Westward feeding range expansion of Northeast Atlantic mackerel from 2007 to 2013: effects of temperature, zooplankton abundance and spawning stock size.

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Summary

Northeast Atlantic (NEA) mackerel (*Scomber scombrus*) is a fast swimming plankton feeding fish which occupy temperate waters of the Northeast Atlantic. Traditionally, majority of the mackerel stock feed in surface layer of the Norwegian Sea and in the North Sea (55-75°N and <6°W) during summer. An annual coordinated ecosystem survey in the Norwegian Sea and surrounding waters conducts swept area trawling in the surface layer (surface to 30 m depth), samples zooplankton from surface to 200 m, and collects CTD profiles from surface to 500 m depth. Analysis of the surface trawling indicates mackerel feeding range expanded westward by approximately 1200 km from 2007 to 2013. In 2013, western boundary of the mackerel feeding migration had entered Greenland waters (longitude 38°W). Range expansion coincided with 75 % increase in spawning stock biomass. Preliminary results suggest that the northern edge of the mackerel westward expansion, into the East Iceland Current, was limited by colder temperatures (temperatures at 10 m depth; $F_{3,218} = 29.0$, $p < 0.001$, $r^2 = 0.28$), whereas the southern edge, into the North Atlantic Current, was defined by higher temperatures and lower zooplankton abundance ($F_{3,223} = 38.6$, $p < 0.001$, $r^2 = 0.33$).

Introduction

In summer 2007, the Institute of Marine Research (IMR), Bergen, Norway, began developing a summer stock assessment survey (IESSNS) for the NEA mackerel stock. During the summer feeding season majority of mackerel is located in the surface 30 m (Diaz, 2013) where they feed on zooplankton, fish larvae and small fish. Furthermore, mackerel have weak acoustic signal due to their lack of a swim bladder. Therefore, the IESSNS survey is employs surface trawling as a method to estimate annual mackerel index. Much effort has been used to standardize the surface trawl used and associated rigging, the method of trawl employment and monitoring of trawl performance (ICES, 2013). The Faroe Marine Research Institute and the Marine Research Institute joined the IESSNS survey in 2009. The general survey design are transects running east to west, and distance between sampling stations is approximately 60 nautical miles. At each IESSNS station a surface trawl is employed and environmental variables measured, zooplankton abundance (surface to 200 m) and temperature measured (surface to 500 m). Development of the IESSNS survey has coincided with expanding summer feeding range of mackerel. Mackerel summer feeding range expansion began in 2006 (Astthorsson *et al.*, 2012), and, in 2013, their range had expanded westward by approximately 1500 km. We explored three hypotheses regarding the observed summer feeding range expansion of mackerel, namely, that increasing temperatures in the western newly occupied feeding area facilitated westward expansion, or that increasing zooplankton abundance in the western area facilitated expansion. Finally, we explored a density dependant hypothesis which predicts mackerel summer feeding range to expand during a period of increasing stock size.

Materials and Methods

The IESSNS survey has been conducted annually during a 5-week time frame in July and early August since 2007. Unfortunately, the IESSNS survey was reassigned to a salmon research project in 2008 and 2009, hence, there are no usable mackerel data for these two years. For the period, 2007 and from 2010 to 2013, a total of 1007 surface trawl stations have been collected in the Norwegian Sea, and within Faroes, Icelandic and Greenland economic exclusion zones (Fig.1a-e). Of the 1007 stations, approximately 80 % had mackerel present. Goal of IESSNS is to cover the whole mackerel summer feeding range, hence, located the migrating edge (zero boundaries). However, continually expanding mackerel range and fixed survey time have prevented locations of mackerel zero boundaries for the whole distribution area. Zero boundaries are routinely located north and south of Iceland whereas zero boundaries, both to the north and the south, in the Norwegian Sea have proven elusive. Standardization of IESSNS survey trawl and trawl employment methods were developed over several years. Beginning in 2012, all vessels have used the same trawl (Multpelt832) and same method of employment (30 min. trawl time; trawl headline visible at surface and footrope at 30 m depth). Same methods have been used for

zooplankton sampling and temperature measurements from 2007 to 2013. For zooplankton sampling a WP2 sampler (mesh size 180 µm or 200 µm) is towed vertically from 200 m depth to surface. Temperature is continually recorded using a CTD from surface to 500 m depth.

