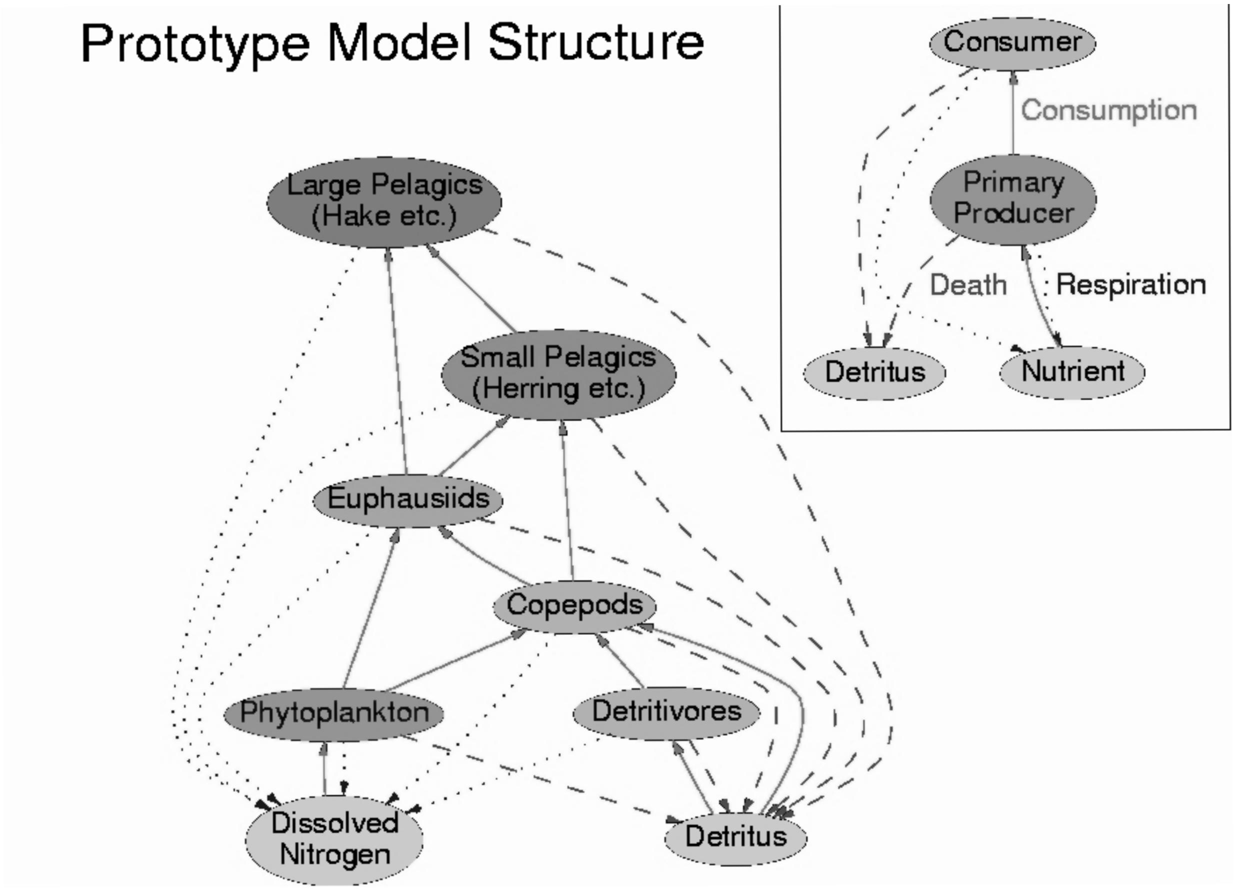

Figure 1. Structure of biological interactions in the prototype model, with flow arrows representing consumption (solid line), death or egestion (dashed line), and respiration (dotted line).

Growth and Condition of Juvenile Salmon in the Northern California Current

E. Casillas (NMFS, Seattle), J. Fisher (OSU, Corvallis), K.C. Jacobson (NMFS, Newport), and G.H. Rau (UCSC, Santa Cruz), M. House (CIMRS, OSU, Newport), C. Bucher (NMFS, Seattle), and S. Hinton (NMFS, Hammond).

Salmon captured from the NEP GLOBEC Mesocscale Surveys in June and August 2000 were subsampled in August (in Seattle, WA) and October (in Newport, OR) 2000, respectively. One of the NEP GLOBEC study goals is to characterize the biological condition of salmon from coastal waters in the California Current off of southern Oregon and northern California. To this end, tissues and external measurements were collected from the fish, and observations of external features were recorded. Muscle, liver, gill, scales, otoliths, stomachs, intestines, kidneys, spleen, eye, and heart samples were taken and distributed to cooperating investigators studying the parasite loads, bioenergetics, genetics and the carbon and nitrogen isotopic abundance in these fish. These analyses are ongoing.

Size characteristics and species identification revealed the following number and length of juvenile and subadult salmon captured and sampled:

Salmon Length [mean (mm)±SD (n)]:

	June	August
Juvenile Salmon		
Subyearling Chinook	—	134±12 (126)
Yearling Chinook	189±32 (16)	235±42 (92)
Coho	159±25 (32)	270±36 (27)
Precocious Coho	—	363±30 (29)
Steelhead Trout	241±31 (20)	313±36 (37)
Cutthroat Trout	225 (1)	297±42 (3)
Subadult Salmon		
Chinook	331±99 (40)	623±136 (34)
Coho	474±136 (4)	634±58 (55)

The length of the fish indicated that substantial growth occurred in juvenile salmon during the study period. Growth and condition of juvenile chinook and coho salmon north and south of Cape Blanco, Oregon showed the following: 1) there were greater numbers of juvenile yearling chinook to the south of Cape Blanco whereas there were greater numbers of juvenile coho to the north, 2) juvenile yearling chinook salmon were smaller to the south of Cape Blanco whereas juvenile coho were smaller to the north, and 3) the condition index (a measure of the health of the animal) was higher in juvenile yearling chinook salmon to the south of Cape Blanco whereas condition was lower in juvenile coho to the north. Significant differences in growth and condition of juvenile salmon indicate different oceanographic environments north and south of Cape Blanco, Oregon. Upon completion of the other analyses, all information will be integrated and evaluated to determine how our findings relate to the ocean conditions.

Biometry of Eggs, Brood Size, and Egg Sinking Speed of the Euphausiids Euphausia pacifica and Thysanoessa spinifera from the Oregon Coast Population

Jaime Gómez-Gutiérrez (College of Oceanic and Atmospheric Sciences, Oregon State University; William Peterson, Leah Feinberg, and Julie Keister (all at NOAA/NMFS, Hatfield Marine Science Center)

To learn to identify the recently spawned eggs of *Thysanoessa spinifera* G.O. Sars and *Euphausia pacifica* Hansen from the Oregon upwelling populations, the biometry and morphology of eggs spawned during ship incubations were studied. Although the egg size distributions of the two species overlap, they can be identified by the egg diameter. The average egg diameter was significantly smaller for *T. spinifera* (0.392 mm, range 0.320 to 0.440-mm, n=256) than for *E. pacifica* (0.417 mm range 0.360 to 0.460-mm, n=991). The perivitelline space of *T. spinifera*, when present, was narrow about 0.018 mm (embryo diameter 0.357-mm), and the corium was typically sticky and not completely spherical. The *E. pacifica* eggs usually have a greater perivitelline space of about 0.022 mm (embryo diameter 0.373-mm), and the corium is transparent, smooth, and completely spherical. Fecundity estimated in four oceanographic cruises, expressed as brood size, was 3 times higher for *E. pacifica* (127 eggs, range 7 to 396, n=50) than for *T. spinifera* (46 eggs, range 6 to 132, n=22). *Euphausia pacifica* has a larger percentage of female weight as eggs (9.7%) than *T. spinifera* (2.4%), indicating the former species expends about four times more energy in reproduction.

Observations on vertical distribution of eggs, nauplii, calyptopis, and furcilia of euphausiids collected over the Oregon continental shelf during summer 1977 indicate that most eggs are laid near the surface (above 30 m), while nauplii are distributed in deeper layers. This suggests that the eggs are denser than seawater and sink. Egg sinking rates of *T. spinifera* and *E. pacifica* were measured under laboratory conditions during April and August 2000. Average egg sinking speed during an April experiment for *T. spinifera* was 70 m d^{-1} (range 30 to 124 m d^{-1}, n=29 eggs). Average sinking rate of eggs measured during August was not significantly different between the species, 126 m d^{-1} (range 60 to 193 m d^{-1}, n=22 eggs) for *T. spinifera* and 128 m d^{-1} range (60 to 193 m d^{-1}, n=14 eggs) for *E. pacifica.* The egg densities for both species, calculated applying the Stokes's Law, were always higher than the seawater density. Theoretical egg sinking rates applying Stokes's equation were calculated to simulate egg-sinking speeds at water density ranges commonly recorded in the field in a homogeneous water column. Vertical transport (upwelling), stratification, turbulence in the mixing layer, and bottom boundary layer stress probably are important physical processes reducing the egg-sinking speed in the field. However, observational results suggest that these forces are not enough to keep the eggs in a particular layer of the column water or allow net upward transport of the eggs. The implications of sinking of euphausiid eggs as a potential source of mortality within the Oregon upwelling region are discussed.

