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Operational fisheries in New England: Linking current fishing patterns to proposed ecological production units

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ABSTRACT

The Northeast US continental shelf has a rich tradition of commercial fishing. These fisheries have been managed using single species/stock assessments. Recently, there has been a movement toward a more holistic ecosystem-based management approach. This ecosystem-based approach is a departure from traditional single species management in that both spatial and multispecies considerations are paramount. To facilitate the place-based aspect of ecosystem-based management, management units are being established that take account of oceanographic, biological, and socio-economic properties. Here, we define operational fisheries for this region on the basis of landings composition by gear type and the spatial and temporal dimensions associated with them. Using vessel trip catch reports of New England commercial fishing vessels operating during 2004–2008, we defined operational fisheries using k-means clustering. The landings data from these vessels were assembled by ten minute latitude/longitude rectangles and segregated by six major gear types: otter trawls, dredges, pots, longlines, gillnets, and seines. The seasonality of each fishery was examined, as was the vessel sizes and their species catch composition. Patterns of resource usage were detected that will be useful in identifying appropriate ecosystem-based management units.

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1. Introduction

The waters off the coast of New England have historically contained some of the most productive fisheries in the world. Although species are managed independently under the provisions of the Magnuson–Stevens Fishery Conservation and Management Act (MSFCMA; last reauthorized and amended in 2006), a majority of the fisheries are multispecies in nature. The management challenges posed by multispecies fisheries prosecuted using non-selective fishing gear have long been recognized. In a prescient review, McHugh (1959) suggested that successful single species management would be difficult or impossible in the multispecies fisheries of this region (see McHugh (1988) for an updated perspective). McHugh instead argued for management targets based on total biomass of the harvested fish community rather than for individual species or stocks. Murawski (1991) further considered interspecific (competition and predation) and fishery (by-catch) interactions within the harvested fish community as well as impacts on threatened and endangered species taken incidentally in fishing gear in assessing management options in a multispecies context.

The recently developed U.S. National Ocean Policy (WHCEQ, 2010), establishes an overall framework for Ecosystem-Based Management (EBM) as the guiding principle in ocean resource management for the nation. Contained within this multi-sectoral approach is Ecosystem-Based Fisheries Management (EBFM). EBFM departs from single species management by attempting to incorporate interactions among the various components of the ecosystem to achieve sustainability (Botsford et al., 1997; Christensen et al., 1996; FAO, 2003; Larkin, 1996; Sissenwine and Murawski, 2004). This includes but is not limited to accounting for tropic interactions, by-catch, as well as physical forcing. Under EBFM, humans are treated as part of the ecosystem rather than an outside influence (Larkin, 1996) and allows managers to address tradeoffs between multiple interests (Link, 2010).

Ecosystem-based fisheries management is inherently place-based, managing all species within a defined area collectively (Christensen et al., 1996; Lackey, 1998). To this end, management units, or ecological production units (EPU), are defined by oceanographic, biological, and socio-economic properties. Recently, four EPUs have been developed for the Northeast United States Continental Shelf Large Marine Ecosystem (NES LME): the Mid-Atlantic, Georges Bank, Gulf of Maine, and Scotian shelf. They are based on physiographic and oceanographic variables and consideration of primary production (Fogarty et al., submitted for publication). Three of the units fall within US jurisdiction (Gulf of Maine, Georges Bank, and Mid-Atlantic) and have been historically considered

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sub-regions of the NES LME (Clark and Brown, 1977). Ultimately, the success of EBFM will be tied to the involvement and buy-in of stakeholders. To be successful, the EPUs need to define sustainable fishing practices while at the same time simplifying regulations. Therefore, they need to not only incorporate the biological and physical structure of the system, but also be the appropriate scale for the structure of the fishing community (Hilborn, 2004).

For the purpose of this paper, we define community in terms of operational fisheries. We define operational fisheries as spatial units where commercial fishermen are using similar gear to catch a similar mix of species. Murawski et al. (1983) delineated operational fisheries for the otter trawl fleet of New England by grouping spatial and temporal units that exhibit similar species compositions in the catch. Here, we conduct similar analyses on six major gear categories using updated catch records. Our goals were to identify operational fisheries in the NES LME and relate them to proposed EPUs to be used for EBFM.

2. Methods

Operational fisheries were determined using landings data from vessels operating primarily out of New England ports. Under federal regulations, commercial vessels are required to submit vessel trip reports (VTRs) that record the species caught and area fished. VTR data are maintained by the Northeast Regional Office of the National Marine Fisheries Service. VTR provides the only synoptic data for areas fished. Although there are known issues with the self-reported data, there are routine auditing procedures as well as entry protocols and compliance reviews in place (Palmer and Wigley, 2009; Rago et al., 2005; Wigley et al., 2008). Data from the commercial clam industry are maintained in a separate database, but were merged prior to analysis. To reflect recent trends in fishing patterns, data were drawn from 2004 to 2008 for this analysis. This time frame allowed for enough data to conduct the cluster analyses. We acknowledge recent changes in the fishing regulations, in particular with respect to New England Multispecies Fishery Management Plan (FMP). Because of the ever changing nature of fisheries management, this analyses will need to be periodically revisited.

