Opportunistic feeding of longhorn sculpin (*Myoxocephalus octodecemspinosus*): Are scallop fishery discards an important food subsidy for scavengers on Georges Bank?

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There has been much recent interest in the effects of fishing on habitat and non-target species, as well as in protecting certain areas of the seabed from these effects (e.g. Jennings and Kaiser, 1998; Benaka, 1999; Langton and Auster, 1999; Kaiser and de Groot, 2000). As part of an effort to determine the effectiveness of marine closed areas in promoting recovery of commercial species (e.g. haddock, *Melanogrammus aegelfinus*; sea scallops, *Placopecten magellanicus*; yellowtail flounder, *Limanda ferruginea*; cod, *Gadus morhua*), nontarget species, and habitat, a multidisciplinary research cruise was conducted by the Northeast Fisheries Science Center (NEFSC), National Marine Fisheries Service. The cruise was conducted in closed area II (CA-II) of the eastern portion of Georges Bank during 19–29 June 2000 (Fig. 1). The area has historically produced high landings of scallops but was closed in 1994 principally for groundfish recovery (Fogarty and Murawski, 1998). The southern portion of the area was reopened to scallop fishing from 15 June to 12 November 1999, and again from 15 June to 15 August 2000. While conducting our planned sampling, we observed scallop viscera (the noncalcareous remains from scallops that have been shucked by commercial fishermen at sea) in the stomachs of several fish species at some of these locations, namely little skate (*Raja erinacea*), winter skate (*R. ocellata*), red hake (*Urophycis chuss*), and longhorn sculpin (*Myoxocephalus octodecemspinosus*). We examined the stomach contents of a known scavenger, the longhorn sculpin, to evaluate and document the extent of this phenomenon.

Fishery discards provide food subsidies that help maintain fish populations, but to what extent is unclear. There is some evidence that fishery discards allow fish populations to be more abundant than they would be with just ambient resources (e.g. Polis and Strong, 1996). Others would counter that these discards may maintain a population but not necessarily lead to population growth (Fonds and Groenewold, 2000). As an extension of our opportunistic field observations from the closed area (CA)-II 2000 cruise, we examined NEFSC historical bottom trawl survey and food-habits databases to ascertain the role of fishery discards in the Georges Bank ecosystem, with particular respect to the longhorn sculpin population.

Materials and methods

Our sampling was conducted concurrently with the scallop fishery, therefore it was necessary to continuously monitor vessel activity in the area opened to fishing prior to our arrival and during our sampling. Prior to sampling, we collected biweekly summaries of scallop fishing vessel activity during the 1999 open season, and day by day summaries of the 2000 season were obtained from the northeast region vessel monitoring system (VMS), National Marine Fisheries Service. With this system, individual vessel locations are transmitted to NMFS every 30 minutes (McSherry[1]). The location of each fishing vessel was plotted (with Surfer 7.0; GSI, 1999) on a map overlaid with the sampling sites occupied during the 1999 study (June 1999). Stations from the 1999 study were chosen on the basis of fleet activity during the 1999 open season and our sampling goals. Each day while the RV *Albatross IV* was in CA-II, current individual scallop-vessel activity data were transmitted to us by email, plotted, and sampling stations were selected after an examination of the data.

As part of our sampling protocol, a 15-minute otter trawl haul was made at each station, towed at a speed of 6.5 km/h. A standardized NEFSC no. 36 Yankee otter trawl rigged with a rubber-disc-covered chain sweep, 11 floats, 5-m ground cables, and 450-kg polyvalent trawl doors (commonly referred to as a “flatfish net”) was used. Once the trawl was on deck, we sorted fish and macro-invertebrates by species, weighed each species (0.1 kg), measured lengths of all fish (cm), examined subsamples of the fish to determine sex, maturity, and stomach contents, and collected structures to determine ages. For further details of the survey and food habits methods used in our study see Azarovitz (1981) and Link and Almeida (2000), respectively.

