Trawl-induced Damage to Sponges Observed From a Research Submersible

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Introduction

There is growing concern that anthropogenic disturbance, particularly commercial fishing activity, impacts the sea floor and associated biological communities. In response to these concerns, a variety of investigations concerning effects of mobile and nonmobile fishing gear on biotic and abiotic components of seafloor habitat have been carried out. Auster and Langton (1999) reviewed the majority of these studies and noted that certain types of commercial fishing have generally caused changes in species composition and diversity and a reduction in habitat complexity. Mobile fishing gear can reduce habitat complexity by removing emergent epiflora (Peterson et. al., 1983; Fonseca et al., 1984; Peterson et al., 1987; Guillen et al., 1994) and epifauna (Bradstock and Gordon, 1983; Van Dolah et al., 1987; Collie et al., 1996, 1997; Engel and Kvitek, 1998) that provide structural habitat components, and also by smoothing biogenic (Auster et al., 1996; Currie and Parry, 1996) and non-biogenic (Bridger, 1970, 1972) bedforms.

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ABSTRACT—Three experimental trawl paths subjected to a single pass with the trawl in 1996 in about 200 m of water on the eastern Gulf of Alaska continental shelf were revisited in July 1997, 1 year post-trawl. Many large, erect sponges, the taxa impacted most significantly, had been removed or damaged by the trawl. Sponges in the cold, deep water of the Gulf of Alaska were slow to recover from trawling effects. These findings contrast with recovery times for shallow, warmwater sponges and may have fishery management implications for cold-water regions.

Work carried out in hard bottom (boulder, cobble, pebble) habitat on the continental shelf in the Gulf of Alaska (GOA) (Freese et al., 1999) showed that a single trawl pass can displace boulders and remove or damage large epifaunal invertebrates. Both of these changes reduce habitat complexity on such substrata in the GOA. In this area, the invertebrate taxa most likely to be removed or damaged by bottom trawling include gorgonian corals (Krieger, 2002) and several species of large, erect sponges, which, along with boulders, provide most of the three-dimensional relief on the sea floor (Fig. 1). Sponges account for most of the invertebrate biomass because of their large size and relatively high population density. The capacity of damaged sponge communities to regenerate may have long-term management implications for essential fish habitat (EFH) (Sainsbury et al., 1997; Kaiser et al., 1999).

Van Dolah et al. (1987) and Tilmant (1979) showed that experimental trawling in hard bottom habitat in warm, shallow waters of the southeastern United States resulted in similar immediate effects to those found by Freese et al. (1999). Van Dolah et al. (1987) returned to their study site 1 year post-trawl and found that sponge population densities had returned to pre-trawl levels and that damaged sponges had regenerated. However, no quantitative data exist regarding the recovery of sponges in deep, cold-water habitats such as the GOA following trawling. Objectives of this study were to determine 1) whether reductions in numbers of sponges observed by Freese et al. (1999) in experimental trawl paths immediately post-trawl persisted after 1 year, and 2) whether individual sponges damaged by the trawl showed signs of recovery or delayed mortality during that period.

Methods

The submersible vehicle *Delta* was chartered in July 1997 by the NMFS Alaska Fisheries Science Center (AFSC) to revisit sites in the GOA that had been subjected to experimental trawling in August 1996 (Freese et al., 1999). The *Delta* is a two-person research submersible capable of diving to a depth of 365 m; it can travel up to 6 km/h for up to 4 h. It is equipped with external halogen lighting, an external Hi-8 video camera, a handheld digital video camera, magnetic and gyro compasses, sub-to-tender communications, and an acoustic transponder for tracking the vehicle (Freese et al., 1999).