Long Term Monitoring and Analysis of Currents and Water Properties on the Southern Oregon (Coos Bay) and Mid Washington (Grays Harbor)

B. M. Hickey (School of Oceanography, University of Washington)

The objectives of this project are: 1) to provide data on alongshore and temporal variability in the coastal ocean nearshore environment of the Pacific Northwest region on scales of hours to several years; and, 2) in conjunction with other GLOBEC investigators, to determine dominant factors controlling alongshore and temporal variability in ocean water properties and currents.

To fulfill these objectives we are maintaining moored arrays measuring currents and water properties at two locations, one off southern Oregon (Coos Bay); the other off the central Washington coast (Grays Harbor). In the first year of this grant, instruments were serviced and mooring designs completed. The Coos Bay mooring was deployed in April, recovered and redeployed in September. The Grays Harbor mooring was deployed in April and will be recovered and redeployed in November.

Results to date indicate that both water property and velocity signals are adequately resolved at the two sites. For example, time series of temperature at selected depths at the Coos Bay site in spring 2000 show the seasonal cooling as well as the presence of the seasonal thermocline (Figure 1). Warming of upper layers following storms (indicated by northward flow) is illustrated as well as cooling of lower layers following upwelling events. The warming signal decreases with distance from the surface and the cooling signal decreases with distance from the bottom. The placement of the bottom temperature sensor 5 meters above the bottom is clearly critical for adequate resolution of the structure and magnitude of an upwelling event. Salinity signals are also well resolved, generally following an inverse relationship to temperature signals, indicating the dominance of advective processes (not

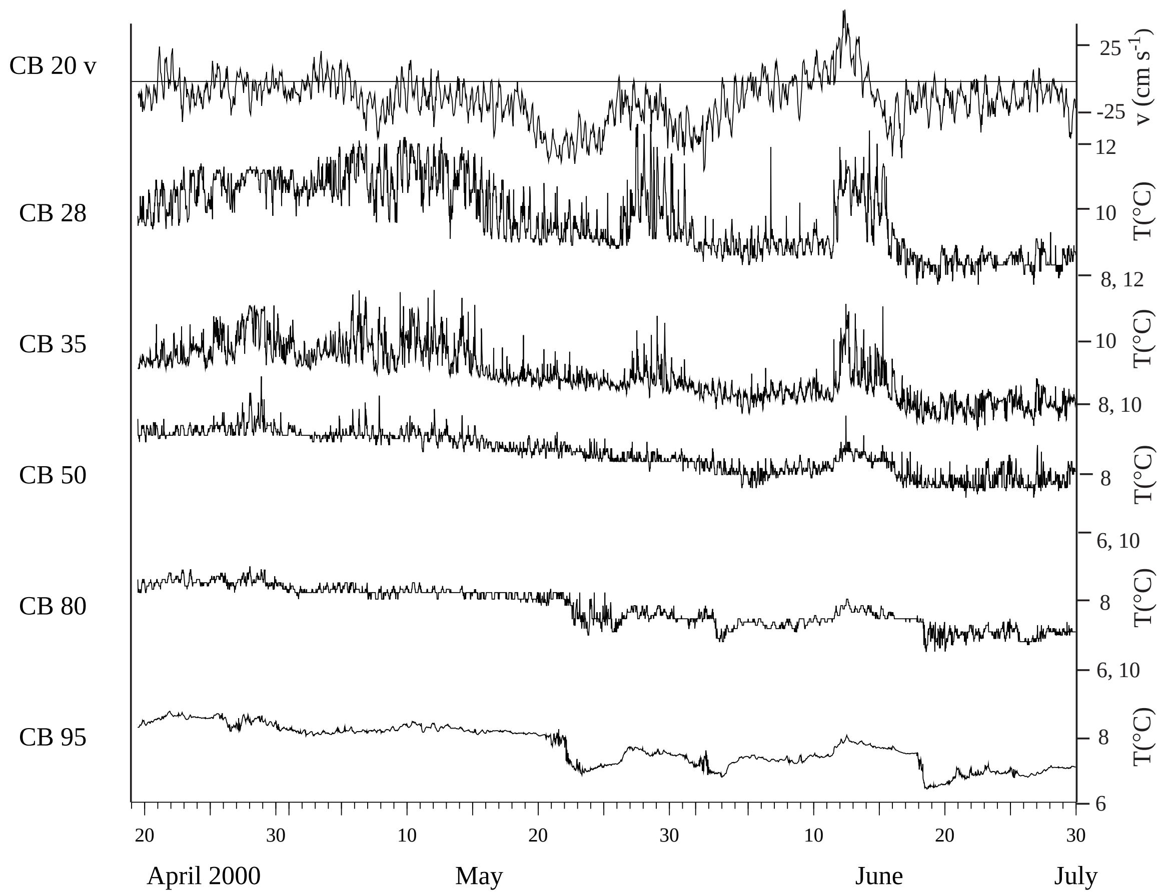

Figure 1. Hourly temperature time series at selected depths over the shelf off Coos Bay, Oregon in a water depth of 100 m during April-June 2000. North-south velocity is shown on the top of the figure (positive northward).

shown).

Time series from winter 1998 through summer 2000 show that currents on the Coos Bay shelf are nearly vertically uniform in fall and winter (not shown), but strongly sheared in summer (Figure 2). In particular, velocity time series at ~80 m indicate the seasonal development of a northward undercurrent on the shelf from late spring through summer in both years. Near surface southward flow is stronger and more continuous in summer 2000 than in summer 1999.

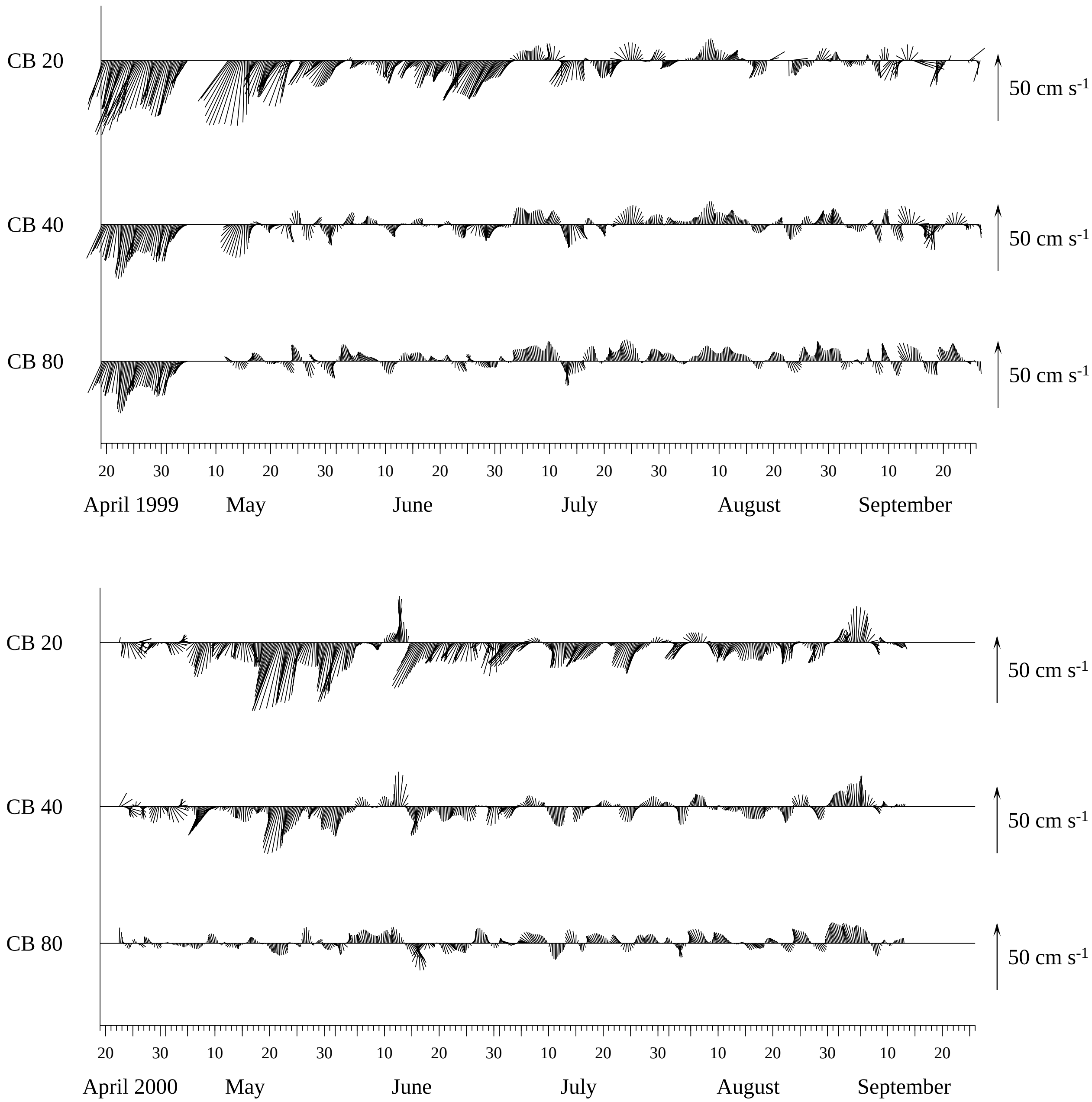

Figure 2. Subtidal vector velocity at selected depths over the shelf off Coos Bay, Oregon in a water depth of 100 m during April to September 1999 and 2000 (positive northward and onshore). The time series indicate more persistent upwelling during summer 2000 than summer 1999 (as indicated by southward flow at 20 m) and the seasonal development of an undercurrent in both years (indicated by the northward mean flow at 80 m).

