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Acoustic data collected on pelagic fishing vessels throughout an annual cycle: Operational framework, interpretation of observations, and future perspectives

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ABSTRACT

Acoustic data collection trials on pelagic freezer-trawlers were realised in 2012 during several fishing trips targeting blue whiting west of the British Isles in spring, North Sea herring in summer, and horse mackerel in the English Channel and Celtic Sea in autumn. Echosounders were calibrated and time- and position-stamped data logged along the path covered by the vessels. The acoustic detections recorded during different types of trawler activity within a fishing trip ('searching', 'stationary', and 'fishing') were compared between target species. The highest proportion of time spent for activity 'fishing' was observed in the blue whiting fishery (82%), while that value was lower in the horse mackerel and herring fishery (68% and 54%). In all fisheries the quantified mean fish densities recorded were significantly higher during 'fishing' than during 'searching'. Changes in recorded fish density magnitudes over time before and after trawling also showed different patterns between fisheries. The quantified peculiarities exhibited by the specific fishing trip data is discussed in light of incorporating them in monitoring programs and analysis methods that can advance ecosystem understanding. Potential future approaches for analysis methods of opportunistically recorded acoustic fishing vessel data are discussed.

1. Introduction

Sustainable management of marine resources and services is increasingly being based on an ecosystem approach (Bianchi and Skjoldal, 2008; Levin et al., 2009; McLeod and Leslie, 2009; Link, 2010; Katsanevakis et al., 2011; Kruse et al., 2012). Apart from a holistic understanding about how human activities impact on the system, such an approach requires quantitative knowledge about fundamental ecosystem processes (Curtin and Prellezo, 2010). To develop this knowledge, information on the distribution, abundance and productivity of different biological ecosystem components are required (Demer et al., 2009; Handegard et al., 2013). However, the specific monitoring and sampling programmes currently in place are largely designed to assess individual ecosystem components. Available data therefore often do not satisfy the requirements of advanced ecosystem models (Fulton, 2010; Rose et al., 2010). The latter are designed to enhance our ecosystem process understanding and to make predictions based on biological and physical characteristics of the ecosystem over extended spatio-temporal scales.

Scientific acoustic surveys are an essential source of information for current stock assessments of widely distributed pelagic fish populations, which show distinct migration patterns throughout their life cycles (e.g. Iversen, 2002). Echosounders are used to continuously collect fish density data along systematic survey transects. The acoustic intensity reflected by the fish can subsequently be converted into average fish density-per-area values inside the covered area. A survey age-structured biomass index for the targeted stock can then be derived from the acoustic data in combination with collected biological samples. However, scientific surveys are limited by practical and financial constraints and the resulting coverage often provides only a snapshot view of the stock abundance at a very particular point in time. Furthermore, many commercial stocks cannot be sufficiently covered by a directed acoustic survey due to resource limitations or survey practicalities. The resulting lack of spatially resolved abundance information for many species severely constrains the parameterisation and prediction capabilities of advanced ecosystem models needed to serve as a foundation for ecosystem-based management.

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One possible solution to the increased data requirements for the ecosystem approach was discussed by Koslow (2009), Trenkel et al. (2011), and Handegard et al. (2013), who specifically suggested the combination of different acoustic sampling platforms in a framework to simultaneously collect information on species distributions at previously inaccessible spatio-temporal scales. Godø et al. (2014) have thoroughly discussed and termed this integrated monitoring concept 'Marine Ecosystem Acoustics' (MEA). They highlighted adequate temporal and spatial coverage as one of the main challenges that poses to be unsurmountable with traditional sampling methods. To extend the temporal scales of data collection, Godø et al. (2014) proposed the possibility of enhanced and increased collection of acoustic data from ships of opportunity (e.g. ferries or fishing vessels), which are already becoming advanced and increasingly important acoustic platforms (Karp, 2007).

Acoustic equipment available on pelagic fishing vessels is nowadays of comparable design and performance as those used on scientific research vessels. On many occasions, fishing vessels have in fact been chartered to carry out dedicated acoustic surveys following a standardised design (Honkalehto et al., 2011; Hordyk et al., 2011; Karp 2007; Ressler et al., 2009). Providing that a list of protocols are defined to insure quality standards (Karp, 2007), these vessels can therefore serve as acoustic data collection platforms and provide useful information complementing or in some cases compensating for the lack of scientific survey data. The Dutch pelagic fleet is composed of a small number of large (80–145 m length) freezer-trawlers which are operational all year round on different fishing grounds in the northeast Atlantic, off western Africa and in the south Pacific. A considerable amount of quantitative information on fish distribution and biomass could potentially be made available at negligible costs by simply recording acoustic data from these vessels during regular fishing trips. In order to make scientific use of these data, they would need to be collected routinely and at the required quality (Karp, 2007). Furthermore, it is evident that the behaviour of commercial vessels exhibited during fishing activities does not follow a systematic sampling design. Therefore, to allow for these data to be used as a source of useful information, it is essential to understand the mechanisms affecting the way they are collected.

