GLOBEC Northeast Pacific Study: Mesoscale zooplankton distribution and productivity

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(Report period: 05/01/00 – 04/30/05)

1. Participants

University of Massachusetts Boston Team:
- Meng Zhou, Associate Professor, University of Massachusetts Boston
- Yiwu Zhu, Research Associate, University of Massachusetts Boston
- Di Wu, Ph.D. student, University of Massachusetts Boston
- Jay O. Peterson, Ph.D. student, University of Massachusetts Boston
- Alejandro González, Research Assistant, University of Minnesota Duluth

University of Hawaii Team:
- Mark E. Huntley, Professor, University of Hawaii
- Delphine Thibault-Botha, Assistant Research Scientist, University of Hawaii
- Robert W. Campbell, Ph.D. student, University of British Columbia
- Terra Bowen, undergraduate student, Hawaii Institute of Marine Biology

2. Objectives:

Our overall objective addresses one of the main goals of U.S. GLOBEC Northeast Pacific Study, i.e., "*to quantify how physical features in the California Current System impact zooplankton biomass, production, distribution, and the retention and loss of zooplankton from coastal regions.*" We have approached this objective by:

1) measuring spatiotemporal distribution and abundance of zooplankton,
2) estimating relative productivity of zooplankton in mesoscale features, and
3) elucidating the causes of spatiotemporal anomalies in zooplankton productivity.

3. Scope of proposed work

1) Development

(1) integrating the Optical Plankton Counter (OPC) with the SeaSoar-CTD Package,
(2) developing OPC data processing and visualization software, and
(3) developing mathematical methods to interpret zooplankton size structure.

2) Participation in cruises:

Survey cruise tasks: small-mesoscale surveys of zooplankton abundance and size structure using the integrated SeaSoar-CTD-OPC package.

Process cruise tasks: zooplankton compositions, carbon/nitrogen contents, body weight/length, gut fluorescence, egg production (Mark, please revise these.)

Proposed cruises:

Survey cruise:	May 29 to June 16, 2000
Process cruise:	May 29 to June 16, 2000
Survey cruise:	July 29 to August 17, 2000
Process cruise:	July 29 to August 17, 2000
Survey cruise:	May 30 to June 17, 2002
Process cruise:	May 30 to June 17, 2002
Survey cruise:	July 30-August 17, 2002
Process cruise:	July 30-August 17, 2002

3) Expected results

(1) inter-comparison of zooplankton biomass estimates between acoustic and optical sampling devices,
(2) spatial distributions of zooplankton biomass and size structure,
(3) statistical results of zooplankton diel vertical migration,
(4) proxies of scope for growth: gut fluorescence, condition factor, C:N ratio, egg production
(5) impacts of current advection on zooplankton distributions, and
(6) zooplankton productivity.

4. Major research accomplishments

1) Successful participation in all cruises and proposed studies

Survey cruise: May 29 to June 16, 2000
Participants: Alejandro González
Process cruise: May 29 to June 16, 2000
Participants: Mark Huntley, Robert Campbell
Survey cruise: July 29 to August 17, 2000
Participants: Alejandro González
Process cruise: July 29 to August 17, 2000
Participants: Robert Campbell, Jay Peterson
Survey cruise: May 30 to June 17, 2002
Participants: Jay Peterson, Di Wu
Process cruise: May 30 to June 17, 2002
Participants: Delphine Thibault-Botha
Survey cruise: July 30-August 17, 2002
Participants: Meng Zhou, Di Wu
Process cruise: July 30-August 17, 2002
Participants: Delphine Thibault-Botha, Terra Bowen

2) OPC data processing and graphing

(see details at http://www.eeos.umb.edu/faculty/mzh/files/nep/nep.htm)

(1) All OPC data have been processed by filtering noises and bad data strings.

(2) All OPC data have been integrated into 4-m depth bins along the SeaSoar tracks with 50 body size intervals from 200 μm to 16 mm.

(3) Inter-comparison of biomass estimates between HTI acoustic backscattering and OPC data.

(4) Graphs: horizontal distributions and vertical transects of zooplankton biomass along survey lines.

3) Zooplankton process rates based on laboratory experiments

(1) Proxies of scope for growth (copepods): On several cruises, copepods proved to be so rare that sufficient animals could not be obtained for live experiments (e.g. egg production). Gut fluorescence measurements were made, and these data have been analyzed.

(2) Predation rates of gelatinous zooplankton: Experimental measurements have been completed and analyzed.

4) Presentations

(1) Zhou, M., Y. Zhu, Mesoscale Physical Processes and Population Dynamics of Zooplankton in the California Current Region, EOS, Vol. 80, 66-66, 1999.

