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Fish assemblages in a north Atlantic coastal ecosystem: Spatial patterns and environmental correlates

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ABSTRACT

Analyses of six years of bottom trawl data collected from Northumberland Strait, southern Gulf of St. Lawrence revealed four major fish assemblages, two of which occurred in the same two geographic areas each year. One of the two persistent assemblages occurred in deeper water off northwestern Prince Edward Island and consisted mostly of demersal fishes. The other persistent assemblage contained a mixture of demersal and pelagic fishes and occurred primarily in shallow water of central Northumberland Strait. Analyses of abiotic (depth, bottom temperature, substratum type) and biotic (presence of American lobster *Homarus americanus*, northern lady crab *Ovalipes ocellatus*) factors revealed bottom temperature and catches of lady crab correlate best with the fish assemblage structure each year, but correlation values were low ($\rho_w \leq 0.48$). Combinations of all abiotic and biotic variables only marginally improved the strength of the correlations in four of six years (2002, 2003, 2005, 2006). Changes observed in the Northumberland Strait ecosystem over the six years included an increase in the ratio of pelagic to demersal fishes, disappearance of one of the four assemblages, and increased spatial overlap between the two persistent assemblages, which coincided with an increase in bottom temperature. The increasing importance of pelagic fishes, relative to demersal fishes, suggests a shift in food web structure may be occurring in Northumberland Strait.

1. Introduction

Continental shelf ecosystems of the north Atlantic and throughout the world have experienced changes in community structure due to habitat destruction (Collie et al., 2005) and overfishing (Hutchings and Myers, 1994). Changes in community structure include reduced abundance of top predators (Myers and Worm, 2003), such as Atlantic cod (*Gadus morhua*) (Bundy, 2001). Reduced abundance of top predators is typically associated with declines in mean lengths and weights of the population (Hanson and Chouinard, 1992; Haedrich and Barnes, 1997), contractions in the distribution of the population (Swain and Wade, 1993), and changes in trophic structure of the entire ecosystem (Bundy, 2005). Declines in abundance of top predators can result in increased abundance at lower trophic levels due to the cascading effects of prey released from predation (Frank et al., 2005; Myers et al., 2007). Increased abundance of smaller prey, often pelagic fishes such as Atlantic herring (*Clupea harengus*) and capelin (*Mallotus villotus*), can trigger a subsequent decrease in zooplankton, an important food of many small pelagic fishes, and an increase in phytoplankton (Bundy, 2005; Frank et al., 2005). Trophic cascades can shift an entire ecosystem from one state to another, however it is uncertain whether the shift can be reversed (Frank et al., 2005; Scheffer et al., 2005).

As the loss of exploitable fisheries resources continues in aquatic ecosystems, more researchers have emphasized the need for an ecosystem-based approach to fisheries management (Grumbine, 1994; Tolimieri and Levin, 2006). A goal of ecosystem-based management is to maintain the structure and function of the entire ecosystem by recognizing relationships among species and the environment in addition to maintaining a sustainable yield of commercial species (Mabee et al., 2004; Babcock et al., 2005). A first step in the complex process of ecosystem management is to search for patterns underlying ecosystem structure and dynamics by describing species abundance and distribution and identifying assemblages (Mahon and Smith, 1989; Gomes et al., 1992; Tolimieri and Levin, 2006). Assemblages are groups of species that co-occur due to factors such as biological interactions (e.g. predation) or due

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to similar responses to the environment (Capone and Kushlan, 1991; Jaureguizar et al., 2003). Once persistent assemblages have been identified, a next step is to identify abiotic and biotic variables that may be responsible for structuring the observed fish assemblages (Gaertner et al., 1999; Jaureguizar et al., 2004).

Studies on fish assemblages are made possible by the increasing number of large data sets available from long term research vessel surveys (Gomes et al., 2001). These surveys typically occur at the same time of year and cover the same area, and are most often conducted by government scientists to determine annual change in abundance, size- and age-structure of commercially important fishes. In the northwest Atlantic, these surveys are typically conducted by large research trawlers operating far from shore on the continental shelf and slope waters (e.g. Hurlbut and Clay, 1990). The few shoreline surveys appear to be largely restricted to waters up to a few metres in depth and are conducted using a beach seine (e.g. Lekve et al., 1999; Methven et al., 2003); however, there is relatively little survey effort directed towards sampling fish in coastal waters of intermediate depths (c. 4–40 m), a habitat that is not accessible to large research vessels. These coastal waters can be highly productive and provide nursery, feeding, and spawning grounds for numerous fish species and important decapod crustaceans (Jaureguizar et al., 2004; Hanson, 2009).

Since 2000, a bottom trawl survey has been conducted during July–August in the intermediate-depth coastal waters of Northumberland Strait (Hanson, 2001; Voutier and Hanson, 2008). Northumberland Strait is part of the southern Gulf of St. Lawrence ecosystem that has undergone a major shift in trophic structure from one dominated by large predatory demersal species (e.g. cod, white hake *Urophycis tenuis*, haddock *Melanogrammus aeglefinus*) and planktivorous pelagic species (e.g. capelin, herring, mackerel *Scomber scombrus*) in the mid-1980s to one dominated primarily by planktivorous pelagic species and seals in the mid-1990s (Savenkoff et al., 2007; Morissette et al., 2009). Objectives of our study were to: 1) describe the structure of the fish assemblages in Northumberland Strait; 2) determine if assemblages are persistent in terms of species composition, abundance, and location from year to year; and 3) determine if any available information on abiotic (e.g. depth, bottom temperature, substratum type) and biotic (e.g. catches of American lobster *Homarus americanus* and northern lady crab *Ovalipes ocellatus*) variables are correlated with the observed Northumberland Strait fish assemblage structure.