In 1996, Freese et al. (1999) completed eight tows from a 42.5 m commercial trawl vessel towing a 4-seam, high-opening polyethylene Nor'eastern[1] bottom trawl. The trawl was modified with 0.6 m tires in the bosom and fitted with 0.45 m rockhopper discs and steel bobbins along the wings. This type of trawl was chosen because it is similar to gear used over rough bottom in the commercial rockfish fishery in the GOA (Stark and Clausen, 1995). Owing to time

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

constraints, only three of the eight 1996 trawl paths were revisited in 1997. These trawl paths were chosen for further study because of the large number of sponges there in 1996. The beginning and end of all trawl paths had been marked in 1996 with numbered orange flags on flexible whips fitted to lead weights; differential global positioning system (DGPS) coordinates of marker locations and compass bearings between markers were noted to facilitate relocation of the trawl paths in 1997. The area sampled within trawl paths was estimated by using coordinates at the markers to determine trawl path length, and multiplying this figure by 5 m, the width of the trawl tire gear. The tire gear and trawl doors were the only parts of the trawl that were consistently in contact with the sea floor. Trawl tows in 1996 had been kept relatively short to preclude the cod end of the net from filling and thereby narrowing the width of the net mouth. Only those sponges that were within the footprint of the trawl tire gear were counted.

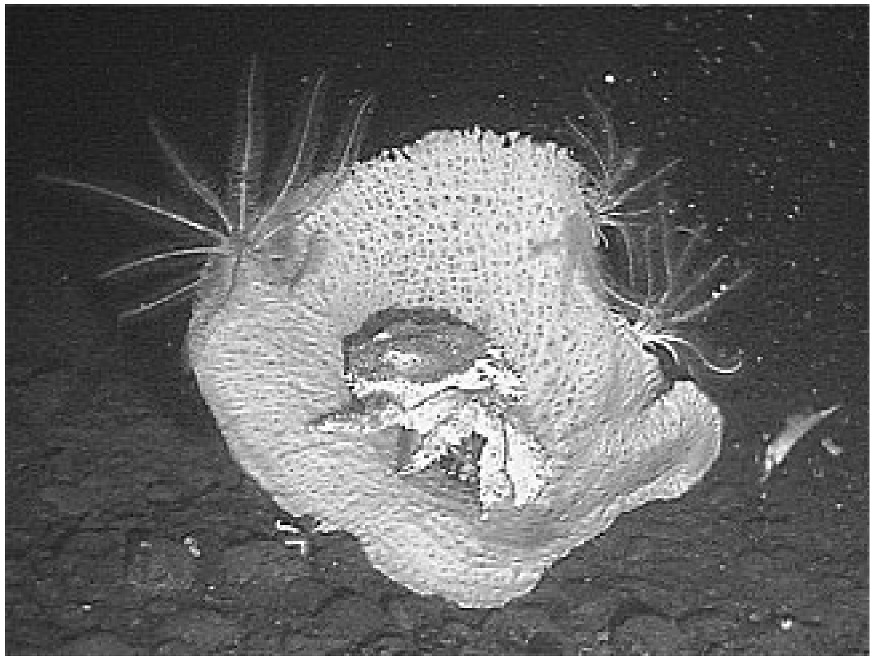

Figure 1.—Large, erect sponges provide habitat complexity on hard-bottom substrates in the Gulf of Alaska.

After descending to the sea floor, the submersible pilot located a trawl path marker using coordinates supplied by the support vessel tracking system. The submersible then followed the trawl path for its entire length, with the starboard side of the vehicle remaining just outside of the trawl marks on the sea floor. Continuous images of the trawl paths were obtained with the external video camera. When sponges were located in the trawl paths, the submersible pilot approached and circled them while the observer recorded images of the sponges with the digital video camera. The audio track on the camera was used to record descriptions of damage to sponges, as well as general observations. Sponges were categorized as 1) undamaged, 2) upright but torn, or with pieces of the sponge body missing, or 3) lying on the bottom, either torn or intact. Tears to the body of the sponge were counted only if the tears were longer than 10% of the length of the longest axis of the body of the sponge. Similarly, sponges with less than 10% of their bodies missing were not counted as damaged. Damage category 3 included sponges that were still attached to cobble or boulders that had been rolled or dragged by the trawl so that the sponges were touching or lying on the substrate. Only sponges >20 cm high were counted. Sponges were also examined (both in situ and with videotapes in the laboratory) for regrowth or repair of damaged body parts, as evidenced by rounding of jagged wounds or partial healing of tears.

After completing operations in the trawl path, the submersible pilot maneuvered the vehicle approximately 100 m away and completed a reference transect approximately parallel to and equal in length to the trawl path. Observations were recorded in a manner identical to those made in the trawl path. Because trawl gear tire marks were not present in the reference transects, a distance of 5 m (the width of the tire gear on the trawl) from the submersible's viewing port was estimated visually, and sponges within only that distance were counted and examined.