(2) Zhou, M., Observing and modeling spatiotemporal distribution and population dynamics of

zooplankton, invited keynote speech, International Council for the Exploration of the Sea (ICES) Symposium – Population Dynamics of Calanus in the North Atlantic, Tromsø, Norway, 1999.

(3) Zhou, M., U.S. GLOBEC: An ecosystem model in the California Current region, the GLOBEC Northeast Pacific Study Workshop, San Francisco, 1999.

(4) Zhou, M., A. González, Y. Zhu and J. Peterson, U.S. GLOBEC Northeast Pacific Study: Mesoscale zooplankton distribution and productivity, Annual Workshop, Corvallis, OR, November 2000.

(5) Zhou, M., and Y. Zhu, U.S. GLOBEC: A zooplankton population dynamics model in the California Current region, Annual Workshop, Corvallis, OR, November 2000.

(6) Zhou, M. and Y. Zhu, Mesoscale zooplankton distribution and its correlation with physical and fluorescence fields in the California Current in 2000, AGU Ocean Science Meeting, Honolulu, February, 2002.

(7) Campbell, R.W. and M. E. Huntley, Mesoscale distributions of lipids in the copepods of the California Current, AGU Ocean Science Meeting, Honolulu, February, 2002.

(8) Thibault-Botha, D.M. and M. E. Huntley, Mesoscale zooplankton productivity in the NEP region in May and August 2000, AGU Ocean Science Meeting, Honolulu, February, 2002.

(9) Wu, D. M. Zhou, J.O. Peterson, and Y. Zhu, Zooplankton population dynamics within mesoscale physical fields in the California Current off Oregon, International GLOBEC Open Science Meeting, Qindao, China, 2002.

(10) Zhou, M., Population dynamics of zooplankton: Observations, theories and models, the Gordon Research Conference of Coastal Ocean Modeling, USA, June 2003.

(11) Thibault-Botha, D., T. Bowen and M.E. Huntley, Importance of gelatinous zooplankton in the NEP Ocean in August 2002, 3rd International Symposium on Zooplankton Production, Gijon, Spain, May 2003.

(12) Huntley, M.E. and M. Zhou, Influence of animals on turbulence in the sea, 3rd International Symposium on Zooplankton Production, Gijon, Spain, May 2003

(13) Wu, D. and M. Zhou, Zooplankton Distribution and Transport in the California Current off Oregon in 2002, AGU Ocean Science Meeting, Portland, January, 2004.

(14) Huntley, M.E and M. Zhou, Seasonal dynamics and ecosystem impact of zooplankton in the oligotrophic Pacific Ocean, Estimated from Optical Plankton Counter, ASLO Meeting, Honolulu, February, 2004.

5) Publications

(1) Zhou, M. Survey, objective interpolation and population dynamics of zooplankton, Proceedings of International Symposium on Zoo-ichthyoplankton, Swakopmuud, Namibia, 1999.

(2) Huntley, M. E., A. Gonzalez, Y. Zhu, M. Zhou, and X. Irigoien, Zooplankton dynamics in a mesoscale eddy-jet system. Marine Ecology Progress Series, 201, 165-178, 2000.

(3) Pinca, S. and M.E. Huntley, Spatial organization of particle size composition in an eddy--jet system off California, Deep-Sea Research I*,* 47, 973-996, 2000.

(4) Zhou, M. and K.S. Tande, Optical Plankton Counter Workshop Report, International Global Ecosystem Dynamics Program (GLOBEC) Report, No. 17, 67 pp, 2002.

(5) Zhou, M. Size-structured zooplankton population dynamics theories, International Global Ecosystem Dynamics Program (GLOBEC) Report, No. 17, 34-38, 2002.

(6) Edvardsen, A., M. Zhou, K. S. Tande, and Y. Zhu, Zooplankton population dynamics: Measuring in situ growth and mortality rates using an Optical Plankton Counter. Marine

Ecology Progress Series, 227, 205-219, 2002.

(7) Huntley, M.E and M. Zhou, Influence of animals on turbulence in the sea. Marine Ecology Progress Series, 273, 65-79, 2003

(8) Thibault-Botha, D. and T. Bowen, Impact of formalin preservation on *Pleurobrachia pileus* (Ctenophora), Journal of Experimental Marine Biology and Ecology, 303, 11-17, 2004.

(9) Huntley, M.E, M.D.G. Lopez and M. Zhou, Seasonal dynamics and ecosystem impact of zooplankton in the oligotrophic Pacific Ocean, estimated from Optical Plankton Counter. Journal of Geophysical Research - Oceans, in review.

