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Reserve And Habitat Effects On The Distribution, Abundance And Feeding Ecology Of Goosefish, Lophius Americanus (Valenciennes 1837) In The Western Gulf Of Maine

Melissa Dawn Smith
University of New England

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RESERVE AND HABITAT EFFECTS ON THE DISTRIBUTION, ABUNDANCE AND FEEDING ECOLOGY OF GOOSEFISH, *LOPHIUS AMERICANUS* (VALENCIENNES 1837) IN THE WESTERN GULF OF MAINE

BY

Melissa Dawn Smith
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Thesis Co-Director, Dr. Jonathan H. Grabowski,
Benthic Ecologist, Gulf of Maine Research Institute
Adjunct Professor of Biological Sciences, UNE

Thesis Co-Director, Dr. Philip O. Yund
Research Associate Professor of Biological Sciences
Director of Marine Science Center

Dr. Stephan Zeeman
Professor of Biological Sciences

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ABSTRACT

RESERVE AND HABITAT EFFECTS ON THE DISTRUBUTION, ABUNDANCE AND FEEDING ECOLOGY OF GOOSEFISH, *LOPHIUS AMERICANUS* (VALENCIENNES 1837) IN THE WESTERN GULF OF MAINE

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Melissa Dawn Smith

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Over two-thirds of the world's harvested fish stocks are considered to be either reduced or threatened because of overexploitation, which suggest that one of the central challenges facing coastal managers is the recovery and sustainable harvesting of these species. One promising fishery management strategy is the use of marine reserves, or conservation areas where fishing is prohibited, to rebuild depleted populations. In the Gulf of Maine (GoM), several closed areas have been established to restrict fishing activities such as gillnetting, scallop dredging, and mid-water and bottom trawling. These closures in the GoM not only protect diminished fish stocks, but also protect seafloor habitat utilized by these demersal fish species from the detrimental effects of dredging and bottom trawling. The largest closure in the GoM is the Western Gulf of Maine Closure Area (WGMCA) which encompasses parts of Stellwagen Bank, Jeffrey's Ledge, and Wildcat Knoll. Within the WGMCA, there are several habitat types such as mud, gravel, cobble, exposed rock ledge, and a mix of biogenic structures that are potentially used by groundfish. The goal set for the WGMCA is to ensure nursery habitat protection for dwindling cod and other groundfish species such as goosefish (*Lophius* *americanus*) while also reducing groundfish mortality from mobile gear fisheries. Goosefish 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 goosefish abundance. Furthermore, it is unknown whether reserves such as the WGMCA will effectively benefit this species. I used otter trawl surveys to investigate whether season (spring vs. fall), habitat (mud vs. edge of structured habitat) and reserve status (in vs. out) collectively influence goosefish distribution, abundance, feeding ecology, and goosefish in the Gulf of Maine.

A total of 121 goosefish were caught during the spring and fall sampling trips ranging in size from 65 to 775 mm TL. Goosefish abundance was greater outside the reserve while mean length was greater inside the reserve; neither abundance nor mean length varied significantly with season and habitat. The abundance of goosefish measuring < 400 mm was significantly greater outside the reserve while adult goosefish (> 400 mm) abundance did not vary with reserve status. Condition factor of goosefish was higher in the spring and on the edge habitat, but there was no interaction between these two factors. Reserve status did not influence condition factor. The diet of juvenile goosefish was composed of both crustaceans and small Gadiformes while adult goosefish primarily fed on large Gadidae and Clupeidae. Prey composition was dependent on season and prey availability.

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

INTRODUCTION

Over two-thirds of the world's harvested fish stocks are considered to be either reduced or threatened as a consequence of overexploitation (Hutchings 2000, Jackson et al. 2001, Pauly et al. 2002). Technological advancements combined with increased fishing pressure in many regions of the world continue to undermine efforts to conserve and rebuild fish stocks (FAO 2000, Gell and Roberts 2003, Myers and Worm 2003). Traditional management methods have varied in their effectiveness for sustaining fish stocks of commercially important species. Yet, one promising fishery management strategy is the use of marine reserves, or conservation areas where fishing is prohibited to enhance depleted populations (Russ and Alcala 1996, Kelly et al. 2000, Roberts et al. 2001). Marine reserves can potentially benefit multiple commercially harvested fish species within one region (Auster 1998, Murawski 2000, Lindholm et al. 2001). A reprieve from fishing pressure may allow fish to aggregate within the reserve, which potentially increases spawning stock biomass. If spawning biomass increases within the reserve, broadly dispersed larvae may spill over into open fishery areas and potentially increase regional fish productivity (Bohnsack 1998, Gell and Roberts 2003, Russ et al. 2003, Murawski et al. 2004).

Marine reserves augment population growth in several ways. First, reserves provide a spatial refuge in which directed fishing mortality is either reduced (partial reserve) or eliminated (no-take reserve). By limiting overall fishing pressure, by-catch and fishing mortality is also reduced. Fish species that are heavily targeted may show the greatest effects once fishing pressure is removed (Halpern and Warner 2002).

Second, reserves can protect site-specific spawning aggregations (i.e., seasonal or year-round spawning sanctuaries) (Bohnsack 1998, Dayton et al. 2000). Reserves that protect traditional spawning grounds of overfished species may reduce fishing pressure during mating season. Fish protected within reserves may also attain larger sizes and thus increase fecundity. No-take zones have been implemented in Belize to protect historical spawning grounds for the dwindling Nassau grouper (*Epinephelus striatus*) spawning aggregations (Sala et al. 2001). Seasonal closures intended to protect the spawning stocks may be enough to increase recruitment regionally potentially increasing future harvest yield (Roberts 1997). Excess larvae from a reserve or closure may be transported by water currents to locations outside the reserve and, consequently, increase the recruitment potential of an over harvested fish stock. Reserves that encompass a source population have a greater seeding potential as source populations are self-sustaining and may produce excess eggs and larvae to seed outlying areas.

Lastly, marine reserves may protect seafloor habitat types including sandy bottom, eel-grass beds, gravel based substrate and complex cobble/boulder landscapes. Destructive fishing practices, for example dredging and bottom trawling, degrade the benthic habitat by flattening vertical structure created by sponges and corals (Collie et al. 1997, Auster 1998, Watling and Norse 1998). These habitats have been associated with juvenile and adult demersal species such as Atlantic cod, *Gadus morhua*, (Witman and Sebens 1992, Cote et al. 2004). Lindholm *et al*. (1999) suggested that juvenile Atlantic cod use complex habitat to reduce predation risk. Restricting benthic fishing methods from local areas known as traditional nursery grounds may allow biogenic structures to rebuild, increasing the complexity of habitats within established reserves. Increased habitat complexity may benefit juvenile groundfish, although juvenile habitat usage is not yet completely understood. Usage may depend on fish activities such as feeding, resting or hiding from predators. Therefore, it has been suggested reserves not only provide relief from fishing mortality but also a safe refuge for fish aggregations to grow, thus restoring depleted populations (Bohnsack 1998).

Although marine reserves have been used effectively to facilitate the recovery of depleted fish stocks, they do not represent a panacea for overexploited fish resources (Bohnsack 1998, Dayton et al. 2000, Botsford et al. 2003, Halpern 2003). How the reserve will effect surrounding fish populations will depend on settlement cues, larval retention and current dynamics of both the reserve and outlying areas (Crowder et al. 2000). Placing a reserve in an area known to be a sink population will not be sustainable because a sink population relies on another distinct population to supply new recruits. The potential influence of reserves on adjacent fisheries through larval dispersal or adult spawning aggregations will be dependent on the location and goals set for the reserve. Fish species with high mobility and ambiguous migration patterns pose temporal and spatial problems (Polacheck 1990) because it is difficult to design reserves that fully encompass their movements among habitat patches and thus these fish species may not reap the benefits of marine reserves as would less mobile, territorial species. Correspondingly, traditional management tools such as quotas, total allowable catch limits and single-species moratoriums have been vital in certain stock recovery programs (i.e., goliath grouper, *Epinephelus itajara*, has rebounded since a 1990 moratorium in the Gulf of Mexico; see Shipp 2004). Thus, reserves may not be applicable considering the fish stock in question and traditional management tools may be the only option.

Marine scientists and managers have struggled with choosing the appropriate size and shape that maximize benefits while attempting to also minimize the costs associated with closing an area. Reserves should be large enough to protect sessile and mobile species during important life history stages (e.g., postlarval settlement, spawning aggregations) while minimizing the economic loss to the industry (Bohnsack 1998). Halpern (2003) suggests reserve effects scale directly with reserve size. Large reserves may protect a multitude of species, incorporating life-histories of resident and transient fish species. Larger reserves encompass more diverse habitats potentially utilized by juvenile and adult fish (Halpern 2003, Hastings and Botsford 2003). However, small reserves in close proximity to each other (a reserve network) have been utilized especially in tropical regions where target fish are territorial and less mobile and sessile animals are patchily distributed (i.e., coral colonies). These networks allow small localized protection where target species are known to occur. Thus, size and shape of the reserve should be scaled appropriately after careful consideration of the goals set for the reserve and the ecology (spawning behaviour, migratory routes, and feeding patterns) of the targeted species.

Reserves must be established with clear management directives and monitored to ensure these directives are being achieved (Bohnsack 1998, Shipp 2004). Thus, transfer of fishing pressure must be considered when planning a reserve. If restrictions to some fishing methods are not to be included in the reserve mandate, then managers should institute additional guidelines such as effort control and fish quotas to ensure that these alternative fishery methods remain sustainable. To ensure future sustainability of fish resources, a combination of marine reserve management and traditional fishery management practices should be examined (Dayton et al. 2000).

In the Gulf of Maine (GoM), several closed areas have been established to restrict fishing activities such as gillnetting, scallop dredging, and mid-water and bottom trawling (Murawski et al. 2000). A portion of these reserves have been designated essential fish habitat closed areas due to specific regulations that eliminate fishing activities using bottom tending gear. These fishing practices are thought to have degraded valuable habitat prior to the closure's inception. The loss of critical fish habitat could limit settlement and survival rates of post-larval fish species that have specific habitat requirements. Thus, the closures in the GoM not only protect diminished fish stocks, but also protect seafloor habitat utilized by these demersal fish species from the detrimental effects of dredging and bottom trawling.