Age Structure, Nutritional Status and Potential for Trophic Transfer in the Euphausiids Euphausia pacifica *and* Thysanoessa spinifera

Se-Jong Ju, H. Rodger Harvey,
Chesapeake Biological Laboratory, University of Maryland Ctr. for Environmental Science, Solomons

in collaboration with Bill Peterson, Julie Keister and Leah Feinberg,
Oregon State University, Hatfield Marine Science Center, Newport

Euphausiids (krill) serve an important role in the marine ecosystem as a link between primary producers and top predators, particularly for the commercially important fisheries in the north east Pacific. Using cellular peroxidation products (collectively called lipofuscins) and lipid biomarkers, we hope to determine the population age structure and nutritional condition of the two major euphausiid species *E. pacifica* and *T. spinifera* as part of NEP GLOBEC. Initial efforts have focused on the characterization of lipofuscin fluorescence properties extracted from neural tissues (eye and eye-stalk) of field collected euphausiids. In contrast to our work on blue crabs (Ju et al, 1999), lipofuscins in euphausiids show different fluorescence properties, with a maximum at excitation of 450 nm and emission of 520 nm. Individuals can be measured, but variability is significant at the very low concentrations encountered. Continued examination and methods refinement is underway, with planned comparisons using known age animals used to determine the demographic structure of krill populations in the field.

Nutritional status and trophic transfer measures employ both lipid classes and individual lipid biomarkers of collected euphausiids. Total lipid content of seston (as potential diets) and krill ranged from 25 to 46 (mg/g dry weight) and 74 to 152 (mg/g dry weight), respectively. Phospholipids were the major lipid class in seston and krills (more than 70%). Lipid class and fatty acid composition of krill showed significant ontogenetic shifts, particularly

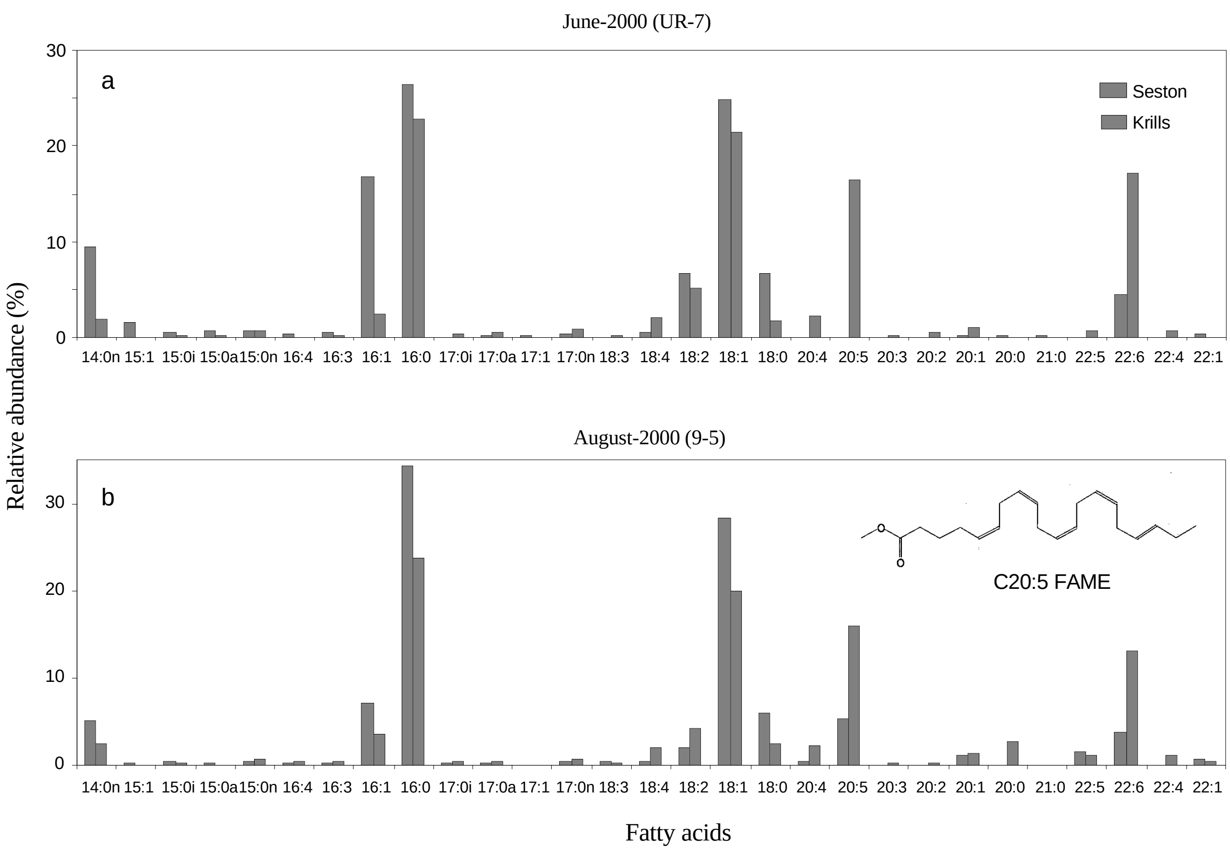

Figure 1. The relative abundance (%) of total fatty acids in seston (potential diets) and krills (*E. pacifica*) collected from two stations (a:UR-7; b:9-5) during cruises on June and August 2000, respectively.

