High-frequency multi-frequency acoustical backscatter observations from a small moving vessel used to investigate fish-zooplankton interactions in tidally mixed Sansum Narrows, British Columbia

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Background

Using observations from small vessels is a cost-effective and efficient approach to ecosystem monitoring and surveying. Multi-frequency backscatter measurements have the potential to provide insight into a number of trophic levels in the upper ocean simultaneously from near the surface to the bottom. Here, a modified ASL Acoustic Zooplankton and Fish Profiler (AZFP), originally developed in the late 1990's for autonomous moored observations of zooplankton and fish, was successfully used from a 23-foot RHIB to observe zooplankton and fish in time and space in a tidally active area on the West Coast of British Columbia (Fig. 1). Travelling at 2m/s, the boat could survey the whole area of interest within an acceptable portion of the tidal cycle.

Using the backscatter information from four frequencies, zooplankton and fish of different sizes, and perhaps species, can be identified. This work is part of a larger program to investigate salmon survival and dynamics in the Salish Sea.

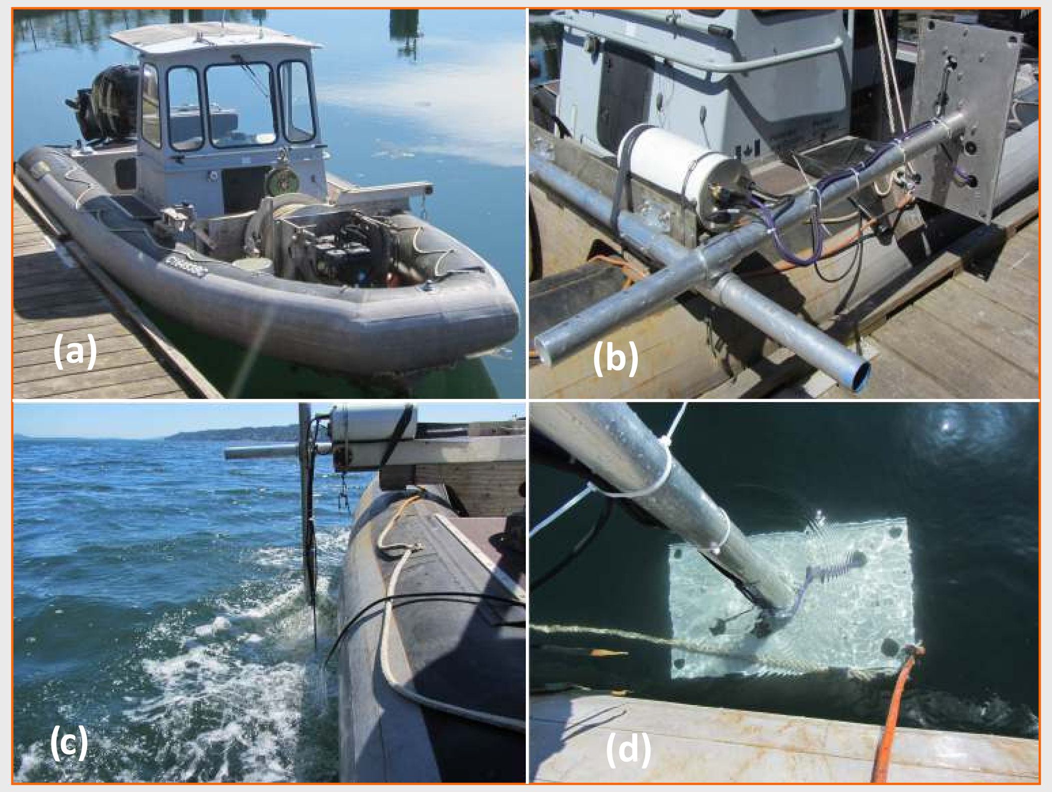


Fig. 1: (a) 23' RHIB equipped with oceanographic sampling gear. (b) Strut out of water showing AZFP electronics housing and mounting plate with acoustic transducers. (c) Strut in water and moving at 2m/s. (d) Bottom of mounting strut with transducers seen from above.

Instrumentation

The AZFP operated at four frequencies (38, 67.5, 125 and 200 kHz), transmitting sequentially, resulting in a ping rate of 0.5Hz per channel (Fig. 2). Data were stored internally for download following the survey.

