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Species and size selectivity of two midwater trawls used in an acoustic survey of the Alaska Arctic

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ABSTRACT

Acoustic-trawl (AT) survey methods are widely used to estimate the abundance and distribution of pelagic organisms. This technique relies on estimates of size and species composition from trawl catches along with estimates of the acoustic properties of these animals to convert measurements of acoustic backscatter into animal abundance. However, trawls are selective samplers, and if the catch does not represent the size and species composition of the animals in the acoustic beam the resulting abundance estimates will be biased. We conducted an experiment to quantify trawl selectivity for species encountered during an AT survey of the Alaska Arctic. The pelagic assemblage in this environment was dominated by small young-of-the-year (age-0) fishes and jellyfish, which may be poorly retained in trawls. A large midwater trawl (Cantrawl) and a smaller midwater trawl (modified Marinovich) were used during the survey. The Marinovich was equipped with 8 small-mesh recapture nets which were used to estimate the probability that an individual that enters the trawl is retained. In addition, paired hauls were made with the Cantrawl and Marinovich to estimate the difference in selectivity between the two trawls. A statistical model was developed to combine the catches of the recapture nets and the paired hauls to estimate the length-dependent selectivity of the trawls for the most abundant species (e.g., age-0 fishes and jellyfish). The analysis indicated that there was substantial size and species selectivity: although the modified Marinovich generally had a higher catch per unit effort, many of the animals encountered in this environment were poorly retained by both trawls. The observed size and species selectivity of the trawls can be used to select appropriate nets for sampling pelagic fishes, and correct survey estimates for the biases introduced in the trawl capture process.

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1. Introduction

Acoustic-trawl (AT) survey methodology relies on trawl sampling to estimate the species and size composition of sound-scattering organisms. The catches from survey trawls are used to convert observations of volume backscattering into animal abundance (Simmonds and MacLennan, 2005). However, fishing gear is selective (i.e. there are size and species differences in the probability of capture), and the trawl catch is likely to have a different size and species composition than the population in the volume sampled (Maclennan, 1992; Wileman et al., 1996; Bethke et al., 1999). If the trawl gear is size or species selective this can cause substantial biases in AT abundance estimates (Nakashima 1990; Bethke et al., 1999; Williams, 2013). Biases in trawl-based species or size composition introduce errors in all size or species classes in AT surveys. This occurs because the acoustic measurement detects backscatter from all species (and sizes) present in the acoustic beam, and this echo energy is converted to species abundance based on the acoustic scattering expected from the animals retained in the trawl (Bethke et al., 2010). For example, in the case of a mixture of strong and weak sound scattering organisms, underestimates in the proportion of the strong scatterers due to net selectivity will result in comparatively large overestimates of the weakly scattering organisms, as a larger proportion of the observed backscatter is allocated to the weakly scattering organisms in the calculation of animal abundance from acoustic backscatter (e.g. McClatchie and Coombs, 2005).

Trawls used in commercial fishing are species and size selective, and there has been considerable interest in quantifying and altering the selectivity of trawls to reduce unwanted bycatch (reviewed in Maclennan, 1992; Wileman et al., 1996). However, the size and species selectivity of survey trawls is commonly assumed to be negligible (i.e. catchability is constant across species and size

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classes), and trawl catches are often used to estimate fish abundance with no correction for trawl selectivity. Trawls capture fish primarily by exploiting herding behavior (Wardle, 1984, 1993), and the probability of retention in the trawl is often strongly size and species dependent (Nakashima, 1990; Wardle, 1993; Williams et al., 2011). When fish aggregations are dominated by a single species, and size classes are spatially segregated, trawl selectivity may have relatively minor impacts on acoustic estimates of abundance. However, in many environments, fish occur in aggregations of mixed species and sizes, and the species and size compositions of acoustic scatterers are inferred from trawl samples. The assumption of negligible selectivity is likely to be untenable in these mixed species or size class situations, and trawl selectivity is likely to introduce large biases into AT survey results. For example, Williams (2013) found that accounting for trawl selectivity in an area of mixed age aggregations of walleye pollock resulted in large underestimates of the poorly retained juvenile pollock and comparatively small changes in the biomass of adults.

This study was a part of a large-scale baseline survey of the Arctic Ecosystem integrated survey (Arctic Eis) of the eastern Alaska Chukchi Sea in 2012 and 2013. A large midwater trawl (Cantrawl) was used for the AT survey in 2012 to estimate the abundance and distribution of near-surface and midwater fishes. The trawl had been used in earlier surface trawl surveys and was used in the 2012 and 2013 surveys to continue that surface trawl survey time series (Farley et al., 2009; Eisner et al., 2013). During the 2012 AT survey, it became clear that the fish assemblage in the eastern Chukchi Sea was dominated by small and/or juvenile fishes which were likely to be poorly retained by the Cantrawl. During the 2013 survey, a smaller modified midwater herring trawl (hereafter mod-Marinovich) was used to target acoustically observed fish aggregations, as it was expected to be better at retaining the small size classes of fishes present in the survey area in 2012.