6) Manuscripts in preparation

The following topics are primarily based on Di Wu's Ph.D. thesis:

(1) Distribution, transport and retention of zooplankton in the California Current off Oregon.

(2) Temporal variation and processing rates of zooplankton off Oregon Coast.

(3) Mesoscale physics and process rates: genesis of biological hot spots off Oregon.

Additional manuscripts in preparation include:

(4) Thibault-Botha, D. and T. Bowen, Importance of the gelatinous zooplankton (Ctenophora, Siphonophora) in the Northeast Pacific Ocean in summer: Potential impact on the pelagic food web.

(5) Thibault-Botha, D. and M.E. Huntley, Feeding rates of the principal copepods in the Northeast Pacific Ocean in summer 2000 and 2002.

7) Outreach

(1) Zhou, M., A zooplankton population dynamics model in the California Current region, Mathematics Department seminar, University of Minnesota, Duluth, MN, 1999.

(2) Zhou, M., Survey, objective interpolation and population dynamics of zooplankton, Marine Institute, Namibia, 1999

(3) Huntley, M. The U.S. GLOBEC program – current status, ICES-PICES Joint Working Group on Zooplankton Ecology, Honolulu, Hawaii, Apr 2000

(4) Zhou, M., Mesoscale physical and biological processes in the California Current System: A modeling study, ECOS Department seminar, University of Massachusetts Boston, 2001

(5) Huntley, M. History and applications of optical particle counting in marine science, Keynote address, Workshop on Optical Particle Counting, Alliance for Coastal Technologies (NOAA), Honolulu, Apr 2004

5. Major research findings

1. Permanent zooplankton abundance maxima associated with upwelling areas and shallow banks

Upwelling events were found in Heceta Bank and off Cape Blanco (Figure 1). Associated with these upwelling areas, chl-a maxima were found near the upwelling fronts (Figures 1 and 2), and zooplankton maxima were found in nearshore areas.

2. Onshore-offshore difference in chl-a and zooplankton distributions

High chl-a concentrations were found at the upwelling fronts, and deep chl-a maxima at the thermocline in offshore areas (Figure 2). In upwelling areas, zooplankton distributed over most of the water column, and were not correlated with chl-a maxima. In offshore areas, zooplankton maxima coincided with chl-a maxima at the thermocline.

3. Differences in size structures between nearshore and offshore regions

Zooplankton in nearshore areas were dominated by large organisms in the upper maxima, and small organisms in the lower water column, and in offshore areas by small organisms in both upper and lower water column (Figure 3).

4. Seasonal variability and differences in abundance and sizes between warm and cold water zooplankton populations

In the spring, abundance and biomass maxima coincided in nearshore upwelling areas. In the summer/fall, abundant small zooplankton were found in nearshore cold upwelling areas, and large zooplankton were found in offshore warm water areas (Figure 4).

5. Offshore transport of zooplankton

Abundant zooplankton were found in the Heceta Bank region, and transported offshore by the California Current (Figure 5) which led to the deep zooplankton maxima.

6. Diel migration

The day and night vertical zooplankton distributions in different size classes are shown in Figures 6 and 7. Results show that there are no statistical differences in zooplankton vertical distributions between day and night.

7. Relatively high productivity in upwelling areas

The relative productivity of zooplankton was strongly correlated with the phytoplankton distribution in May-June 2000 (Figure 8).

8. Extraordinarily high predation rates by gelatinous zooplankton

Gelatinous zooplankton were sufficiently abundant, especially in spring, and their measured predation rates high enough, to incur substantial mortality on prey populations dominated by copepods. These predation rates could have accounted for the very low observed abundances of copepods.