Landings data were combined into specific spatial and temporal units based on fishing gear: otter trawl, dredge, gillnet, pot, longline, and seine. These categories are similar to those established by the Food and Agriculture Organization (FAO, 2005). Landings data by gear types that did not fall into any of the six categories were omitted from the analysis (11% of all VTR records).

Landings data were further segregated within each gear category prior to clustering. Empirical evidence suggests that the size of a vessel influences their fishing patterns with smaller vessels conducting shorter trips than larger vessels. Because of this, landings were further divided by vessel size. Small vessels were designated as those with a gross registered tonnage less than or equal to 150 tonnes, while large vessels were designated as those with a gross registered tonnage of greater than 150 tonnes. We also segregated the landings by quarter year blocks (January–March, April–June, July–September, and October–December). This allowed us to detect differences in resource use throughout the year.

Once categorized by gear, vessel size, and quarter year, the relative proportion of landed species was determined within specific spatial units. The smallest resolution that can reliably be used from VTR data is a grid of ten minute latitude by ten minute longitude squares. This is the same spatial resolution that was used to determine the EPUs (Fogarty et al., submitted for publication). The weights of individual species were summed from VTRs within each ten minute square and converted to percentages. We then arc sine transformed the data which is standard for proportional data (0–1).

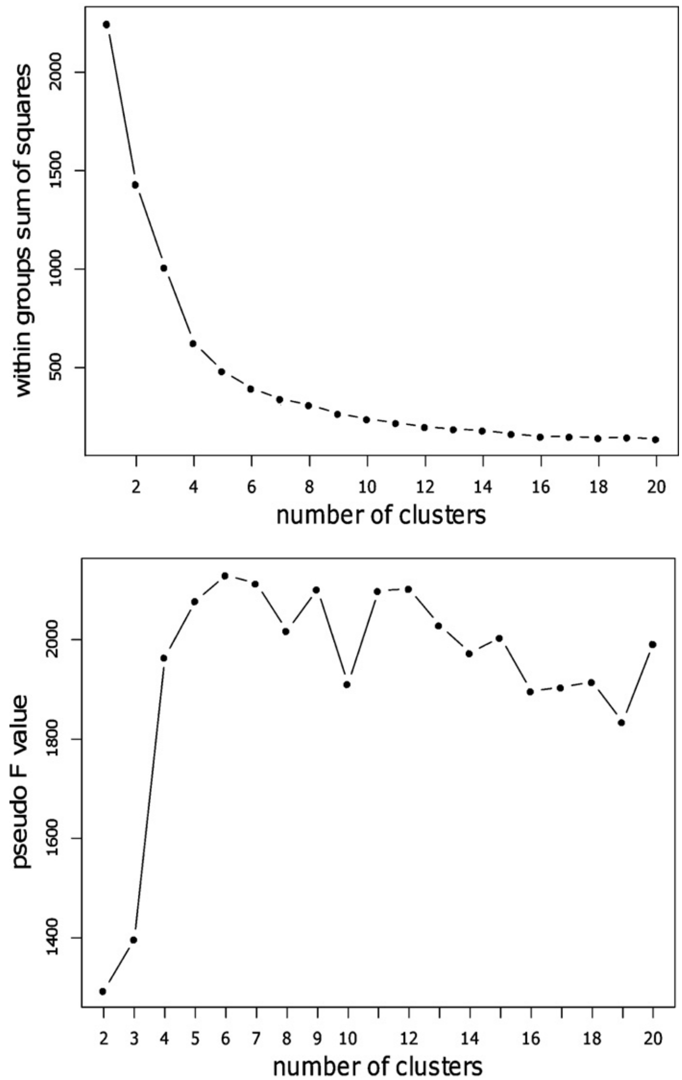

Fig. 1. Example of a scree plot (upper) and pseudo-F plot (lower) used to determine the optimal number of clusters for k-mean cluster analysis. This example is from the pot gear category. The optimal number of clusters was determined to be 6.

Operational fisheries for each gear category were determined using a k-means clustering algorithm, *kmeans*, in the base package of R (version 2.11.1, R Foundation for Statistical Computing). k-Means cluster analysis is a reliable method of objectively defining the underlying cluster structure. It is less affected by outliers in the data than hierarchical clustering methods and with comparable or superior performance (Milligan, 1996). The analysis starts with K centroids. It then assigns each object to the nearest seed and iteratively re-evaluates the centroid to minimize the total error sum of squares (Legendre and Legendre, 1998).

A crucial step in k-means cluster analysis is the determination of the appropriate number of clusters (Milligan, 1996). The number of clusters for each gear type was determined via agreement between two different methods. In the first method, we plotted the cumulative within groups sum of squares with the optimal number of clusters being determined by the position of the inflection in the plot (Fig. 1). The second method was the Calinski and Harabasz pseudo-F statistic (function *index.G*1 from the package clusterSim in R). The optimal number of clusters is determined by the local maximum of this statistic (Fig. 1). In cases where the two were in disagreement, the number of clusters was determined by