Results

Water depths along the three trawl paths and three reference transects were 206–209 m. Lengths of trawl paths between markers were 350, 570, and 860 m. Lengths of reference transects were 370, 500, and 770 m. Lateral underwater visibility along all trawl paths and reference transects was approximately 10 m. Trawl path markers were relocated easily and appeared undisturbed. Furrows in the substratum caused by the trawl tire gear were still prominent after 1 year and showed little evidence of backfilling (Fig. 2). Boulders that had been moved by the trawl in 1996 were identified easily by the deep gouges they made in the substratum where they had been dragged; the gouges showed no evidence of backfilling (Fig. 3). Furrows and dragged boulders made the trawl paths easily recognizable.

Sponge morphology is highly variable, and visual identification in the field is problematic. Taxonomists often resort to a combination of histological, cytological, embryological, and biochemical methods for positive identification of specimens (Brusca and Brusca, 1990). With this caveat in mind, sponges encountered in this study were tentatively identified on the basis of gross morphology by comparing video images to plates and photographs in the literature (particularly Pavlovskii, 1955) and by comparison with specimens in the AFSC Auke

Bay Laboratory reference collection. The species so identified included the demosponges *Esperiopsis* sp. (Fig. 4a), *Mycale* sp. (Fig. 4b), and *Geodia* sp. (Fig. 4c), and the hexactinellid glass sponge *Rhabdocalyptus* sp. (Fig. 4d).

Esperiopsis and *Mycale* are similar in appearance (brownish-yellow, with a delicate basket or bell shape) and grow as high as 1 m. When nudged by the submersible, both species appeared to be flexible, quickly assuming their original shape after deformation. *Esperiopsis* and *Mycale* were found growing on large cobbles and boulders. *Geodia* was grayish-white and of a more robust basket shape. Specimens were smaller than *Esperiopsis* and *Mycale*, attaining a maximum height of about 50 cm, and were more rigid, becoming broken or upended when nudged by the submersible. *Geodia* grew on cobbles and boulders. *Rhabdocalyptus* was dark brown, columnar or barrel-shaped, and grew to a height of over 1 m, although the average height was about 40 cm. Specimens usually had long, needlelike spicules protruding from the body. *Rhabdocalyptus* was flexible and was usually found growing on finer substrate, including small pebbles and gravel. In this paper, the four species are referred to as basket sponges (*Esperiopsis* and *Mycale*), glass sponges (*Rhabdocalyptus*), and *Geodia*.

A total of 246 sponges >20 cm high were present in the three trawl paths (Table 1). These sponges were those that had not been removed by the trawl in 1996. No new colonization of sponges was apparent in any of the three trawl paths. Mean density of the four species for all trawl paths combined was 2.76 sponges/100 m^2 (2.20–3.37 sponges/100 m^2). Basket sponges, *Geodia*, and glass sponges comprised 66.7%, 26.0%, and 7.3% of total sponges in the three trawl paths. We observed 115 (46.8%) sponges that showed evidence of damage (Table 1). Incidence of damage for basket sponges, *Geodia*, and glass sponges was 43.3%, 59.4%, and 33.3%. Of the damaged sponges, 31.3% were upright but torn (category 2, Fig. 5), and 68.7% were lying on the bottom, either torn or intact (category 3, Fig. 6). Approximately equal numbers (34 vs. 37) of basket sponges were in categories 2 and 3. In contrast,