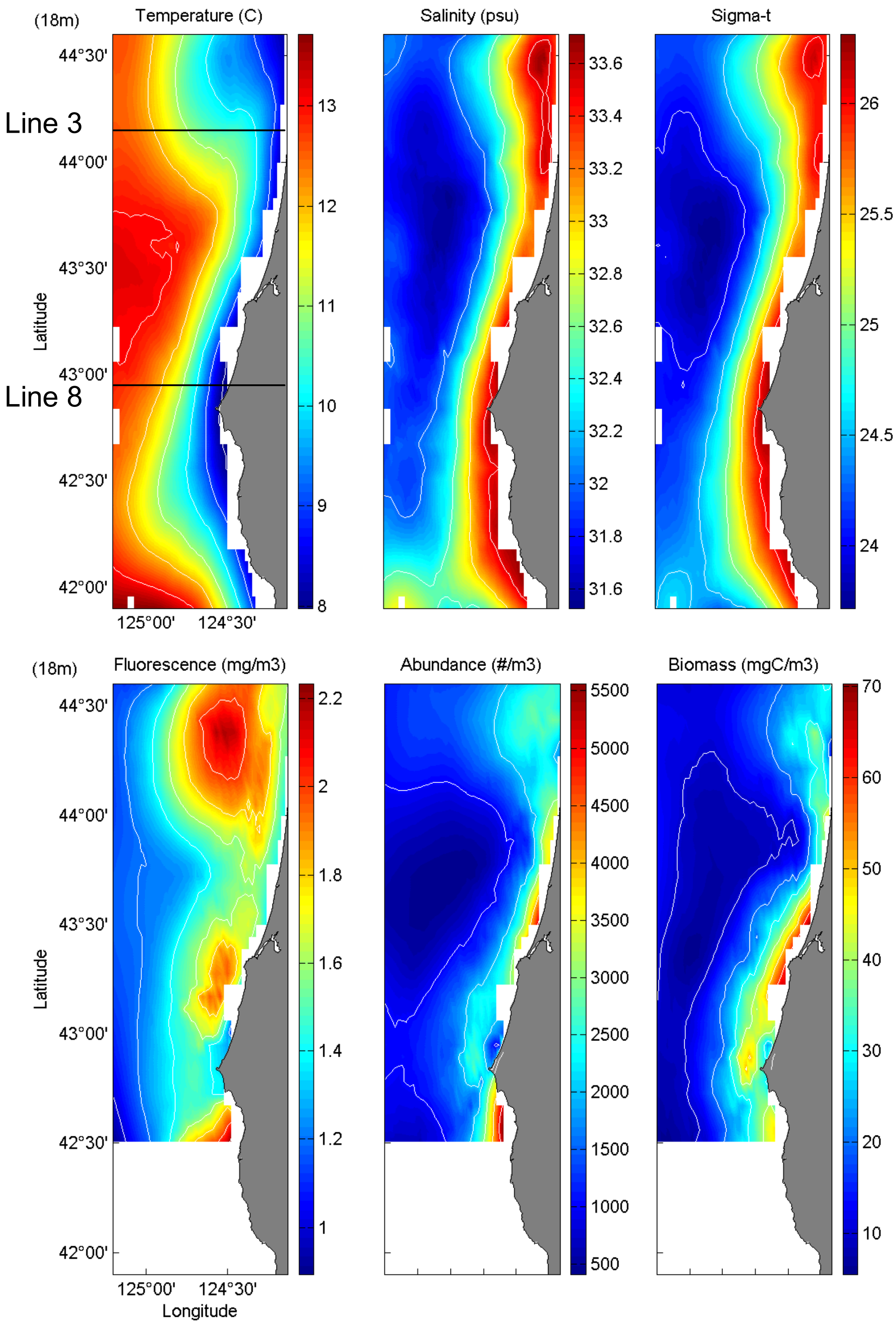

Figure 1. Distributions of surface temperature (upper left), surface salinity (upper middle), surface sigma-t (upper right), surface fluorescence (lower left), mean zooplankton abundance (lower middle) and mean zooplankton biomass (lower right) based on the mesoscale survey in May-June 2000.