The largest closure in the GoM is the Western Gulf of Maine Closure Area (WGMCA) which covers 2,962 km^2 of seascape (Fig. 1). The WGMCA was established May 1, 1998 under the Sustainable Fisheries Act (SFA) of 1996 (Public Law 104-297). The SFA reauthorized and amended the Magnuson-Stevens Fishery Conservation and Management Act to include measures to protect essential fish habitat during various life stages of fish, reduce by-catch and to rebuild overfished stocks (Rosenberg et al. 2000). The WGMCA encompasses parts of Stellwagen Bank, Jeffrey's Ledge and Wildcat Knoll. Within the WGMCA there are several habitat types such as mud, gravel, cobble, exposed rock ledge and a mix of biogenic structures that are potentially used by groundfish. These shallow waters were historically productive fishing and nursery grounds (Ames 1997, Kurlansky 1997), especially for cod. The WGMCA's overall goal was to reduce cod mortality and preserve juvenile habitat (Anon 2004).

Currently, the WGMCA is off-limits only to vessels capable of catching groundfish with bottom-tending gear under the New England Multispecies Fishery Management Plan. As a partial fish reserve, mid-water trawling for pelagic fish species is allowed and charter boats using rod and reel or hand-lines are authorized to enter the closure. The western portion of the WGMCA also overlaps with the goosefish gillnet exempted area fishery (see Fig. 1). This targeted gillnet fishery for goosefish is seasonal: July 1 to September 14. The partial protection offered in the WGMCA should reduce by-catch, which occurs frequently during bottom trawl fishing (Thrush et al. 1998). Managers need to be wary of partial reserves, however. Although a partial reserve may reduce fishing induced mortality by limiting specific types of fishing activities and protecting habitat, this reduced effort may be counterbalanced by increased effort from other, unregulated fishing activities. This transfer of fishing pressure is difficult to assess and thus can hinder managers and scientists ability to gauge reserve effectiveness. The partial reserve status of the WGMCA might cause such a problem to scientists and managers.

In the WGMCA, none of the exempted fisheries (i.e., mid-water trawling, charter boat companies) target juveniles or affect benthic habitat. The goal set for the WGMCA is to ensure nursery habitat protection for the dwindling cod population while also reducing groundfish mortality from mobile gear fisheries. Commercially important groundfish species in the GoM managed by the New England Multispecies Fishery

Management Plan include cod, haddock (*Melanogrammus aeglefinus*), American plaice (*Hippoglossoides platessoides*) and goosefish (*Lophius americanus*).

Goosefish have been commercially fished since the early 1970's as by-catch. A directed fishery for goosefish was established in 1991 in an effort to compensate for a decline in other traditional groundfish species. Landings have steadily increased by an order of magnitude from 2,600 MT in 1982 to 27,000 MT in 1998. However, records indicate a noticeable drop in landings between 1998 and 2000 to 20,900 followed by a slow rise since 2000, averaging 24,100 MT between 2001-2003 (NEFSC 2000). Perhaps one of the more discouraging fishery trends has been the consistent decrease in mean goosefish size over the past three decades. Previous studies using similar trawling methods have illustrated this decrease: 1780 mm reported by Wenner (1978) in the 1970's, 1115 mm sampled by Armstrong (1987) in the 1980's and 790 mm recorded in the Maine-New Hampshire Inshore Trawl Survey during Spring 2004 (Sherman et al. 2005). Of further concern is that size at maturity has decreased over the last two decades. Armstrong (1987) reported length at 50 percent maturity (L_{50}) as 368.6 mm for males and 487.0 mm for females, whereas Hartley (1995) more recently calculated L_{50} to be 361 mm and 319 mm for males and females, respectively. Atlantic cod (Barot et al. 2004, Hutchings 2005), American plaice (Barot et al. 2005) and North Sea plaice, *Pleuronectes platessa*, (Grift et al. 2003) have all experienced similar decreases in size at maturity as a consequence of fishing pressure.

Seasonal differences in the distribution and abundance of goosefish have been documented in previous studies conducted in the GoM, Southern New England and in the Northwest Atlantic (Armstrong 1987, Hartley 1995, Maravelias and Papaconstantinou

2003, Laurenson et al. 2005). Diet composition has also been shown to vary with season (Crozier 1985, Laurenson and Priede 2005). Yet, it is unknown how a reserve effect interacts with seasonal differences in goosefish distribution, abundance and feeding ecology. The WGMCA may have an increased diversity of prey available that might increase condition and survivorship of goosefish.

It is unclear which types of habitat limit juvenile and adult groundfish abundance and whether reserves such as the WGMCA will effectively benefit this species. I investigated whether season, habitat and reserve status collectively influence goosefish distribution, abundance, feeding ecology, and condition in the Gulf of Maine. I hypothesized that the abundance of *L. americanus* would be higher inside the reserve due to reductions in fishing pressure. Because the fishing industry targets large goosefish, I posited that larger goosefish should be more abundant inside the reserve. Steimle (1999) reports goosefish favour open, sandy bottoms. I suspected adult goosefish would use mud bottom more frequently as they do not need to hide from predators and are able to bury while waiting for prey. Juvenile goosefish, on the other hand, may need to balance the risk of foraging with predator avoidance and thus may utilize more complex habitats. Lastly, incorporating season into the survey design permitted investigation of seasonal differences in diet composition over habitats and to determine if habitat usage by goosefish changed depending on season and prey composition. I hypothesized that diet composition will change as community composition and available prey choices change with season.

MATERIALS

Study Species

Goosefish (F. Lophiidae) range from the southern Grand Banks of Newfoundland down to Cape Hatteras, North Carolina with a eurybathic distribution from mean low water to a depth of 900 m (Bigelow and Schroeder 1953, Markle and Musick 1974, Wenner 1978, Scott and Scott 1988). After a pelagic larval phase, goosefish settle and become a slow-growing, benthic dwelling, sit-and-wait predator that consume both pelagic and benthic fish prey, as well as invertebrates (Crozier 1985, Armstrong 1987). Goosefish utilize the first spine of their dorsal fin to attract prey (Fig. 2). Due to their large mouth and elastic stomach, goosefish are capable of consuming prey equal in length to themselves and up to one half of their own body weight. Goosefish are relatively slow swimmers and at times walk over substrate by using their pectoral fins (Steimle et al. 1999, Laurenson et al. 2004). Because goosefish are less mobile than many other groundfish species such as cod and haddock, populations may be more likely to benefit from a reserve. Thus, if goosefish do not benefit from the protection of the WGMCA, its effectiveness for other groundfish species is likely to be limited.

Site Selection and Sampling Design

A factorial design using an otter trawl to sample fish was employed to test the effects of season (spring vs. fall), reserve (in vs. out) and habitat type (mud vs. edge of structured habitat) on the distribution, abundance, feeding ecology, and condition of goosefish. In September of 2004, trawl sites were selected using a drop tow camera to classify the following two habitat types: (mud) relatively featureless mud bottom isolated (~1.5 km) from gravel or cobble structure, and (edge) bottom adjacent to these more complex habitats. Sampling was conducted in the fall (2005) and spring (2006), with 4 replicate sites each inside and outside the reserve (8 total sites). Each site included two habitat stations. A total of 16 tows (2 reserve treatments X 4 sites X 2 habitats) were conducted during each season. Depth ranged from 16.5 – 26.2 m over the 16 sites.

Sampling Protocol

All sampling was conducted from the F/V De Dee Mae II. This vessel is a Down East 54 foot (16.5 m) stern trawler with a 22 foot (6.7 m) beam and a 9 foot (2.7 m) draft. Goosefish were sampled with a 20 m otter trawl net with a 5 cm cod end fitted with a 2.5 cm mesh liner to retain juveniles as well as adults (see Sherman et al. 2005 for net specifications). Trawl tows were fixed at 15 minutes long at a towing speed of 2.3 - 2.5 knots. Tow time began when the winch brake was tightened, signifying that the net was on the seafloor bottom. The tow ended when the brake was loosened and cable hauling commenced. Upon retrieving the net, goosefish were enumerated, measured to the nearest millimetre (TL – total length) and individually weighed. Stomachs were removed on board and preserved in 10% formalin and seawater. Goosefish continued to feed in the trawl, as evidenced by the occasional prey that was located in the goosefish’s buccal cavity and esophagus. Consequently, these “prey” items, plus an additional prey item located in the stomach of one individual fish with no visible signs of digestion were excluded from our analysis. In the laboratory, samples were transferred from the 10%

formalin to 70% Ethanol. Excess fluid was removed prior to recording weight of whole stomachs. Prey contents were enumerated, identified to the lowest taxonomic level possible and weighed to the nearest tenth of a gram.

Data Analyses

The effects of season, reserve and habitat on abundance, size, Fulton's K condition factor (Fulton 1904), and prey fullness index (PFI) were analyzed using two- and three-way ANOVAs. Abundance was quantified as the total number of goosefish per tow. Thus, abundance had only one value per tow. Replication for all other dependent variables depended on the abundance of goosefish sampled. Total length (TL; mm) was used as an indicator of size. Length frequency distributions were also calculated for *L. americanus* in and out of the WGMCA. In particular, the frequency of four non-overlapping 200 mm TL size classes were used determine which length classes of goosefish may differ with reserve status. Differences in abundance of goosefish in vs. out of the reserve for each size category were assessed using t-tests. A condition factor (Fulton's K) was used to assess overall goosefish physiological status by evaluating how weight scales with length. Fulton's K was calculated for each fish as:

$$K= W/L^3 * 1000 \qquad (1)$$

where W = weight of goosefish (g) and L= length (mm). A PFI was constructed for each prey category by:

$$PFI= W\ prey_i\ in\ stomach_j / W\ of\ fish_j * 100 \qquad (2)$$

A 3-way ANOVA was used to analyze the effects of season, reserve and habitat on PFI of adult fish. However, juvenile goosefish were not prevalent inside of the reserve. Thus, for the juvenile PFI analyses, reserve effect was excluded and only the effects of habitat and season on Mysidacea, Pandalidae and Gadidae PFI in juveniles were analysed via a 2-way ANOVA.