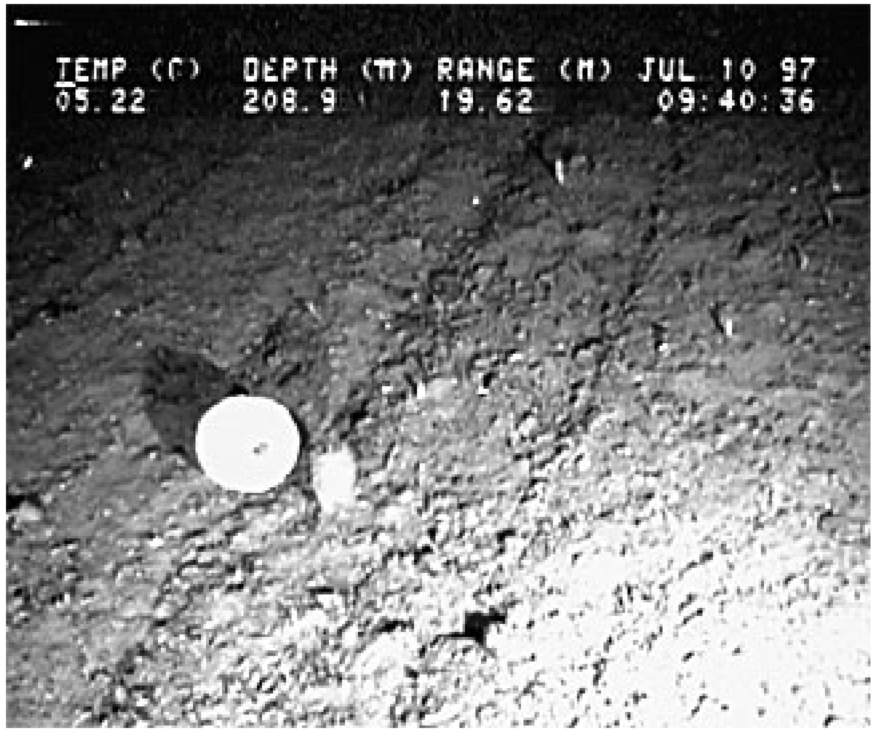

Figure 2.—Furrows in the substrate caused by a trawl were visible after 1 year; a damaged and an undamaged sponge are visible in the trawl track.

Figure 3.—Gouges made by dragged boulders were present 1 year post trawl.

Table 1.—Incidence of damage to sponges in trawl paths in the Gulf of Alaska in 1997, 1 year post-trawl. Figures are mean percentages for each damage category for each type of sponge for three trawl paths, one trawl tow per path.

Damage category[1]	Basket sponges		*Geodia*		Glass sponges		All sponges	
	%	Number[2]	%	Number[2]	%	Number[2]	%	Number[2]
1	56.7	93	40.6	26	66.7	12	53.3	131
2	20.7	34	3.1	2	0.00	0	14.6	36
3	22.6	37	56.3	36	33.3	6	32.1	79
Total	100.0	164	100.0	64	100.0	18	100.0	246

[1] Damage category 1=undamaged; 2=upright but torn; 3=lying on the bottom, torn or intact.
[2] Actual numbers of sponges.