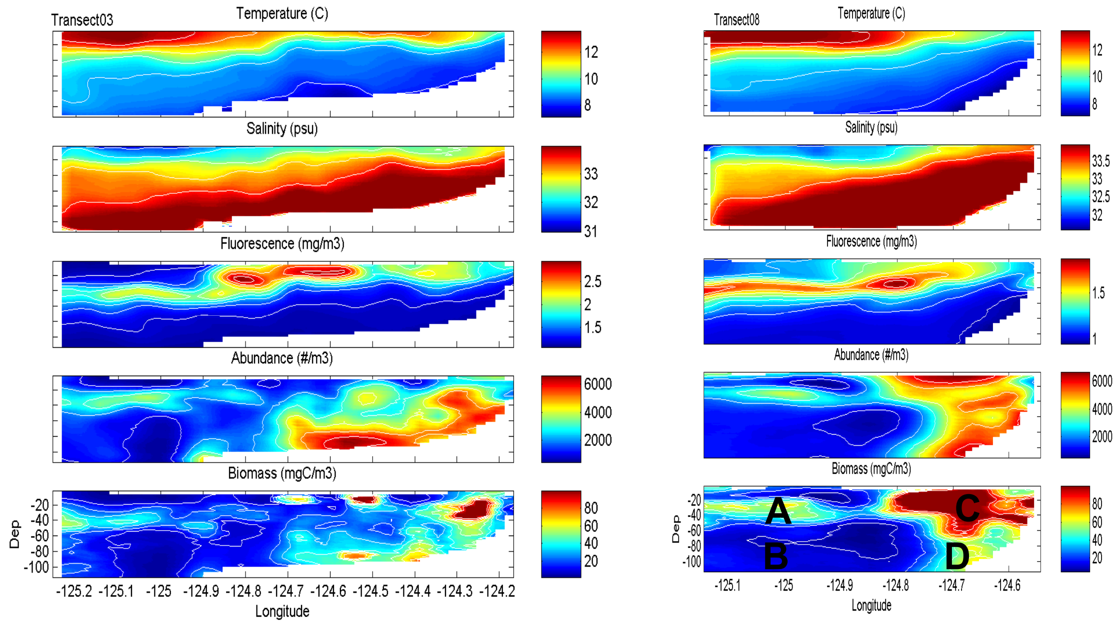

Figure 2. Transects along line 3 (left) and line 8 (right) of temperature (from the top), salinity, fluorescence, zooplankton abundance, and zooplankton biomass based on the mesoscale survey in May-June 2000.

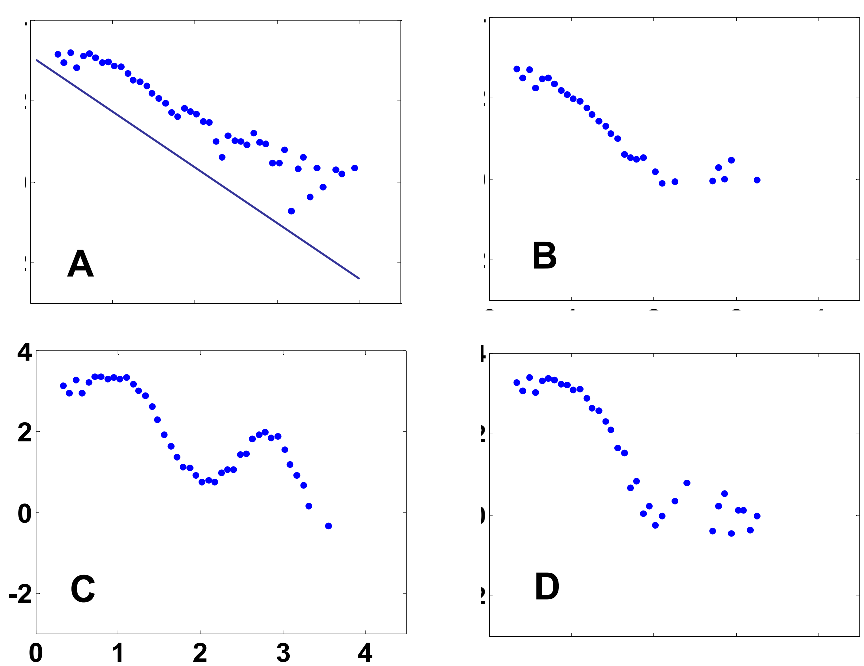

Figure 3. Size-structures of zooplankton in the offshore surface (A) and bottom (B), and the nearshore surface (C) and bottom (D) indicated in Figure 2.