Stomach content analyses were also conducted separately for juveniles and adults. Information on goosefish diet from Armstrong *et al.* (1996) and size at maturity from Steimle *et al*. (1999) indicate goosefish experience an ontogenetic diet shift around 200-250 TL as well as a physiological shift towards reproductive maturity beginning at 320 mm TL (males) and 360 mm TL (females). From these estimates, and for the purpose of this study, goosefish less than or equal to 300 mm TL were considered juveniles whereas those above 301 mm TL were classified as adults. Diet analyses were calculated to determine an index of relative importance (IRI), modifying the methods of Pinkas *et al.* (1971).

$$IRI_i = (\%N_i + \%W_i) \text{ x } FO_i \qquad (3)$$

Where the frequency of occurrence (FO_i) is the number of stomachs with $prey_i$ divided by number of stomachs with food, the weighed abundance ($\%W_i$) is the total weight of $prey_i$ divided by the total weight of all prey, and the numerical abundance ($\%N_i$) is the total number of $prey_i$ divided by total number of all prey). These individual components of an IRI were calculated based on methods described by Hyslop (1980).

RESULTS

Abundance and Distribution

A total of 121 goosefish were caught during the spring and fall sampling trips ranging in size from 65 to 775 mm TL. Habitat and season did not affect *L. americanus* abundance (Table 1). Counter to my hypothesis, twice as many goosefish were caught outside the reserve (significant reserve effect - Table 1; Fig. 3). Goosefish mean length (mm) did not vary significantly with habitat or season, but did differ as a function of reserve status (Table 2). In particular, mean length of goosefish within the reserve was 27% higher than that of goosefish outside the reserve (Table 2; Fig. 4). To examine the combined pattern of size and abundance, length frequency distributions in and out of the reserve were calculated *a posteriori*. Student's T-Tests on the effects of reserve status on goosefish abundance in each size class indicated that there were significantly fewer individuals inside the reserve for the two smaller size categories (Fig. 5; 0-200 size class: F=6.3158, P=0.018; 201-400 size class: F=5.9471, P=0.021; 401-600 size class: F=0.3797, P=0.542; 601-800 size class: F=0.0838; P=0.774).

Condition Factor

Both season and habitat, but not their interaction, influenced goosefish condition factor (Table 3). Goosefish condition was significantly higher in the edge habitat for both seasons (Table 3; Fig. 6). Goosefish condition was significantly higher in the spring than the fall (Table 3; Fig. 7). Finally, a marginally non-significant trend was observed for the interaction between habitat and reserve status. The increase in goosefish condition in edge habitats was much more pronounced inside the reserve (Table 3, Fig. 8).

Diet Composition

One-hundred and eighteen stomachs were collected over two seasons. Of the fifty-five juvenile (<300 mm TL) goosefish stomachs sampled, 12 were empty (21.8%). Table 4 shows the breakdown of stomach contents for juvenile goosefish caught in each habitat type both in and out of the reserve pooled over spring and fall sampling seasons. Prey species from the family Mysidacea were found only in stomachs outside of the reserve, occurring in 22% of stomachs in the edge habitat and 6.3% of stomachs in the mud habitat. Although mysid relative weight was low in both the edge (0.06%) and mud habitat (0.1%), numerically mysids constituted a much larger fraction of the available prey (59.6% on the edge and 7.1% in the mud). Another shrimp, *Pandalus borealis*, was also found in stomachs of fish caught outside of the reserve, occurring both in edge (18.1%) and mud (12.5%) habitat. Relative weight contribution of *P. borealis* was 3.3% and 4%, respectively, for mud and edge habitat treatments, while numerical abundance was 8.5% in edge and 14.3% in mud habitat.

Juvenile goosefish preyed upon a variety of demersal fish species. Four-bearded rockling (*Enchelyopus cimbrius*) was found in stomachs caught inside the reserve on edge habitat (100%) and outside the reserve on both mud (0.5%) and edge (22.7%) habitat. *Enchelyopus cimbrius* relative weight contribution ranged from 0.5% to 83.3% in the mud habitat outside the WGMCA and in the edge habitat inside the reserve, respectively. Their numerical contribution to total prey also was dependent on habitat type and location (0.4% to 60%). Other gadiformes that occurred less frequently included silver hake, *Merluccius bilinearis*, (FO=4.5%, W=19%, N=2%) and the true hakes, *Urophycis* spp. (FO=4.5%, W=8%, N=2%). Other demersal species that were consumed included Acadian redfish, *Sebastes fasciatus*, (FO=4.5%, W=0.3%, N=2%), ocean pout, *Macrozoarces americanus*, (FO=50%, W=65%, N=50%) and American plaice, *Hippoglossoides platessoides,* (FO=9%, W=31.5%, N=4%). Unidentified fish tissue was common among all sites sampled (see Table 4).

Sixty-three adult goosefish stomachs were analyzed and 10 were empty (15.9%). *Pandalus borealis* was found in one-third of the stomachs of adult goosefish inside the reserve in both habitats, but contributed only 2.8-3.1% of the relative weight of prey (Table 5). Total prey composition of adult goosefish inside the reserve was comprised of 20% or more of *P. borealis*. *Pandalus borealis* had a slightly higher frequency of occurrence in adult goosefish stomachs outside the reserve compared to adult goosefish stomachs sampled inside the reserve (FO=50% edge; FO=35% mud). Weight contribution of *P. borealis* in adult goosefish stomachs analyzed outside the reserve was lower in the mud habitat than the edge habitat (W=7.9% edge, W=2.1% mud). Numerically, *P. borealis* accounted for at least 20% of the prey items found in stomach inside the reserve and at least 32% of prey items found in stomachs outside of the reserve (see Table 5).

Adult *L. americanus* preyed on several demersal and pelagic fish species, including the following Gadiformes: *E. cimbrius, M. bilinearis, Urophycis* spp and unidentified Gadidae. *Sebastes fasciatus* were found in a quarter of adult goosefish stomachs sampled within the reserve. Yet, numerically, all these species only comprised 13% of the prey components sampled from edge and 26% from mud habitat. American plaice occurred in adult goosefish stomachs sampled outside of the reserve only (FO= 8.3% edge; FO=28.6% mud) and were numerically only 17% of total prey items consumed by adult goosefish in both mud and edge habitat outside the reserve. Clupeidae occurred in adult goosefish stomachs in both habitats, regardless of reserve status. The relative contribution of clupeids to the diet of goosefish ranged from 18 to 78% when present (Table 5).

Prey Fullness Index

To further investigate how season and habitat affect goosefish diet and potentially condition, I analyzed prey composition in juvenile and adult goosefish. For juvenile goosefish, mysids, *P. borealis*, and four-bearded rockling (*E. cimbrius*) were important prey items comprising 71.6% of the total prey items consumed (see Table 4). The PFI for both mysids and *P. borealis* did not vary significantly with habitat or season (Table 7, 8). However, the PFI for four-bearded rockling was significantly higher in juvenile goosefish sampled in the mud habitat in the fall season (significant habitat x season interaction, Table 6; Fig. 9).

Adult goosefish prey on more fish species than juveniles. Prey species important for adult *L. americanus* include Gadiformes, Pleuronectidae and Clupeidae. Season, reserve status, and habitat type did not affect the PFI of Gadiformes and Pleuronectidae in the diet of adult goosefish (Table 9, 10). Clupeids were found only in adult goosefish stomachs. Clupeid PFI in the diet of adult goosefish differed seasonally (Table 11). The interaction between habitat and reserve also significantly affected clupeid PFI in adult goosefish (Table 11). The PFI of Clupeids in the spring was 32 times greater than in the fall (Fig.10). Clupeids contributed significantly to the adult goosefish's diet on the edge habitat inside the reserve, but PFI did not differ between habitats outside the reserve (Fig. 11).

DISCUSSION

Goosefish Distribution within the WGMCA

Reserve status had a large influence on the distribution and abundance of goosefish in our study. Typically, marine reserves are established to protect juvenile fish populations by providing safe refuge to ensure juvenile survival and growth (Alcala and Russ 1990, Bohnsack 1998, Russ and Alcala 2003). Marine reserves have also been established to protect the benthic habitat and communities from destructive fishing practices (Thrush et al. 1998, Murawski et al. 2000). Surprisingly, goosefish were overall less abundant inside the WGMCA than out. This differential occurred because juvenile (<400 mm) goosefish were much more abundant (~5 times greater) outside the reserve. This result suggests that the WGMCA does not contain critical habitat for juvenile goosefish, in spite of eight years of protection to allow recovery of important benthic habitats and prey resources. Furthermore, contrary to my hypothesis, the abundance of larger goosefish did not differ as a function of reserve status. Thus, it appears that the WGMCA also does not provide typical reserve benefits (i.e., reduced fishing mortality) for adult goosefish.

There are several possible hypotheses to explain the counterintuitive result of greater juvenile goosefish abundance outside of the reserve. First, differences in larval supply may be influencing the population structure of juvenile goosefish inside versus outside the WGMCA (i.e., goosefish recruitment may be lower in the WGMCA). Second, reduced fishing pressure in the WGMCA may have resulted in locally increased predator abundance that leads to increased predation on juvenile goosefish. Third, nursery habitat required for settlement, survival and growth of juvenile goosefish may either be limited or nonexistent inside the WGMCA. And lastly, the reduced abundance of juvenile goosefish within the reserve might be explained by a limitation of food resources.

Recent studies on goosefish spawning and larvae patterns have suggested that the spawning areas are centered in the Middle Atlantic Bight. Fewer larvae were collected in plankton tows in the Gulf of Maine, though effort was comparable (Steimle et al. 1999; Able and Chambers 2003). Although large scale dispersal of goosefish larvae has been observed on the outer shelf, there is no evidence of dispersal gradients on smaller scales. Therefore, larval recruitment differences would probably not occur within our study due to the small study location.