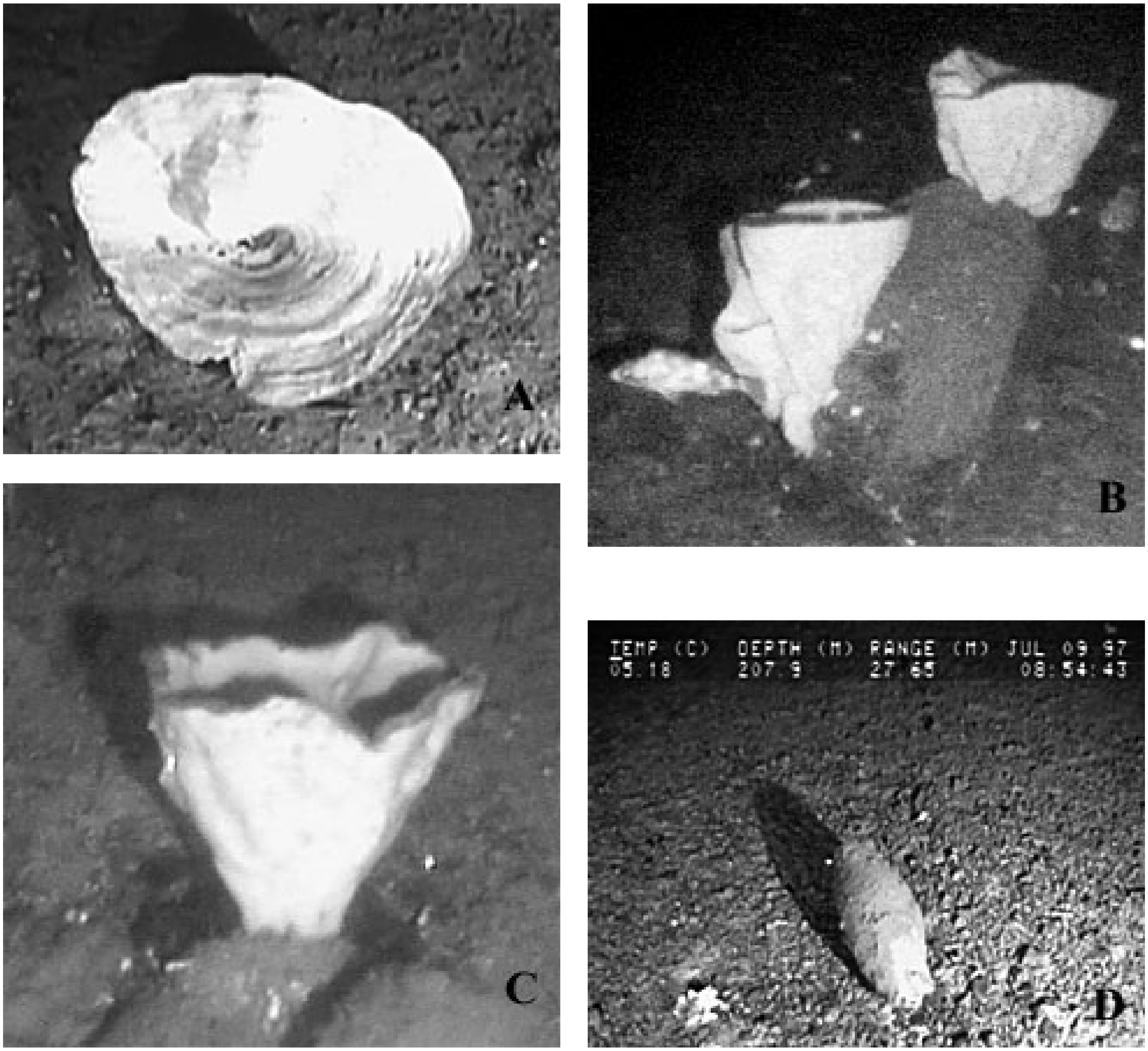

Figure 4.—Sponges tentatively identified as a) *Esperiopsis* sp., (note ringed pattern on interior of funnel) b) *Mycale* sp., (lattice structure of irregular funnel can be observed upon close inspection) c) *Geodia* sp., (note velvety appearance of spicules on upper edge of funnel), and d) *Rhabdocalyptus* sp., a barrel-shaped glass sponge.

almost all damaged *Geodia* (36 vs. 2) and all six damaged glass sponges were in category 3.

Of the damaged basket sponges, 9.9% showed some degree of necrotization of the sponge body. Necrotic areas ranged from 5 to 90% of the entire organism. Necrosis appeared to begin with bruising and subsequent discoloration of the pinacoderm in the immediate vicinity of the area where the sponge was torn, crushed, or otherwise damaged, and subsequently radiated away from the site of damage. The mesohyle was eventually necrotized, leaving large areas of the supportive framework of fibrous collagen (spongin) visible (Fig. 7). Only the basket sponges appeared to be affected; *Geodia* and glass sponges showed no evidence of necrosis.

Sponges were examined for evidence of repair or regrowth of damaged or missing body parts. None of the 115 damaged sponges in the trawl paths showed signs of repair or regrowth. All wounds and tears appeared to be fresh with irregular surfaces, and no evidence of rounding due to regrowth was noted (Fig. 8). On the other hand, many sponges that had been knocked over, or pieces of sponge

Figure 5.—Damaged sponges, category 2, upright but torn.

Figure 7.—Necrotic sponge.

Figure 6.—Damaged sponge, category 3, lying on bottom, intact or torn.

Figure 8.—Damaged sponge, no evidence of regrowth or regeneration after 1 year.

that had been torn free and were lying on the bottom, still appeared viable after 1 year (Fig. 9).

A total of 287 sponges of the same species observed in the trawl paths were present in the reference transects (Table 2; mean density = 3.50 sponges/100 m^2 (2.63–4.79 sponges/100 m^2)). Basket sponges, *Geodia*, and glass sponges made up 74.6%, 20.9%, and 4.5% of total sponges, respectively. Only four sponges (1.4%) were slightly damaged, having tears or missing body parts that had been partly regenerated, as evidenced by rounding of jagged edges of wounds. No necrotization of any sponge in the reference transects was observed.

