Autonomous Zooplankton Sampling for Ocean Observing Systems

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INTRODUCTION

Continuous operation of autonomous instrumentation is essential for implementation of the U.S. Integrated Ocean Observing System in Alaska (AOOS). A multi-frequency acoustical sensor, appropriate for the size-abundance estimation of zooplankton from ca. 0.25 mm to > 25 mm total length, was successfully deployed and recovered during three sequential summers from a Gulf of Alaska biophysical shelf mooring. The instrument package autonomously sampled a single depth in the upper water column every 24 minutes in 2002 for >130 days, every 20 minutes in 2003 for >113 days, and every 20 minutes in 2004 for > 142 days. Volume backscattering strengths (S_v) revealed significant, interannual differences in the sound scattering. In the spring of 2002 we observed the highest biovolume of all three years; total biovolume was similar in the spring of 2003 and 2004, but was distributed differently among copepod-like and euphausiid-like scatterers. Within a single year, 2004, we observed both an increase in biovolume and the presence of a wider range of sizes when comparing April and August data. The same instrument was deployed on the Bering Sea shelf in the spring 2006 with the capability to transmit data in near real-time. The trial was successful with transmission of 5.9 GB of acoustic data. Successful autonomous operation of acoustical instruments for estimation of zooplankton size and abundance and optical size and biomass for phytoplankton will be crucial for observing these often undersampled elements in remote locations such as the Bering Sea and Gulf of Alaska.

METHODS

Mooring

The biophysical mooring was located on the continental shelf of the northern Gulf of Alaska, west of Prince William Sound (Figure 1). The biophysical mooring consists of a large, surface toroid buoy with a meteorological suite of sensors mounted on a tripod (Figure 2 - left panel). Below the toroid buoy is a string of instruments that includes a single acoustic instrument (TAPS-8) at ca. 20 m depth, plus SeaCat CTDs, Miniature Temperature Recorders (MTR), fluorometers, nitrate, and current meters.

Acoustics

There are several different acoustical methods to determine zooplankton biomass and distribution (Greene and Wiebe, 1990). We chose the multifrequency method because of our familiarity with this technique. A mature sampling technology (U.S. GLOBEC, 1991, 1993; Smith et al., 1992), it builds upon the earlier success of a 21-frequency acoustic profiler (MAPS), and uni-or multi-scattering model inverse solutions to resolve acoustic volume backscatter by zooplankton into size bins (Holliday, 1977, 1996, 2001; Napp et al., 1993; Holliday and Pieper, 1995; Holliday et al., 2003). 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 case with 8 side-looking transducers and 2 battery cases (Figure 2 - right panel). Data from the TAPS-8 consist of mean integrated echo intensities and echo variance ratios at each of the 8 frequencies, computed over 32 individual pings. Time between ensemble averages is user defined. In the Gulf of Alaska and Bering Sea deployments measurements were made every 24 (2002) or 20 (2003, 2004 and 2006 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 volumes). This latter mode is useful for estimating the abundance of larger, less numerous scatterers such as euphausiids, amphipods, and pteropods.

CONCLUSIONS

- The TAPS-8 was successfully operated as a self-contained instrument for three sequential summers in the northern Gulf of Alaska.
- The resultant zooplankton biovolume data are rich in detail, showing many of the expected modes of diel, event, seasonal, and interannual variability.
- Temporal resolution of the data from the mooring was far superior to what was collected from ships during NEP GLOBEC.
- The TAPS-8 was successfully operated for a single summer in near real-time mode on the eastern Bering Sea shelf. Bioacoustic and other mooring data were telemetered from subsurface instruments to a surface transmitter via acoustic modems. The data were then transmitted to our laboratory computer via an Iridium satellite telecommunications link.
- Initial inspection of the Bering Sea data show many of the same modes of variability as the Gulf of Alaska data.
- Our next step is to create data products from the near real-time TAPS that can be posted on the world wide web.

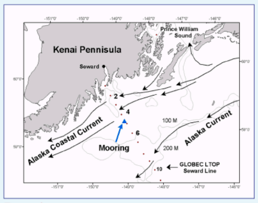

Figure 1.
Location of Biophysical Mooring. The mooring was located in the middle of the shelf in the vicinity of GAK 5 on the Seward Line in ca. 180 m of water. See the FOCI web site - http://www.pmel.noaa.gov/foci/mooring/ for additional mooring data.

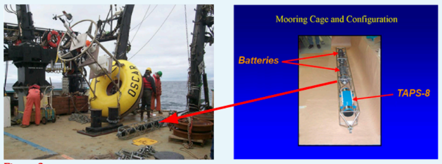

Figure 2.
Left Panel; Oscar PMEL Biophysical Mooring.
A toroid buoy and meteorological tower assembled on the deck of the R/V Maurice Ewing awaiting deployment. The transducers and battery cases are in a cage on the deck. The FOCI biophysical moorings are similar to the PMEL TOGA/TAO moorings on the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

Right Panel; TAPS-8 Multifrequency Zooplankton Acoutics Sensor

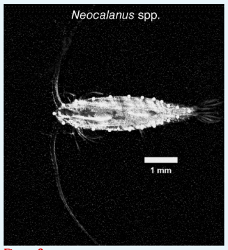

Figure 3a.

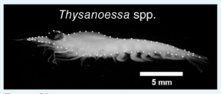

Figure 3b.