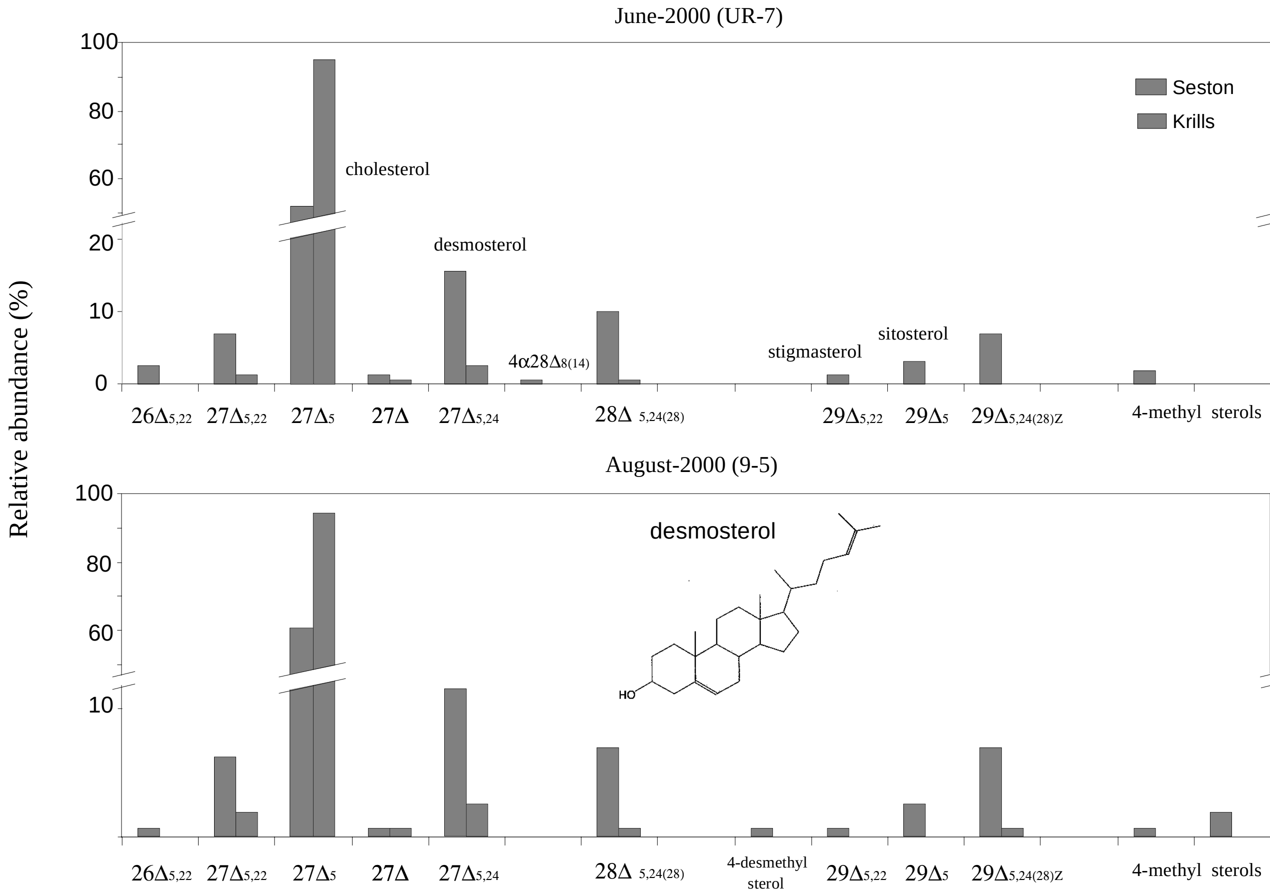

Figure 2. The relative abundance (%) of free and esterified sterols in seston and krill (*E. pacifica*) collected from two stations (a:UR-7; b:9-5) during cruises on June and August 2000, respectively.

increases in the relative proportion of phospholipids and polyunsaturated fatty acids (PUFA) with maturity. Among all samples analyzed thus far, four fatty acids including the 16:0, 18:1, 20:5, and 22:6 are the major fatty acids in krill (Figure 1) and show only minor shifts between the two cruises and over spatial scales. In seston, however, the 16:1, 16:0, 18:1, and 18:0 were the major fatty acids with significant temporal and spatial compositional changes (Figure1). Particularly, long chain polyunsaturated fatty acids such as 20:5 (rich in diatoms) and 22:6 (rich in dinoflagellates and chrysophytes), which are also known as essential fatty acids for the growth and development of fish larvae and juveniles, were not detected or observed at significantly low concentrations within offshore stations. Cholest-5-en-3β-ol (cholesterol) was the dominant sterol in all animals (≥ 92% of total sterols), with furcilia, also containing a number of other sterols from dietary sources (Figure 2). Although cholesterol was also the dominant sterol (30 - 60 % of total sterol) in seston, a suite of 15 other sterols were also found (Figure 2), a number of which represent specific algal taxa. These preliminary results suggest that lipofuscin can be measured among individuals, and that krill show ontogenetic changes of lipid composition with less variability as age increases.

Interannual And Interdecadal Changes In Zooplankton Assemblages Off Newport, Oregon

Julie E. Keister and William T. Peterson (Oregon State University, Hatfield Marine Science Center, Newport)

Zooplankton was sampled off Newport, Oregon in 1969-1973 and 1996-1999 allowing comparison of zooplankton assemblages across seasonal, decadal and annual timescales and through the strong 1997-1998 El Niño. Preliminary analyses reveal strong evidence of interdecadal and interannual variation in zooplankton communities. Boreal species that dominated the plankton during the 1970's were less common in the late 1990's whereas several species with southern affinities have increased in relative dominance. The 1997-1998 El Niño was particularly evident in the zooplankton; species richness and diversity were high in 1998 as species with strong southern or off-shore affinities were brought north and onshore. Species richness and diversity was very low in 1999, possibly indicating that a change in ocean conditions is moving zooplankton communities in another, so far unknown, direction.

Proportion (± 1 SE) of dominant zooplankton species averaged over the time periods 1) 1996-1973, 2) 1996-1999, 3) 1998 (el Niño) only, and 4) 1996, '97, and '99.

	Pseudo-calanus	Acartia longiremis	Oithona similis	Acartia clausi	Calanus marshallae	Larvaceans
1969-1973	0.14 ±0.005	0.11 ±0.006	0.10 ±0.004	0.05 ±0.005	0.05 ±0.004	0.03 ±0.004
1996-1999	0.08 ±0.005	0.03 ±0.004	0.11 ±0.005	0.02 ±0.003	0.03 ±0.004	0.07 ±0.004
1998 only	0.03 ±0.003	0.02 ±0.003	0.08 ±0.003	0.01 ±0.001	0.03 ±0.002	0.05 ±0.003
1996,'97,'99	0.10 ±0.004	0.04 ±0.005	0.13 ±0.004	0.02 ±0.003	0.04 ±0.004	0.08 ±0.004

Species with strong correlations (r>0.5) to Axis 1 in the Non-Metric Multidimensional Scaling (NMS) ordination. A negative correlation indicates that the species decreased across years; a positive correlation indicates increased importance across years.

Species	r
Acartia longiremis	-0.83
Pseudocalanus	-0.80
Corycaeus	0.76
Ctenocalanus	0.70
Calocalanus styliremis	0.58
Larvaceans	0.57
Siphonophores	0.57
Paracalanus	0.54
Acartia clausi	-0.55

Analysis of Ichthyoplankton Distribution, Abundance and Species Associations in the Western Gulf of Alaska

Ann C. Matarese, Kevin M. Bailey, Miriam J. Doyle
(all at Joint Institute for the Study of Atmosphere and Oceans, University of Washington)
Susan J. Picquelle, Deborah M. Blood, Jan L. Benson, Kathryn L. Mier, Morgan S. Busby and Richard D. Brodeur
(all at Northwest Fisheries Science Center, Newport, Alaska Fisheries Science Center, Seattle)

The coastal Gulf of Alaska supports large, economically valuable fisheries resources and provides nursery areas for many fish species. Over the past few decades, there have been dramatic shifts in species composition and abundance in this region. In order to document and understand such fluctuations, it is crucial to study the spawning patterns and early life history stages of fish in this ecosystem and to examine relationships between spatial and temporal patterns in the ichthyoplankton and the oceanographic environment. Ichthyoplankton and oceanographic sampling has been carried out since 1972 in the Gulf of Alaska under a variety of research programs of NOAA's National Marine Fisheries Service. From these collections an ichthyoplankton database has been developed at the Alaska Fisheries Science Center in Seattle and the present GLOBEC-funded study utilizes this database to describe and investigate spatial patterns and temporal trends among eggs and larvae of fish species in the Gulf of Alaska.

A first draft has been completed of a comprehensive atlas based on 11,379 ichthyoplankton collections from 100 Alaska Fisheries Science Center (AFSC) cruises spanning 25 years (1972-1996) off the U.S. west coast, Gulf of Alaska, and eastern Bering Sea. The distribution and abundance patterns of 101 taxa (in 34 families) that are important contributors to ichthyoplankton assemblages are described and illustrated. This atlas is currently undergoing in-house review prior to submittal to the NOAA Technical Report series. The atlas includes a detailed introduction reviewing the history of distributional studies in the Northeast Pacific and a discussion of the sampling history at AFSC. For each taxa included, graphs are provided summarizing data such as abundance and percent occurrence by month and year and relative abundance by length interval by season. A large map is provided for each species depicting larval distribution and abundance patterns. Egg and adult distribution maps, showing presence/absence of pelagic eggs and adult fish, are also included.

Investigation of spatial patterns and temporal trends in the AFSC ichthyoplankton data is ongoing. Based on collections from the southeast Bering Sea, Gulf of Alaska and U.S. West Coast, regional variation in springtime ichthyoplankton assemblages in the northeast Pacific Ocean have been described and related to local topography and prevailing oceanographic conditions (manuscript accepted for publication in GLOBEC Special Issue of Progress in Oceanography - Doyle et al.). For all three sampling regions, the assemblage structure is primarily related to bathymetry and Shelf, Slope and Deep-Water assemblages are described. This shallow to deep-water gradient in species occurrence and abundance reflects the habitat preference and spawning location of the adult fish. Another degree of complexity is superimposed on this primary assemblage structure and seems to be related to local topography and the prevailing current patterns. Investigation of temporal variation in the occurrence and structure of larval fish assemblages in the Gulf of Alaska from 1978 to 1998 continues. In addition, an examination of seasonal and interannual variation in mean abundance of the dominant taxa of fish larvae in this region is being undertaken. The interannual trends are being investigated with a view to detection of any decadal-scale change that might reflect the late-seventies to early-eighties oceanographic regime-shift that has been documented in the environment and adult fish populations in the Gulf of Alaska.

Another study has been completed that examines advective processes associated with the onshore transport of eggs and larvae of deepwater spawning flatfish species (arrowtooth flounder and Pacific halibut) in the Gulf of Alaska (Bailey and Picquelle, in press). Based on a 20-year time series of AFSC data, the authors test the hypotheses that larvae of both species are more abundant in coastal areas during El Niño events, and that a higher proportion of larvae are transported to inshore nursery grounds during El Niño years.

