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The adaptation of acoustic data from commercial fishing vessels in resource assessment and ecosystem monitoring

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ABSTRACT

The collection of scientific data from commercial fishing vessels will play an important role in the future assessment of fish stocks and ecosystem monitoring. Currently fishing vessel acoustic data collections range from fully structured random/systematic surveys to the *ad hoc* search patterns of pelagic vessels during standard fishing operations, and are used primarily in single species stock assessment. To effectively use these data a good understanding of the data collection methods, analytical procedures, and the limitations of the data is required. Consideration of the limitations and interpretation of the data are a major factor in evaluating the validity of the outputs, the uncertainties associated with the data and the acceptance of the results by the scientific community. In this paper we provide 3 case studies of how acoustic data from commercial fishing vessels are being used to provide information on fish resources and advice to management. We categorize a fishing trip into 3 phases: transiting, searching, and fishing, and we discuss the attributes and limitations of data collected during each phase. Examples of current fishing vessel data collections and their application in resource assessment and environmental monitoring are presented. In addition, we explore opportunities for acoustics to support broad-scale ecosystems monitoring, without interfering with the day-to-day operations of the vessels.

1. Introduction

The concept of using commercial fishing vessels to collect scientific resource and environmental data during fishing excursions is not new, but the acceptance of such data as quantitative and relevant is relatively recent. Traditionally, information on the distribution and abundance of biological organisms from fishing vessels was considered anecdotal unless the vessel's operations were adjusted to meet scientific requirements (*e.g.*, directed survey design, scientific monitoring equipment, and on-board supervision of data collection) (Karp et al., 2007; Shotton et al., 2012). Technological developments in the last twenty years have established the foundation for the unsupervised collection of acoustic and sensor data during all phases of the commercial fishing operation. Now quantitative scientific data covering a broad spectrum of temporal and spatial environmental, biological and habitat information can be collected by autonomous systems aboard fishing vessels. Albeit the data are somewhat limited in overall scope depending on the operational activities of the vessel. Furthermore, the governance of resource monitoring and assessment has also changed, moving away from government to industry responsibility in many countries (O'Driscoll and Macaulay, 2005; Kloser et al., 2007). Here the focus is on the sustained use of fishing vessels to collect quantitative data for input into stock assessments and environmental/ecosystem monitoring.

Until the last decade most attempts to introduce fishing vessel-based acoustic data into the stock assessment and ecosystem monitoring process have been met with scepticism from the scientific community. The validity of the data was inevitability questioned unless the efforts involved on-board supervision and followed both strict protocols and a science-based survey design. Canada began examining non-supervised, non-structured (*i.e.*, no survey design) fishing vessel acoustic data from Atlantic herring (*Clupea harengus*) spawning grounds in the Gulf of St. Lawrence and the southwest Nova Scotia region in the mid-1990s to estimate biomass (Melvin et al., 2001; Claytor, 2001). Both initiatives looked

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at ways to utilize the *ad hoc* acoustic information collected during a fishing trip in the analytical stock assessment. However, the data and the approach were soon dismissed by the stock assessment scientific community due to the inconsistency in coverage between observations. Fishing vessel data were not integrated into the stock assessment models until 1999 when the industry implemented an unsupervised scientific survey design (O'Boyle and Atkinson, 1989; Jolly and Hampton, 1990; Melvin and Power, 1999).

Many countries commonly employ fishing vessels as scientific platforms under strict scientific protocols. Small-scale, supervised acoustic surveys have been conducted by fishing vessels on southern blue whiting (*Micromesistius australis*) and hoki (*Macruronus novaezelandiae*) in New Zealand (O'Driscoll and Macaulay, 2005; O'Driscoll, 2011), and on walleye pollock (*Gadus chalcogrammus*; hereafter pollock) in Alaska (Barbeaux and Fraser, 2009). In the Australian blue grenadier fishery unsupervised acoustic surveys have been undertaken annually since 2002 by fishing vessel usually during down time, whilst the vessel is processing the catch, with minimal interruption to fishing operations. These fishing vessel collected data are analyzed and used in the stock assessment of the species (Kloser et al., 2007). Today numerous countries commonly employ fishing vessels as scientific platforms under strict protocols, but the data these same vessels collect during regular fishing trips are rarely, if ever, used to monitor the resource.