2. Materials and methods

2.1. Study area

The Gulf of St. Lawrence off eastern Canada is a semi-enclosed sea connected to the Atlantic Ocean through the Strait of Belle Isle and Cabot Strait, and to the Great Lakes by the St. Lawrence River (Loring and Nota, 1973; Koutitonsky and Bugden, 1991) (Fig. 1). It is approximately 226,000 km^2 with a mean depth of 152 m (Dickie and Trites, 1983). The Gulf is thermally stratified during summer with a warm surface layer (15–20 °C, c. 30 m deep), intermediate cold layer (<1 °C, 100–120 m deep), and a deep warmer layer (4–6 °C, >150–200 m deep) (Koutitonsky and Bugden, 1991; Gilbert and Pettigrew, 1997). Prevailing surface currents flow in a counterclockwise direction, with a major source of fresh water provided by the St. Lawrence River (Dickie and Trites, 1983).

Northumberland Strait is a shallow channel within the southern Gulf of St. Lawrence separating Prince Edward Island (PE) from eastern New Brunswick (NB) and northern Nova Scotia (NS) (Fig. 1). Northumberland Strait is over 200 km long and 15 to 30 km wide (Dickie and Trites, 1983), with maximum depths of about 20 m in the central portion and 40 m in the western and eastern ends (Voutier and Hanson, 2008). Bottom water temperatures can exceed 20 °C in summer (Voutier and Hanson, 2008). Temperatures are warmest in the central Strait and cooler towards the west and east during summer. Residual surface currents typically flow from west to east during summer months, although transient eddies occur at both ends (Kranck, 1971; Dickie and Trites, 1983; Koutitonsky and Bugden, 1991). An amphidromic point, a point where the tidal range is zero (Thurman, 1988), occurs near the western end of the Strait, off Buctouche, NB (Farquharson, 1970; Koutitonsky and Bugden, 1991). Tidal currents are stronger in the west (>1.9 km h^{-1}) than in the central and eastern portions (<0.9 km h^{-1}) (Kranck, 1971). Differences in tidal currents result in a variety of sediments with coarse gravel and sand mix in the western end and fine mud, clay and silt mixes in the eastern end (Kranck, 1971).

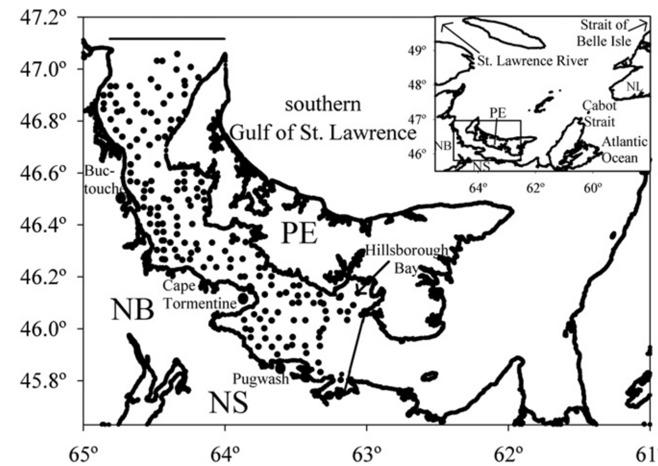

Fig. 1. Location of Northumberland Strait sampling area examined in this study (between the two solid lines) with the location of sites sampled in 2001 (n = 167). Number of sites sampled varied from 139 to 189 from 2001 to 2006. Place names mentioned in the text are included. NB = New Brunswick; NS = Nova Scotia; PE = Prince Edward Island; NL = Newfoundland.

2.2. Sampling

Data were collected from an annual bottom trawl survey conducted by Fisheries and Oceans Canada in the western and central portions of Northumberland Strait (Fig. 1) during July and August 2000 to 2006 aboard the 18.2 m research trawler CCGV *Opilio*. Data collected in 2000 were excluded because a different bottom trawl was used. Sampling sites were selected randomly each year from a grid containing over 1000 permanent stations positioned 3.7 km apart (Voutier and Hanson, 2008). Number of sites sampled varied each year (n = 167, 2001; n = 139, 2002; n = 167, 2003; n = 185, 2004; n = 140, 2005; n = 189, 2006) due to weather conditions and ship time. Sampling generally proceeded from west to east to avoid gear conflicts with the August to October lobster fishery. Depths sampled ranged from 4 m (shallowest depth at which the vessel could operate) to 40 m (maximum depth in the study area).

A No. 286 otter trawl with rockhopper footgear was used to sample fishes and invertebrates. This bottom trawl had a wingspread of 14.8 m, a height of 1.8 m and headrope and footrope lengths of 17.7 m and 22 m respectively. The mesh size was 140 mm diamond mesh throughout (double twine mesh in the belly, extension piece and codend) with a 19 mm liner in the codend (Hanson, 2001; Voutier and Hanson, 2008). The net width averaged (±95% CI) 9.0 ± 0.16 m (n = 149) (Voutier and Hanson, 2008). At each sampling site (fishing station) the net was towed at a speed of approximately 4.6 km h^{-1} for 15 min. Sampling was done during