Interpretation of acoustic data at two frequencies to discriminate between fish aggregations of different species compositions

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Introduction

Our specific objective was to test whether ΔMVBS could be used to distinguish between juvenile pollock and capelin aggregations.

The difference between mean volume backscatter strength at 120 and 38 kHz (ΔMVBS) has successfully been used to acoustically discriminate between different macrozooplankton species, and between macrozooplankton and larger organisms such as fish and squid, or smaller organisms such as small zooplankton. We examined whether this technique can be used to discriminate between fish species of different sizes.

This research is part of a larger program designed to evaluate the effect of commercial fishing activity on the prey availability to endangered Steller sea lions, *Eumetopias jubatus*, in the Gulf of Alaska. Because the distribution and abundance of sea lion prey are assessed using acoustic survey methodology, one challenge is identifying the species composition of mid-water scatterers, predominantly juvenile pollock (*Theragra chalcogramma*) and capelin (*Mallotus villosus*).

Figure 1a. Gulf of Alaska with study area off the east side of Kodiak Island enclosed in a box

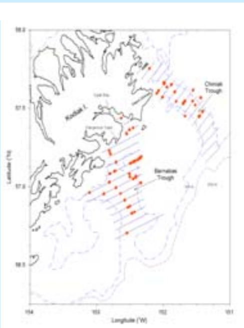

Figure 1b. Detail of study area showing survey transects and trawl locations (circles).

Methods

Acoustics Acoustic surveys have been conducted in the study area (see Fig 1a and b) during August 2000 and 2001 aboard the NOAA Research Vessel, Miller Freeman. The surveys consisted of parallel transects uniformly spaced at 3 nautical miles apart. The acoustic data were collected with a calibrated quantitative Simrad EK 500 echosounding system. Two Simrad split-beam transducers operated simultaneously, one at 38 and the other at 120 kHz.

Net sampling Trawl hauls were conducted where significant acoustic sign was encountered to determine the species composition of the scatterers and to collect other biological information such as age and length-frequency.

Aggregation and cell classification Scattering layers or aggregations were selected that had been directly sampled by the trawls. The aggregations were classified as age-1 pollock, age-1/age-2 pollock mix, capelin or capelin/age-0 pollock mix if that species or mix dominated the composition of the trawl sample. The acoustic data corresponding to these aggregations were then binned into cells 0.1 nautical mile (nmi) long and 5 meters (m) deep.

Analysis Mean volume back scattering (MVBS) was calculated over a range of minimum integration thresholds from -69 to -91 dB. MVBS was calculated at two different resolutions: 0.1 nmi x 5 m cells and entire aggregations (defined by the net sample). ΔMVBS was calculated as follows for both cells and entire aggregations: ΔMVBS = MVBS @ 120 kHz - MVBS @ 38 kHz

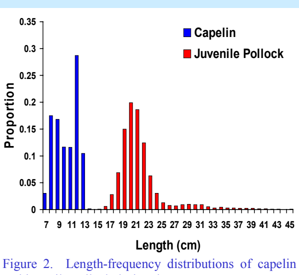

Figure 2. Length-frequency distributions of capelin and juvenile pollock during the surveys

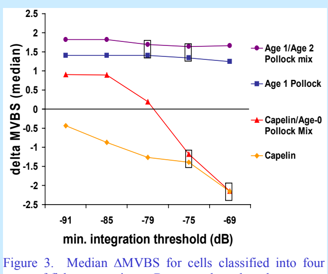

Figure 3. Median ΔMVBS for cells classified into four types of fish aggregations. Boxes enclose data that are not significantly different (Wilcoxon rank sum test, $p<0.05$)

Results

The mean length of capelin was 10.4 cm (Fig. 2). The distribution of juvenile pollock lengths had two modes, one around 20 cm and one around 30 cm (Fig. 2). Net samples consisting of fish with lengths distributed around the 20 cm mod were classified as "age-1 pollock". Net samples consisting of fish with lengths distributed around both modes were classified as "age-1/age-2 pollock mix".

The difference in median ΔMVBS between cells classified as juvenile pollock and capelin (or capelin mixed with age-0 pollock) was greatest at the highest integration threshold, -69dB (Fig. 3). The difference in median ΔMVBS between the two types of capelin aggregations, with and without age-0 pollock, increased as the integration threshold decreased. The difference in median ΔMVBS between the two types of juvenile pollock aggregations, age-1 and mixed age-1 and -2, was relatively unchanged across the range of integration thresholds examined (Fig. 3).

