Long-term Continuous Observations of Zooplankton and Fish from a Cabled Ocean Network

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1. Introduction

Long time-series of continuous data from moored acoustic instruments offer a low-cost method to study ecosystem changes by monitoring the behaviour and abundance of fish and zooplankton in the ocean and lakes. Calibrated sonars with several frequencies allow some information about species composition and abundance to be deduced from acoustic backscatter data. In this paper we describe an improved low power, battery-operated sonar with up to four frequencies capable of autonomously collecting data at high temporal and spatial resolution for periods of several months.

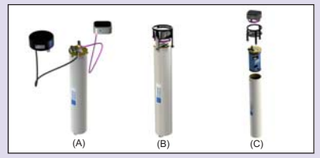


Figure 1. The AZFP (A) with 38 kHz channel, (B) without 38 kHz and (C) exploded view.

2. Instrument Characteristics

The Acoustic Zooplankton Fish Profiler (AZFP) contains up to 4 acoustic channels; the frequencies available are 38, 125, 200, 455 and 770 kHz. The transducers for the four higher frequencies are located within a single housing, with nominal beamwidths of 7°. The 38 kHz transducer has a nominal beamwidth of 12° and a separate housing. There is 16 GB of data storage available, and the standard battery pack of 200 AHr allows the instrument to sample on four channels to a 100 m range, pinging every 2 seconds for 150 days.

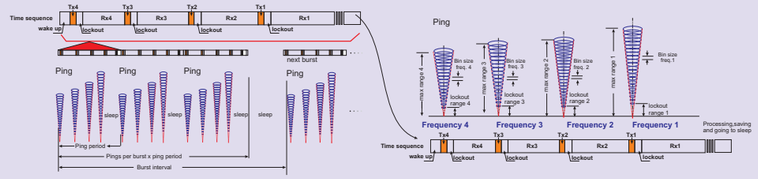


Figure 2. Sampling scheme.

Sampling may be regularly spaced or in bursts; averaging in range and time is optional.

3. Instrument Calibration

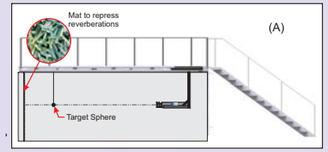


Figure 3. Calibration procedure with (A) schematic and (B) photo of outdoor test tank.

The AZFP is calibrated using a reference hydrophone (calibrated to ± 1 dB) and a calibrated source to measure the source level and receiving sensitivity at 1 m range in an indoor test tank. The calibrations are then confirmed at 4 m range in the larger exterior tank using precision tungsten-carbide spheres of various sizes. Agreement between the two methods is normally within ± 2 dB.

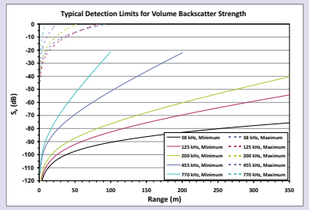


Figure 4. Summary detection limit plot.

The logarithmic detector has an effective instantaneous dynamic range of approximately 90 dB; the output of the detector is linearly proportional to the logarithm of the echo intensity at the transducer.

The typical minimum and maximum detectable volume backscatter strength (Sv in dB) as a function of range for each of the AZFP frequencies, for average temperate zone coastal ocean conditions are shown in figure 4.

The AZFP can be deployed in an upward-looking mode either on a taut-line mooring or a bottom frame. The maximum deployment depth with the standard pressure case is 600 m. It can also be deployed looking downward from a surface buoy.

4. Single Frequency Long Time-Series

The data cube (figure 6) shows two sections of a 4 year time series of acoustic backscatter collected by a series of 200 kHz upward-looking echo sounders (an older more limited version of the AZFP) at the University of Victoria VENUS site in Saanich Inlet on the Pacific Coast of Canada (figure 5). Variation of instrument noise floor is apparent.

Figure 5. AZFP deployments in Saanich Inlet.