After initial observations of scallop viscera in fish stomachs at several previous locations, we developed an *ad hoc* study that deliberately selected two stations located in areas of high scallop fishing effort and two stations in areas of little or no scallop fishing effort. On 21–22 June 2000 we sampled stations 8B, 7D, 7E, and 8E in the northeast portion of the region open to the scallop fleet (Fig. 1). At stations 8B and 7E, we observed a high frequency of scal-

[1] McSherry, M. 1998. NMFS Northeast vessel monitoring system—operations logic and geographical display interface. NMFS NE Law Enforcement Office Internal Document, 20 p. [Available from NMFS, NEFSC, 166 Water St., Woods Hole, MA 02543.]

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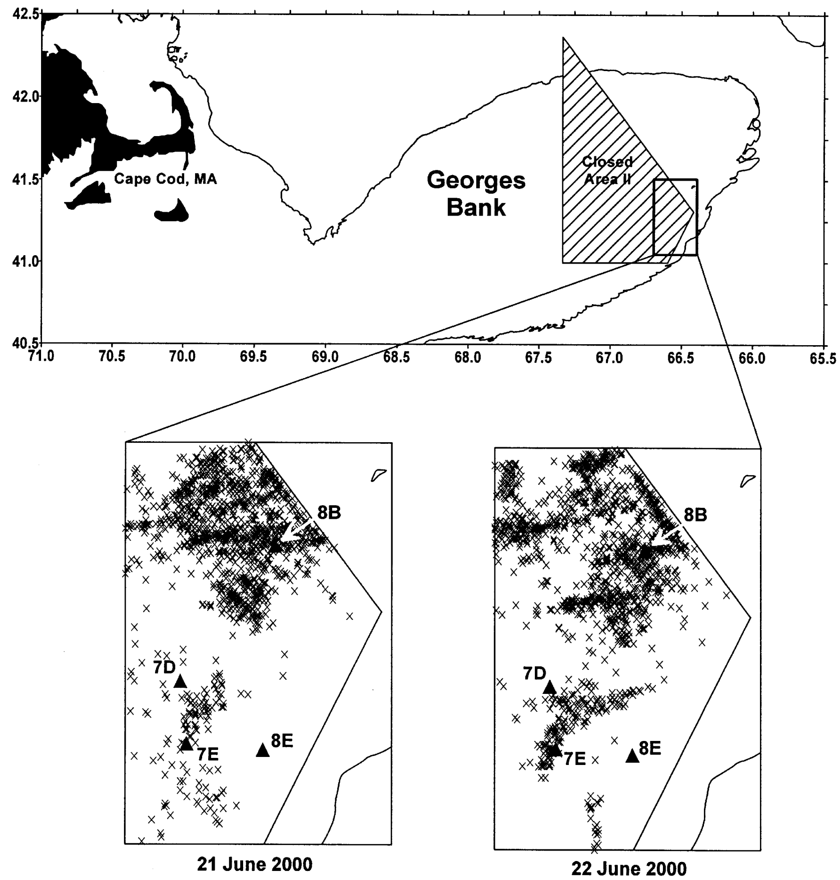

Figure 1

The northeast U.S. continental shelf region, with scallop fishing fleet activity (×) in closed area II of Georges Bank on 21–22 June 2000 overlaid with the sampling sites (▲) occupied by the NOAA FRV *Albatross IV* (Cruise AL 00-03).

lop viscera in the diets of longhorn sculpin, among other species, and undertook extra sampling of sculpin stomachs to assess the magnitude of this phenomenon. We also undertook extra sampling of sculpin at the other two stations. We present mean stomach volume and mean percent (by volume) diet composition for longhorn sculpin at these four stations.

