The role of closed areas in rebuilding monkfish populations in the Gulf of Maine.

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Abstract:

The use of fish reserves as a management tool to protect juvenile fish habitat and adult spawning grounds has become increasingly popular even though knowledge of the direct effects of marine reserves on juvenile fish populations is limited. Given that monkfish landings account for a considerable percentage of the monetary value derived from the groundfish industry in the western Atlantic, investigating the factors that influence monkfish population dynamics will assist managers in sustaining this important natural resource. We conducted trawl surveys to determine the effects of reserve (inside vs. outside the Western Gulf of Maine Closure Area [WGMCA]) and habitat type (mud bottom in isolation from gravel or cobble bottom vs. mud that is adjacent to these more complex habitats) on the distribution, abundance, and diet composition of monkfish, *Lophius americanus* in the Gulf of Maine. Surprisingly, the abundance of adult monkfish did not differ in vs. out of the reserve, and juvenile monkfish were more abundant outside of the WGMCA. Reserve status also did not affect the condition of monkfish. Therefore, our results suggest that this reserve is not important habitat for monkfish.
Introduction:

Fisheries managers have responded to the heightened pressures on fish populations globally through a number of proactive and retroactive measures, such as setting fish quotas, restricting entry to the fishery, and setting up temporal and spatial closures. In the United States, with the 1996 Amendment to the Magnuson-Stevens Fishery Conservation and Management Act, the National Marine Fisheries Service and fishery management councils have had the difficult task of identifying and describing essential fish habitat for all federally managed species (National Oceanographic and Atmospheric Administration 1998). Determination of EFH will require information on which habitats are important foraging and refuge grounds, and consequently contribute disproportionately to fish production locally and regionally. Protection of fish populations will hinge upon effective determination of EFH (Lindholm et al. 2001). Yet data on several life history phases of the vast majority of fish species are severely lacking and hinder this process. Therefore, studies that increase our understanding of fish demographics as a function of habitat will benefit efforts to manage fisheries more effectively.

Fully understanding the habitat requirements of a demersal fish necessitates identifying all of the habitats occupied at each life-history stage and the impacts of habitat on population dynamics (Lindholm et al. 2001). While adult habitat usage can be inferred from fishery-dependent catch data, modern fishing gear is designed to reduce or eliminate juvenile catches. Consequently, catch data alone provide little insight into juvenile habitat usage. Catch patterns prior to reductions in trawl mesh size provide evidence of habitat usage by slightly smaller sub-adults, but even the smallest meshes previously fished were not effective at catching very young juveniles (especially 0 and 1 year age classes).

Field surveys of nursery habitats for demersal fishes have demonstrated the importance of vegetated habitats in estuarine waters of Maine (Lazzari et al. 2001). Yet few field studies of juvenile habitat usage have been conducted in nearshore waters of the Gulf of Maine with the exception of some recent work by Peter Auster and colleagues on Stellwagan Bank (e.g., Auster et al. 2001, Lindholm and Auster 2003). Assessment of juvenile fish usage of and population dynamics in nearshore habitats elsewhere in the Gulf of Maine is necessary to determine which bottom types function as juvenile groundfish habitat (i.e., which habitats should be designated as EFH) and contribute disproportionately to the production of adult fish such as cod. Because strong linkages between juvenile habitat and cod population dynamics have been identified elsewhere, critical foraging and refuge habitats for juvenile groundfish need to be examined throughout the Gulf of Maine. We collected critical data on how habitat affects the growth and survival of juvenile cod and other important groundfish species, which has important implications for cod population dynamics and fishery management.

The habitat experienced by a fish includes both non-living, physical (i.e., abiotic) and biological (i.e., biotic) components. For example, a given habitat may be valuable to a fish because it contains physical shelter from predators and food to eat. However, these biotic and abiotic components are not independent because the nature of the physical substrate largely determines
which organisms are present. Although habitat is most often recognized on physical criteria, the importance of different habitat types is as much biological as physical (e.g., Auster and Langton, 1999).

Most juvenile fish can utilize a variety of habitats. Therefore simple evidence of abundance patterns (where fish are and how many are present) may not indicate the true ecological value of each habitat. Juvenile fish utilize critical habitat as foraging grounds and to avoid predators. Coupling an understanding of these processes with abundance patterns will enhance our understanding of which habitats are critical to fish production locally and regionally. This information will in turn provide fisheries managers with the data needed to more clearly identify and define essential fish habitat for groundfish species in the Gulf of Maine.

Monkfish (*Lophius americanus*) have been fished heavily over the past three decades and have exhibited signs of reduced abundance (*i.e.* decreased landings and smaller average size of fish landed). It is unclear which types of habitats limit juvenile and adult monkfish abundance. Furthermore, it is unknown whether reserves such as the WGMCA will effectively benefit this species. We conducted a trawl survey to determine how season, closure status, and landscape setting influence the ecology of juvenile stages of important groundfish species including monkfish in the Gulf of Maine. We hypothesized that juvenile monkfish abundance, growth, condition factor, and survivorship would be greatest along the edges of structured habitat. We also predicted that sites within the Western Gulf of Maine Closure Area would contain elevated abundance of groundfish with high condition and greater gut fullness if the WGMCA is achieving its intended goal of rebuilding fish stocks by providing critical foraging and refuge habitat for juvenile groundfish.