With the transducers mounted at a depth of 0.5 m on a strut over the side of the boat, it was possible to travel at speeds up to 2 m/s without flow interference. (With a suitable fairing it is likely that higher boat speeds can be achieved without compromising the data quality). Acoustic data are converted to volume backscattering strengths, Sv, (dB re $1m^{-1}$) by using the AzfpLink software (ASL Environmental Sciences, 2016), speed of sound information and acoustic absorptions at the different frequencies.

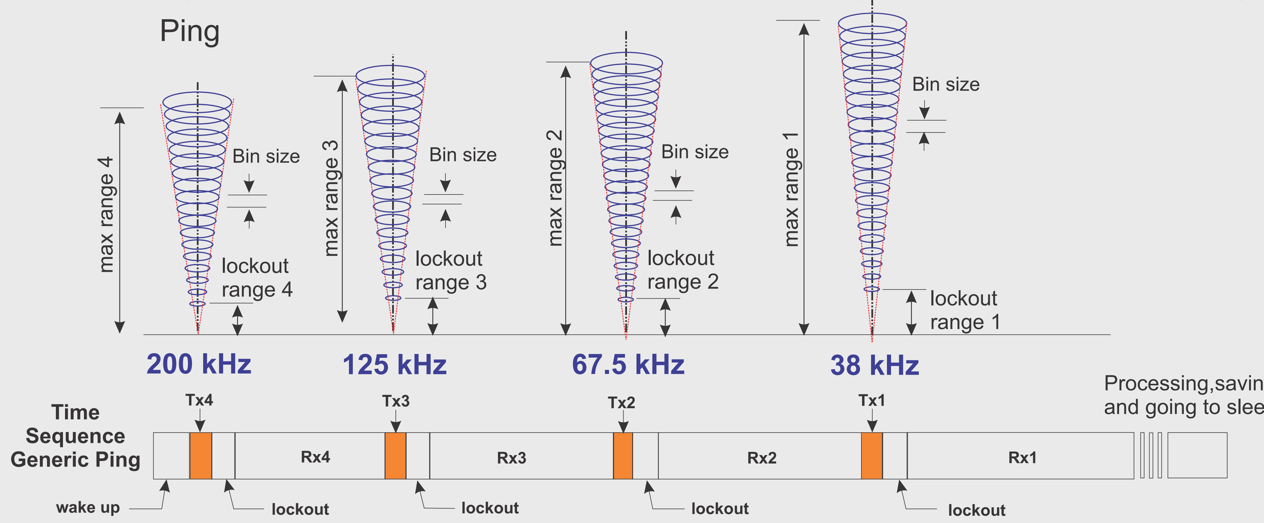


Fig. 2: Operation of 4-channel sequentially pinging sonar system. Ping rates, bin sizes, and maximum range are all programmable. Data are stored internally for easy upload to a computer following a given study.

Study Area

Cowichan Bay is an important area for juvenile Chinook salmon and the nearby Sansum Narrows is a productive area with strong tidal currents (Fig. 3). The boat transect started in the NW corner of Cowichan Bay and ended up in Sansum Narrows (A to K in Fig. 3).