The WGMCA is a multispecies reserve. After eight years of protection, some fish species found within the reserve may have considerably increased in abundance because of the release of fishing pressure or a reduction in by-catch mortality. It is possible that an increase in juvenile goosefish predators inside the reserve may be limiting the abundance of juvenile goosefish. Predators of juvenile goosefish include tiger shark (*Galeocerdo cuvier*), sandbar shark (*Carcharhinus plumbeus*) and skates (*Raja* spp.). This goosefish study was a part of a larger project. Of the ~600 predator stomachs analyzed, only two juvenile goosefish were observed (Smith et al., unpub. data) suggesting that consumption rates for teleost predators are very low. However, our sampling methods did not catch any large sharks. Therefore, I cannot definitively evaluate the possibility that elevated predation rates from other types of predators are affecting the distribution of juvenile goosefish.

The higher abundance of juvenile goosefish outside the WGMCA might be the result of an interaction between fishing disturbance and goosefish feeding ecology. The diet components of juvenile and adult goosefish overlap somewhat, but each group uses specific prey items not utilized by the other. Juvenile goosefish utilize crustaceans and smaller fish while adult goosefish prey upon larger and more bulky fish species (Table 4-5) (Crozier 1985, Armstrong et al. 1996). Dominant prey items for juvenile goosefish include mysids, pandalid shrimp and small, eel-like fish (i.e., four-bearded rockling, *E. cimbrius*, silver hake, *Merluccis bilinearis* and the true hakes, *Urophycis* spp) (Table 4). In turn, the prey utilized by this eel-like fish group also includes mysids, as well as polychaete worms, and small bivalves (Bowman et al. 2000, M. Smith, unpubl. data). Bottom trawling around the periphery of the WGMCA creates a disturbance of the benthic habitat (Watling and Norse 1998, Freese et al. 1999, Murawski et al. 2005). Polychaetes, brittle stars, and molluscs may become readily available to a host of vertebrate predators including juvenile fish species that juvenile goosefish in turn prey upon (Engel and Kvitek 1998). Flatfish, for example, prey predominately on polychaetes and bivalves (Bowman et al. 2000) and have been linked with foraging on damaged invertebrate fauna from trawling activity (Piet et al. 2000). Flatfish biomass tended to be higher in tows outside the reserve (Smith et al., unpub. data) suggesting that flatfish may also be utilizing the additional prey resources made available by trawling. If the disturbance created by trawling outside the reserve increases available prey resources, juvenile goosefish may aggregate outside of the reserve to forage.

Yet, if food availability is increased outside the reserve, why did adult goosefish abundance not also vary with reserve status? In contrast to the pattern for juvenile goosefish, adult abundance was similar inside vs. outside the reserve. This result could be a consequence of similar food resources for the adults in and out of the reserve. Alternatively, the partial reserve status of the WGMCA, which allows a directed gillnet fishery for adult goosefish during several months of the year may also explain why adult populations did not differ in vs. out of the reserve.

Larger fish prey that juvenile goosefish are physically incapable of consuming due to gape limitations (Gordoa and Macpherson 1990) contributed substantially to the diet of adult goosefish. Adult goosefish prey items were also more varied, including a wider variety of fish species (Table 5). One probable explanation for adult goosefish distribution and abundance patterns is an increase in available prey for larger goosefish inside the reserve. Adult goosefish are capable of consuming larger prey sizes and thus are not as limited as juvenile goosefish (Laurenson and Priede 2005). Additionally, adult goosefish were opportunistic foragers, consuming a variety of prey, both small and large.

Clupeids, which contributed largely to adult goosefish diet in both habitats, were found in goosefish stomachs inside and outside of the reserve (Table 5). Further, clupeid biomass was similar throughout sampling tows, suggesting wide-spread distribution (M. Smith, pers. ob.). Clupeids migrate daily within the water column, rising to the surface to feed before returning to depths. When clupeids are near the seafloor, they are available as prey to goosefish. Clupeid consumption has also been documented for white anglerfish, *L. piscatorius*, (Crozier 1985, Laurenson and Priede 2005). Clupeids are a schooling pelagic fish group and this schooling behaviour may explain the large quantities of clupeids identified in adult goosefish stomachs. Goosefish digestion rates are suspected to be slow (Crozier 1985) and a pattern of decreased feeding rate with an increase of goosefish length has been documented by Armstrong *et al.* (1996). Therefore, adult goosefish may not need to forage as often if their diet consists of clupeids or other large fish prey. A large foraging event may sustain energy demands of adult goosefish over a longer period of time. Consequently, adult goosefish may have a more sedentary lifestyle because of their opportunistic foraging practices and may remain within the reserve boundaries. Clupeids are consumed in large quantities when present, satisfying adult goosefish dietary needs and possibly reducing their foraging distance and time inside the reserve.

Diet and Trophic Ecology

Although habitat and seasons effects on goosefish abundance and size were minimal, these factors, along with reserve status, influenced goosefish condition. Reserve effects on diet and condition factor of goosefish were dependent upon habitat type. Prey fullness index results indicated that clupeids contributed significantly to adult goosefish diet in the edge habitat only inside the WGMCA (Fig. 11) which might explain why the condition factor of goosefish was also higher in the edge habitat rather than mud only inside the reserve (Fig. 8). Clupeids are consumed in large quantities and are nutritionally valuable prey item. Although abundance of clupeids did not differ significantly inside vs. outside of the reserve, these results suggest that adult goosefish inside the reserve utilized clupeids more often then other fish species. Thus, habitat and reserve status apparently influence together not only goosefish foraging behaviour, but assimilation of important dietary components which impacts goosefish condition. These results also suggest that edge habitat may offer more prey opportunities than mud habitat, especially when protected from bottom damaging activities.

Although results did not indicate significant differences in habitat usage during this study, it is plausible that goosefish still may benefit energetically from edge habitat more so than mud. Condition factor results indicate goosefish have a higher weight to length scale over the edge habitat than mud habitat type. By making the assumption that a higher weight at a given length for an individual goosefish translates to an increase in net energy intake once body maintenance is completed, this increase in energy should be a result of an increase in food consumption. Therefore, juvenile and adult goosefish may benefit from foraging near the edge habitat. Coincidently, trawling activity typically occurs near edge habitat, thus potentially disturbing habitat that is accessible for juvenile goosefish. Juvenile goosefish may have increased benefits utilizing the edge habitat aside from food resources. Edge habitat may provide shelter space to reduce the risk of predator interactions. Goosefish sampled in the edge habitat during both seasons had a higher condition factor than goosefish sampled in the mud habitat inside the reserve only. This suggests that edge habitat protected from destructive fishing methods may indeed benefit both juvenile and adult goosefish condition factor by allowing goosefish adjacent to structured habitat to forage more effectively.

Goosefish condition was higher during the spring than in the fall. Goosefish migrate seasonally between shallow and deep waters (Hartley 1995, Able and Chambers 2003). These seasonal migrations might also be linked with prey resource availability. Seasonal variation in condition factor may be influenced by changes in community structure and prey abundance. Clupeid biomass was higher in the spring than in the fall

(Smith et al., unpub. data), which could explain why the condition of goosefish was greater in the spring. During the spring, the PFI for clupeids was substantially higher than the PFI in the fall (Fig. 10). Goosefish may be able to follow the schools of pelagic prey as these prey schools enter shallower waters during the spring months. An alternative explanation for seasonal variation in goosefish condition could be that goosefish spawning in the summer reduces their condition substantially because of large energy allocation required by this activity.

Changes in community structure may influence competition for shared prey resources between adult goosefish and other predators. Spiny dogfish (*Squalus acanthias*) were abundant in the tows conducted during the fall sampling season only (Smith et al., unpub. data). On examination of spiny dogfish stomach contents, those with food items consisted mostly of silver hake and herring, *Clupea harangus*, (M. Smith, pers. ob.). Both silver hake and herring were found in the stomachs of goosefish from the fall sampling season (Table 5). Therefore, dogfish may compete directly with adult goosefish during the fall for clupeids and silver hake. This pattern could possibly lead to reduced availability of clupeid resources for adult goosefish in the fall and lower the condition factor of the individuals sampled.

The comparison of the diet composition of goosefish collected in the western GoM with those in previous studies confirms that goosefish forage on a wide variety of prey and that prey availability varies by location (Bowman et al. 2000). Clupeids were commonly found in goosefish stomachs in this study, but were rare in Armstrong *et al.* (1996). However, Bowman *et al.* (2000) documented stomach content analysis of goosefish from six geographical locations in the northwest Atlantic including the GoM.

Results from the Bowman *et al*. (2000) study indicated clupeids comprised 13% of total prey weight. Thus, diet composition results from previous diet studies of *L. americanus* along with this study emphasize the regional differences that occur in goosefish prey species. Prey composition is dependent on community structure found within the goosefish's environment.

Goosefish diet was comparable to other studies conducted on *L. americanus* (Armstrong et al. 1996; Bowman et al. 2000), and the congeneric white anglerfish, *L. piscatorius*, (Crozier 1985; Laurenson and Priede 2005). Cannibalism has been documented for this species (Bigelow and Schroeder 1953; Armstrong 1987); however, no evidence of cannibalism was observed during this study. There was a clear ontogenetic diet shift towards piscivory around the 200-250 mm TL as seen by Armstrong *et al.* (1996). In my diet analyses, the occurrence of four-bearded rockling in juvenile goosefish predominately around 200 mm TL suggested that goosefish begin consuming four-bearded rockling at the inception of its ontogenetic shift to a piscivorous lifestyle. During the spring, ocean pout (*Macrozoarces americanus*) was frequently observed in juvenile goosefish at the cusp of the diet shift while four-bearded rockling was less frequent. The occurrence of ocean pout in the stomachs of juvenile goosefish may imply that four-bearded rockling were not readily available as a prey resource during the spring, and ocean pout was utilized instead as it is similar in body shape. The PFI of four-bearded rockling (Fig. 9) suggests that rockling may have been available in higher quantities during the fall, thus comprising a larger portion of juvenile goosefish prey. These results suggest that juvenile goosefish utilize a functional fish group that is characterized by slender, eel-like fish such as four-bearded rockling, ocean pout, and juvenile silver hake, white hake (*Urophycis tenius*) and red hake (*Urophycis chuss*). Crozier (1985) reported small *L. piscatorius* consuming common dragonette (*Callionymus lyra*) and snake blenny (*Lumpenus lampretaeformis*) more often than large *L. piscatorius*. Laurenson and Priede (2005) found that small *L. piscatorius* (less than 300 mm) forage primarily on sandeel (*Ammodytes marinus*). The diet composition of small *L. piscatorius* differed seasonally. For instance, Laurenson and Priede (2005) showed that the importance of sandeel in goosefish diet was inversely related to the presence of Norway pout (*Trisopterus esmarkii*). Norway pout was found to occur frequently and in high abundance in L. piscatorius stomachs sampled during January to March, but was rarely occurred during April to June, when sandeel was prevalent. Both of these north-west Atlantic studies on *L. piscatorius*, a species once confused with *L. americanus* (Armstrong 1987), support my hypothesis of juvenile goosefish utilizing a functional prey group of slender, eel-like fish and also that seasonal variation may dictate which prey fish in this functional group is consumed.

