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# Examining influences of environmental, trawl gear, and fish population factors on midwater trawl performance using acoustic methods

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ABSTRACT

The performance of midwater trawls used during acoustic surveys for walleye pollock (*Gadus chalcogrammus*) was estimated using a novel method of combining acoustic and catch information. Direct comparisons of acoustic and catch derived density showed a poor correlation between the two ($r^2 = 0.07$), suggesting this discrepancy might be in part due to trawl performance. Trawl efficiency and selectivity were determined by comparing acoustically derived fish density within the trawling volume with catch-based density in a modeling framework. Additional factors thought to potentially influence trawl performance, consisting of environmental conditions including water temperature, bottom and fishing depth, variables relating to survey methodology including survey vessel, codend liner, and the time of day when trawling occured, and fish population characteristics including spawning state and condition factor were evaluated in the models. Incorporating efficiency and selectivity parameters resulted in improved model fits, as did the addition of explanatory variables. Efficiency was found to be associated with the proportion of spawning fish in the catch, water temperature, and the time of day, while selectivity appeared to be influenced by condition factor and the survey vessel used. The acoustic-catch modeling approach confers advantages of making available large historic datasets where acoustic data was collected during trawling and providing sufficient contrasts in parameters of interest not easily achieved with direct trawl performance experiments.

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## 1. Introduction

Trawls are used as scientific tools in fishery-independent surveys of fish abundance and demographic structure. The value of trawl sampling depends on knowing its ability to provide accurate data. For example, acoustic trawl (AT) surveys rely predominantly on midwater trawl catches to interpret acoustic backscatter and scale it to fish abundance (Simmonds and MacLennan, 2005). Fish behavior during trawl capture can bias trawl samples, and these biases are propagated into abundance estimates. Critical parameters of trawl performance are the efficiency of capturing target species, sometimes termed trawl catchability, and selectivity in retaining different sizes and species of fish that enter the trawl (Hilborn and Walters, 1992).

Catchability is often defined in the context of fitting trawl data to stock assessment models (Arreguín-Sánchez, 1996), and represents one component of the expected difference between survey and model estimates of abundance (Lauth et al., 2004). In this population level context, catchability is usually estimated by comparing trawl catch per unit effort with model estimates of abundance. Generally, this method only addresses systematic, relative differences between catch and model-derived abundance, not interannual changes in trawl performance due to environmental or other influences (Francis et al., 2003). To make a distinction between population level catchability and trawl efficiency, the latter term is used in this study. To estimate efficiency and selectivity of a survey trawl for an individual haul event (e.g. not on the survey level) and thus evaluate changes in trawl performance due to environmental influences, survey methodology, and fish population factors, an independent, unbiased measurement of fish size composition and density is needed to compare with trawl catch derived estimates. Acoustic estimates of density have been used for this purpose for bottom trawl catches (Aglen, 1996; Hjellvik et al., 2003; Kotwicki et al., 2013), primarily to estimate how many

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fish are in the near bottom acoustic "dead zone", and to evaluate vertical downward herding into the trawl.

Trawl efficiency and selectivity are critical factors for estimating abundance directly from trawl catch. Trawl efficiency is less important for acoustic surveys if the catch is representative of the population species and size composition, because abundance is calculated using acoustic backscatter rather than catch-per-unit-effort (Simmonds and MacLennan, 2005). Biases in fish lengths and species composition (i.e. selectivity) in trawl catches due to species or size specific differences in retention in the trawl can cause substantial errors in biomass estimated for acoustic surveys (Williams, 2013). It is therefore critical to understand and quantify the magnitude of selectivity as well as the potential influences on these variables associated with the conditions present during capture. In addition, understanding environmental influences on trawl efficiency and selectivity may help optimize harvest effort while minimizing impacts of commercial trawling such as bycatch (Valdemarsen and Suuronen, 2001).

In this study we evaluate midwater trawl performance used in acoustic surveys of walleye pollock (*Gadus chalcogrammus*; hereafter pollock), an important commercial fish species in the North Pacific. We use acoustic data collected during trawling to provide independent density estimates against which trawl catch-based density can be compared, with the assumption that the difference in these quantities can be explained by a combination of fish reactions during the process of capture by the trawl and physical size-dependent sorting of fish thought the trawl panels. The approach presented here is an extension of methods described in Somerton et al. (2011) to assess efficiency, selectivity, and potential environmental, physiological, and methodological influences on these variables.

