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Research Paper

Development of stereo camera methodologies to improve pelagic fish biomass estimates and inform ecosystem management in marine waters

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ABSTRACT

To understand and manage marine ecosystems, long-term monitoring of fish biomass is needed. A challenge in estimating fish biomass using sampling nets is varying catchability with habitat, weather, or vessel traffic conditions. Underwater stereo cameras have shown promise in providing a non-lethal, efficient, and cost-effective method to observe and measure fish in areas that cannot be sampled otherwise. These methods, however, have yet to be demonstrated for mid-water pelagic or semi-pelagic fishes. We designed, built, and tested a stereo camera for its potential to augment survey assessments of pelagic fish biomass in areas where trawl net samples cannot be collected. In a pilot test, the stereo camera was used to identify fish species and to measure fish length, depth, tilt, and yaw. Five paired stereo camera deployments and pelagic midwater trawl hauls were compared during an acoustic survey in the Strait of Georgia, British Columbia. Fish sometimes moved in response to the stereo camera deployment, but acclimated quickly to its presence at depth. Pacific hake, *Merluccius productus*, and walleye pollock, *Gadus chalcogrammus*, were the two dominant species in both midwater trawl haul catches and stereo camera images, but fish sizes were significantly larger in most cases in stereo camera images compared to trawl haul catches. Fish length measurements were most accurate when yaw angles were < 30°. Higher abundances of fish in the stereo camera images were associated with higher midwater trawl catch-per-unit-effort values. Fish orientation was close to horizontal for pollock, but slightly downward for hake (15.56°), which could have implications for acoustics-based biomass estimates. The challenges of using stereo cameras in acoustic surveys include smaller sample sizes than those of midwater trawl catches, time required for processing of images, and identification of small fish. However, stereo cameras can be viable tools for acoustic target verification of fish species and measurements of fish lengths, with the advantages of additional information on specific fish depth, tilt, and yaw. Cameras can also sample non-lethally in areas where trawling is not logistically possible, such as in shipping lanes, or permitted, such as marine protected areas. Our results suggest that stereo camera technology is a useful tool for studying fish in the water column.

1. Introduction

Integrated research and long-term monitoring are required to support the management of sustainable ecosystems (Samhouri et al., 2014; Long et al., 2015). Monitoring marine fish populations can involve a variety of assessment methods, including acoustic-trawl surveys, which provide biomass time series for targeted fish species. These abundance time series are commonly used in species-specific stock assessments or ecosystem reports that are then applied in setting total allowable catch of species or used to assess the state of ecosystems (e.g., Mundy et al., 2010; Ressler, 2014; Grandin et al., 2016). Development of methods and technologies that improve these estimates can, therefore, have broad applications for decision-making in ecosystem-based fisheries management.

Acoustic volume backscattering data, as well as fish species and size information from trawl catches, are required in acoustic-trawl surveys to generate estimates of fish biomass. Estimating fish biomass is difficult where catchability or availability of fish to the survey gear changes with habitat, weather, or vessel traffic conditions (Cordue, 2007; Rooper et al., 2010). In pelagic (i.e., water column) surveys, a midwater

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trawl cannot be used in some situations, such as vessel traffic lanes in foggy weather, or in marine protected areas. Additionally, trawl samples are costly in terms of the large vessel size required to tow a midwater trawl net, and the time and effort required to deploy the net and process the resultant catch. Alternative non-lethal methods to obtain length and species identification data may be more suitable in some situations.

Underwater stereo cameras provide a non-lethal, efficient, and cost-effective method to observe and measure fish in areas that cannot be sampled otherwise (Klimley and Brown, 1983; Costa et al., 2006; Rooper et al., 2010; Williams et al., 2010). Stereo camera technology has been successfully used to estimate biomass of near bottom rockfish in untrawlable habitats (Rooper et al., 2010; Jones et al., 2012). Midwater moored, and baited stereo-video cameras have been used to acquire species composition and demersal and pelagic fish lengths (Heagney et al., 2007; Santana-Garcon et al., 2014). The benefits of this technology may have applications to monitoring pelagic and semi-pelagic fish resources; however, these methods have yet to be tested in large-scale acoustic surveys of the water column. Field tests are needed to determine the success of incorporating stereo camera technology to complement trawl sampling.

A number of important issues need to be resolved before stereo camera sampling efforts can be fully implemented in acoustic surveys. There have been a number of recent studies that addressed the behavioural effects of underwater survey vehicles on benthic fishes (Laidig et al., 2013; Rooper et al., 2015; Somerton et al., 2017), but the effect of the presence of stereo camera devices on pelagic fish behavior is largely unknown and likely important (Stoner et al., 2008). Another concern is the number of samples (both in terms of individual fish observations and volume sampled) that are needed to resolve the size and species structure of acoustic targets encountered during an acoustic survey with an acceptable level of precision. Finally, as with any sampling device, biases in size and species composition estimates need to be addressed and taken into account.