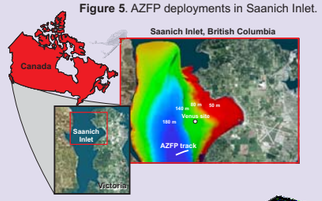


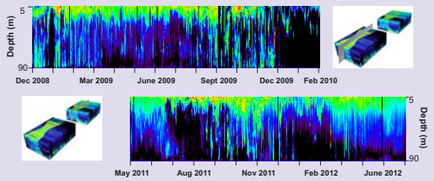
Figure 6. We use a *data cube concept* to organize our thinking about the depth/hour/day time series from the AZFP.

The front of the data cube illustrates the variation of scattering depth profiles during one day, averaged at 10 minute intervals. Subsequent days are conceptually arranged behind.

The top surface of the data cube represents the daily variation of scattering strength at 5 m depth for the entire time series, clearly showing seasonal changes in vertical migration timing associated with day length.

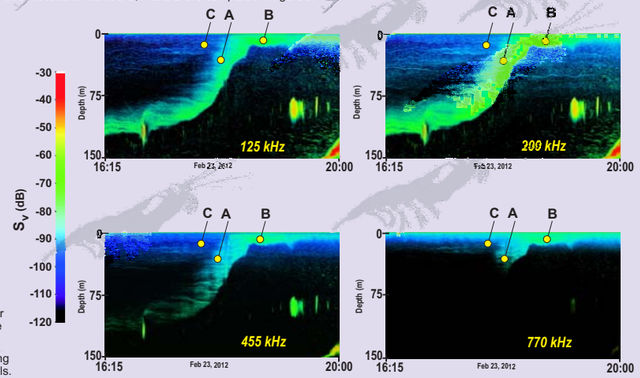
The right side of the cube represents depth profiles for 1600 hours PST (2400 UTC) on each day of the profile. At this time of day, most scatterers are at depths below about 70 m. In 2009, a summer increase in scattering above 30 m is visible, but this is partially obscured in 2011 because of (as yet) uncompensated variation of instrument noise floor in the particular instrument deployed between July and September.

Figure 7. A time-series of backscatter profiles averaged for the midnight hour, created by making a cut through the conceptual data cube in figure 6.



5. Multifrequency Time-Series

Figure 8. Four hours of multifrequency data from a downward-looking AZFP drifting along the track shown in figure 5 February 23, 2012. The data span the evening ascent of the zooplankton. The scatter strengths at each frequency in the three locations marked C, A and B are compared in figure 9.



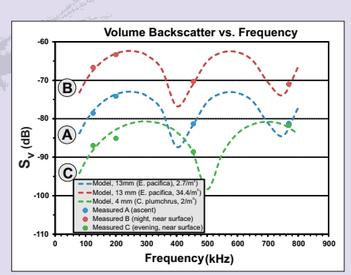


Figure 9. AZFP data acquired in Saanich Inlet on February 23, 2012 shows a vertically migrating population (A and B) whose spectral acoustic signature agrees very well with that modelled for 11 mm *Euphausia pacifica* (according to Stanton et al. 1994). *E. pacifica* is known to be the dominant migrating scatterer in Saanich Inlet (Pieper 1971).

The zooplankton at (C) did not migrate vertically, but exhibits strong scattering at 770 kHz indicating a smaller organism, such as *Calanus plumchrus* commonly found in nearby Strait of Georgia (Harrison *et al.*, 1983). We do not have net tows to identify this population.

References

Stanton T.K., Wiebe P.H., Chu D., Benfield M.C., Scanlon L., Martin L., Eastwood R.L. 1994. On acoustic estimates of zooplankton biomass. ICES Journal of Marine Science 51:505-512.

Harrison, P., J. Fulton, F. Taylor and T. Parsons, 1983. Review of the biological oceanography of the Strait of Georgia: pelagic environment. Can. J. Fish. Aquat. Sci. 40:1064-1094.

Pieper, R. 1971. A study of the relationship between zooplankton and high frequency scattering of underwater sound. PhD dissertation, University of British Columbia.