## 2. Materials and methods

### 2.1. Acoustic and catch data

Acoustic surveys for pollock from 1995 to 2010 conducted by the Alaska Fisheries Science Center in the eastern Bering Sea and Gulf of Alaska were included in this study. Surveys from 1995 to 2007 were conducted using the NOAA ship *Miller Freeman* (MF), which was replaced by the NOAA ship *Oscar Dyson* (DY) for surveys conducted in 2008–2010. The latter vessel (DY) was specifically designed for low underwater radiated noise levels to reduce potential vessel avoidance by fish (De Robertis and Wilson, 2010). Acoustic data, consisting of the volume backscatter coefficient $S_V$ (dB re 1 m$^{-1}$, MacLennan et al., 2002) measured at 38 kHz, were collected during AT survey trawling operations, along with trawl position and trawl mouth opening dimensions. Trawl positions during fishing were used to estimate fish density using acoustic data within the path of the trawl. This was done by integrating acoustic returns from a layer starting at the measured headrope depth and extending to the footrope of the trawl (Fig. 1). Because acoustic data were collected on each ship's echosounder, there is a trawling depth-dependent temporal offset between backscatter received from fish under the vessel and same fish when they encounter the trawl. To adjust for this offset, the start and end points for the integrated region representing the trawl path were translated by calculating the horizontal distance between the trawl and the vessel's echosounders. The computation consisted of a sum of the distance from the main trawling wire blocks to the echosounders, an estimate of the horizontal offset from the blocks to the trawl doors based on the Pythagorean theorem using the mean length of the trawl warps and headrope depth during trawling as inputs, and finally the distance from the trawl doors to the trawl itself. The horizontal distance was divided by the vessel speed to derive an offset time. An index of echosign variability was also estimated by subdividing the trawling path integration region in 0.05 nmi horizontal bins, and computing the variance of the absolute difference between adjacent bins. When echosign consisted of intermittent high density schools, this index value would be high, and in instances where fish distribution was uniform it would be low. Analyses were performed using Echoview (Myriax Software PLT, Version 4.9).

The AT survey used an Aleutian wing trawl (AWT, Net systems, Bainbridge Island, Washington) for catch sampling during the study period. The AWT has nominal vertical and horizontal trawl opening dimensions of 25 m and 45 m. The mesh size in the forward portion of the trawl is 3.25 m, with progressively smaller mesh openings ending with 10 cm in the codend. A small-mesh liner was placed in the codend, with a stretched mesh length of either 1.3 or 3.2 cm, depending on the survey. For a detailed description of the trawl, please see Williams et al. (2011). All hauls were carried out with a targeted trawling speed of 3.5 knots.

Trawl catches were sorted by species and ~300 pollock were measured for length to the nearest 1.0 cm. When juvenile pollock

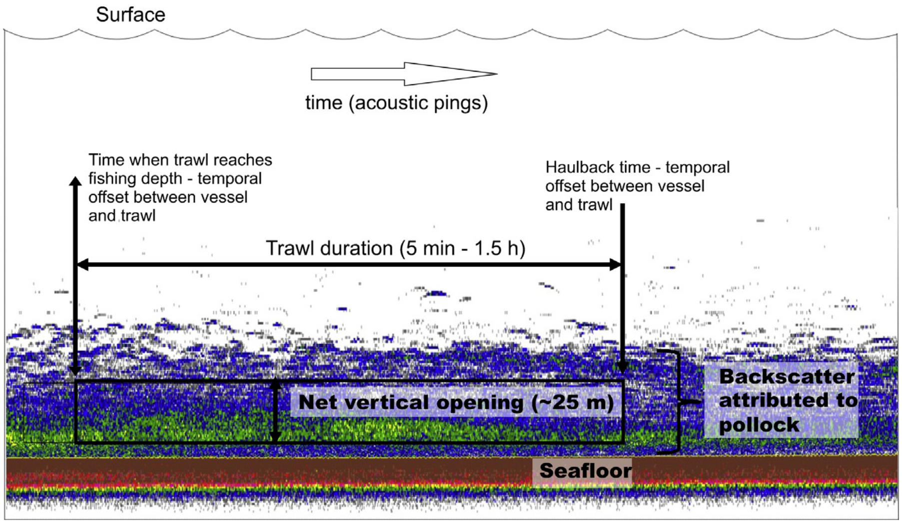

**Fig. 1.** Method for estimating mean acoustic backscatter of pollock within a rectangular block representing the path of the midwater trawl, with start and end times for the trawl adjusted for the difference in time between when fish are observed acoustically under the vessel and when they encounter the trawl. Background image represents an echogram at 38 kHz.