Advection of Shelf Zooplankton in a Predominantly Down-Welling Ecosystem: Bioacoustic Detection of the Dominant Modes of Variability

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Introduction

The highly productive Gulf of Alaska shelf ecosystem is unique in that the dominant mode of wind forcing produces downwelling at the coast for most of the year. The persistent downwelling may, in part, explain how large calanid copepods with oceanic affinities (*Neocalanus* spp.) enter the coastal domain. *Neocalanus* spp. play an important role in the tropho-dynamics of the shelf ecosystem, especially in the transfer of energy to hatchery-raised and wild pink salmon (*Oncorhynchus gorbuscha*) from Prince William Sound. To test the hypothesis that transport of zooplankton is highly correlated with wind events, we are collecting continuous bioacoustical measurements of zooplankton concurrently with measurements of physical oceanographic and meteorological variables from a single mooring on the Seward Line in the coastal Gulf of Alaska (Figure 1).

Methods

Mooring. The biophysical mooring consists of a large, surface toroid buoy with a meteorological suite of sensors mounted on a tripod (Figure 2). Below the toroid buoy is a string of instruments that includes a single acoustic instrument (TAPS-8) plus SeaCat CTDs, Miniature Temperature Recorders [MTR], fluorometers, nitrate, and current meters.

Acoustics. There are several different acoustic methods to determine zooplankton biomass and distribution (Greene and Wiebe, 1990). We chose the multi-frequency method because of our familiarity with this technique; it is a mature sampling technology (U.S. GLOBEC, 1991, 1993; Smith *et al*., 1992) that builds upon the earlier success of a 21-frequency acoustic profiler (MAPS) and a uni- or multi- scattering model inverse solution to resolve acoustic volume backscatter by zooplankton into size bins (Holliday, 1977, 1996; Holliday and Pieper, 1995).

The TAPS-8 is an 8-frequency acoustic device (104, 165, 265, 420, 700, 1100, 1850, 3000 kHz) suitable for size-abundance estimation of zooplankton from ca. 0.25 mm to > 25 mm total length. The device consists of an electronics can with (8) side looking transducers and (2) battery cases (Figure 3). Data from the TAPS-8 consist of mean integrated echo intensities and echo variance ratios at each of the eight frequencies, computed over 32 individual pings. Time between ensemble averages is user defined. In this deployment measurements were made every 20 minutes. Echo intensities for all 8 frequencies were measured from a small (2 liter) sample volume at a range of ca. 1.5 m from the transducers. In addition, echo intensities were measured for the lowest 4 frequencies using longer transmit pulses that extended the sample range to ca. 16 m from the instrument (50 m^3 sample volume). This latter mode is useful for estimating the abundance of larger, less numerous scatterers such as euphausiids, amphipods, and pteropods.

Summary

- TAPS-8 was successfully deployed in May and recovered in September of 2002. Continuous data collection was achieved.
- A two-model inverse solution was successfully applied to a subset of the data. Several of the biovolume peaks agree with our expectations.
- The range-binned, low-frequency data suggests that “large” scatterers may be aggregating close to the mooring.
- The timing of peak biomass by *Neocalanus* spp. is such that we should be able to distinguish it from other similarly sized organisms using acoustics, and be able to determine when *Neocalanus* spp. arrive on the shelf.

Next steps

- Optimize the inverse solution for the shapes of our particular organisms.
- Merge the physical and biological time series.
- Recover Instrument #2 in early March and re-deploy Instrument #1 for measurements March to May, 2003.

Acknowlegements

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References

Green, C.H. and P.H. Wiebe 1990. Bioacoustical oceanography: New tools for zooplankton and micronekton research in the 1990s. Oceanography 3:12-17.

Holliday, D.V. 1977. Extracting bio-physical information from acoustic signatures of marine organisms, pp. 619-624. In: N.R. Andersen and B.J. Zahuranec (eds.), Oceanic Sound Scattering Prediction, Plenum Press, NY.

Holliday, D.V. 1996. Multifrequency, multimodel inverse methods. J. Acoust. Soc. Am. 100: 2736.

Holliday, D.V. and R.E. Pieper 1995. Bioacoustical oceanography at high frequencies. ICES J. Mar. Sci. 52: 279-296.

Incze, L.S., D.L.W. Siefert, and J.M. Napp 1997. Net zooplankton of Shelikof Strait, Alaska: Abundance and community composition. Cont. Shelf Res. 17: 287-305.

Smith, S.L., R.E. Pieper, M.V. Moore, L.G. Rudstam, C.H. Greene, J.E. Zamon, C.N. Flagg, and C.E. Williamson 1992. Acoustic techniques for the in situ observation of zooplankton. Arch. Hydrobiol. Beih. Ergebn. Limnol. 36: 23-43.

