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Fine-scale spatial patterns in the demersal fish and invertebrate community in a northwest Atlantic ecosystem

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ABSTRACT

The abundance, biomass, diversity, and species composition of the demersal fish and invertebrate community in Rhode Island Sound and Block Island Sound, an area identified for offshore renewable energy development, were evaluated for spatial and seasonal structure. We conducted 58 otter trawls and 51 beam trawls in the spring, summer and fall of 2009–2012, and incorporated additional data from 88 otter trawls conducted by the Northeast Area Monitoring and Assessment Program. We used regionally-grouped abundance, biomass, diversity, and size spectra to assess spatial patterns in the aggregate fish community, and hierarchical cluster analysis to evaluate trends in species assemblages. Our analyses revealed coherent gradients in fish community biomass, diversity and species composition extending from inshore to offshore waters, as well as patterns related to the differing bathymetry of Rhode Island and Block Island Sounds. The fish communities around Block Island and Cox's Ledge are particularly diverse, suggesting that the proximity of hard bottom habitat may be important in structuring fish communities in this area. Species assemblages in Rhode Island and Block Island Sounds are characterized by a combination of piscivores (silver hake, summer flounder, spiny dogfish), benthivores (American lobster, black sea bass, *Leucoraja* spp. skates, scup) and planktivores (sea scallop), and exhibit geographic patterns that are persistent from year to year, yet variable by season. Such distributions reflect the cross-shelf migration of fish and invertebrate species in the spring and fall, highlighting the importance of considering seasonal fish behavior when planning construction schedules for offshore development projects. The fine spatial scale (10 s of kms) of this research makes it especially valuable for local marine spatial planning efforts by identifying local-scale patterns in fish community structure that will enable future assessment of the ecological impacts of offshore development. As such, this knowledge of the spatial and temporal structure of the demersal fish community in Rhode Island and Block Island Sounds will help to guide the placement of offshore structures so as to preserve the ecological and economic value of the area.

1. Introduction

An ecosystem-based approach to management is essential to attain system-wide sustainability and to ensure the continued availability of marine resources that humans want and need (McLeod et al., 2005; Pauly and Chuenpagdee, 2007). Designing an effective ecosystem-based management plan requires a comprehensive understanding of the distributions, population structures, interactions and trends of local fish and invertebrate species. Such detailed information, however, is rarely available even in the most well-studied ecosystems (Cury et al., 2005).

Recent interest in offshore energy development combined with the ongoing need to assess the status of overfished groundfish species has focused attention on ecosystem-based spatial management planning in the Rhode Island's offshore waters. The broad-scale (100 s of km) distribution of fish species in this area is well-documented by standardized trawl surveys (Gabriel, 1992; Jordaan et al., 2010). However, spatial management is often implemented at smaller scales (Collie et al., 2013), requiring knowledge of fish distributions and fish-habitat associations at 10-km scales (Smith et al., 2013).

Rhode Island Sound and Block Island Sound separate the estuaries of Narragansett Bay and Long Island Sound from the outer continental shelf (Fig. 1). As such, they provide important

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linkages between near-shore and offshore processes, including nutrient fluxes, larval transport, and migration of the adult stages of resource species, such as the American lobster (*Homarus americanus*) and winter flounder (*Pseudopleuronectes americanus*) (Costa-Pierce, 2010). Furthermore, Rhode Island Sound and Block Island Sound support a variety of commercial and recreational fishing activities, such as scallop dredging, otter trawling, long-lining and gill-netting, producing over $60 million in seafood landings in Rhode Island every year (Smythe and Beutel, 2010; Hasbrouck et al., 2011). Despite their heavy use and close proximity to a number of marine science institutions, Rhode Island and Block Island Sounds have been neglected in terms of scientific research, resulting in a poor understanding of the distribution and dynamics of the fisheries resources in this area.

Studies to support the management of the Rhode Island's offshore waters have become a priority since 2000, when interest in developing artificial reefs, aquaculture sites, and offshore wind turbines emerged in this region. Combined with traditional fisheries and existing dredge-disposal sites, these multiple uses require integrated spatial management planning to site activities in appropriate habitats that will minimize, to the extent possible, the cumulative impacts on resident species and the ecological and economic services derived from this near-shore region (Gilliland and Laffoley, 2008; Crowder and Norse, 2008; Foley et al., 2010). Since 2008, the Rhode Island Coastal Resources Management Council has taken the lead to develop a spatial management plan for Rhode Island and Block Island Sounds (RI SAMP, 2010). But, while a general understanding of the ecology of Rhode Island Sound and Block Island Sound exists, there is a lack of site-specific data to guide spatial management planning (Mahon et al., 1998; Costa-Pierce, 2010; Hale, 2010). Compounding the challenge, this spatial planning process is being conducted against a background of changing coastal climate (Nixon et al., 2009; Nye et al., 2009). As a result, historical baseline data may no longer represent current conditions (Collie et al., 2008).