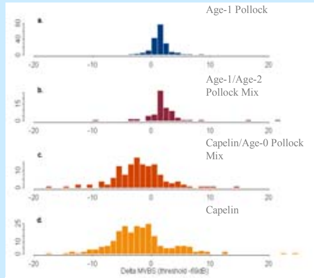

Figure 4. Frequency distributions of ΔMVBS of 1 n.mi x 5 m cells at the highest integration threshold (-69 dB).

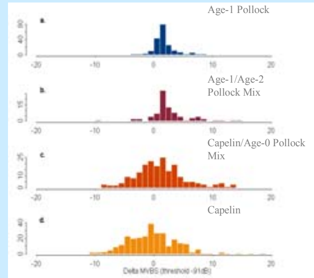

Figure 5. Frequency distributions of ΔMVBS of 1 n.mi x 5 m cells at the lowest integration threshold (-91 dB).

Although ΔMVBS values were significantly different at the –69 dB threshold (Fig. 3), there was overlap in the frequency distributions of juvenile pollock and capelin ΔMVBS (Fig. 4a and b vs. Fig. 4 c. and d.). At the –91 dB threshold there is substantial overlap in the frequency distributions of all four types of aggregations (Fig. 5).

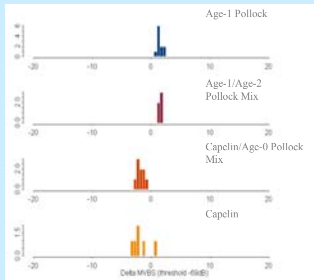

Figure 6. Frequency distributions of ΔMVBS of aggregations at the highest integration threshold (-69 dB).

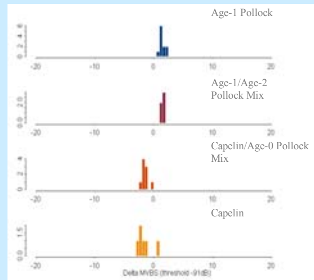

Figure 7. Frequency distributions of ΔMVBS of aggregations at the highest integration threshold (-91 dB).

In contrast to the results shown in Figures 4 and 5, there was virtually no overlap in the frequency distributions of juvenile pollock and capelin ΔMVBS at the larger resolution (aggregations). This is true for both the high (Fig. 6) and low (Fig. 7) integration threshold.

Conclusions

We conclude that acoustic differencing at the spatial resolution of entire aggregations and at a high integration threshold can be an effective technique to supplement net tows used for distinguishing juvenile pollock and capelin aggregations during acoustic surveys.

Our results show that it is possible to discriminate between different types of fish aggregations by comparing their ΔMVBS values (mean volume backscatter at 120 kHz minus mean volume backscatter at 38 kHz). Previous studies have used this technique to distinguish fish from zooplankton, and large species of zooplankton from small species of zooplankton. This is the first report of results showing the utility of ΔMVBS to distinguish between different species of fish.

The ΔMVBS values for juvenile pollock and capelin aggregations observed during this study agree with previously published work on frequency-dependent target strengths for these species. Miyanohana, et al. measured target strength of tethered pollock at frequencies of 25, 50, 100 and 200 kHz (1990, Measurements and analyses of dorsal-aspect target strength of six species of fish at four frequencies. *Rapp. P.-v. Réun. Cons. int. Explor. Mer.* 189:317-24.) Although target strength was highest at the lowest frequency, target strength at 50 kHz was actually lower than target strength at 100 kHz by approximately 1 dB. This is consistent with our observed ΔMVBS of approximately 1.5 dB for juvenile pollock aggregations. Rose measured target strength of capelin *in situ* and found that target strength at 120 kHz was approximately 1.5 dB less than target strength at lower frequencies (38 and 49 kHz) (1998, Acoustic target strength of capelin in Newfoundland waters. *ICES Journal of Marine Science* 55:918-23.). We observed ΔMVBS for capelin ranging from -2 to -0.5 dB (depending on the integration threshold), which is consistent with Rose's findings.

Although the statistical analysis of ΔMVBS at the small scale (0.1 nmi x 5 m cells) indicates significant differences between juvenile pollock and capelin, there was considerable overlap in the frequency distributions of ΔMVBS at this scale, which diminishes the utility of acoustic differencing to discriminate between different fish species in real time (i.e., during a survey). However, there was virtually no overlap in ΔMVBS values at the larger scale of resolution, that of entire aggregations.