Fisheries Research 178 (2016) 71–81

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Industry-based acoustic survey of Atlantic herring distribution and spawning dynamics in coastal Maine waters

Katharine V. Wurtzell[a,b], Adam Baukus[a], Curtis J. Brown[a], J. Michael Jech[c], Andrew J. Pershing[a], Graham D. Sherwood[a,*]

[a] Gulf of Maine Research Institute, 350 Commercial St, Portland, ME 04101, USA
[b] University of Maine, Orono, ME 04469, USA
[c] Northeast Fisheries Science Center, 166 Water St, Woods Hole, MA 02543, USA

ARTICLE INFO

Article history:
Received 28 February 2015
Received in revised form
12 November 2015
Accepted 14 November 2015
Available online 10 December 2015

Keywords:
Fisheries acoustics
Hydroacoustics
Cooperative research
Spawning phenology
Survey design
Herring

ABSTRACT

We describe a unique survey method that is able to cover a wide spatial and temporal range at a low cost. We utilised 10 individual small fishing vessels (lobster vessels) as acoustic research platforms to systematically survey a coastal population of Atlantic herring (*Clupea harengus)* in the Gulf of Maine. We examined 38 transects spanning more than 200 miles of coastline. Due to the low cost of chartering the vessels, the survey was repeated weekly for nine weeks, resulting in over 2300 nautical miles of on-transect data. We calibrated single beam systems using a split beam guiding transducer to increase our confidence in the accuracy of the data and allow inter-ship comparisons. Although only one year of data has been analysed, the large spatial and temporal coverage of this survey provides preliminary information on herring population dynamics including spatial distribution throughout the survey area, timing of spawning and habitat associations of spawning aggregations. This survey will provide the template for longer term monitoring of herring spawning dynamics in Coastal Maine and how this may respond to climate and ocean variability.

1. Introduction

Progressive development of scientific instrumentation has led to sophisticated fisheries acoustic methods that have advanced our understanding of marine organisms and are often essential components in fisheries stock assessments (Fernandes et al., 2002). However, as funding has decreased for research vessel-based acoustic studies, there has been a push to collect data opportunistically. In this case, vessels of opportunity can collect high resolution data efficiently and provide valuable insights on fish distribution and behaviours that would otherwise be unobtainable (Barbeaux et al., 2013). Indeed, many agencies now engage with commercial fishing vessels to perform scientific research for both scientific and fisheries objectives (Karp et al., 2007; Hartley and Robertson, 2009). Acoustic surveys are particularly well suited for cooperative research as many commercial fishing vessels already have high quality echosounders installed (O'Driscoll and Macaulay, 2005). If a vessel has an appropriate acoustic system the costs of collecting fisheries data are low, consisting mainly of the media to record data, staff time to install and collect media from vessels, and resources to process and analyse the data (Honkalehto et al., 2005). Collecting opportunistic data from fishing vessels works well when the vessels are allowed to fish, but not at all when stocks are unavailable or closed to fishing.

This paper describes a prototype survey involving the coastal Gulf of Maine population of Atlantic herring (*Clupea harengus*) surveyed in the fall of 2012 by 10 lobster vessels which were contracted to complete dedicated acoustic transects using affordable single beam acoustic systems (Simrad ES70). Lobster vessels were used because, in aggregate, they can cover a large area compared to one research or herring vessel, they are relatively inexpensive to charter, and most importantly, the lobstermen themselves are highly motivated to contribute to sound herring management. This is because there is a strong economic linkage between the herring and lobster fisheries as herring are the preferred bait for lobster traps (Lehuta et al., 2014).

The Atlantic herring resource in the US Northeast is composed of numerous spawning components which are assessed and managed as one stock complex (NEFMC, 2011) due to mixing during the fishing season. Major assumed spawning locations include coastal Gulf of Maine (outer Penobscot Bay and eastern Maine), Jeffreys Ledge, Cape Cod/Nantucket Shoals and the northern flank of Georges Bank (Overholtz et al., 2004). Spawning also takes place off Nova Scotia (German and Browns Banks). To capture some of

* Corresponding author.
E-mail address: gsherwood@gmri.org (G.D. Sherwood).