**Methods:**

We conducted trawl sampling efforts at 4 pairs of sites in and out of the closed area in the fall of 2004 and spring of 2005 inside and just outside of the northern portions of the Western Gulf of Maine Closure Area (WGMCA). Each site pair included 1 site that was adjacent to (“edge landscape”) and 1 that was isolated by > 2 km (“mud landscape”) from rock bottom. Prior to initiating trawl sampling efforts, we verified that edge landscapes were in fact adjacent to rock ledge and cobble bottom using a drop camera system. Specifically, we deployed a drop camera along a transect that was perpendicular to the hard bottom and surveyed from within the rock ledge and boulder habitats to the mud habitat directly adjacent to this hard bottom. This factorial design permitted us to examine the individual and interactive effects of season, closure status, and landscape setting.

Because we were unable to sample within rocky habitats with trawl nets, we focused on the ecology of juvenile fish assemblages within mud habitat adjacent to rock-ledge and boulder fields vs. mud habitat isolated from these structured habitats. This landscape-scale approach permitted us to identify how these suites of habitats influence the ecology of juvenile groundfish. Ecologists elsewhere have demonstrated that mud bottom adjacent to more complex seagrass beds provides critical foraging grounds for predators and prey that reside within vegetated habitat that is rich in refuge (Summerson and Peterson 1984).
All fish and crustaceans captured in each tow were separated by species (or species groups for some non-target invertebrates and pelagic fish), counted and weighed for each tow. Stomach contents were removed from each individual monkfish and stored in 10% formalin. Individual dietary items were identified to species (where possible), counted, and weighed in the laboratory. Intact stomachs were weighed, and this value was divided by the weight of the whole fish in order to create an index of stomach fullness for comparison among habitats. In addition to stomach fullness measures, fish condition was compared using fish weight relationships and Fulton’s K ($K=100*[$\text{Fish Weight}$/\text{Fish Length}^3]$). Fulton’s K has been used effectively to determine differences in cod stock condition at larger spatial scales throughout the north Atlantic (Ratz and Lloret 2003).

**Results:**

A total of 121 monkfish were caught during the spring and fall sampling trips ranging in size from 65 to 775 mm TL. The distribution and abundance of monkfish were influenced primarily by closure status. Monkfish were more abundant (Figure 1) and smaller (Figure 2) outside than in the closure. Careful examination of size frequency distributions for monkfish in vs. out of the closure revealed that juvenile monkfish abundances are very low inside the closure. In contrast to monkfish abundance and size patterns, only season and habitat influenced the condition of monkfish (Figure 3). Monkfish condition was greater in the spring, whereas the condition of monkfish caught in the edge was greater than those caught in the mud.

Juvenile monkfish consumed mostly crustaceans (mysids and northern shrimp) and small, eel-like fishes (silver hake, fourbeard rockling, and eelpouts). Outside of the closure, fish were more prevalent in the diet of juvenile monkfish in the edge than in the mud habitat. Adult monkfish consumed a wider diversity of fish including larger individuals than those consumed by juveniles, but northern shrimp were still an important component (especially by number) of the diet composition of adult monkfish.

**Discussion:**

These results suggest that the WGMCA does not contain critical habitat for juvenile monkfish, in spite of eight years of protection to allow recovery of important benthic habitats and prey resources. Habitat may play a role in juvenile monkfish condition factor depending on the prey species available. The greater abundance of juvenile monkfish outside the reserve suggests prey may be concentrated outside the reserve in trawled areas. The effects of reserve on adult monkfish abundance and distribution may not be detectable with the sampling method used for this study due to monkfish mobility. Adult monkfish condition factor may have been influenced by clupeids, which were consumed in large quantities when present, satisfying adult monkfish dietary needs and possibly reducing their foraging distance and time inside the reserve.

Monkfish are a slow growing, demersal fish species and might be slow to respond to reserve protection. Reserves may contain important foraging grounds for juvenile and adult groundfish including monkfish. With fewer disturbances inside the WGMCA, benthic community structure should be more complex than habitats that are routinely trawled. However, it is still unclear if habitat inside the WGMCA offers better foraging grounds for monkfish.
Reserves may contain important foraging grounds for juvenile and adult groundfish including monkfish. With fewer bottom disturbances inside the WGMCA, benthic community structure should be more complex than habitats that are routinely trawled (Collie 1998, Watling and Norse 1998). But it is still unclear if habitat inside the WGMCA offers better foraging for monkfish. Isotope sampling may provide additional trophic level information not attainable through stomach content analysis.

The Western Gulf of Maine Closure Area was designed to permit recovery of bottom habitat and associated fauna to provide refuge and foraging grounds for commercially valuable groundfish species such as Atlantic cod, haddock, and monkfish. This region was selected in part because it contains important habitats such as the cobble, gravel, and rock-ledge bottom that comprise Jeffreys Ledge. These habitats are thought to serve as an important nursery for juvenile groundfish, motivating managers to close a large section of the western Gulf of Maine to mobile gear that encompasses the entirety of Jeffreys Ledge. However, we found that juvenile monkfish were far more abundant outside the closure, suggesting that the northern portion of the WGMCA is not important nursery habitat for this critical species.

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Literature Cited:


Figure 1. The effect of closure status on the abundance of monkfish caught in trawls conducted in the Gulf of Maine. Error bars represent +1 SE.
Figure 2. The effect of closure status on the size (TL) of monkfish from trawls conducted in the western portions of the Gulf of Maine.
Figure 3. b. The effects of i. season & ii. habitat on the condition of monkfish caught in trawls in the western portions of the Gulf of Maine. Error bars represent +1 SE.