To determine the prevalence of this phenomenon and whether discarded scallop viscera are a regular food subsidy that significantly influences the sculpin population, we examined the stratified mean number of sculpin per tow on Georges Bank (Azarovitz, 1981). We calculated this index of abundance across the fall bottom-trawl survey time series from 1963 to 1998. Additionally, we examined the mean stomach contents (cm^3), maximal stomach contents, percent frequency of occurrence of bivalve, mollusk, or pectinid viscera, and an index of gorge feeding on an annual basis from the food habits time series (Link and Almeida, 2000). The index of gorge feeding (or more simply, the gorge index) was calculated as the percent of stomachs examined with total stomach contents greater than 10 cm^3. We executed a simple linear correlation between the sculpin food-habit metrics and the index of abundance to determine if any significant relationship exists between gorge feeding and sculpin population abundance.

Results

On 21 and 22 June 2000, scallop fishing clearly occurred at stations 8B and 7E, whereas no scallop fishing occurred at 7D or 8E (Fig. 1). Rock crabs (both *Cancer irroratus* and *C. borealis*) and small crustaceans typify the diet of longhorn sculpin (Fig. 2). However, at stations in areas with scallop fishing activity, the diet of sculpin was predominately made up of scallop viscera. Crabs and small crustaceans were still a part of the diet at those stations, but did not comprise as large a percentage as was found at nondredged stations.

The volume of food in sculpin stomachs was also an order of magnitude higher at stations with intense scallop fishing activity (8B=38.7 cm^3 ±6.9; 7E=19.4 cm^3 ±12.7) than at those with no scallop fishing (8E=1.7 cm^3 ±1.4; 7D=0.3 cm^3 ±0.1). When scallop remains were present at

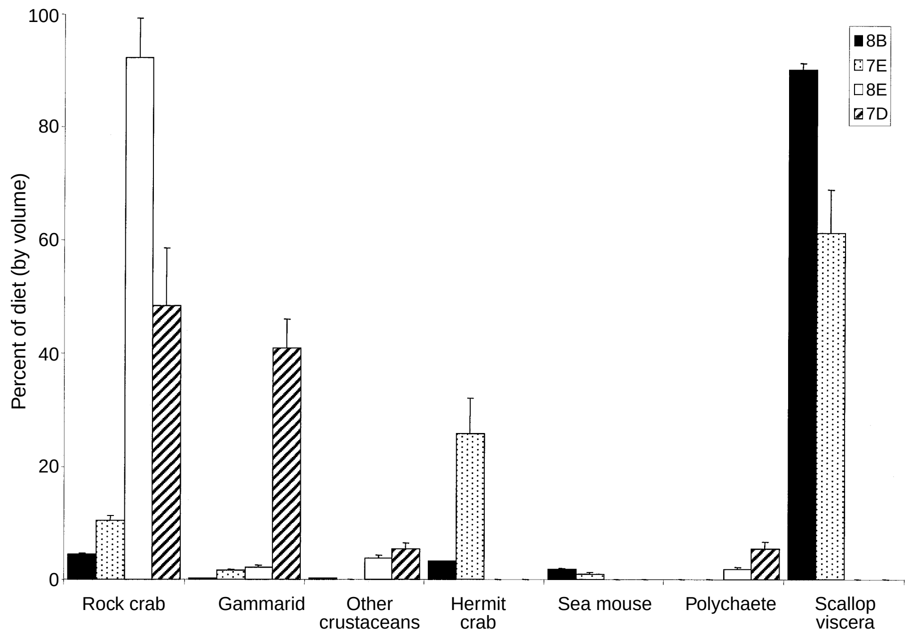

Figure 2

Diet composition (% by volume) of longhorn sculpin at two dredged and two undredged locations in closed area II. Bars are 95% confidence intervals. Sample sizes are 15, 8, 11, 6 fish at stations 8B, 7E, 8E, and 7D respectively.

a location, the amount of food consumed by sculpins increased significantly, suggesting that sculpins continued to feed on crabs and small crustaceans, but opportunistically gorged on the remains of scallops that had been shucked and thrown overboard from scallop fishing vessels operating in the region. Although anecdotal, the stomachs of all sculpins at station 8B, the station most intensely dredged, were distended beyond normal proportions for 20–25 cm fish, often extending below the pectoral fins.