Retrospective Study of Sablefish Growth and Year Class Strength

William Pinnix, Steven Berkeley (both at Oregon State University, Dept. of Fisheries and Wildlife, Hatfield Marine Science Center), Dudley Chelton (Oregon State University, College of Oceanic and Atmospheric Sciences)

Otoliths of long-lived fishes provide a record of individual growth that directly or indirectly reflects past environmental conditions. Sablefish (*Anoplopoma fimbria*) is a long-lived, widely distributed species in the Northeast Pacific that may live 70 years or more. They occur in two discrete stocks, one in the Gulf of Alaska and another in the California Current System (CCS). During their first 6-9 months they reside in pelagic waters over the shelf and slope where their growth and survival are directly impacted by climatic and oceanographic variables. We analyzed a 35-year time series of year class strength for each stock and created a 45-year time series (1950-1994) of first year growth for both stocks from archived collections of otoliths. These time series were compared to various environmental indices to test the hypothesis that growth of sablefish during their first year is modified by variability in the pelagic environment, that early juvenile growth influences subsequent recruitment success, and that a common juvenile environment results in correlative relationships between growth and recruitment in sablefish and ocean survival and growth of salmon.

Results indicate that otolith area provides a precise index of sablefish growth in their first year, and that first year growth for both stocks declined significantly between 1950 and 1989 (Alaska, p=0.012; West Coast, p=0.021) (Figure 1). The environmental indices that are most predictive of growth patterns differ between stocks; Alaskan sablefish growth is modeled by the PDO and June NOI (Figure 3); West Coast sablefish growth is modeled by year class index (YCI), PDO, and June NOI (Figure 2), but growth for the west coast stock is negatively related to the PDO and NOI suggesting that warmer temperatures reduce growth but El Nino conditions (negative NOI) enhance growth. Alaskan sablefish growth is positively related to both the PDO and June NOI suggesting that warmer temperatures increase growth while El Nino conditions reduce growth. Since the bulk of sablefish growth occurs from June-September, these results suggest that the two ecosystems respond differently to large scale forcing mechanisms at the interannual scale during summer.

Both Alaska and west coast YCI are positively related to the PDO at the interdecadal scale, suggesting that winter conditions control sablefish recruitment in the NE Pacific (Figure 4). Alaskan sablefish recruitment is best modeled by winter SST (Figure 6). West coast recruitment is best described by two regression models, one fit prior to 1977 and another for 1977-94 (Figure 5). The west coast YCI is modeled at the interannual scale by size at age 1 (negative), the PDO (positive), and the January NOI-lag 1 (positive). This suggests that cool temperatures the previous year (NOI lag 1) followed by warm temperatures (PDO) create a strong year class. However, in the first regime, PDO is the most significant variable (weight = 0.307) and NOI has a minimal effect (weight = 0.002) whereas in the second regime, NOI is the most important variable (weight = 0.322) and PDO has a minimal effect (weight = 0.0001). This suggests that the sign of the PDO regulates the extent to which equatorial processes (El Nino) affect the California Current System.

Growth models suggest that summer ocean conditions are out of phase between the GOA and CCS. Recruitment models suggest that large-scale processes during winter affect environmental conditions similarly in the GOA and CCS prior to 1977. After 1977, the CCS is influenced more strongly by equatorial events. A weak but significant relationship was found between west coast sablefish growth and Oregon coho salmon weight suggesting that coho growth is generally increased at colder temperatures.

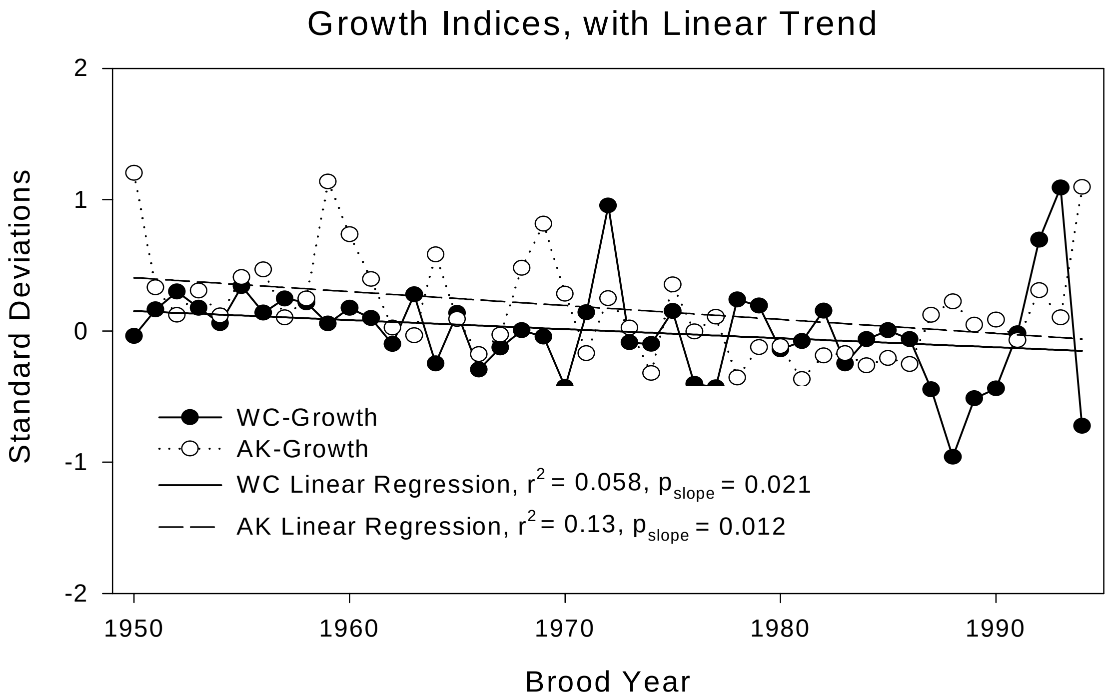

Figure 1. Growth indices for the West Coast (WC) and Alaska (AK). Lines represent linear trend over time, r-squared and p-values of the slope are presented.

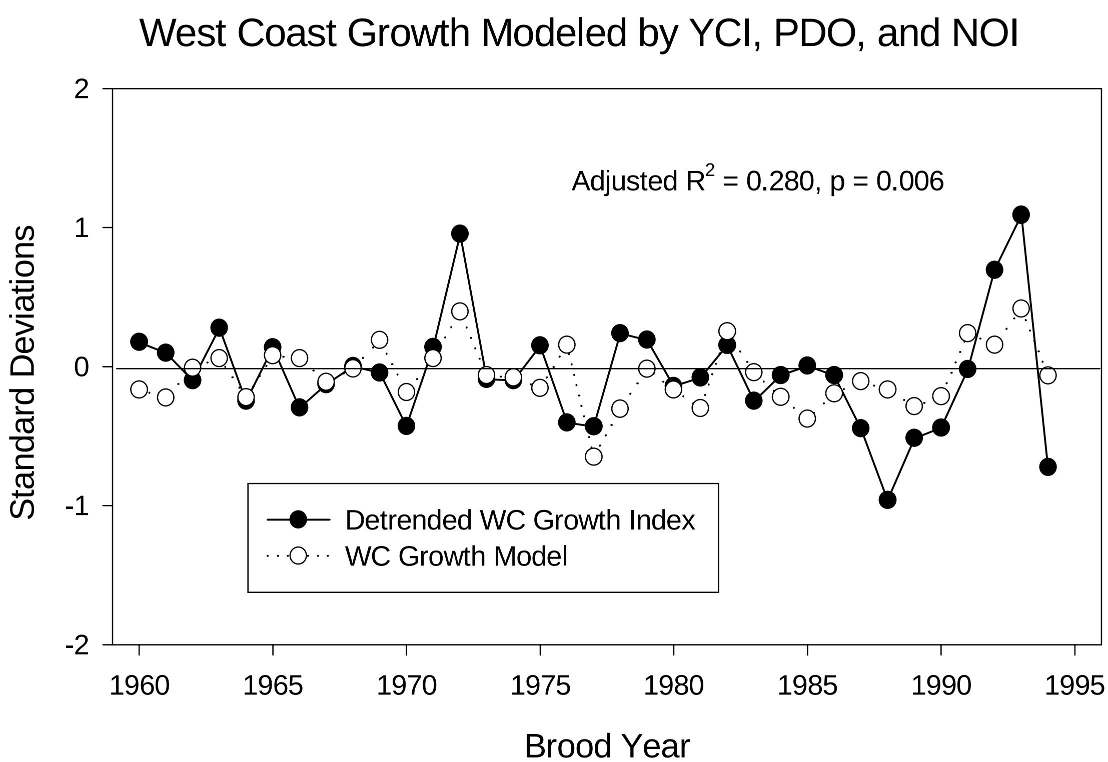

Figure 2. West coast growth model plotted against detrended growth index.