This work aims to quantify the size and species selectivity of the two trawls used in the Arctic Eis AT surveys. The information is necessary to correct the trawl-based estimates of species and size composition used to convert acoustic backscatter to species abundances so that accurate and comparable estimates of animal density are generated from the two surveys. A two-part experiment was conducted in 2013 in which 1) the mod-Marinovich was equipped with small-mesh recapture nets to capture fishes that escaped from the trawl, and 2) a series of paired trawls with the Cantrawl and mod-Marinovich were conducted during the survey. The results of these fishing trials are analyzed jointly in a model framework to estimate the size-dependent selectivity of the trawls for the abundant species.

2. Materials and methods

2.1. Trawl sampling

A series of hauls with the mod-Marinovich trawl equipped with small-mesh recapture nets to capture fish exiting out the trawl meshes, as well as back-to-back trawl hauls with the mod-Marinovich and a large Cantrawl 400/601 rope trawl were conducted as part of an interdisciplinary survey of the Chukchi Sea. These midwater trawl hauls were conducted aboard the F/V *Bristol Explorer*, a chartered 55 m commercial stern trawler during an AT survey conducted between 7 August and 11 September 2013 (Fig. 1). Both nets were fished with 5 m^2 alloy doors at a vessel speed of ~2 m s^{-1} during daylight hours. The trawl opening during fishing (measured after the doors had spread the net and the net depth was stable) was observed with a Wesmar trawl sonar attached to the headrope, and the depth of the trawl was measured with Seabird SBE-39 temperature and pressure recorders attached to the headrope.

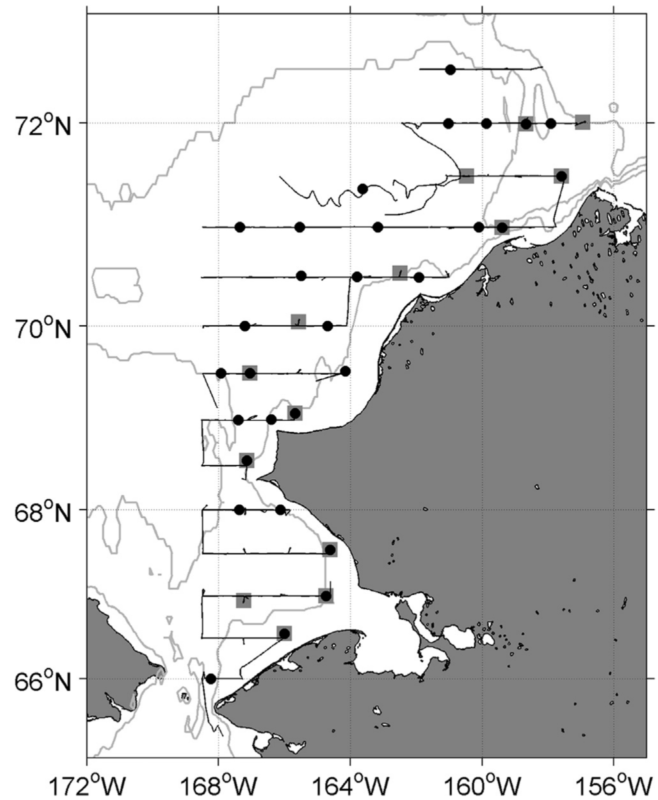

Fig. 1. Map of the study area. The locations of paired Cantrawl and mod-Marinovich trawl stations are shown as grey squares, and stations where the mod-Marinovich was fished with 8 recapture nets are given as black circles. Locations with both a circle and a square indicate the trawl stations where paired trawls and resample nets were deployed. The vessel survey track is shown as a black line and the 25, 50 and 100 m depth contours are shown as grey lines.

The Cantrawl is ~198 m long, has a 122 m headrope, and is constructed with ropes at the leading edge of the net followed by meshes reducing from 162 to 1.2 cm stretched length in the codend liner (Farley et al., 2009). The Cantrawl was equipped with floats to keep the headrope near the surface and towed for 30 min at predetermined locations. A trawl vertical opening of 19.7 ± 2.7 m (mean ± SD) and a horizontal opening of 45.8 ± 3.6 m was measured while surface trawling.

The mod-Marinovich herring trawl is ~31 m long, has a 12 m headrope, and is constructed as a symmetrical 4 seam box trawl with meshes reducing from 6.4 cm in the wings to 3.8 cm in the aft panel (Fig. 2). The body of the trawl is constructed from four panels. The aftmost panel was covered by 2 by a 3 mm knotless oval mesh liner. Hereafter, the two forward panels are referred to collectively as the forward section, the remaining unlined panel as the aft section, and the rear lined panel as the codend (Fig. 2). The trawl was modified from the original design to allow it to be fished effectively (i.e. with minimal overspreading of the net) with the same 5 m^2 trawl doors used for the Cantrawl by adding larger wings and fishing it with 55 m bridles. A trawl vertical opening of 5.7 ± 0.6 m (mean ± SD) and a horizontal opening of 8.3 ± 0.9 m was observed while fishing.

The mod-Marinovich was equipped with recapture nets designed to recapture organisms that escape from inside the trawl by exiting through the trawl meshes (e.g. Zijlstra, 1969; Nakashima, 1990; Matsushita et al., 1993; Williams et al., 2011). The trawl was divided into the codend and 8 additional partitions, defined by each trawl side (i.e. top, bottom, left, right), with each side divided into front and aft sections (Fig. 2). Recapture nets were attached to the

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