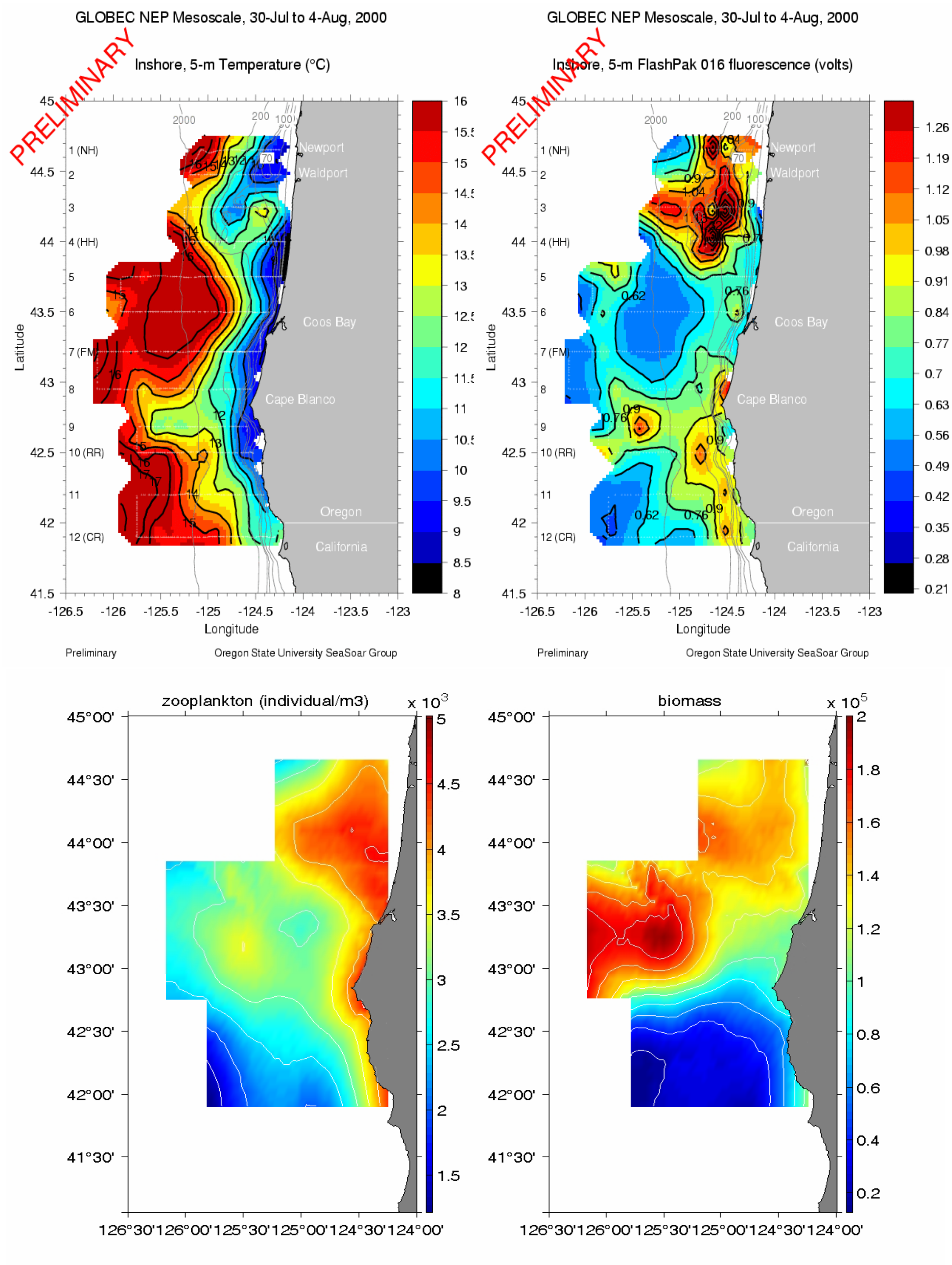

Figure 4. Surface temperature (upper left), surface salinity (upper right), mean zooplankton abundance (lower left) and mean zooplankton biomass (lower left) in August 2000.