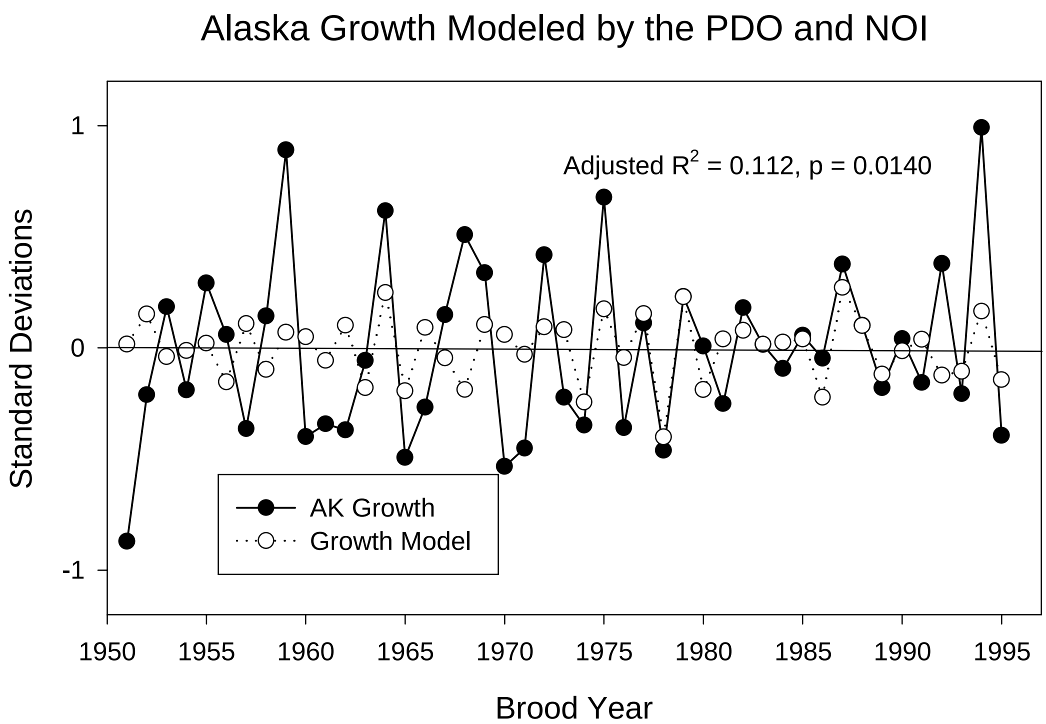

Figure 3. Alaskan growth index modeled by the PDO and NOI.

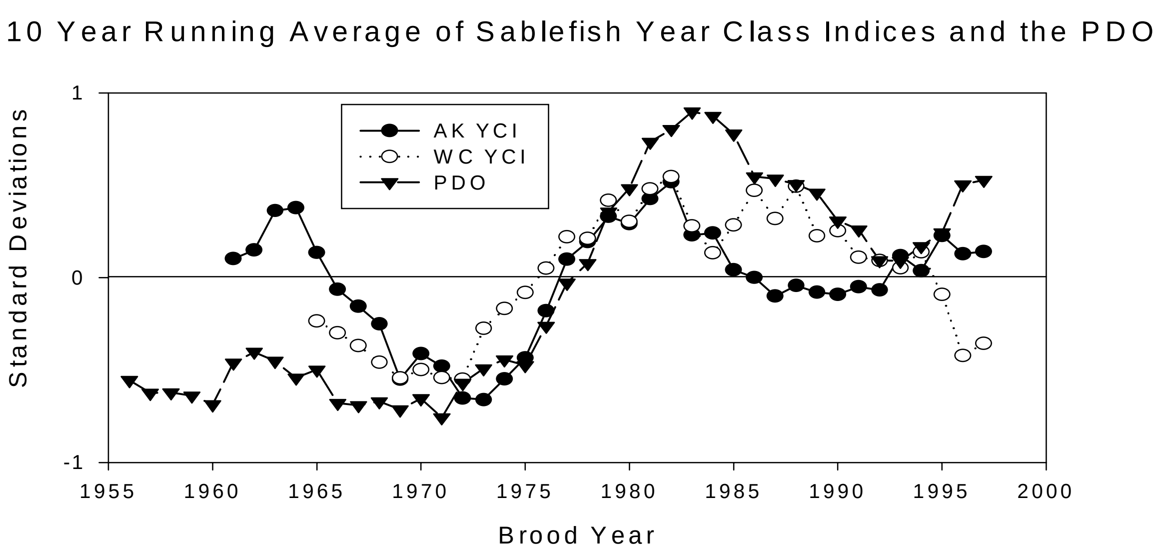

Figure 4. Ten year running averages (values plotted at year 5) of Alaska and West Coast year class indices, plotted with the PDO.

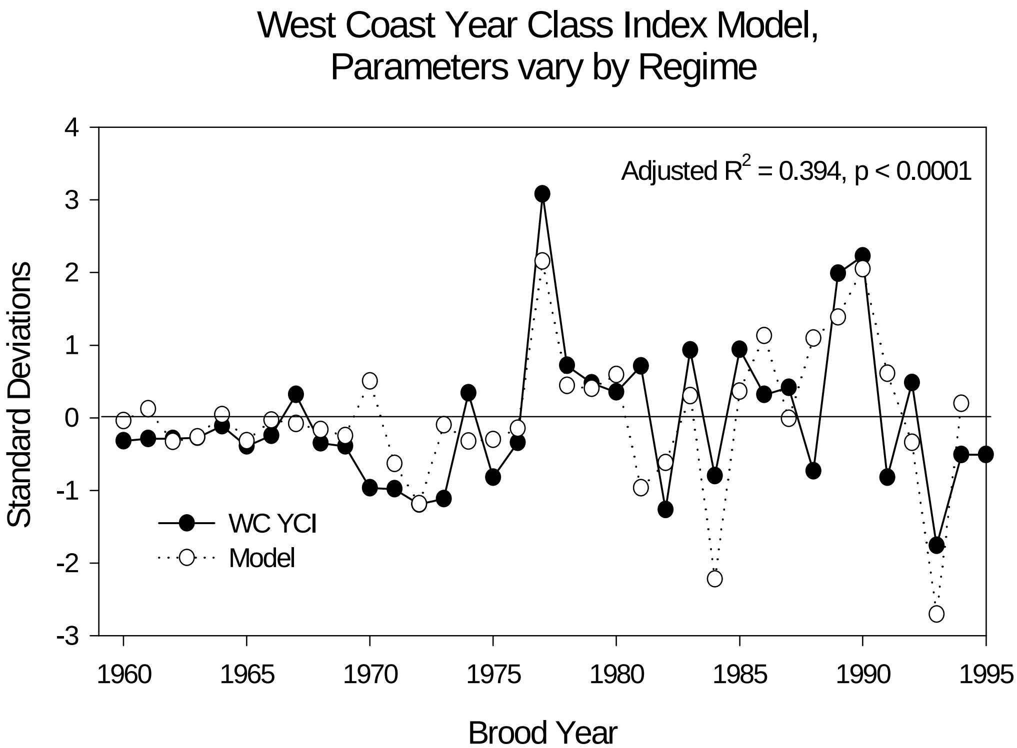

Figure 5. West Coast YCI modeled with Size at age 1, the PDO, and the NOI as predictors. The parameter values were allowed to vary by regime, essentially creating two separate regressions; one prior to 1977, and one from 1977 on. The r-squared value has been adjusted to account for the two regressions and added parameters.

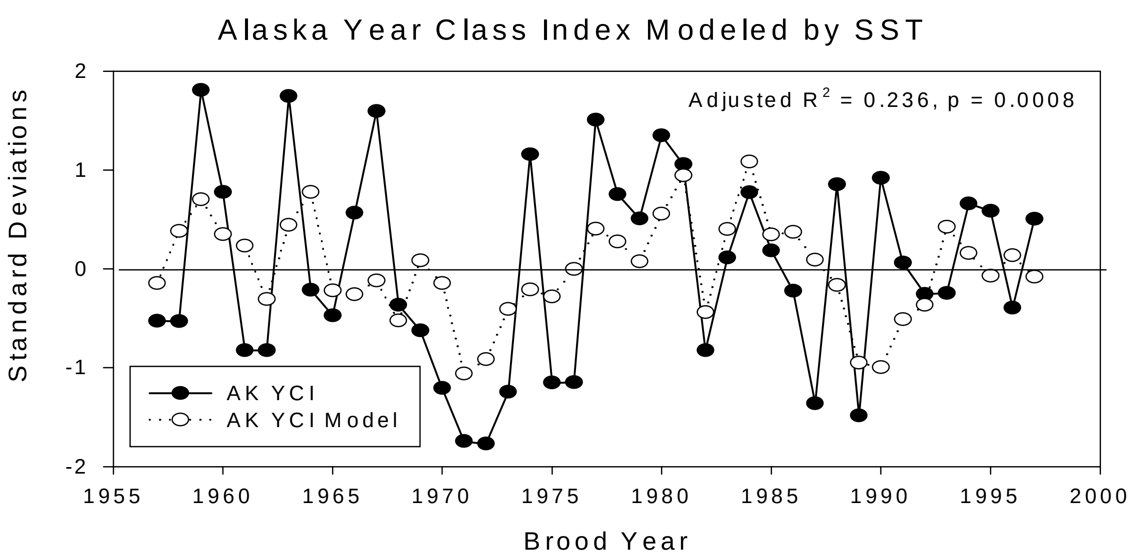

Figure 6. Alaskan year class index modeled by winter SST.