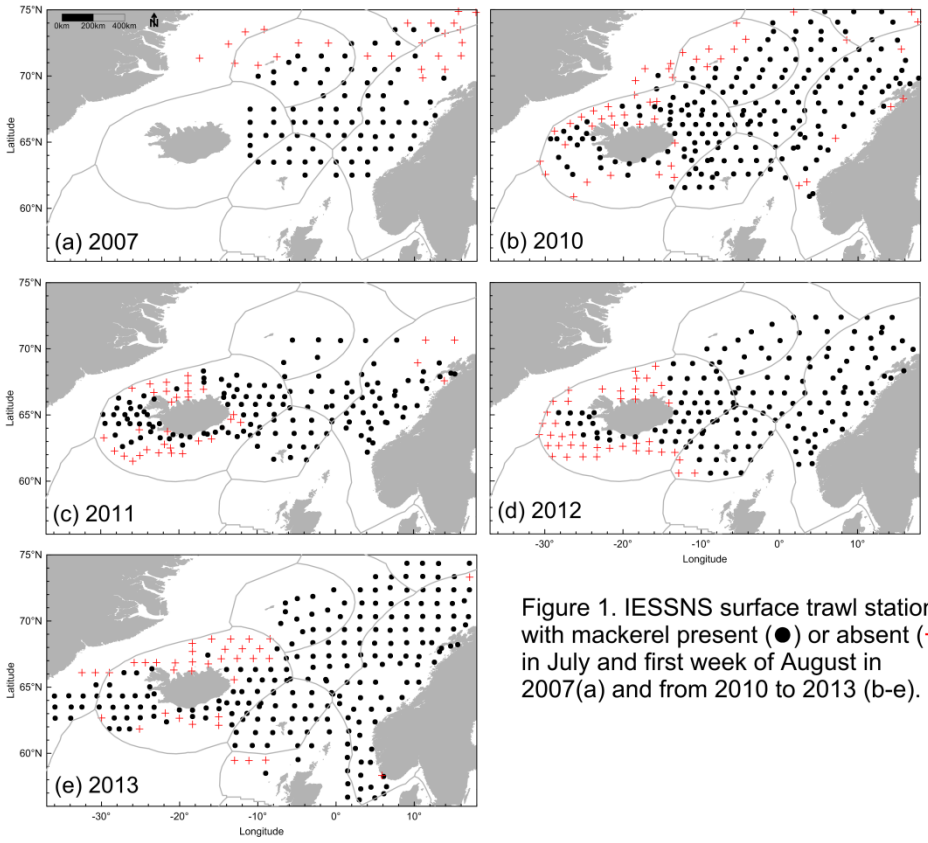

Figure 1. IESSNS surface trawl stations with mackerel present (●) or absent (+) in July and first week of August in 2007(a) and from 2010 to 2013 (b-e).

Results and Discussion

Mackerel summer feeding range expansion from 2007 to 2013 coincided with 75 % increase in spawning stock biomass (SSB, ICES, 2014). Temperature data from IESSNS surveys do not indicate that increasing temperatures have caused summer feeding range expansion as cumulative frequency distribution of stations with mackerel present has not shifted towards warmer temperatures from 2007 to 2013 (Fig. 2). Preliminary results suggest that the northern edge of the mackerel westward expansion, into the East Iceland Current, was limited by colder temperatures (temperatures at 10 m depth; $F_{3,218} = 29.0$, $p < 0.001$, $r^2 = 0.28$), whereas the southern edge, into the North Atlantic Current, was defined by higher temperatures and lower zooplankton abundance ($F_{3,223} = 38.6$, $p < 0.001$, $r^2 = 0.33$). In conclusion, results of preliminary analyses suggest that summer feeding range expansion of NEA mackerel could be correlated to increasing SSB. Furthermore, mackerel distribution into the East Iceland current is limited by unfavourably cold temperatures whereas low zooplankton abundance limits distribution into the Irminger Seas south of Iceland. Therefore, this study suggests westward feeding migration expansion into Greenland waters is the most favourable summer feeding grounds for NEA mackerel.

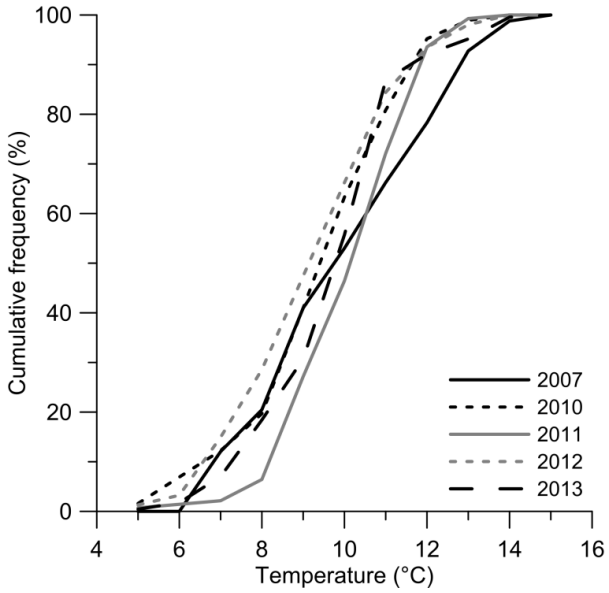

Figure 2. Cumulative frequency distirbution for temperature (at 10 m depth) for trawl stations where mackerel was present from 2007, and from 2010 to 2013.

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