Smaller goosefish may forage primarily on small, eel-like fishes because of their body shape. When these prey items were excised from the stomach, fish were found to be compactly folded within the stomach; this was not observed for clupeids and other larger and less slender fish prey items (Smith, pers. ob.). Juvenile goosefish have less prey types available due to the limitation imposed by their gape width and buccal cavity (Gordoa and Macpherson 1990).

As lophiids grow, they begin eating larger fish (Crozier 1985, Gordoa and Macpherson 1990, Armstrong et al. 1996, Laurenson and Priede 2005, Walmsley et al. 2005). In adult *L. americanus* stomachs, adult redfish (*Sebastes fasciatus*), flatfish

(Pleuronectidae), gadids and clupeids were dominant fish dietary components. Clupeids appear to be a year-round food source for *L. americanus*, with juvenile and adult specimens identified in goosefish stomachs in the GoM. In contrast, clupeids in the northeast Atlantic were found to be seasonally preyed upon by *L. piscatorius* (Crozier 1985; Laurenson and Priede 2005).

CONCLUSION

The WGMCA was established in part to protect juvenile groundfish habitat, while also reducing the fishing effort of important traditional fish stocks. However, the results from this study indicate that juvenile goosefish are more abundant outside the WGMCA. This pattern suggests that juvenile goosefish may be attracted to trawled habitat locations and potentially benefit energetically from an increase in prey resources. If this explanation holds for juvenile goosefish, what is the likely impact of this reserve and trawling disturbance on juvenile cod and haddock, two of the traditionally harvested groundfish species?

Although goosefish exhibit behaviours different than typical groundfish species, both juvenile and adult goosefish have similarities with juvenile and adult cod. Juvenile goosefish and juvenile cod both prey on invertebrates and juvenile fish species that may aggregate after trawling occurs. It has been documented in previous literature that juvenile cod and haddock predominantly forage on benthic invertebrates and crustaceans that may be drawn to trawling disturbance (Bowmen et al. 2000). Thus, it is possible that juvenile cod and haddock abundance may be influenced by trawling disturbance for prey resources. As well, other juvenile demersal fish species may also be attracted to trawling disturbance aggregations for prey resources. Adult goosefish and cod have similar diets, including herring, silver hake and northern shrimp (Bowman et al. 2000).

The effects of reserve on adult goosefish abundance and distribution may not be detectable with this sampling method due to their mobility. This study may not have had the sampling power to determine if the WGMCA influences goosefish abundance and distribution. However, goosefish are a slow growing, demersal fish species and might be slow to respond to reserve protection (Halpern and Warner 2002). Similarly, after closure areas on Georges Bank, cod were slow to recover (Murawski et al. 2000). Because the WGMCA was not designed to protect and rebuild goosefish populations, goosefish within the reserve may still be exposed to increased fishing pressure because of the Goosefish Gillnet Exemption Area.

The quantity of juveniles sampled in this study was surprisingly high considering larval dispersal and the source-sink dynamics in the Western GoM. The Middle Atlantic Bight is suspected to be the spawning center for goosefish (Armstrong 1987, Steimle et al. 1999). Eggs and larvae are then advected up towards Georges Bank and Western GoM in late summer and early fall. The location of the WGMCA may not be suitable for goosefish stock rehabilitation. If goosefish populations in the western GoM are primarily supplied by larvae from goosefish spawning activity in the Middle Atlantic Bight, the WGMCA goosefish are a sink population. Goosefish tagging studies may be necessary to identify small and large scale migration patterns and to determine whether goosefish populations further south are responsible for repopulating northern populations.

Reserves may contain important foraging grounds for juvenile and adult groundfish including goosefish. With less disturbance 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 goosefish. Isotope sampling may provide additional trophic level information not attainable through stomach content analysis.

The outcome of this study suggests that positive reserve effects should not be assumed, regardless of the long term protections. Regular sampling of closed versus open areas to assess temporal changes is recommended. Management of closed areas should include research initiatives in their mandate including baseline sampling prior to the closure being implemented. There is a definite need to monitor reserves over time so managers can assess whether or not the intended goals are being achieved.

TABLES

Table 1: Results from ANOVA on abundance of goosefish ($\alpha = 0.05$). *SS* Sums of Squares.

	df	SS	P-value
Season	1	19.5	0.16
Reserve	1	87.7	**0.005**
Habitat	1	1.5	0.69
Season X Reserve	1	0.7	0.77
Season X Habitat	1	2.5	0.60
Reserve X Habitat	1	3.7	0.53
Season X Reserve X Habitat	1	0.2	0.86
Error	24	220.2	

Table 2: Results from ANOVA on mean length (mm) of goosefish (α= 0.05). *SS* Sums of Squares.

	df	SS	P-value
Season	1	5008.1	0.66
Reserve	1	169267.0	**0.01**
Habitat	1	3233.1	0.73
Season X Reserve	1	6660.6	0.61
Season X Habitat	1	21838.7	0.36
Reserve X Habitat	1	1248.6	0.83
Season X Reserve X Habitat	1	551.0	0.88
Error	115	2978117.3	

Table 3: Results from ANOVA on condition factor of goosefish ($\alpha = 0.05$). *SS* Sums of Squares.

	df	SS	P-value
Season	1	0.013	**0.0003**
Reserve	1	0.001	0.36
Habitat	1	0.008	**0.004**
Season X Reserve	1	0.001	0.25
Season X Habitat	1	0.001	0.24
Reserve X Habitat	1	0.003	**0.10**
Season X Reserve X Habitat	1	0.001	0.22
Error	115	0.104	

Table 4: Diet analysis for juvenile goosefish (< 300 mm TL).

	IN								OUT							
	MUD				EDGE				MUD				EDGE			
Prey Species	FO	W	N	IRI	FO	W	N	IRI	FO	W	N	IRI	FO	W	N	IRI
Crustacea																
Mysidae	-	-	-	-	-	-	-	-	6.3	0.1	7.1	45.1	22.7	0.1	59.6	1355.2
Pandalidae	-	-	-	-	-	-	-	-	12.5	3.3	14.3	220.0	18.1	4.0	8.5	226.3
Cephalopoda	-	-	-	-	50.0	14.3	25.0	1965.0	-	-	-	-	-	-	-	-
Demersal																
E. cimbrius	-	-	-	-	100.0	83.3	50.0	13330.0	31.3	0.5	0.4	25.6	22.7	22.7	59.6	1868.2
M. bilinearis	-	-	-	-	-	-	-	-	-	-	-	-	4.5	19.4	2.0	96.3
Urophycis	-	-	-	-	-	-	-	-	-	-	-	-	4.5	8.0	2.0	45.0
Unid Gadidae	-	-	-	-	50.0	2.4	25.0	1370.0	6.3	0.1	0.1	1.2	-	-	-	-
Sebastes	-	-	-	-	-	-	-	-	-	-	-	-	4.5	0.3	2.0	10.4
Zoarcidae	50.0	64.8	50.0	5740.0	-	-	-	-	-	-	-	-	-	-	-	-
H. platessoides	-	-	-	-	-	-	-	-	-	-	-	-	9.0	31.5	4.0	319.5
Unid Pleuronectidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid fish tissue	50.0	15.2	50.0	3260.0	-	-	-	-	31.3	0.4	0.4	23.5	22.7	9.2	10.6	449.5
Pelagics																
C. harengus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unid Clupeidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Empty Stomachs	3				1				4				4			
Total Stomachs	6				3				20				26			

Table 5: Adult goosefish (> 301 mm TL) diet analysis.