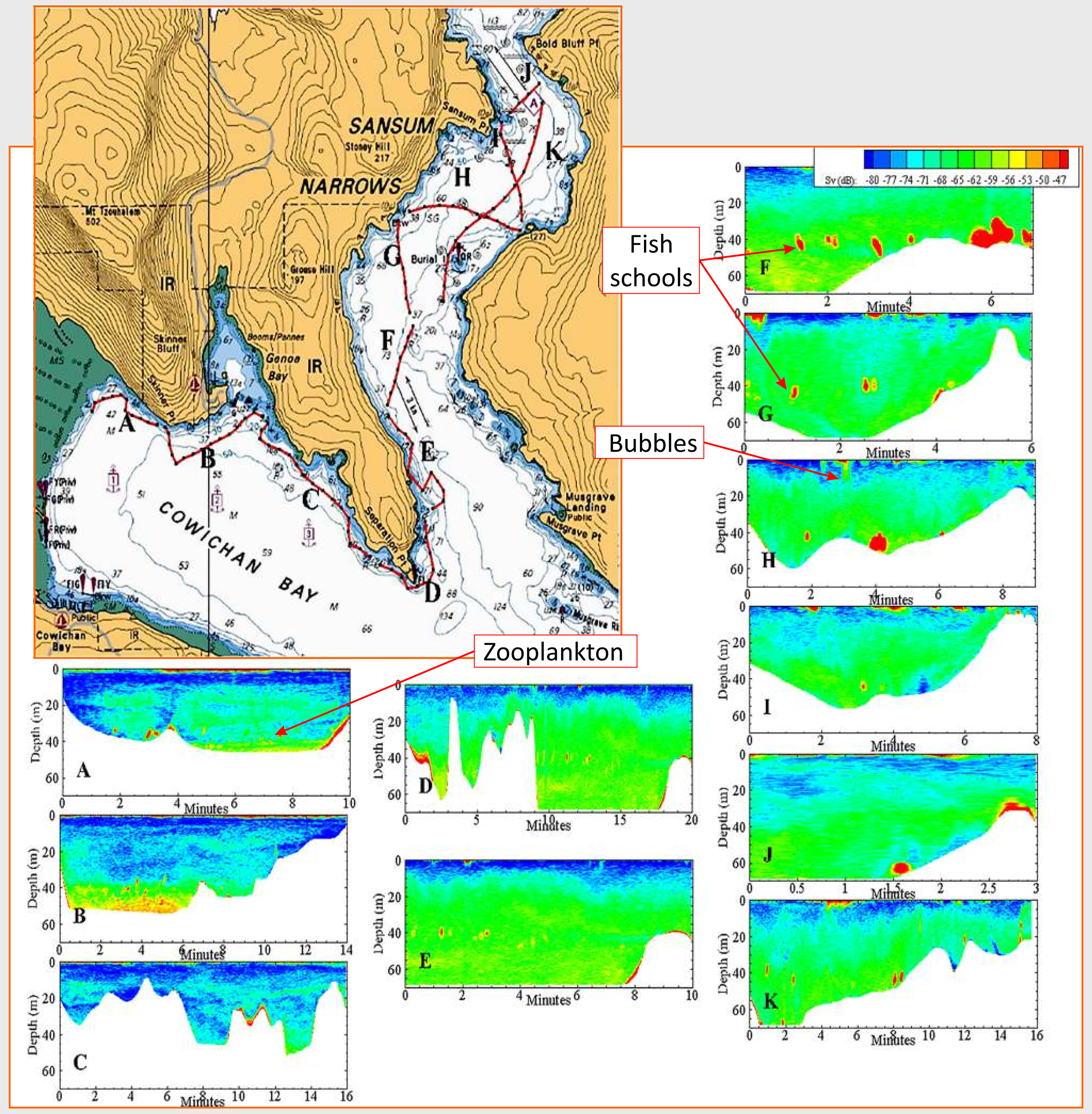


Fig. 3: Cowichan Bay and Sansum Narrows. Volume backscattering strength (Sv) at 200 kHz shown for the 11 segments identified on the chart. Near surface bubble plumes, fish schools at about 40m (Herring?) and zooplankton can all be identified.