The mean stomach contents of sculpin were effectively constant across the time series, averaging approximately 2 cm^3 (Fig. 3). However, the maximal stomach contents, the percent frequency of bivalve viscera, and the index of gorge feeding showed distinct patterns across the time series. All three of these metrics were generally coincident. Years with a higher gorge index corresponded to years with a high occurrence of bivalve viscera in the diet of sculpins (r=0.70, P<0.01). This finding implies that many, but not all, of the gorging events were on scallop viscera and similar discards. The highest values of the gorge index were observed in 1987 and 1998.

Longhorn sculpin abundance exhibited an initial peak and then a relatively steady period for the first 15 years of the survey, followed by a period of lower abundance during the mid-1980s and an increasing trend in the 1990s (Fig. 4). In most years sculpin abundance ranged from 10 to 20 fish per tow. The years with the highest index of sculpin abundance were 1966 and 1998. In relation to the preceding years, the index of sculpin abundance notably increased during 1966, 1987, and 1998. The latter two years correspond to years when the index of gorge feeding was highest. The correlation between the gorge index and sculpin abundance was weak (r=0.21), but significant and positive (P<0.01).

Discussion

Much of the information describing the impact of fishing gear on benthic communities and habitats has been decidedly negative. It is unclear whether populations of scavengers such as crabs, flatfish, or other demersal fish benefit from indirect effects of fishing (Kaiser and Spencer, 1994; Greenstreet and Hall, 1996; Ramsay et al., 1996) if they are not caught by the fishing gear. It is known that in the short term, scavengers, especially those small enough to fit through the mesh, are attracted to trawl and dredge tracts (e.g. Ramsay et al., 1998; Demestre et al., 2000). Additionally, some studies have actually shown that the abundance of scavenger populations increases in areas that have been trawled (reviewed in Greenstreet and Rogers, 2000). Longhorn sculpin on Georges Bank have maintained their ubiquity and abundance, albeit at relatively low levels compared with other species, during a period of intense fishing pressure in this ecosystem (Fogarty and Murawski, 1998). In recent years the sculpin population on Georges Bank has begun to increase.

Opportunistic feeding on scallop viscera appears to have a positive influence on sculpin populations. The relationship between gorge feeding and sculpin abundance is ad-

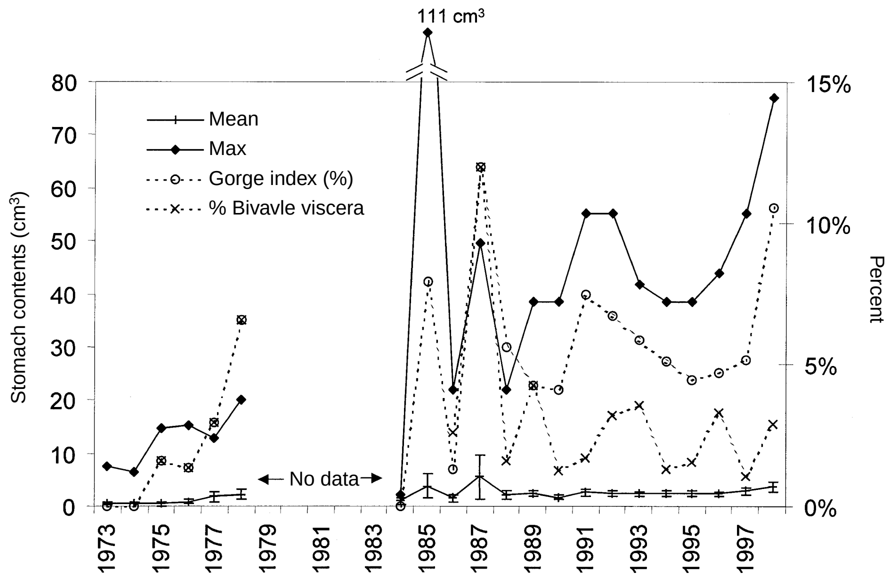

Figure 3

The mean (95% CI) and maximal (largest amount eaten) stomach contents (cm^3) of longhorn sculpin from the NEFSC food habits database. Also, the index of gorge feeding (percentage of stomachs with >10 cm^3) and percentage of stomachs containing bivalve, mollusk, or pectinid viscera.

mittedly weak, yet significant and positive. We recognize that numerous other factors could influence sculpin abundance. However we find it intriguing that the two years with the most drastic increase in sculpin abundance (in the context of recent preceding years; i.e. 1987 and 1996) occurred in years when sculpin gorge feeding was highest.