	IN								OUT							
	MUD				EDGE				MUD				EDGE			
Prey Species	FO	W	N	IRI	FO	W	N	IRI	FO	W	N	IRI	FO	W	N	IRI
Crustacea																
Mysidae	-	-	-	-	-	-	-	-	7.0	0.0	16.1	112.7	-	-	-	-
Pandalidae	33.3	3.1	26.7	992.3	11.1	1.2	15.4	184.3	35.7	2.1	32.3	1228.1	50.0	7.9	40.0	2395.0
Cephalopoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Demersal																
E. cimbrius	-	-	-	-	11.1	1.9	3.8	63.3	7.1	2.3	3.2	39.1	-	-	-	-
M. bilinearis	8.3	0.3	6.7	58.1	-	-	-	-	14.3	12.5	6.5	271.7	-	-	-	-
Phycidae	8.3	22.0	6.7	238.2	11.1	2.3	3.8	67.7	-	-	-	-	-	-	-	-
Unid Gadidae	16.7	15.2	20.0	587.8	11.1	5.2	3.8	99.9	7.1	1.3	3.2	32.0	8.3	62.0	13.3	625.0
Sebastes	25.0	37.2	26.7	1597.5	22.2	6.4	7.7	313.0	-	-	-	-	-	-	-	-
Zoarcidae	-	-	-	-	-	-	-	-	-	-	-	-	8.3	2.9	13.3	134.5
H. platessoides	-	-	-	-	-	-	-	-	28.6	24.3	16.1	1155.4	8.3	7.7	6.7	119.5
Unid Pleuronectidae	-	-	-	-	-	-	-	-	7.1	2.2	3.2	38.3	-	-	-	-
Unid fish tissue	-	-	-	-	22.2	0.3	7.7	177.6	7.1	0.9	3.2	29.1	8.3	1.1	13.3	119.5
Pelagics																
Clupeidae	16.7	22.2	13.3	592.9	66.7	82.3	57.7	9338.0	35.7	54.4	16.1	2516.9	16.7	18.4	13.3	529.4
Empty Stomachs	3				1				4				2			
Total Stomachs	15				13				21				14			

Table 6: ANOVA results for partial fullness index for four-bearded rockling in the diet of juvenile goosefish (α= 0.05). *SS* Sums of Squares.

	df	SS	P-value
Season	1	95.7	**0.09**
Habitat	1	17.0	0.48
Season X Habitat	1	111.7	**0.07**
Error	52	1710.3	

Table 7: ANOVA results for partial fullness index for *P. borealis* in the diet of juvenile goosefish ($\alpha = 0.05$). *SS* Sums of Squares.

	df	SS	P-value
Season	1	0.0004	0.25
Habitat	1	1.479	0.98
Season X Habitat	1	0.019	0.90
Error	52	56.8	

Table 8. ANOVA results for partial fullness index for Mysids in the diet of juvenile goosefish ($\alpha = 0.05$). *SS* Sums of Squares.

	df	SS	P-value
Season	1	0.063	0.18
Habitat	1	0.031	0.35
Season X Habitat	1	0.038	0.30
Error	52	1.800	

Table 9. ANOVA results for partial fullness index for Gadiformes in the diet of adult goosefish (α= 0.05). *SS* Sums of Squares.

	df	SS	P-value
Season	1	3.4	0.48
Reserve	1	5.4	0.38
Habitat	1	1.0	0.71
Season X Reserve	1	7.1	0.31
Season X Habitat	1	12	0.68
Reserve X Habitat	1	0.8	0.74
Season X Reserve X Habitat	1	13.4	0.17
Error	58	394.2	

Table 10. ANOVA results for partial fullness index for Pleuronectids in the diet of adult goosefish (α= 0.05). *SS* Sums of Squares.

	df	SS	P-value
Season	1	0.799	0.72
Reserve	1	12.694	0.15
Habitat	1	0.007	0.97
Season X Reserve	1	0.799	0.72
Season X Habitat	1	0.484	0.78
Reserve X Habitat	1	0.007	0.97
Season X Reserve X Habitat	1	0.484	0.78
Error	111	679.953	

Table 11: ANOVA results for partial fullness index for Clupeids in the diet of adult goosefish (α= 0.05). *SS* Sums of Squares.

	df	SS	P-value
Season	1	107.881	**0.0099**
Reserve	1	38.909	0.12
Habitat	1	21.643	0.24
Season X Reserve	1	21.538	0.24
Season X Habitat	1	12.534	0.37
Reserve X Habitat	1	81.806	**0.024**
Season X Reserve X Habitat	1	35.607	0.13
Error	58	880.633	

FIGURES

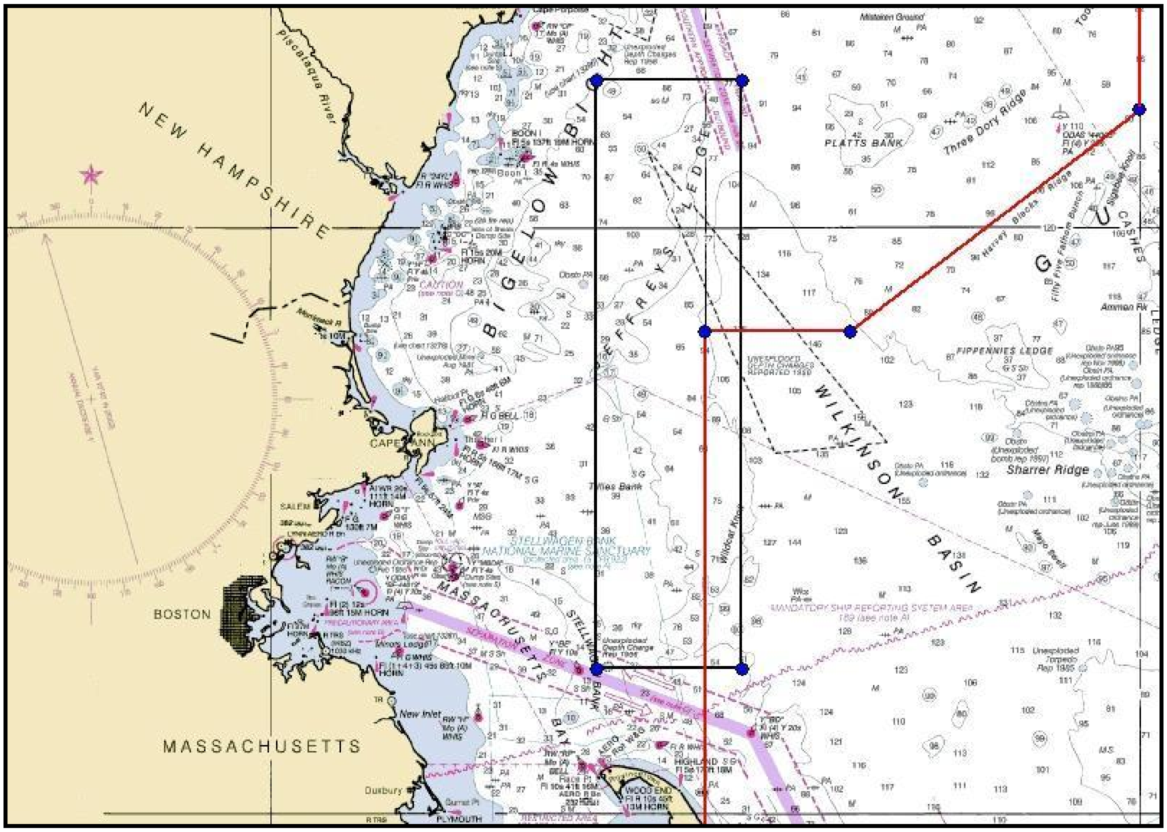

Figure 1: Western Gulf of Maine Closure Area is shown in black. The Goosefish Gillnet Exemption Area extends from the shoreline east to the red line during July to September.

Figure 2: Goosefish, *Lophius americanus*, with lure.

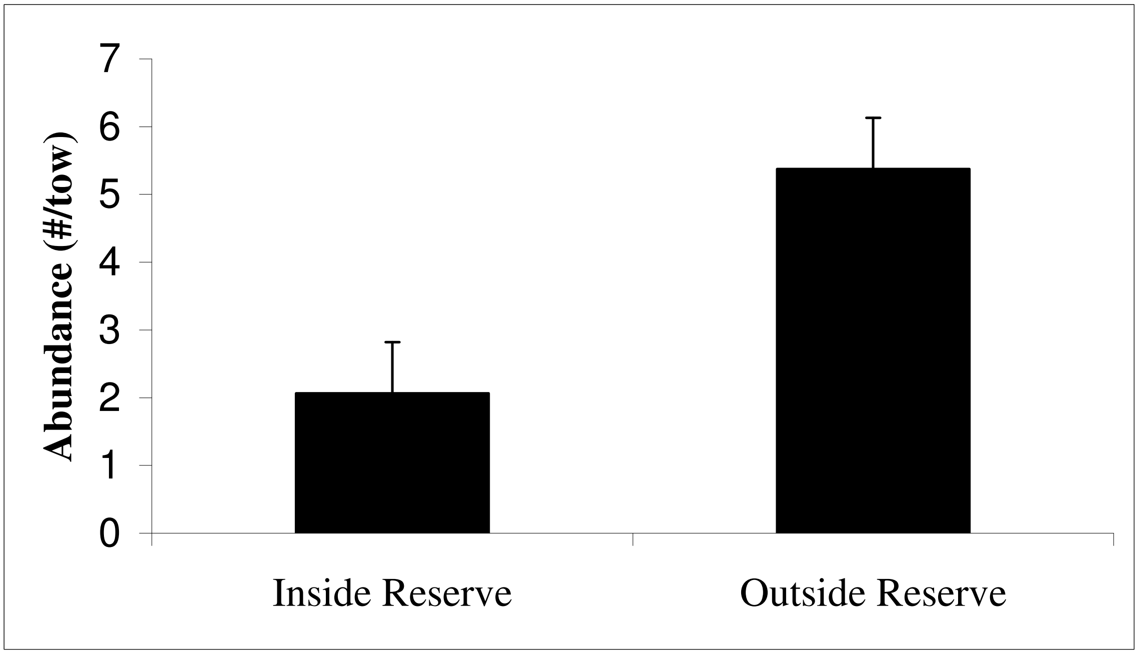

Figure 3: Mean abundance of goosefish caught inside the reserve vs. outside the reserve. Bars indicate one standard error.