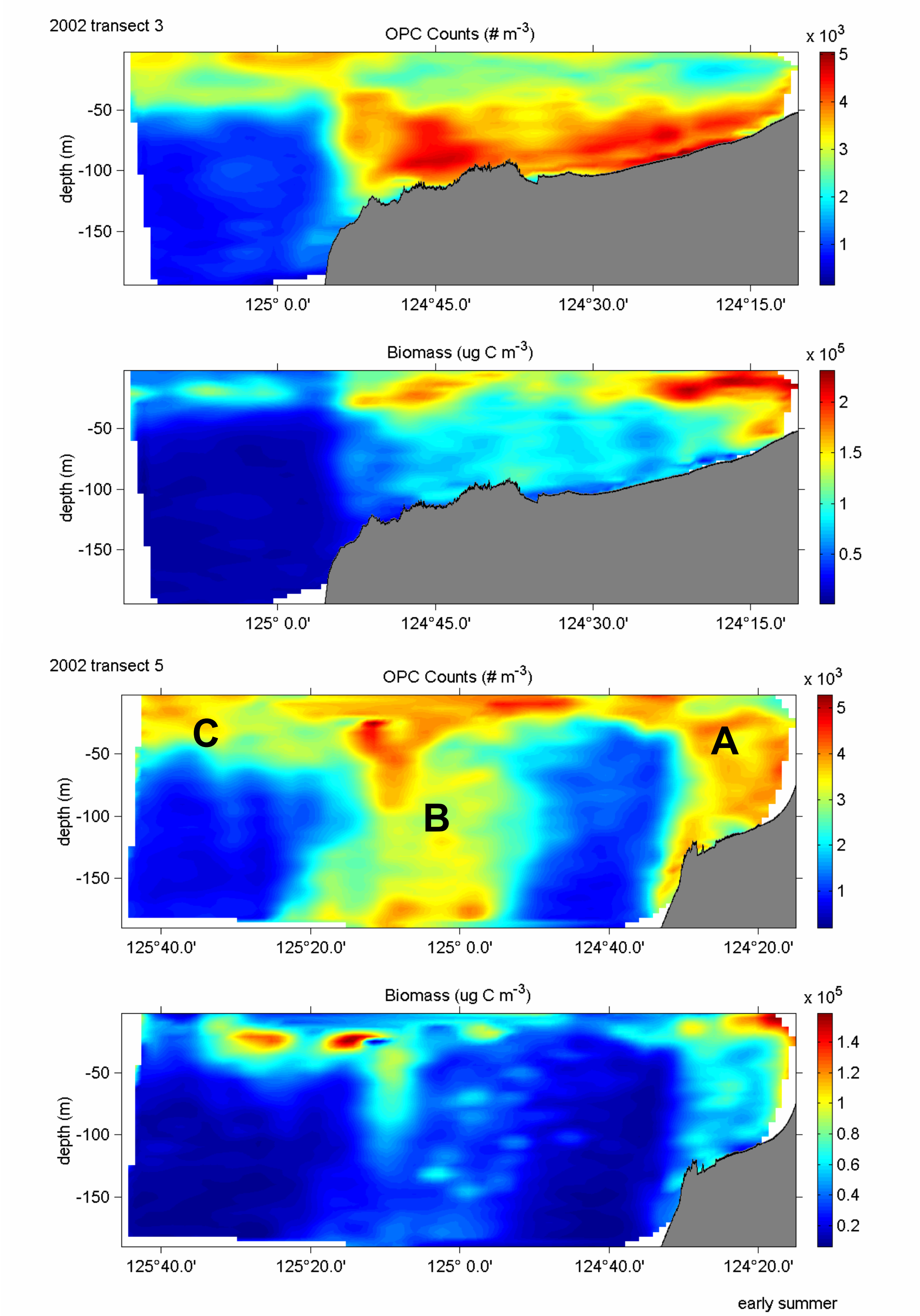

Figure 5. Transects of zooplankton abundance and biomass from the mesoscale survey along Line 3 and 5 in June 2002.

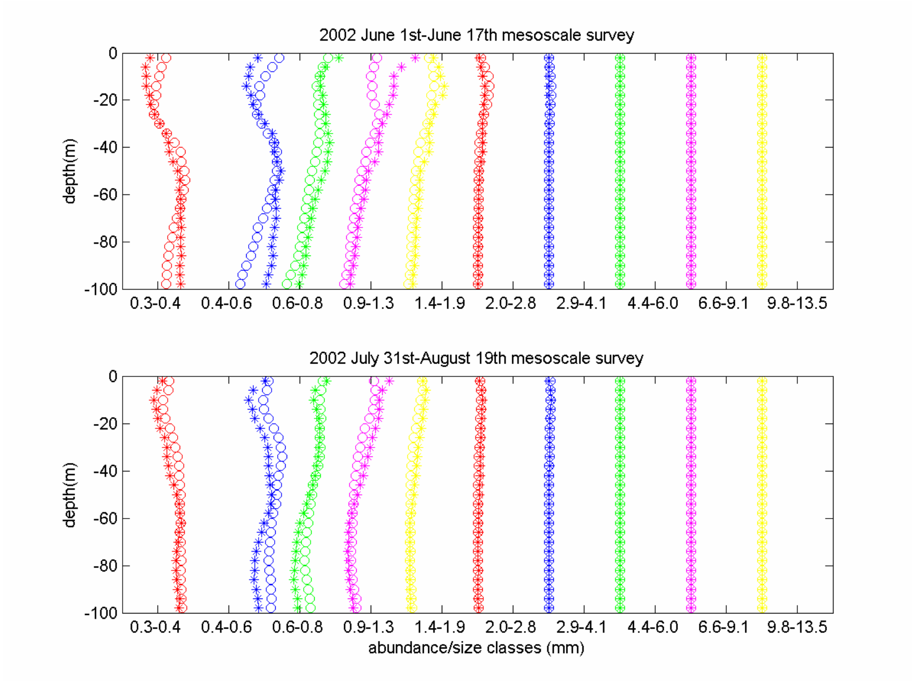

Figure 6. Day (*) and night (O) vertical profiles of zooplankton abundance within different size groups.