U.S. GLOBEC 1991. GLOBEC Workshop on Acoustical Technology and the Integration of Acoustical and Optical Sampling Methods. U.S. GLOBEC Report No. 4. Joint Oceanographic Institutions, Inc., Washington, D.C.

U.S. GLOBEC 1993. Optics Technology Workshop Report. U.S. GLOBEC Report No. 8. University of California, Berkeley, CA.

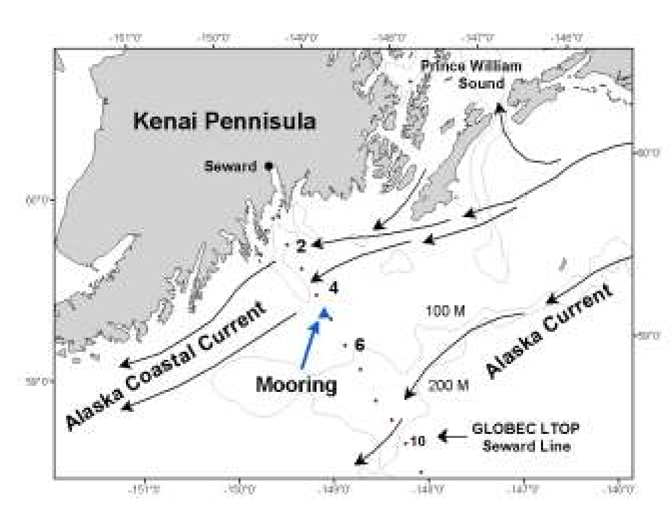

Figure 1.
Location of Biophysical Mooring.
The mooring is located in the middle of the shelf in the vicinity of GAK 5 on the Seward Line in ca. 180 m of water.

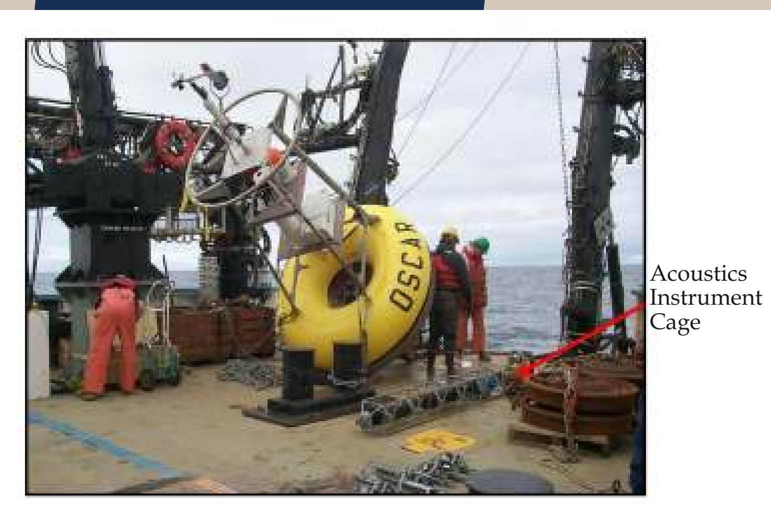

Figure 2.
Oscar PMEL Biophysical Mooring.
A toroid buoy and meteorological tower assembled on the deck of the R/V Maurice Ewing in May 2002 awaiting deployment. The transducers and battery cases are in a cage on the deck. The FOCI biophysical moorings are similar to the successful PMEL TOGA/TAO moorings on the equator that help to predict El Niños.

Figure 3.
Instrument Assembly.
Shown is the mooring cage with the TAPS-8 and (2) battery cases. The cage is hung vertically with the acoustic transducers pointing horizontally away from the mooring. With two battery packs, 6 MB of data storage and 3 samples per hour, the instruments will collect and record data for 5.7 months.

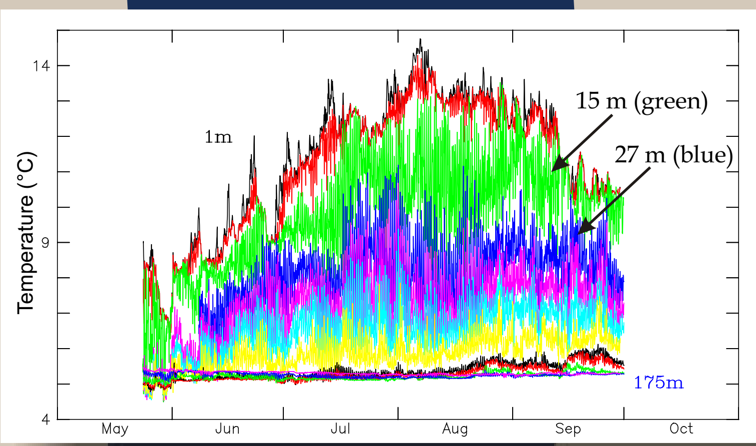

Figure 4.
Example of Environmental Data Time Series.
Temperature increased during the deployment reaching a maximum at the surface of 14 °C in early August. The range of temperatures at 20 m, location of the TAPS-8, was much less than at the surface. The instrument was below the mixed layer for most of the deployment. Time series analysis will be used to examine cross-correlations between wind, salinity, and currents, and the biomass of zooplankton (as a whole and within particular size categories representative of *Neocalanus* spp. copepodites).