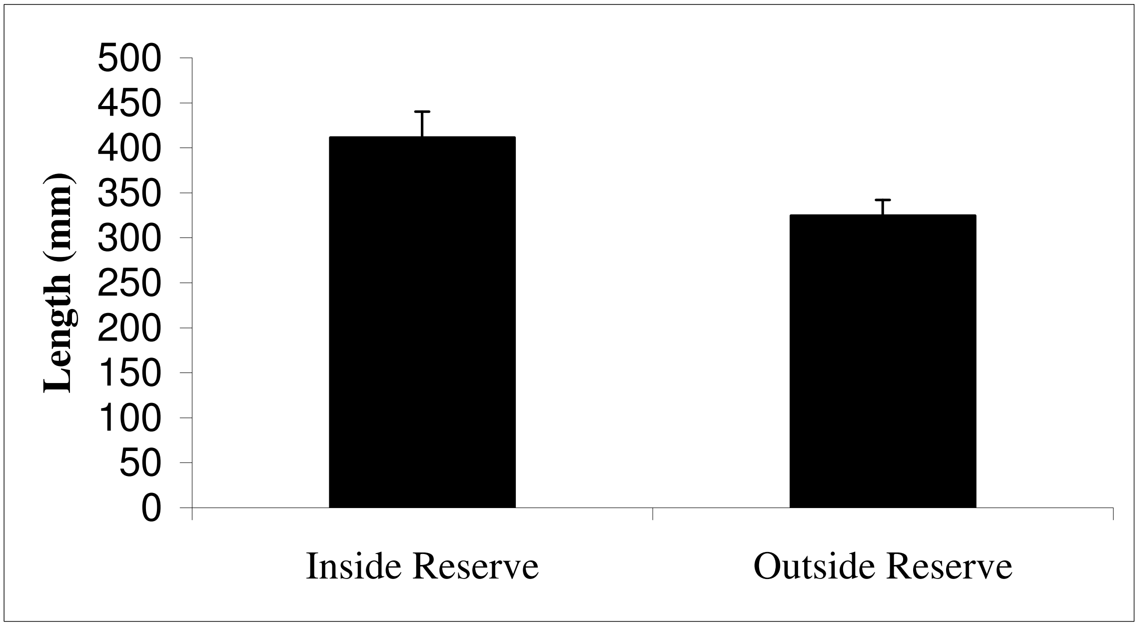

Figure 4: Mean length of goosefish caught inside the reserve vs. outside the reserve. Bars indicate one standard error.

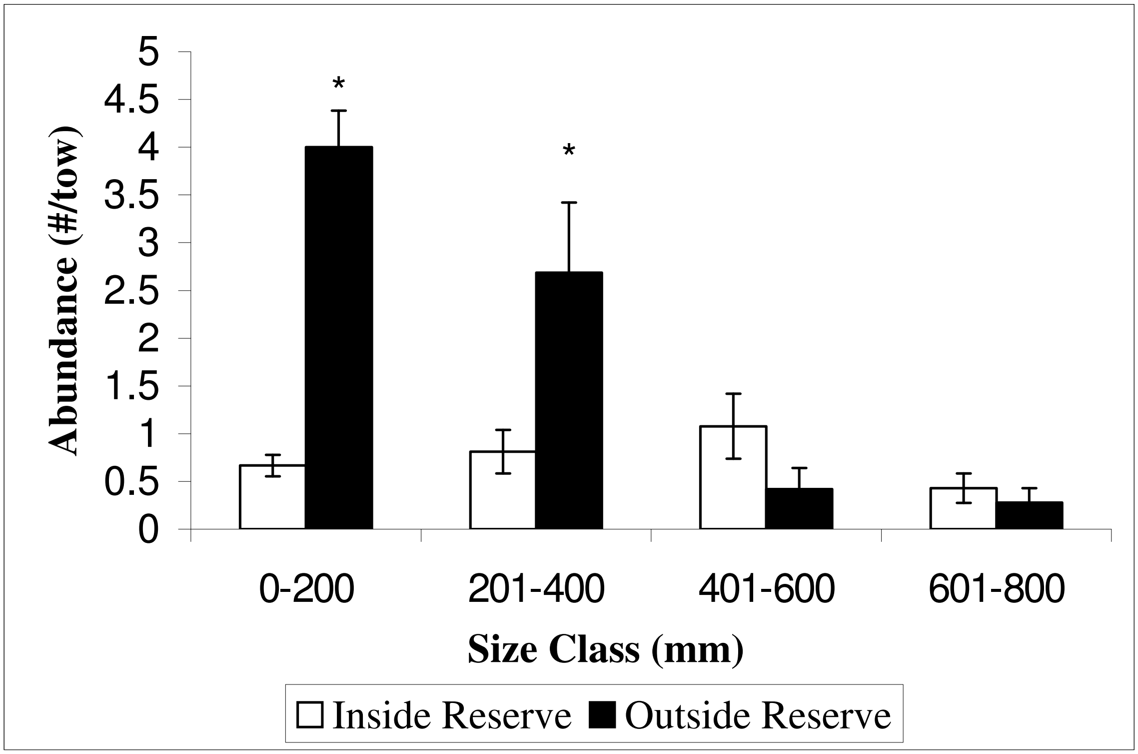

Figure 5: Average goosefish abundance per tow for four size classes. Bars indicate one standard error. Asterisk (*) denotes significant difference in abundance inside the reserve vs. outside the reserve (*P* ≤ 0.02).

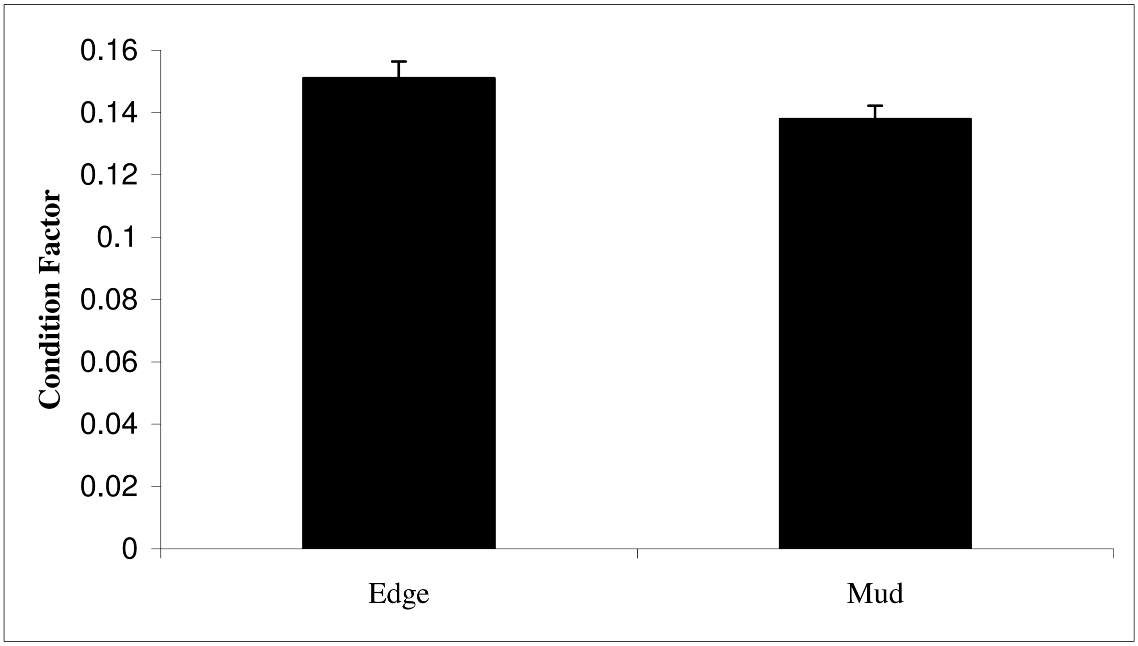

Figure 6: Mean condition factor of goosefish was significantly higher in the edge habitat over both seasons. Bars indicate one standard error.

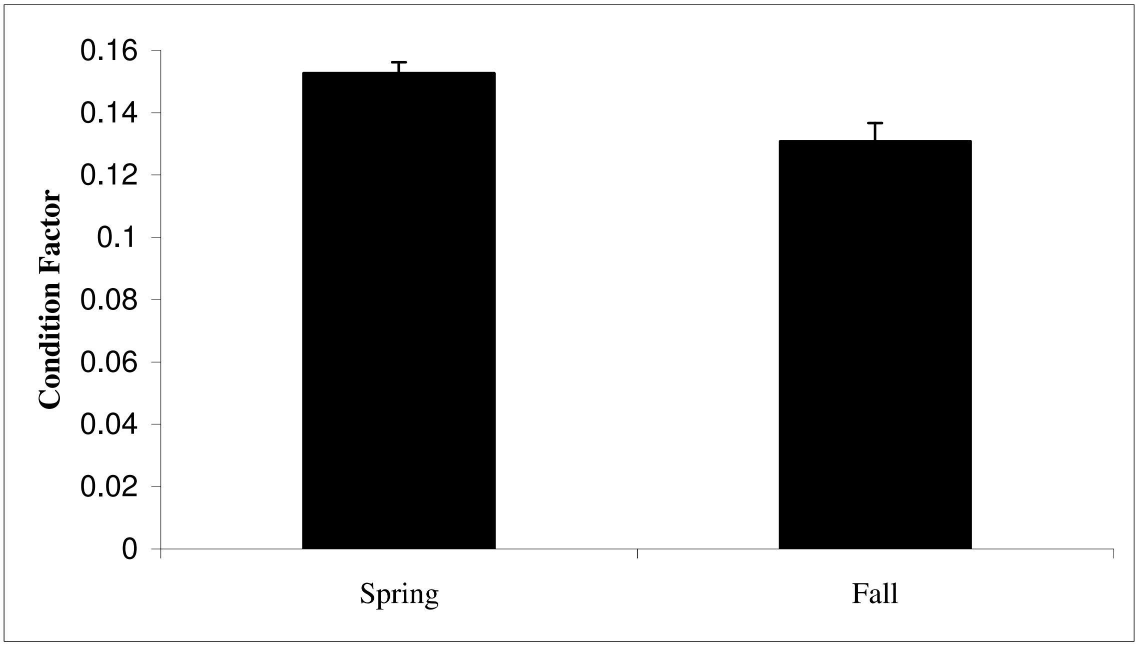

Figure 7: Mean condition factor of goosefish was significantly higher in the spring season than in the fall season. Bars indicate one standard error.