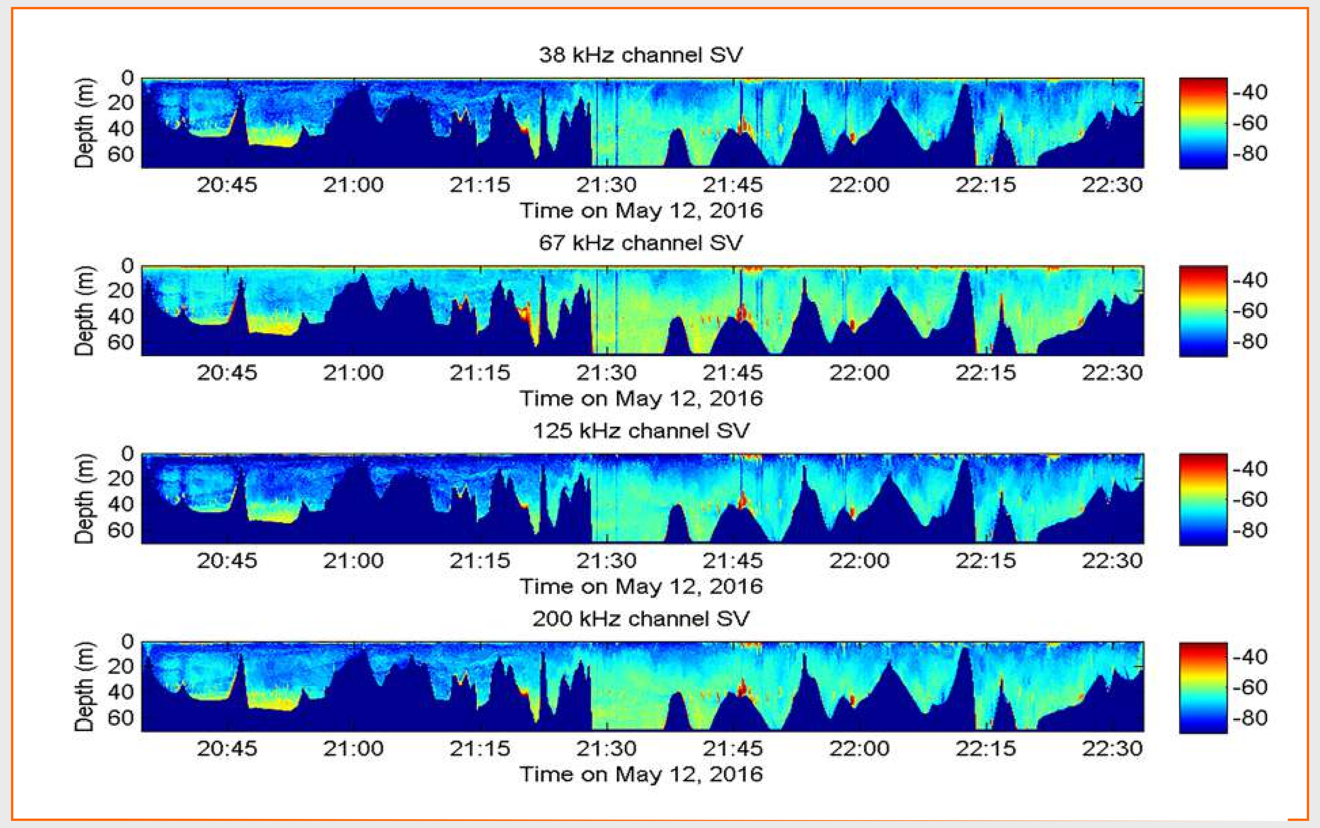
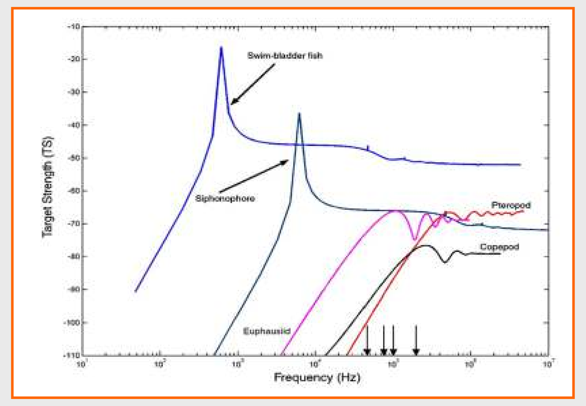


Fig. 4: Sv at each of the 4 frequencies used in this study. Significant differences can be seen (e.g., near the bottom at ~21:20).

Sound Scattering

Using the four acoustical frequencies we attempted to differentiate between general classes of scatterers in the water column. Theoretical target strengths at different frequencies for a range of organisms and sizes have been calculated (Stanton et al. 1998a,b).



Some of these are summarized in Fig. 5 (from A. Lavery et al., 2002).

Fig. 5: Theoretical target strengths at different frequencies for several different organisms. The four frequencies used here are indicated by arrows along the x-axis.

Relationships have also been determined between fish size, acoustic frequency and target strength (Fig. 6 from McClatchie et al.,1996).