Figure 3. A dual scattering model inverse algorithm was used to assign a fraction of the scattered energy in each acoustical sample to that expected from organisms of different shapes and sizes. A truncated fluid sphere model was used to approximate sound scattering by copepod-shaped organisms found in our study area (e.g. *Neocalanus* spp.; Figure 3a) and a Distorted Wave Born Approximation (DWBA) modeling method was used to approximate sound scattering by elongate organisms in our study (e.g. *Thysanoessa* spp., Figure 3b).

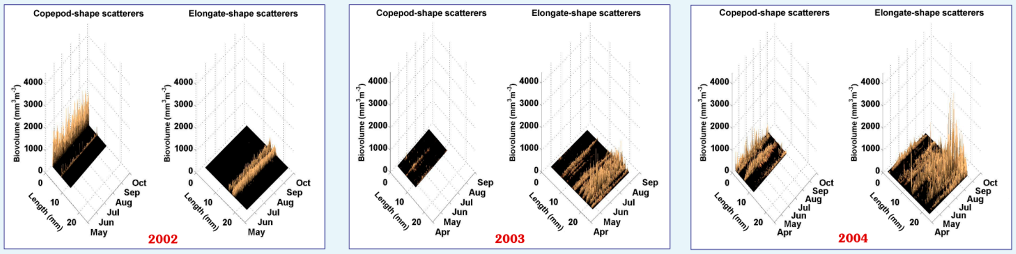

Figure 4. Biovolume of copepod and elongate-shape sound scatterers sampled during three sequential summers in the northern Gulf of Alaska. Small copepods dominated the total biomass in 2002 and the biovolume of elongate-shaped scatterers was confined to two size bins. In 2003 scatterers with elongate-like shapes were most abundant during the sampling period. Also note that the majority of biovolume from copepod-like scatterers was in a longer size bin in 2003 than 2002, and the biovolume of elongate scatterers was contained in more size bins in 2003, than in 2002. In 2004, total biovolume was greater than 2003, but less than 2002, and there was an increase in biovolume towards the end of the sampling period for the largest sized copepod-like and elongate scatterers.

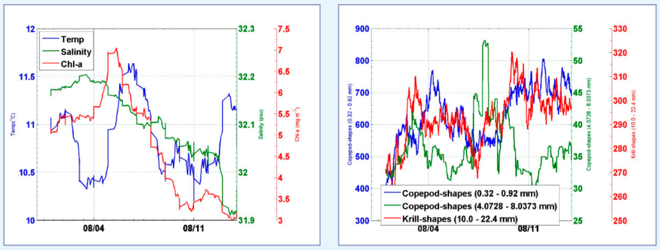

Figure 5. Associations among physical, chemical, and biological variables during August 2002. In early August temperatures at the mooring took a sudden dip, then returned to pre-event levels after which temperature, salinity, and chlorophyll all declined (left panel). During these two "events" zooplankton biovolume oscillated with generally higher small copepod and krill biovolume at the end of the interval, than during the beginning (right panel). Biovolume of copepods 4 – 8 mm peaked in the middle of this short time interval with an ca. doubling of biovolume.

BERING SEA PILOT STUDY

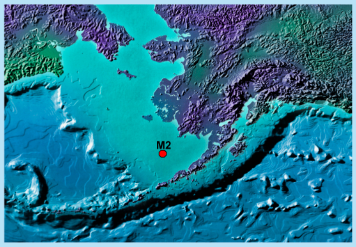

Figure 6. Location of NOAA's long-term biophysical mooring and our 2006 TAPS-8 deployment. This mooring is now in its 12th year of operation, and has been instrumental in elucidating the linkages among climate, upper ocean physics, and biological production in the eastern Bering Sea. The mooring is jointly funded by the North Pacific Research Board and NOAA's North Pacific Climate Regimes and Ecosystem Productivity Program.

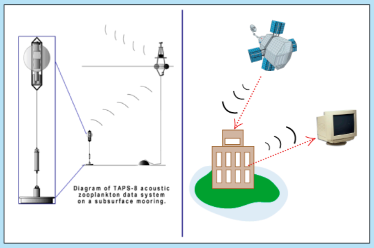

Figure 7. Acoustic telemetry of underwater sensors at NOAA mooring M2. Data from TAPS-8, a SeaCat CTD, and fluorometer are telemetered from an ancillary mooring site to the main mooring via an acoustic signal. A data acquisition unit on the main mooring receives, accumulates, and stores the data before transmitting them to a shoreside computer 4 times a day via the Iridium satellite. During our pilot we successfully transmitted 5760 TAPS records or about 5.9 Gb of data.

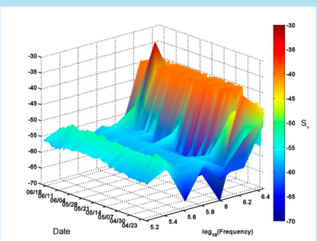

Figure 8. TAPS-8 volume backscatter data telemetered to shore from the eastern Bering Sea shelf during the pilot study of 2006. The TAPS-8 continued to collect and internally store data after June 18th when the battery voltage for the acoustic modem became too low to transmit.

Acknowledgements

We thank Carol DeWitt, William Floering, and William Parker for logistical support and deployment of the mooring and instruments. Funding for research in the Gulf of Alaska was provided by NOAA's Center for Sponsored Coastal Ocean Research (Northeast Pacific GLOBEC). Research in the Bering Sea was funded by the: North Pacific Research Board, NOAA's Climate Goal Team (North Pacific Climate Regimes and Ecosystem Productivity project) and NOAA's Ecosystem Observation Program (IOOS Pilot Projects).

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poster produced by Wendy Carlson, AFSC Graphics Unit, 2007