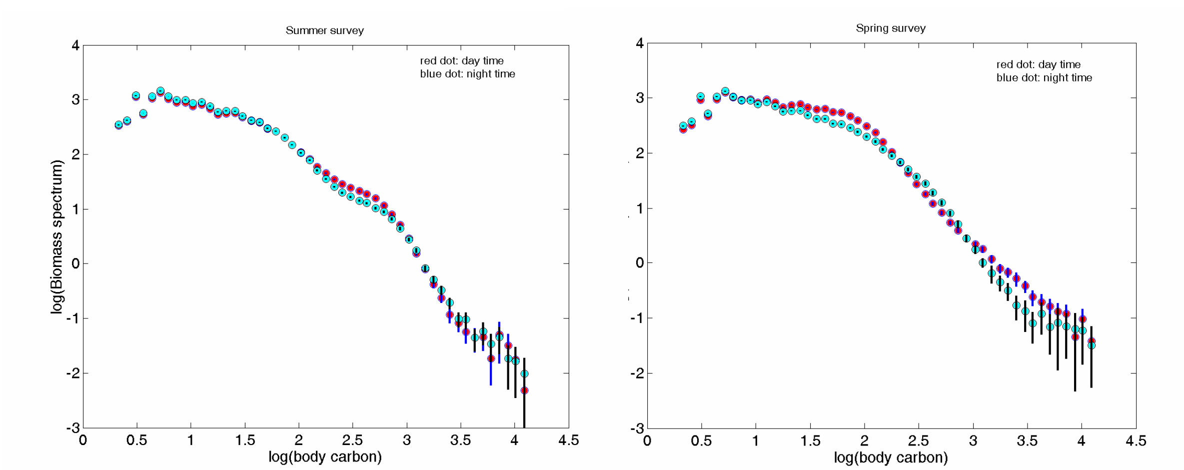

Figure 7. Day and night zooplankton size spectra.

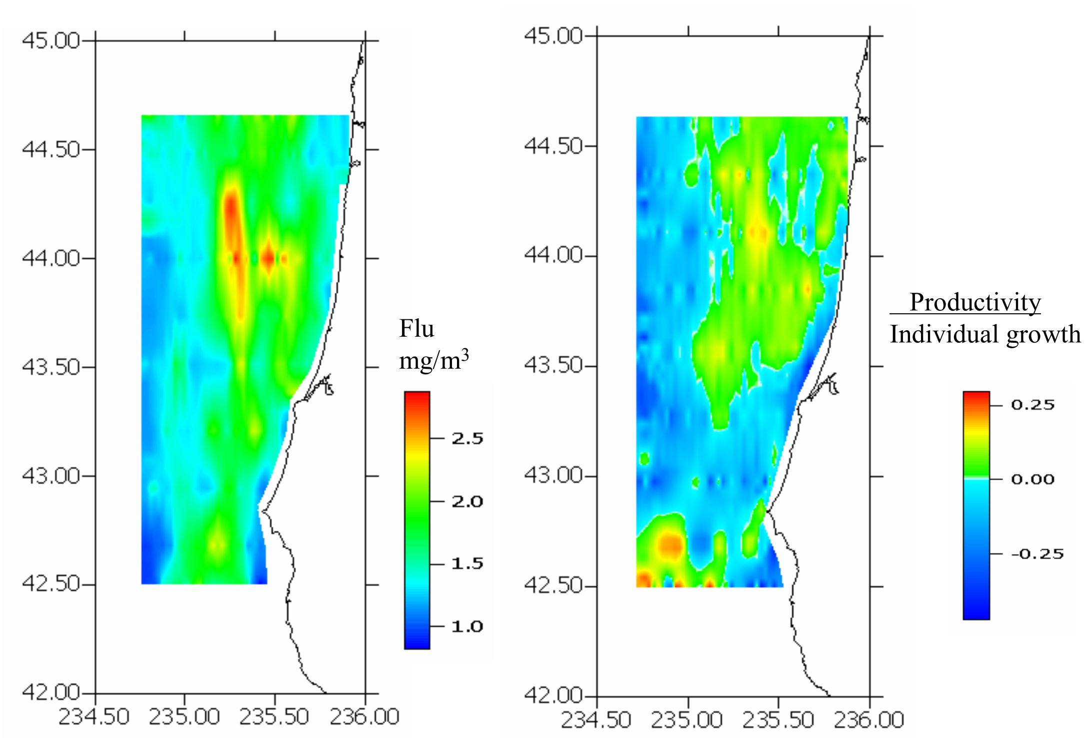

Figure 8. Fluorescence at 30 m and vertically integrated zooplankton productivity from the 2000 spring mesoscale survey.