In this study, stereo camera technologies were applied to the assessment of pelagic fish biomass. This was a pilot test to determine if stereo cameras could be useful tools in verifying fish species and sizes. The objectives of this study included the following: 1.) design and fabricate a stereo camera system to have minimal effect on fish behavior in the pelagic environment; 2.) examine the performance of this camera system to determine pelagic fish species and lengths; 3.) evaluate the effect of fish orientation on stereo camera-based fish measurements; and 4.) on a first-order approximation, compare species composition and size between fish sampled with a stereo camera and fish sampled with a midwater trawl net.

2. Materials and methods

2.1. Survey area and general methodology

A small lowered stereo camera system was deployed during a Fisheries and Oceans Canada (DFO) acoustic-trawl survey conducted during March 14–27, 2016 in the Strait of Georgia (SOG), British Columbia (BC). The SOG is a productive ecosystem within the Salish Sea supporting culturally and commercially valuable fisheries such as Pacific herring (*Clupea palasi*) and Chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon (Heard et al., 2007; Perry and Masson, 2013; Beamish, 2014). Other important fish species in the SOG ecosystem include Pacific hake (*Merluccius productus*), Pacific spiny dogfish (*Squalus suckleyi*), and walleye pollock (*Gadus chalcogrammus*) (Perry and Masson, 2013; Beamish and Sweeting, 2009; Beamish, 2014). To sample this area, parallel transects were placed from a random starting point and spaced 9.26 km (5 NM) apart (Fig. 1). Using the Canadian Coast Guard Research Vessel *W.E. Ricker*, acoustic data were collected along transects during daylight hours and acoustic targets in the water column were verified using the stereo camera and/or a midwater trawl net. The stereo camera was deployed on the same acoustic targets as the midwater trawl to enable comparisons between the two devices.

2.2. Acoustic data collection

Acoustic data were collected with SIMRAD EK60 scientific echo sounders using hull-mounted downward-facing transducers at 18, 38, and 120 kHz. The nominal 3 dB beam width was 11° for the 18 kHz, and 7° for the 38 and 120 kHz transducers. The sounder transmitted 1.064 ms pulses at all frequencies simultaneously at a rate of 1–2 pings per second. The echo sounders were calibrated using standard methods (Demer et al., 2015) with a 38.1 mm tungsten- carbide sphere during the survey. A Seabird SBE 19plus Profiler CTD was deployed to acquire temperature, salinity, and density profiles for computing the speed of sound and absorption coefficients in water for use in calibration and for post-processing data.

Species composition and fish size (length and weight) data from midwater trawl catch, along with video information from an in-trawl camera located in front of the codend, were used to apportion acoustic backscatter data. Volume backscatter was converted to fish density using the backscattering cross-section of a fish and mean length in the associated catch. These values were derived using the target strength-to-length relationships for walleye pollock:

$$TS = 20\mathrm{Log}_{10}(L) - 66 \tag{1}$$

and Pacific hake:

$$TS = 20\mathrm{Log}_{10}(L) - 68 \tag{2}$$

Where TS is the target strength in dB (the logarithmic equivalent to backscattering cross-section) and L is the mean fork length in cm (Traynor, 1996). All acoustic analyses were performed with the Echoview © software (version 7.0). The first 10 m in front of the transducers were removed from analyses to avoid the acoustic near field and areas of vessel- and surface-generated bubbles. The first meter above the sounder-detected bottom was also excluded from analyses and inspected for spurious bottom echo inclusions. The remaining water column data were cleaned of intermittent noise and other unwanted echoes. The backscatter data from layers and aggregations were assigned to species based on all available information, including trawl catches, in-net video camera feed, underwater stereo camera deployments, and acoustic characteristics of the marks.

2.3. Midwater trawl sampling

Acoustic targets were sampled with a model 250/350/14 midwater trawl net (Cantrawl Pacific Ltd., Richmond, BC) with a herring liner in the codend. The midwater trawl net was made up of the four following sections: 1.) heavy-duty front end with hexagonal meshes of 9.5 mm and 7.9 Tenex rope; 2.) tapered body with meshes of 163 cm, 81.3 cm, 40.6 cm, 20.3 cm, and 10.2 cm polypropylene sections; 3.) intermediate section of 7.6 cm polypropylene mesh; and 4.) a codend of 3.8 cm knotted nylon, and fitted with a 6.4 mm mesh liner. Two USA Jet trawl doors (model P) were used with the net. A Wesmar 380 net sonar was used to determine net mouth opening dimensions (width and height). Trawl net catch weight (kg), species composition, and catch per unit effort (CPUE) were recorded. CPUE was estimated as catch weight (kg) divided by volume swept, which was calculated by multiplying net mouth height (m), net mouth width (m), and distance over ground (m). Catches were sorted to species, weighed, and subsamples of up to 250 individuals from each species were measured (fork length to the nearest 0.5 cm) and weighed (to the nearest g).

2.4. Lowered stereo camera system

The stereo camera system (hereafter Slycam) was based on the