Mesoscale Distribution of Acoustically Determined Fish Schools and Plankton Patches in the Eastern Pacific Boundary Current; Their Proximity and the Influence of Currents, Bathymetry and Temperature

Gordon Swartzman and Barbara Hickey (University of Washington, Seattle)

Acoustic survey data, collected by the U.S. National Marine Fisheries Service in summer 1995 and 1998 were analyzed using image processing methods to identify schools of fish, primarily pacific Hake (*Merluccius productus*) and patches of zooplankton along on-offshore transects from 40 to 47° N latitude. Zooplankton were not identified, but, from bongo net sampling along the surveys, are expected to be mostly euphausiids. The two years were quite different in abundance and distribution of both fish and plankton, with fish being more northwardly distributed in 1998, an El Niño year. We have examined three major questions involving the distribution of fish and plankton and their relationship to environmental conditions. These are: 1) The proximity and overlap of large patches of zooplankton and large fish schools; 2) The mesoscale distribution of consistent layers of zooplankton found in deeper waters throughout the survey area; and 3) Comparisons of day and night distributions of fish and plankton and evidence for diel migration patterns. Work in the near future will involve examining the distribution of fish and plankton in the neighborhood of submarine canyons which we hypothesized are regions of elevated production and therefore higher fish and zooplankton abundance.

Fish-plankton proximity

We examined the relative abundance of fish and zooplankton and their proximity over the survey area by dividing the total area into three latitudinal zones, based on hydrological and meteorological conditions. We then assumed that the transects in each zone are replicates of a pattern consistent over that zone. This convenience allowed us to approach the question of relative abundance and overlap statistically. The three zones were separated at Cape Blanco and at the Columbia River. Transects in each area had similar distribution patterns of fish and plankton. The highest relative abundance of fish and plankton was found in the shelf break area independent of region and year differences. This region may provide reliable food resources for feeding hake and perhaps also for euphausiids. This is demonstrated by boxplots of relative abundance of both fish school and plankton patch biomass per transect km (Figure 2). Both fish and plankton abundance density was highest in the shelf break region.

Offshore euphausiid layer

A consistent layer of eupausiids was found offshore of the 200-m isobath, centering in the 140-250 m depth range. Their depth distribution was compared with the temperature, salinity and alongshore current flow patterns in 1995. A similar comparison with 1998 will be made when the CTD are obtained from NMFS and ADCP data processing are completed (Michael Kosro, personal communication). We found this layer to persist throughout the survey area, though more consistently along some transects than others. For 1995, we found the tops of the transect layer to decrease from an average of greater than 200 m in the south to an average of about 150 m in the north (Figure 2). A comparison of the patch tops was made because patch bottoms below 250 m could not be detected due to the 250-m range of the 120 kHz echosounder. The patch tops compared quite favorably with the temperature-depth distribution, with patch tops being restriced to the 7-8 degree range over the entire latitude range of the survey (33-47º N latitude). Furthermore, a high percentage of the tops centered on the 7.5º isotherm. It is not clear whether euphausiids can directly sense temperature. Initial comparison with ADCP data suggest that the patches may occupy a zone just above the maximum northward flow, in an area of high shear; something that we think can be detected by euphausiids. Patch tops in 1998 also showed a reduction in depth south to north, though considerably less striking than in 1995; from an average depth of 135 m in the south to less than 100 m in the north. The 1998 patch tops were consistently shallower than in 1995. It will be interested to see whether this correlates with changes in temperature, density or currents between the two survey years.

Diel migration of offshore euphausiid layer

While the survey was primarily a daytime survey, there were also a small number of nighttime transects. We compared the average depth of the offshore layer for matching transects in both 1995 and 1998. There were between 10 and 20 replicates for comparison, though some night replicates did not cover the deeper zone. We found no consistent pattern in the average depth of the tops of the zooplankton layers between day and nighttime. This suggests that the offshore zooplankton layer does not vertically migrate day to night. The abundance of zooplankton patches (biomass/km), though somewhat lower at night, was not significantly reduced between day and night time, which suggests that the zooplankton were not diel migrating to depths too shallow to be acoustically detected (i.e. above 12 m depth).

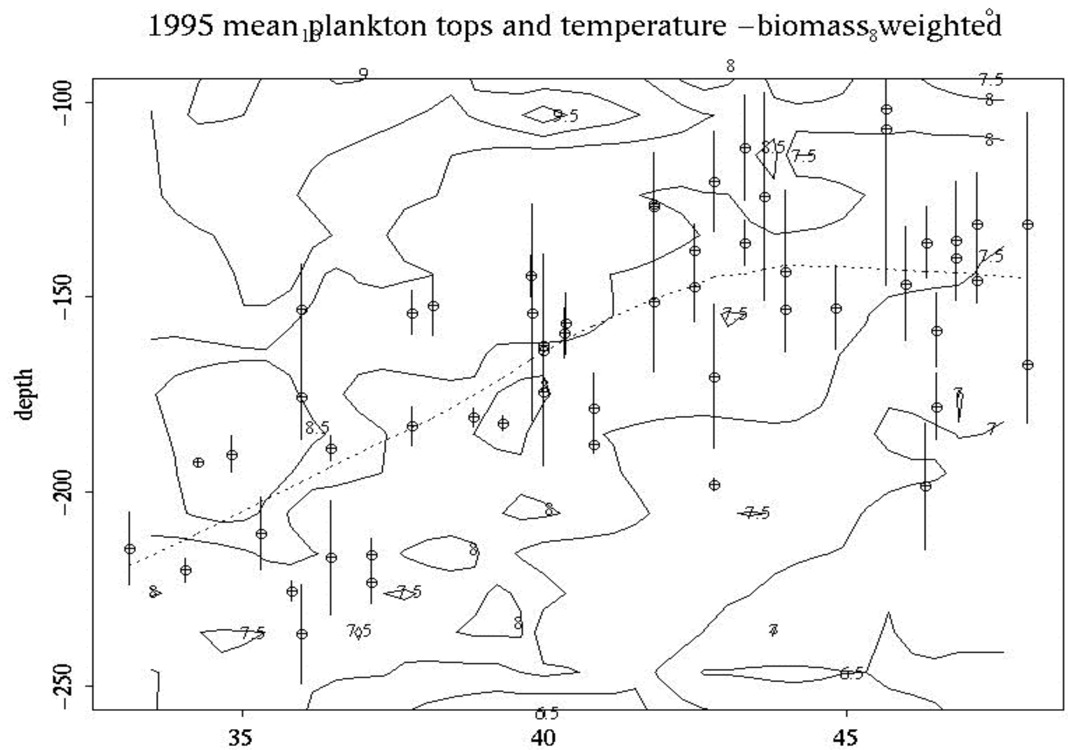

Figure 1. Comparison of the tops of offshore plankton patches in 1995 with temperature isotherms as a function of latitude along the survey. Patches were chosen to be within 1 km of CTD locations. The means of patch tops, weighted by patch biomass as shown, with one standard error lines. A smooth to the means is shown by a dashed line.