We aimed to address these challenges by conducting comprehensive sampling of the demersal fish and invertebrate community in Rhode Island Sound and Block Island Sound. In particular, we sought to: 1) evaluate the spatial structure of the demersal fish community in Rhode Island and Block Island Sounds, and 2) determine whether intra- or inter-annual variations in the composition of these communities exist. This information can then be used to assess the potential impacts of offshore development and climate change in Rhode Island's offshore waters (Punt et al., 2009; BSH, 2013).

2. Methods

2.1. Study area

The study area, encompassing Rhode Island Sound and Block Island Sound, is located on the inner continental shelf in the northwest Atlantic (Fig. 1). This area is seasonally dynamic, with sea surface temperatures ranging from 2 °C in the winter to 25 °C in the summer, and primary production ranging from 59 mgC m^{-2} d^{-1} in the winter to 1738 mgC m^{-2} d^{-1} in the spring (Ullman and Codiga, 2010; Nixon et al., 2010). There are three major bathymetric features in Rhode Island Sound and Block Island Sound: 1) Block Island, a 25 km^2 island that lies in the center of Block Island Sound, 2) Cox's Ledge, an expansive rocky shelf in southeast Rhode Island Sound, and 3) Southwest Ledge, an abrupt rocky shoal southwest of Block Island (Fig. 1). Water depth ranges from 0 to 65 m, with this work sampling from 10 m depth inshore and around Block Island to 55 m depth offshore. Rhode Island and Block Island Sounds lay within the Northeast Shelf Large Marine Ecosystem, and mark the biogeographic boundary between Virginean and Acadian regions (Cook and Auster, 2007, Costa-Pierce, 2010). As such, Rhode Island

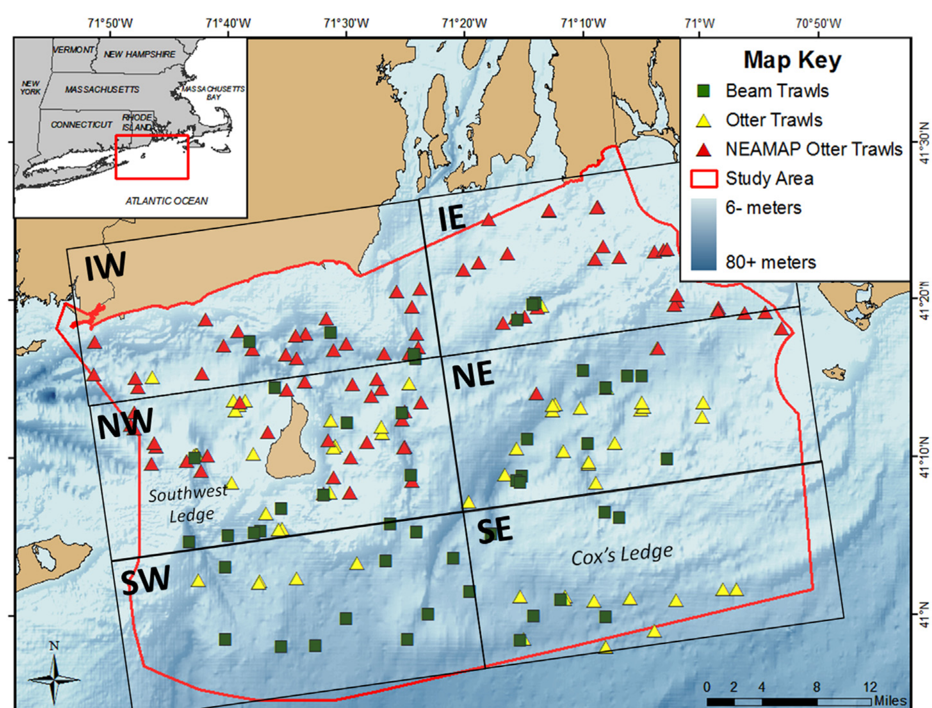

Fig. 1. Map of the study area showing location of trawls conducted from 2009 to 2012 and delineation of subsections. IW = Inshore West, IE = Inshore East, NW = Nearshore West, NE = Nearshore East, OW = Offshore West, OE = Offshore East. The red boundary delimits the Rhode Island Ocean Special Area Management Plan. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)