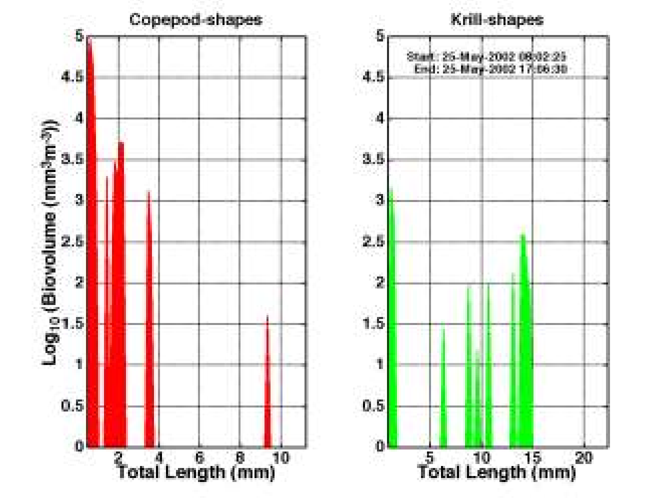

Figure 5.
Preliminary Inverse Solution.
Results from our first attempt at fitting a two-model inverse solution to Gulf of Alaska data. Shown are data from a nine-hour period during daylight on 25 May 2002. The biovolume of "copepod-shaped" plankton was determined using the truncated fluid sphere model, and the biovolume of "krill-shaped" plankton and micronekton was determined using a model which estimates sound scattering from a mysiid. Qualitatively, the first three peaks for the copepod shapes seem to be at about the right total length; it is not known what organisms might be represented by the peak between 9 & 10 mm. The multi-model inverse will be "tuned" and rerun once we have the results from net samples taken during deployment and recovery. In addition, digital images of dominant sound scatterers will be obtained this field season (2003) to assist in refinement of the sound scattering models.

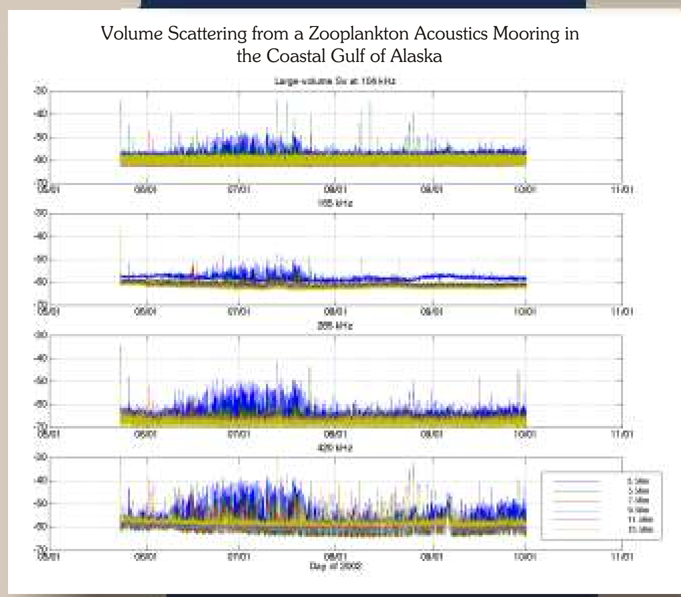

Figure 6.
Acoustic Backscatter Time Series: The Four Lowest Frequencies.
A very recent, and unprocessed, raw data set from our first deployment. The different colors correspond to the horizontal distance from the mooring, not depth. These preliminary data show two interesting features. First is the increase in backscatter volume in July (a seasonal component), and the second is the relatively high backscatter in the bins closest the instrument. At present (until we have our groundtruth samples) we are attribute the seasonal variability to euphausiids and other late spring/early summer plankton spawners. The second feature may indicate a localized aggregation of plankters around the instrument. We speculate that these scatterers are either attracted to the structure (as habitat) or feed on the algae and other organisms that grow on the instruments.

Figure 7.
Expected Scatterers: Size and Identity.
Proportion of Total Plankton Biomass By Taxon (Incze et al., 1997). Shown is the proportion of total copepod biomass from March to October for one year (1985) in Shelikof Strait. Note that *Neocalanus plumchrus* + *N. flemingeri* dominate the copepod biomass from April through July in Shelikof Strait. Newer data from the NEP GLOBEC LTOP project will be examined along with our own groundtruth data to determine the identity of the scatterers, and to specifically look for when *N. plumchrus* and *N. flemingeri* appear on the shelf.