http://dx.doi.org/10.1016/j.fishres.2015.11.011
0165-7836/

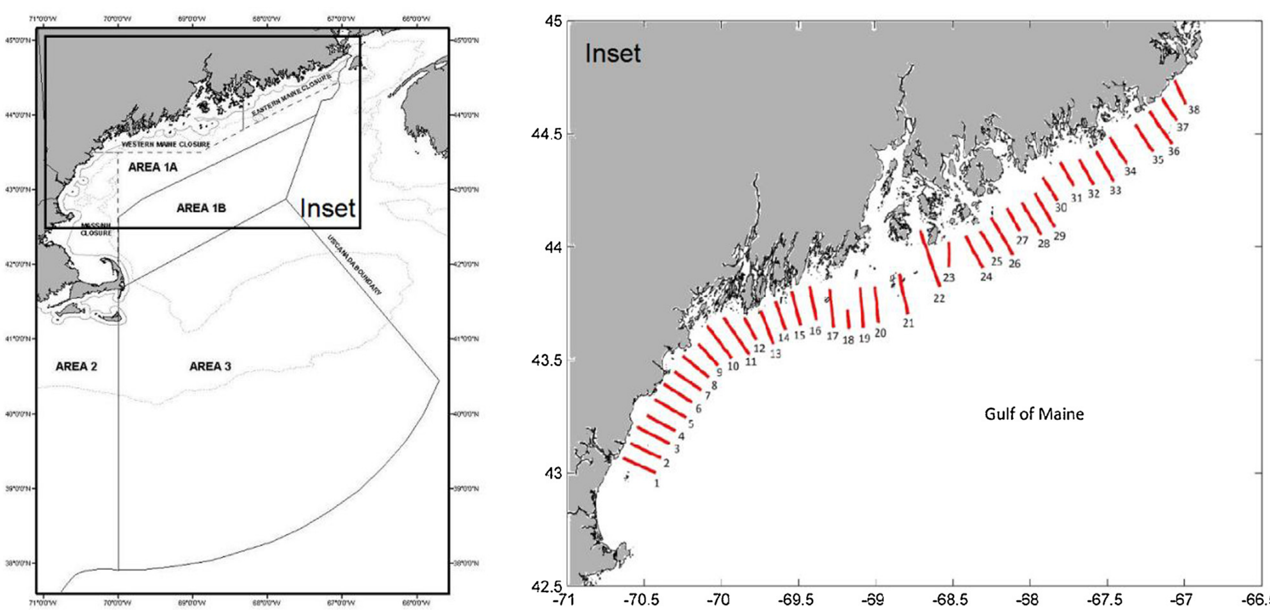

Fig. 1. Study area. Red lines indicate transect lines. Transects run from the New Hampshire/Maine border to the USA/Canadian border. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the biological complexity of the stock, annual catch limits (ACL) are allocated to sub-regions throughout New England and mid-Atlantic waters (Fig. 1). Stock-wide ACL determinations are guided by an assessment based primarily on landings and trawl survey data (NEFMC, 2010); sub-ACLs are based on assumptions about how the total spawning stock biomass segregates among spawning areas as well as practical considerations related to fishing effort distribution. Ideally, yearly sub-ACLs would match biomass trends in each area. However, there are concerns that area-based allocations of the resource may be based on inaccurate or obsolete distribution/abundance data. Providing up-to-date information on biomass trends in the inshore Gulf of Maine (Area 1A) was the primary motivation for the larger study to which this survey and paper contributes.

The spawning season is potentially the ideal time to perform a herring acoustic survey as the fish tend to be more concentrated in dense schools, making them more available to the echosounders. The coastal area is closed to fishing during the spawning season; therefore data cannot be collected opportunistically from vessels fishing for herring in the traditional manner. Scientific surveys using a bottom trawl for this species are not typically performed in Area 1A (Fig. 1), due to highly varied bathymetry and a large amount of lobster fishing gear in the water. Because of these limitations, it has been nearly 30 years since any inshore survey has been performed on the population dynamics of these fish. Despite the lack of data on herring in this area, there is a large fishery with 28–40% of the total allowable catch (TAC) for the entire stock allocated to Area 1A. Our survey filled an important data void and was unique in that it involved 10 fishing vessels distributed over the entire coast of Maine. This allowed for wide spatial coverage and was also cost effective, permitting multiple weeks of data collection. Other studies have utilised multiple research vessels to survey, such as achoveta surveys in Peru (Simmonds et al., 2009), but often lack repeat sampling within a single season. To the best of the authors' knowledge, this is the first acoustic study to employ this multitude of fishing vessels to simultaneously and systematically survey a large area on multiple occasions throughout a season. Our survey represents what may be considered a happy medium between opportunistic acoustic studies and scientific surveys as it has aspects of both which we will describe in this paper.

Table 1
Technical specifications of transducers used in calibrations. The ES70 200-kHz transducer is not included on this table as the data was flawed due to interference with the EK60 200-kHz.

	SIMRAD ES70–38-kHz	SIMRAD EK60–200-kHz
Beam pattern	12° × 20° Elliptical	7.2° Conical
Output power	1000 W	150 W
Pulse duration	0.256 ms	0.256 ms
Ping interval	500 ms	500 ms
Default system gain	17.5 dB	–

2. Methods

2.1. Study area

Acoustic data were collected from mid-September to early November of 2012 from 10 different lobster vessels along the coast of Maine. Vessel size ranged from 33′ to 44′ in length (10–13 m). The region was stratified into 10 zones to distribute effort equally along the coast. Each zone contained four transects with the exception of one zone which contained two. This resulted in 38 transects approximately evenly spaced perpendicular to the coast ranging in length from 9 to 30 nautical miles (mean 16.95 nmi) (Fig. 1). Transects were approximately 7–14 nmi apart. No transect extended past the 90 m bathymetric contour, the maximum depth for known spawning (Collette and Klein-MacPhee, 2002). The same survey tracks were performed each week over the course of 9 weeks. Unfortunately, not all vessels were able to complete the full 9 weeks due to weather, scheduling conflicts, and periodic computer malfunctions.

2.2. Data acquisition

Simrad Combi-D single-beam transducers (38 and 200-kHz) were hull-mounted on the vessels. The side of the vessel (port vs. starboard) for transducer location was on the opposite side of the vessel for the trap hauler. Specifications of the SIMRAD ES70 system are given in Table 1. All but one vessel were calibrated according to the methods described in the next section. The vessels were contracted to collect data once per week. Initially, it was planned