Recognition of the contribution fishing vessels can make to resource and environmental monitoring has resulted in new initiatives, major workshops and scientific publications on the subject of using fishing vessels as scientific platforms (Karp et al., 2007; Mackinson and van der Kooij, 2006; Melvin et al., 2002; Reid, 2001; Shotton et al., 2012; Trillo, 2014). Most studies or reviews have concluded that the vessels must adhere to a standardized survey design for the data to be useful as an ecosystem or resource monitoring tool (O'Boyle and Atkinson, 1989; Shotton et al., 2012). The International Council for exploration of the sea (ICES) Working Group Fisheries Acoustic Science and Technology (WGFAST) established a study group in 2003 to evaluate the collection of acoustic data from fishing vessels and to provide recommendations on how these vessels, and the information they collect, should be used (Karp et al., 2007). The Karp et al. (2007) report devoted a chapter to issues of fishing vessel radiated noise, cautioning about potential bias to survey results due to fish behaviour. Recent work has shown that fish behaviour in relation to vessel noise is complex and careful attention needs to be paid to both "noisy" and "quiet" ships for some survey applications (De Robertis and Handegard, 2013). The United Nations Food and Agriculture Organization (FAO) coordinated an international workshop on using fishing vessels for deep sea surveying (Shotton et al., 2012). All focused on restructuring the vessel's operations to meet scientific requirements for statistically valid surveys, sampling strategy, calibrated equipment and quality control. Recently both the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and the Southern Pacific Regional Fisheries Management Organization (SPRFMO) started programs to collect fishing vessel data to assist in the management of their mandated fisheries. The Australian Integrated Marine Observing System (IMOS) has also recruited fishing vessels as well as ships of opportunity to collect acoustic data on transit to and from fishing grounds.

Other coordinated reviews have taken a different approach regarding the use of fishing vessels as scientific platforms. A global acoustic observation system has been proposed incorporating ships of opportunity (including fishing vessels) to study the mid-trophic ecosystem (Handegard et al., 2010). The 2013 World Ocean Council (WOC) convened a workshop to expand and improve ocean and atmospheric data collection through the use of fishing vessels (Anonymous, 2013). The so called "Smart Fishing Vessels" workshop held by the WOC built upon an earlier program. The objective was to facilitate and coordinate data collection and sharing by ocean industries with the intent of identifying programs, priorities, methods and technologies employable by fishing vessels. In 2014 the Instituto de Recursos Acuaticos (IREA) held a workshop in Lima, Peru, on the use of fishing vessels as scientific platforms. The IREA workshop concluded that although there is still work to be initiated on the standardization of approaches and characterization of bias, acoustic devices aboard fishing vessels can provide unique and valuable scientific data.

Unlike in the past, the collection of quantitative data by fishing vessels is no longer in question; it is the lack of a statistical design under which the data are procured that continues to be of concern. The use of unstructured (*i.e.*, no survey design) data in an analytical stock assessment or ecosystem model is difficult due to the lack of temporal-spatial consistency and uncertainty regarding the representativeness of the resource being monitored (Karp et al., 2007). Here we take a different approach to the problem by addressing not how can we fit, or modify, the fishing vessel data to meet assessment model requirements, but what information can be extracted from the ongoing (or slightly modified) practices during the transit, searching, and fishing phases of a standard fishing trip. We also explore opportunities for acoustic data extraction to support broad-scale ecosystem and resource monitoring, without interfering to any great extent with the day-to-day operations of the vessels.

2. Methods

2.1. Equipment

Modern acoustic hardware enables the autonomous collection of quantitative data from fishing vessels of all sizes. Unlike the older technology, which for scientific purposes required a dedicated operator and constant monitoring, new acoustic systems from several manufacturers can be programmed for a specific configuration. Furthermore, some fishing echo-sounders (*i.e.*, single and multi-frequency), and some multibeam sonar systems, allow the recording of raw (*i.e.*, unedited) acoustic data interfaced with the ships Geographical Positioning System (GPS). They can also be calibrated through the hardware or post-processing software. The theory and standard procedures for calibrating acoustic hardware are well established and described in the literature (Foote et al., 1987; Simmonds and MacLennan, 2005; Demer et al., 2015).

2.2. Vessels and system settings

Not all fishing vessels make good scientific platforms for the collection of acoustic data. Many factors contribute to a vessel's radiated noise (*e.g.*, vessel speed, propeller noise, hydraulics, electronics and other instrument interference) during steaming or fishing operations (Mitson and Knudsen, 2003). Noisy vessels with large amounts of interference can degrade the acoustic signal to render it unusable. Some improvements can be made by turning off non-essential electronic equipment or reducing the vessel's speed. Most acoustic systems have a passive mode option to self-test for noise. The challenge is to minimize the background noise and maximize acoustic signal. Another major consideration for fishing vessels is the instrument settings for data collection. Recommendations for hardware settings are available from several sources and different configurations can be saved within the acoustic hardware (O'Driscoll, 2011; Shotton et al., 2012; Simmonds and MacLennan, 2005). For certain frequencies setting the output power too high can introduce a bias in the data through non-linear effects (Korneliussen et al., 2008; Tichy et al., 2003).