



Gadids and Alewives: Structure within complexity in the Gulf of Maine

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ABSTRACT

The collapse of Atlantic cod (*Gadus morhua*) along the northern 240 km of New England's historically productive coastal shelf has continued for nearly twenty years. Resident spawning groups and their sub-populations have disappeared and have yet to recover, causing local groundfish fisheries to collapse. Three additional gadid species, haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), and white hake (*Urophycus tenuis*) collapsed along the northern coastal shelf during the same period, raising concerns that their resident coastal groups were part of a metapopulation and may have also been lost. Analysis of their distribution and movements in the 1920s appeared to corroborate this. The four gadids had clusters of resident coastal groups along the coastal shelf that coexisted in the same area. Cod, white hake and pollock appeared to exhibit metapopulation characteristics, having resident and migrating components distributed along the coast in three different areas, with migrating components arriving and leaving along common migration routes fall when alewives left. The groups were centered near rivers with alewife spawning runs and disappeared from the area during the 1950s after alewives (*Alosa pseudoharengus*) declined locally. The results suggest that large, stable concentrations of young-of-the-year alewives were a factor in where resident and migrating gadid groups were located.

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1. Introduction

Fishermen have depended on landings of Atlantic cod (*Gadus morhua*) and other gadid species, including haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), and white hake (*Urophycus tenuis*) throughout New England's rich history of groundfishing. While the majority of these landings came from the Gulf of Maine (GOM)'s offshore banks, a significant portion of the catch came from inshore grounds along New England's coastal shelf. Landings there have varied greatly, both spatially and temporally, and while inner grounds have long been abandoned, gadids have continued to be available on grounds somewhat farther offshore. That is no longer true along New England's northern coastal shelf. Approximately 20 years ago cod and three other gadids became depleted throughout the area, raising concerns why such radical changes in their spatial distribution had occurred (NOAA 2010 and earlier reports in the series).

A Gulf of Maine-wide (GOM) tagging study for Atlantic cod completed in 2007 (Tallack, 2007) concluded that a progressive recovery was underway in some areas, but cod were recovering

very slowly if at all along the northern 240 km-long coastal shelf between Casco Bay and Canada. When the results were displayed with the Androscoggin-Kennebec, Penobscot and St. Croix watersheds, the depleted area with the fewest tag returns closely fit the entire section of coastal shelf bordering the watersheds (Fig. 1). Groundfish surveys by Maine Department of Marine Resources found juveniles of cod and other gadids in this area, but very few adults were present (Sherman et al., 2004–2010), corroborating the tagging study results. The depleted area represents the northern third of New England's coastal shelf.

The purpose of this study has been to examine the historical distribution of the four gadids among fishing grounds and to track their seasonal movements by following shifts of fish concentrations (movements) among grounds in the immediate vicinity of the previous season's location. Specific issues addressed include identifying which of the four gadids had coastal groups, where those groups were located and whether there was evidence of common population structures and shared migration corridors; second, comparing the seasonal shifts of individual gadids among fishing grounds with that of other gadids and third; assessing whether their movements appeared to be linked to alewife predation. Finally, were differences in the availability of clupeid prey along the northeastern coastal shelf a factor in the continued depletion of northeastern GOM?

The study examined fishermen's observations gathered during the 1920s about the distribution and abundance of the four gadids

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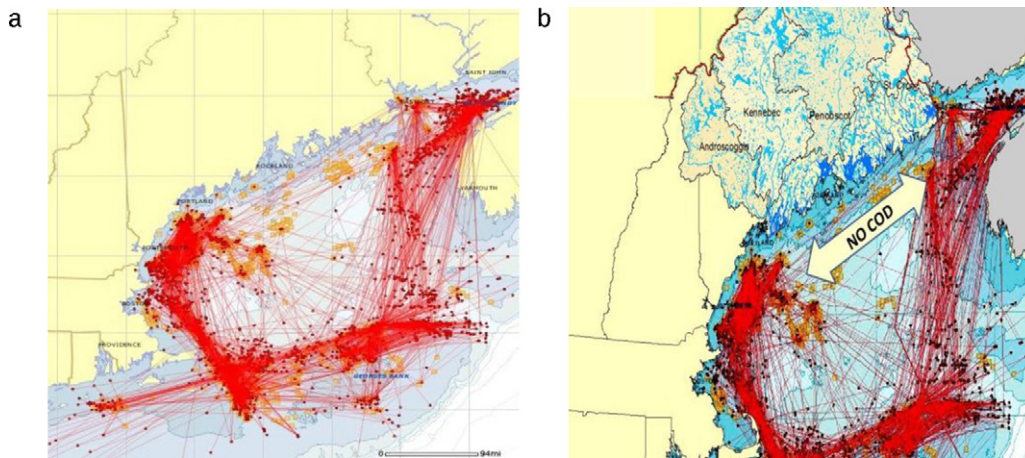


Fig. 1. (a) The results of the recently completed Gulf of Maine Research Institute Cod Tagging Study (Tallack, 2007). Tan squares are tagging sites, red dots are tag recapture sites and red lines connect the two. (b) The results of the GMRI cod tagging project in 2007 and Maine's major watersheds. Note the absence of cod between the Kennebec–Androscoggin River and the St. Croix River. Tan squares = tagging site, red dots = recapture site and red lines connect the two. The arrow stating “No Cod” has been added to identify the area having minimal tag returns. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

on coastal fishing grounds during a period when gadids were more abundant (Rich, 1929).