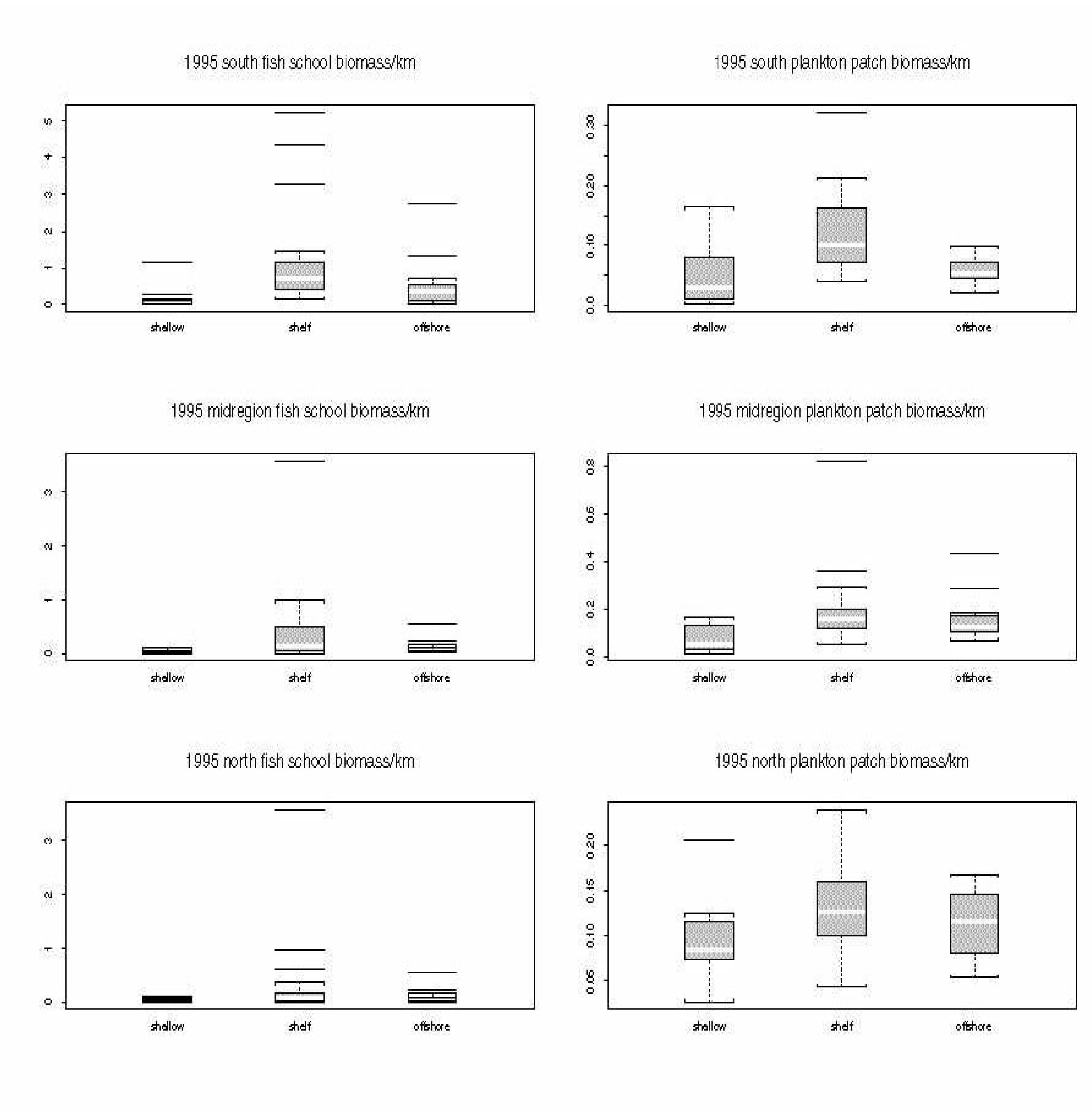

Figure 2a. Boxplots of fish school and plankton patch abundance (biomass/km) for each of three zones in the survey area for 1995. Results are shown for nearshore, shelf break and offshore sections.

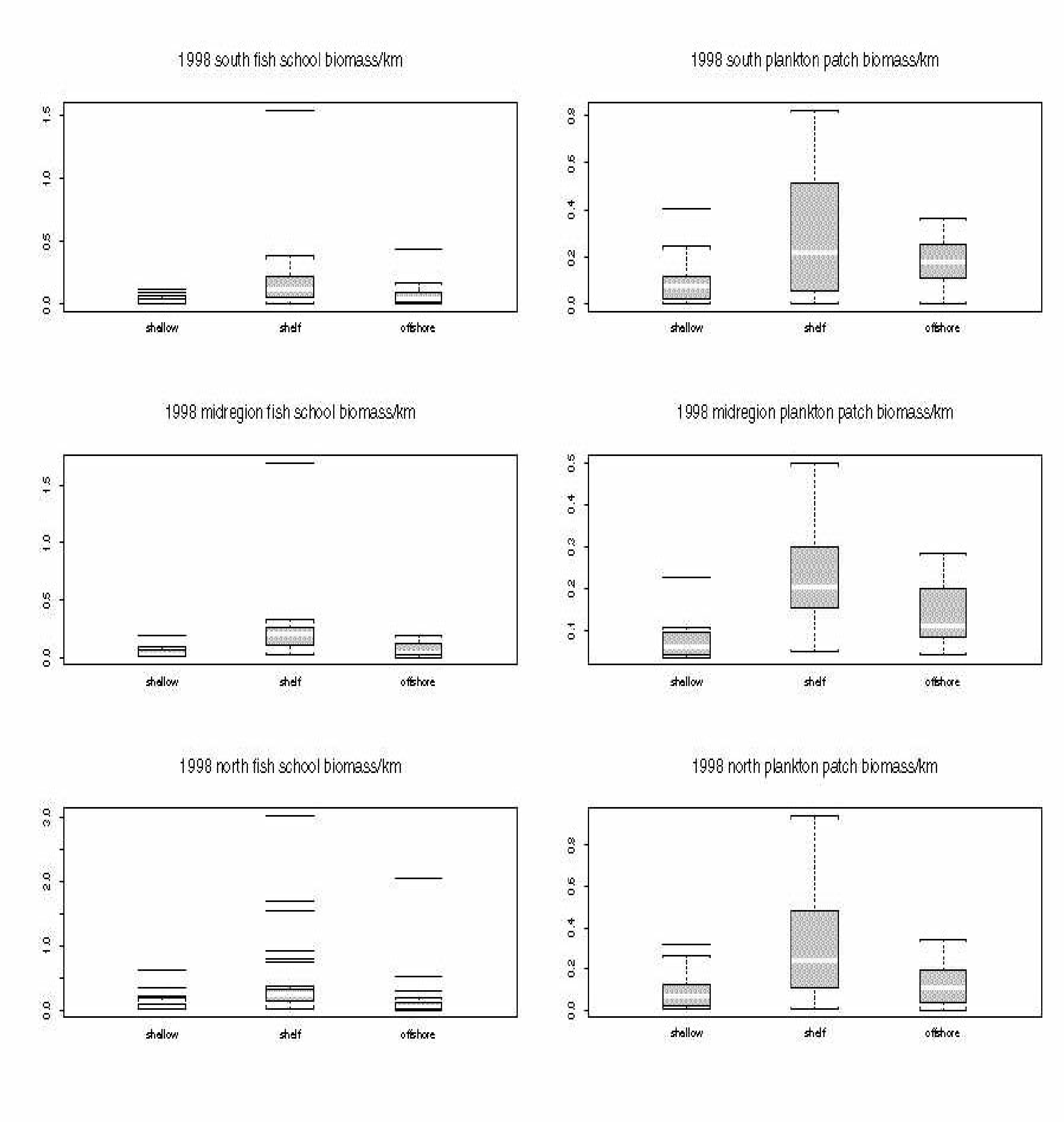

Figure 2b. Boxplots of fish school and plankton patch abundance (biomass/km) for each of three zones in the survey area for 1998. Results are shown for nearshore, shelf break and offshore sections.

APPENDIX I

AGENDA

Agenda

NEP CCS PI/SI Meeting

12-14 November 2000
International Room - Memorial Union East
Oregon State University, Corvallis, Oregon

Sunday, 12 November 2000

0900 Opening Remarks - Welcome, Introduction, Meeting Details/Structure, Possible Products (Strub)

0915 Brief Updates on Project Progress
- Modeling
  - Botsford
  - Haidvogel
  - Edwards
  - Zhou
- Retrospective
  - Berkeley
  - Doyle
  - Ohman
  - Murphree
  - Swartzman

1000 Break
1030 Brief Updates on Project Progress
- LTOP
  - Huyer
  - Kosro
  - Geier
  - Ramp
  - Hopcroft
- Modeling
  - Hermann (late arrival)
- Process-Mesoscale Studies in the CCS
  - Strub
  - Barth
  - Letelier
  - Emmett
  - Casillas
  - Brodeur

1200 Lunch
1300 Retrospective
- Finney (late arrival)
- Process-Mesoscale Studies in the CCS (continued)
  - Zhou
  - Peterson
  - Huntley
  - Harvey
  - Ainley
  - Tynan
  - Teel

1500 Break
1530 Continue discussions
1710 Brainstorming Working Group Session Topics
1730 Poster Sessions
1900 Adjourn

Monday, 13 November 2000

0830 Plenary session - continue brainstorming potential topics for working groups (Strub)
1000 Break
1030 Data management (Groman)
1130 Oral presentations for PISCO, COAST, NOPP, WEST, BPA, & NMFS/NWFSC programs
1200 Lunch
1300 Informal Working Groups
1500 Break
1530 Formal Working Groups
1630 Plenary session - formal working group reports
1730 Adjourn

Tuesday, 14 November 2000

0830 Plenary session - future venues/opportunities for presenting GLOBEC NEP/CCS research at public meetings and in special publications.
0915 Continue working group discussion and poster viewing
1000 Break
1030 Continue working group discussion and poster viewing
1200 Adjourn

APPENDIX II

LIST OF ATTENDEES

U.S. GLOBEC Northeast Pacific Program
PI Meeting Attendance
November 12-14, 2000
Corvallis, Oregon

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