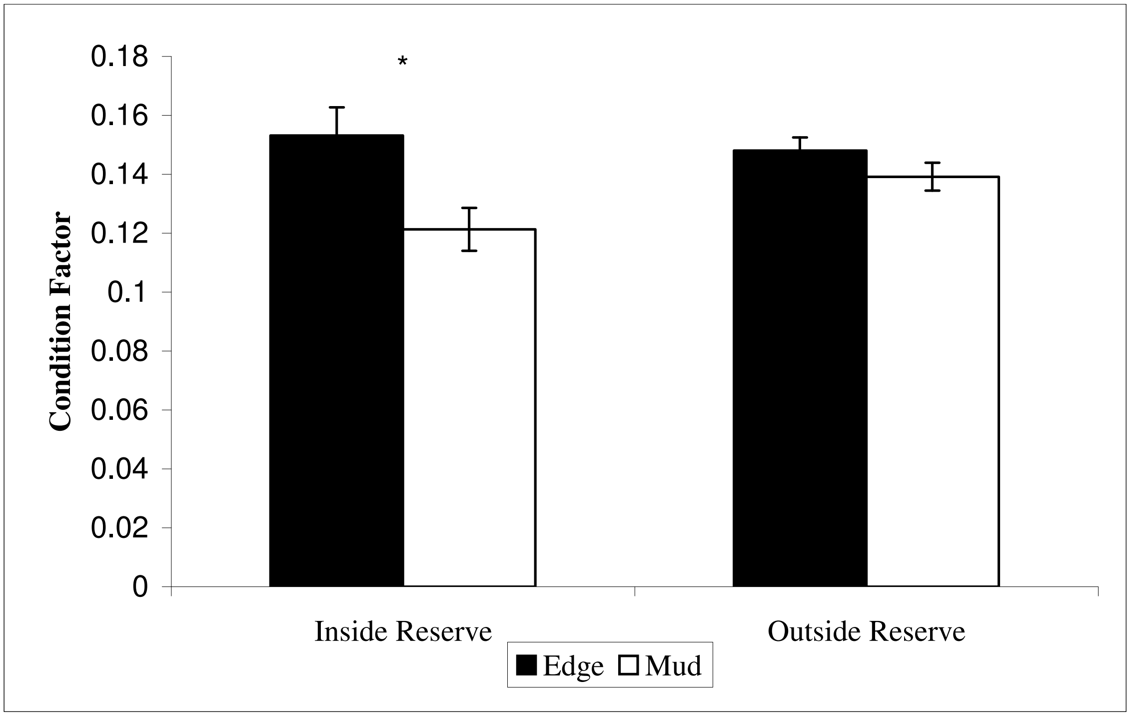

Figure 8: Condition factor of goosefish sampled on edge habitat inside the reserve is significantly higher than mud habitat (denoted by *). Condition factor did not vary between habitats outside the reserve.

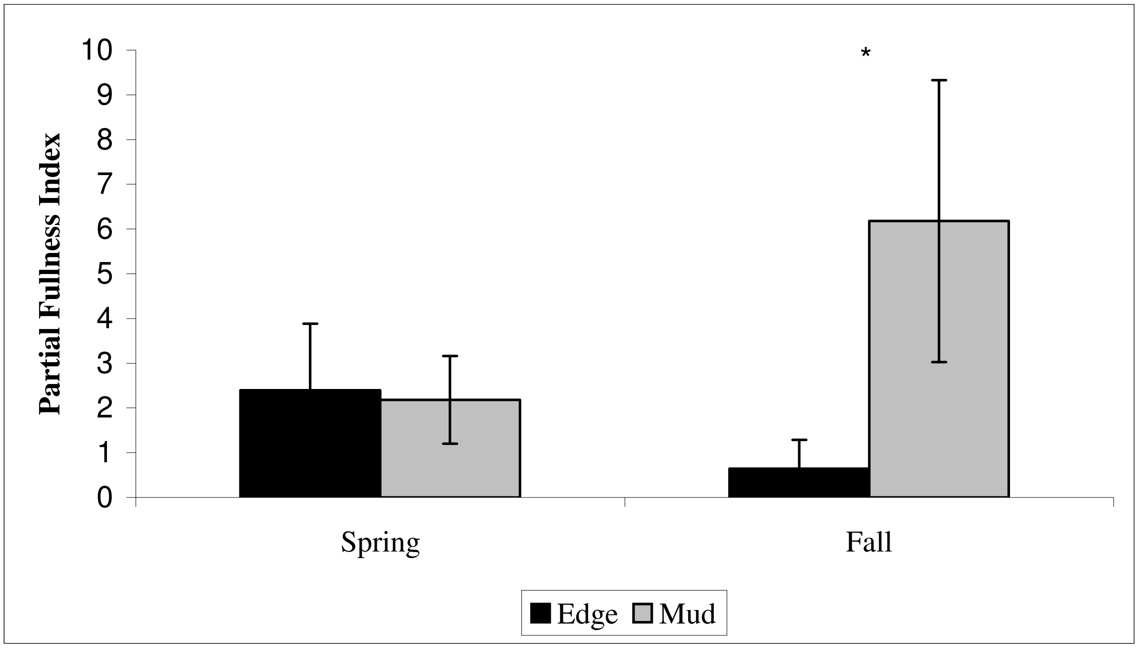

Figure 9: Mean partial fullness index for four-bearded rockling. Mean PFI was significantly higher in the mud habitat than edge during fall (denoted by *), while there was no significant variation in the spring. Bars indicate one standard error.

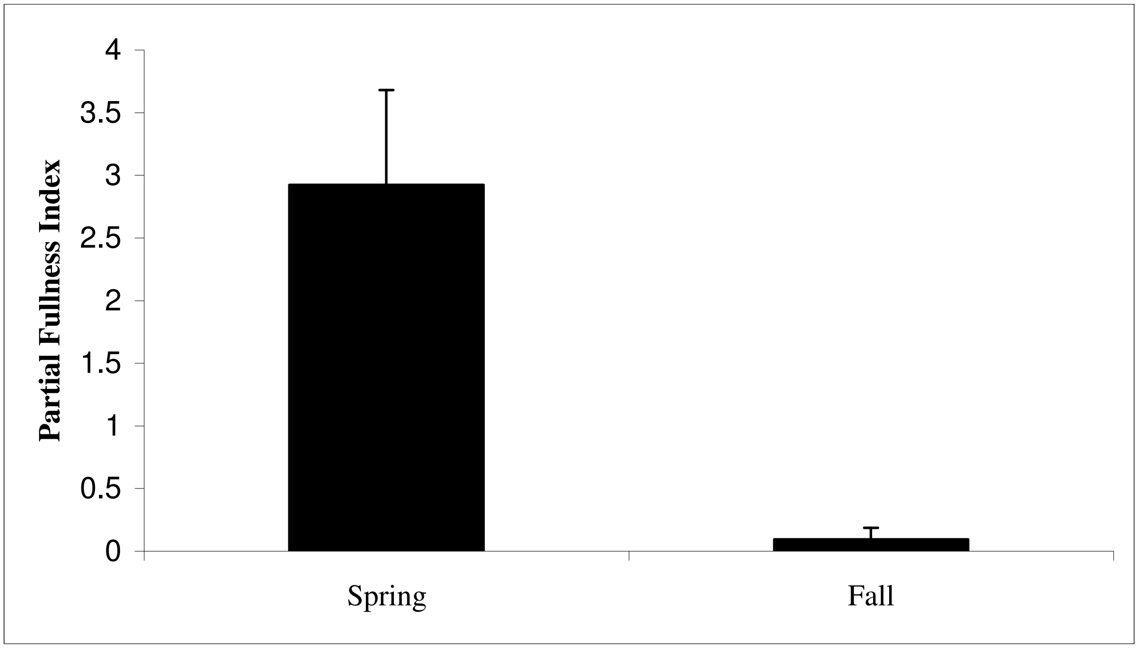

Figure 10: Mean partial fullness index of clupeids in adult goosefish diet PFI clupeids. Clupeids had a significantly higher PFI in spring vs. fall. Bars indicate one standard error.

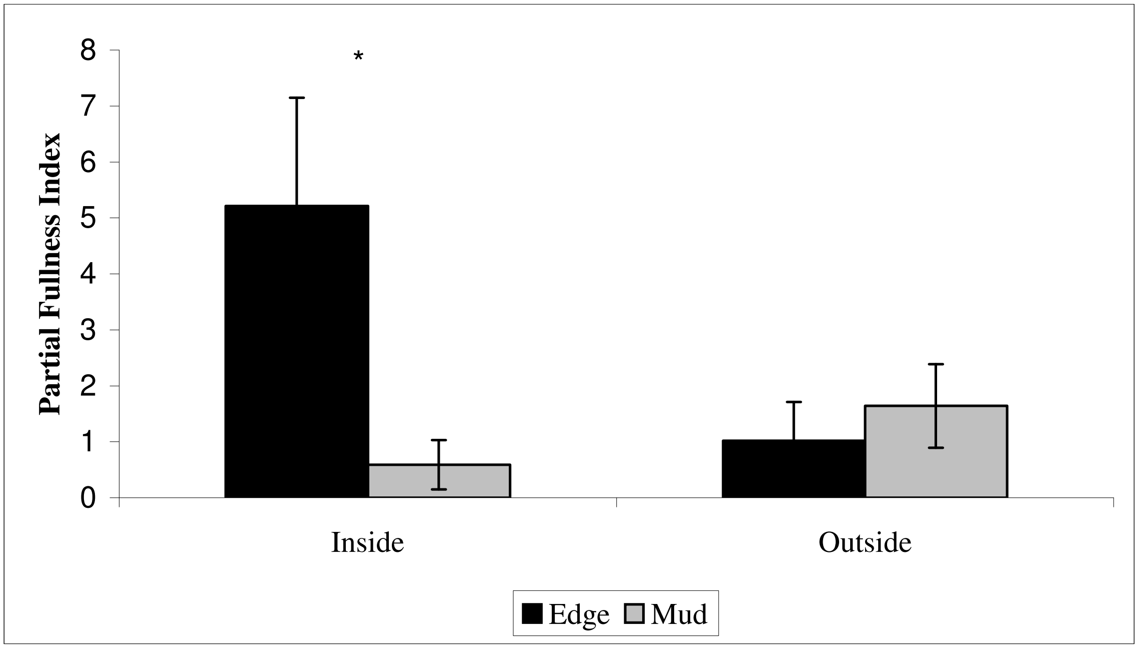

Figure 11: Mean partial fullness index of clupeids in adult goosefish diet. Inside the reserve only, PFI of clupeids was significantly higher on the edge habitat (denoted by *). Bars indicate one standard error.

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