The amount of food eaten and the diet of longhorn sculpin at stations without scallop fishing activity were similar to those reported for the species on the entire northeast continental shelf (Link and Almeida, 2000) and for Georges Bank in particular (Garrison and Link, 2000). The amount of food eaten and diet at stations with scallop fishing activity showed clear evidence of gorge feeding by sculpin. Other studies have documented opportunistic feeding and changes in diet after groundfish trawling (e.g. gurnards and dabs; Kaiser and Spencer, 1994; Kaiser and Ramsay, 1997), however, this note is the first documentation of scavenging after scallop fishing. The long-term trend shows that, although the average amount of food sculpin consume is relatively constant, the composition of the diet and the frequency of gorging events varies notably. These variations may influence sculpin abundance.

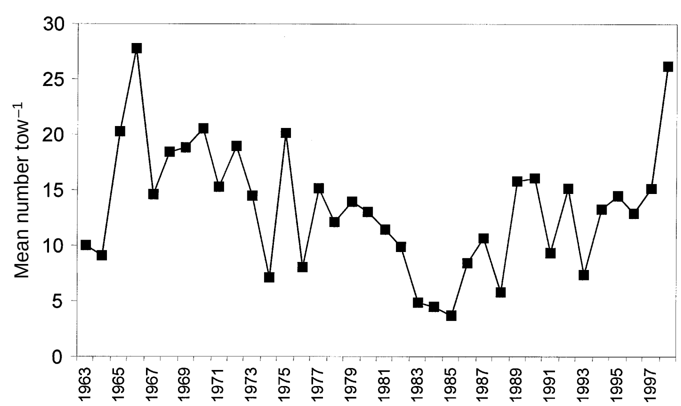

Figure 4

Index of relative abundance of longhorn sculpin from the NEFSC fall bottom trawl survey.

In the 2000 open fishing season in CA-II, more than 760 metric tons (t) of scallop meats were landed (NERO, 2000). If one conservatively assumes that scallop viscera equals the meat weight, then over 760 t (>340,000 lb) of viscera were returned to the southern part of CA-II during this two-month period. The discarded scallop viscera are a relatively small organic input, on an areal basis, to this closed area, which averages ca. 430,000 t in total annual benthic production (111 g/m^2, Cohen and Grosslein, 1987; approximately 3900 km^2 for the southern part of CA-II). How many tons of scallop viscera and similar discards have been deposited across the entire Bank over the past several decades is unknown. Yet, at a local scale scallop viscera may be an important source of energy, akin to similar processes for fish in the deep ocean (Sedberry and Musick, 1978). The biomass of scallop viscera, although previously a part of the system, is returned in a condition much more readily available to benthic scavengers. Even weak links in terms of diet or energy can be important dynamic links in terms of population regulation (reviewed in Polis and Strong, 1996). The reintroduction of scallop viscera may not be a large addition of energy to the Georges Bank ecosystem, but it may be an important one for sculpin and other opportunist populations.

There is evidence that energy derived from fishery discards can cause scavengers to become more abundant than they would be with ambient resources (Polis and Strong, 1996), or at least these discards can help scavengers maintain population abundance under disturbed circumstances (Fonds and Groenewold, 2000). Further studies may indicate that events which produce food subsidies such as those documented in this study may be more common than generally suspected. Given the ubiquity of naval, commercial, and private vessels on the ocean, it likely that organic waste from these ships, from fishing activities, and from similar processes serves as a significant "rain of food" for benthic scavengers.

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