2. Methodology

The study area included that part of the GOM enclosed by a line extending due east from Highland Heights, Cape Cod, MA lying north of a line extending east from Highlands Light, Cape Cod (42° N, 70° W) to Wrights Swell, then to Yarmouth, N.S. ($43^{\circ}50'$ N, $6^{\circ}07'$ W) (Fig. 2), an area similar to that used previously to determine the population structure of 1920s and 1930s Atlantic cod (Ames, 2004) and white hake (Ames, 2011). A smaller area (Fig. 2) in Midcoast Maine was used to examine gadid movement patterns for indications of predator–prey interactions near Muscongus Bay. The small 10 km-wide bay receives two secondary rivers, the Damariscotta and St. George Rivers that had documented landings of alewives during the 1920s (Hall et al., 2011; Spencer, 2006). Unlike most

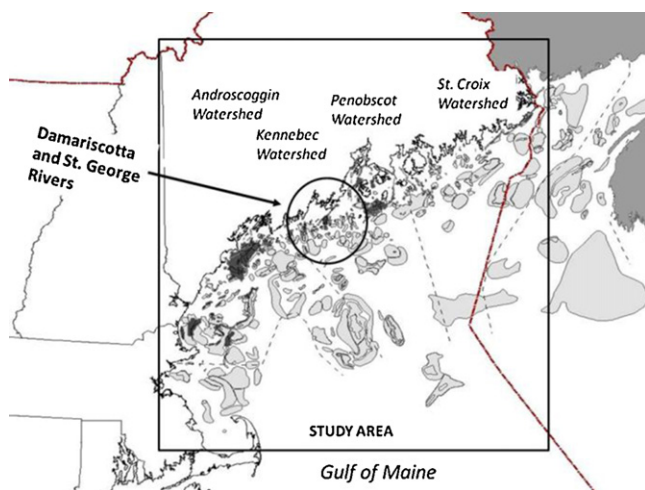


Fig. 2. The Gulf of Maine (GOM) study area. The insert shows the location of the gadid predation study at Muscongus Bay. Historical fishing grounds = grey areas, historical cod and haddock spawning areas = black. The circled area encloses the Damariscotta and St. George Rivers where predation by the four resident gadid groups was studied. Black dashed lines separate migration corridors of historical cod subpopulations (Ames, 2004).

other rivers in New England, the Damariscotta and St. George Rivers remained open to alewives throughout the 20th century (Fig. 2).

The following definitions were used to evaluate population structure (Smedbol and Stephenson, 2001):

- A population is defined as a self-reproducing group of conspecific individuals that inhabit the same range at the same time, are affected by similar environmental factors, and are reproductively isolated from other populations.
- A subpopulation is a semi-independent, self-reproducing group of individuals within a larger population that undergoes some measurable but limited exchange of individuals with other areas within the population.
- A spawning component is a segment of a population that does not differ in genetics or growth, but occupies discrete spawning areas inter-annually.
- A stock is an arbitrary collection of fish large enough to be essentially self-reproducing, with members of the unit exhibiting similar life history.
- A group of fish is a stock component that remains in a local area throughout the year (Wise, 1963).

2.1. Sources of 1920s information about cod, haddock, pollock, white hake and alewives

The study relied extensively on Rich's “Fishing Grounds of the Gulf of Maine (Rich, 1929) and was supplemented by Ames (1997, 2004). Rich interviewed groups of experienced fishing vessel captains who related the seasonality of gadid stocks on the grounds he documented. When disagreements arose about the relative abundance or seasonality of fish on a given ground, the majority opinion was accepted. The work of Rich not only revisited the grounds described by Collins and Rathbun (1887), but included an extensive number of additional grounds mentioned during his interviews. Most of the fishermen used hook-and-line technologies to catch fish on grounds that were feeding stations. Ames conducted interviews of retired fishing vessel captains who were active from the 1920s to 1950s and in addition to employing hooks, most had used other capture methods. Supporting empirical information came from Bigelow and Schroeder (1953) and Collette and Klein-MacPhee (2002). Alewife distribution among Maine rivers was derived from Hall et al. (2011), Lotze and Milewski (2004), Bigelow and Schroeder (1953) and Atkins (1887) and the towns of Newcastle, ME and

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