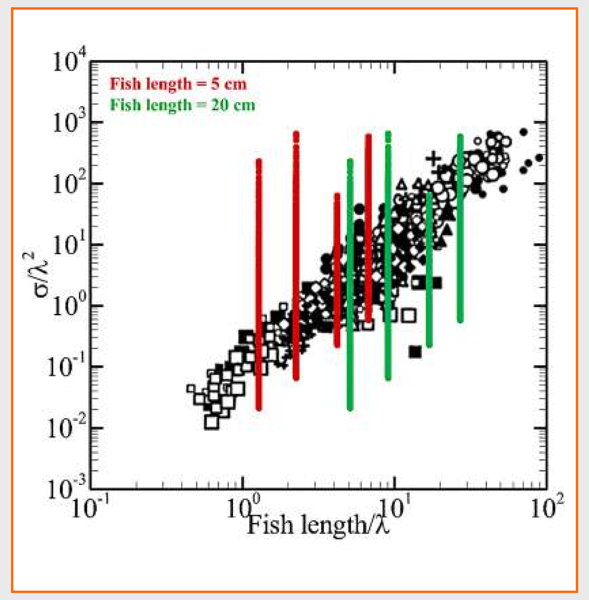


Fig. 6: Acoustic wavelength, λ, (λ=soundspeed/frequency) normalized acoustic cross-section, σ ($TS = 10log(\frac{\sigma}{4\pi})$) against wavelength normalized fish length for experimental results on marine swimbladder fishes (McClatchie et al. 1996). Red and green bars are data from the present study assuming fishes with lengths of 5 and 20cm, respectively.

Results

Using the multi-frequency backscatter data from this study combined with experimental results (Fig. 6) suggest that the individual targets identified are fishes with sizes between 5 and 20 cm, which in this case are most likely herring.

Fitting a straight line through the four Sv data points show varying slopes with depth (Fig. 7). The backscatter from the 2-5m depth range shows the characteristics of bubbles, while deeper down the varying slopes are probably associated with different zooplankton communities (species and/or sizes).

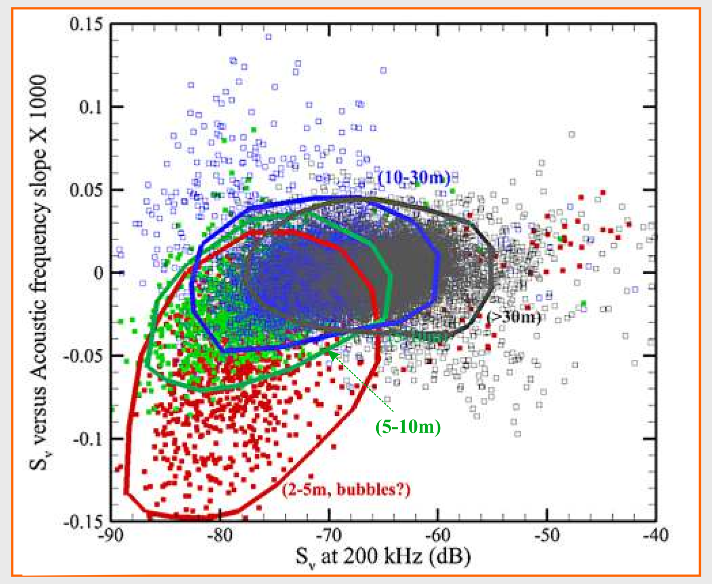


Fig. 7 : Slopes of straight line fits through Sv versus frequency for all the data coloured by depth ranges.

Conclusions

- The multi-frequency AZFP is an easy to use and cost-effective approach to survey large coastal and high-current areas in a timely fashion;
- Survey speeds in excess of 2m/s are easily obtainable;
- Biological scatterers of sound are easily identified in the calibrated volume backscattering strength (Sv) versus time and depth images at any of the four acoustical frequencies used;
- Using the relationship between Sv and acoustical frequency (f), combined with experimental and theoretical estimates of Sv versus f for different types of scatterers, additional information about the type of animals and/or upper-ocean physical processes will be gained.
- With calibrated sonar systems like this and knowledge about the type of animals causing the backscatter, biomass estimates as function of space and time can be obtained.

References

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