This paper describes the potential of regular acoustic data collected by freezer-trawlers to deliver: complementing information to monitoring surveys, relative biomass indices for target species, or population behaviour over wider temporal scales. Echosounders were calibrated and data collected during several fishing trips throughout an annual cycle targeting different commercially important species. The data were analysed to investigate differences caused by the behaviour of the different target species and the resulting fishing activity. Understanding such peculiarities will be vital for developing analysis methods to interpret and make use of these data in the process of ecosystem understanding. Eventually, potential future developments in analysis methods are discussed.

2. Materials and methods

2.1. Data collection

Acoustic data were collected and recorded on pelagic freezer-trawlers during fishing trips between February and September 2012 targeting Northeast Atlantic blue whiting (*Micromesistius poutassou*), North Sea herring (*Clupea harengus*), and horse mackerel (*Trachurus trachurus*) in the English Channel (Fig. 1). All vessels included in the present study, were equipped with either the commercial Simrad ES70 or the scientific Simrad EK60 echosounders operated at 38 kHz. Time- and GPS position-stamped raw acoustic data from the echosounders were recorded to external hard disks. The hard disks were directly connected to the computers operating the echosounders prior to each individual fishing trip and collected after the trawlers returned to port. For operational reasons, echosounders were set to log data from the very beginning of the trip when leaving the home port until arrival back in port to prevent accidental data loss and to monitor the proper functioning of the echosounder during the whole recording period. During data collection, echosounder settings such as pulse duration, input power and transceiver gain remained fixed.

2.2. Calibration of acoustic equipment

Calibration of acoustic equipment used for scientific purposes is vital to ensure the correct functioning of the system, get an estimate of the stability of the recorded data, adjust the uncompensated received signal amplitude relative to that of a reference target, and to gain insights into potential error sources in the resulting dataset. A total of four calibrations of the 38 kHz Simrad ES70/EK60 systems installed onboard three different pelagic freezer-trawlers were successfully performed either directly before, during or adjacent to respective fishing trips. For each calibration, the vessels steamed into a sheltered bay close to the fishing grounds (either SW Ireland or Scapa Flow, Scotland, UK) and followed common recommendations for standard sphere calibrations of scientific split-beam echosounders (Foote et al., 1987; Simmonds and MacLennan, 2005). Each calibration was performed with two spheres attached at least 4 m apart to enable verification of the measurements as well as adding additional weight to the setup to enhance the stability of the top sphere used for calibration measurements. The raw data recorded during the calibration procedure of the ES70 systems were replayed and visualised in the calibration tool of the Simrad ER60 software (Andersen, 2001) to assure a sufficient amount and satisfying spread of data points throughout the beam had been collected. For the vessel where the EK60 system was available, the calibration was conducted completely using the ER60 software.

2.3. Data processing

The calibration settings were used to update the transceiver gains and acoustic beam patterns on the trawler equipped with the Simrad EK60 echosounder before the start of the effective fishing trip. For the other vessels that used Simrad ES70 systems, the calibration values were applied *a posteriori* during post-processing. Data collected by the Simrad ES70 echosounders contain an embedded systematic error component (Ryan and Kloser, 2004). The error has the shape of a periodic triangular wave of approximately 1 dB peak-to-peak amplitude with a period of exactly 2721 data points. Inspection of the wave showed that data points remain stable for 16 pings, after which there is a step over to the next level where the next stable group of 16 data points resides. The structure of the error wave can be identified from the transmit pulse section in the raw data header information and used as a basis for adjusting the entire echogram accordingly. A java applet ('ES60adjust') developed by scientists from the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) was used to remove the triangular wave error (Keith et al., 2005). The wave-corrected acoustic raw data from the Simrad ES70, or the original raw data provided by the Simrad EK60 system, were post-processed and analysed using LSSS v1.6 (Large Scale Survey System, marec, NO, www.marec.no). Implementation of the calibration results were applied through the KORONA module within LSSS. The resulting error-corrected and calibrated datasets were then used for scrutinising procedures, i.e. the data post-processing where acoustic volume backscatter values (s_V) of fish schools are allocated to species. The scrutinising process was based on a combination of expert