Discussion

This study demonstrates that damage to several species of large, erect sponges

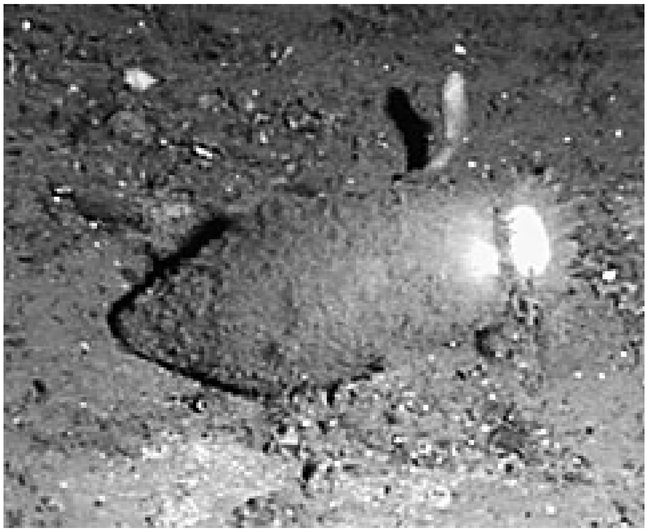

Figure 9.—Damage category 3 sponge, still viable after 1 year.

Table 2.—Incidence of damage to sponges in reference transects in the Gulf of Alaska in 1997. Figures are mean percentages for each damage category for each type of sponge for three reference transects.

Damage category[1]	Basket sponges		*Geodia*		Glass sponges		All sponges	
	%	Number[2]	%	Number[2]	%	Number[2]	%	Number[2]
1	98.6	211	98.3	59	100.0	13	98.6	283
2	0.0	0	0.0	0	0.0	0	0.0	0
3	1.4	3	1.7	1	0.0	0	1.4	4
Totals	100.0	214	100.0	60	100.0	13	100.0	287

[1] Damage category 1 = undamaged; 2 = upright but torn; 3 = lying on bottom, torn or intact.
[2] Actual numbers of sponges.

caused by trawling in deep waters on the continental shelf break off the coast of Alaska may persist for extended periods. In August 1996, immediately post-trawl, density of sponges in eight trawl tracks was 16% lower than the density of sponges in the eight reference transects (3.15 sponges/100 m^2 vs. 3.73 sponges/100 m^2; Freese et al., 1999). In July 1997, 11 months post-trawl, density of sponges in the three trawl tracks was 21% lower (2.76 sponges/100 m^2 vs. 3.50 sponges/100 m^2) than of sponges in the three reference transects.

In addition to the persistent reduction in population density of sponges, damage to individual sponges also appears to be long lasting. In 1996, Freese et al. (1999) observed that 67% of large sponges (therein referred to as "vase" sponges) in eight trawl tracks were damaged, compared to 2% in reference transects. Incidence of damage to the sponges in the three trawl paths examined in this study was 47%, compared to 1% in the reference transects. The fact that the incidence of damage to sponges in the three 1997 trawl paths is 20 percentage points less than the incidence of damage observed in 1996 should not be taken as evidence that individual sponges had repaired wounds such as tears, or regenerated missing body parts. Examination of the video data yielded no instance of a sponge undergoing repair or regeneration of damaged or missing body parts. All tears and other wounds appeared jagged and freshly made during the 1997 survey, 11 months post-trawl. No evidence of rounding or smoothing of rough wound edges, which would indicate the occurrence of healing, was noted.

A likely explanation for the seeming reduction in incidence of damaged sponges between 1996 and 1997 is the necrotization of damaged sponges observed in 1997. Approximately 10% of damaged basket sponges were partially to nearly completely necrotized in 1997. In addition to necrotized sponges, remnants of the supportive skeletons (spongin) of basket sponges were observed lying on the sea floor in the trawl path. Probably a percentage of damaged basket sponges are unable to repair wounds or regenerate body parts rapidly enough to counteract ongoing necrosis (presumably caused by bacterial or fungal agents) and eventually succumb. Thus, the observed decrease in incidence of damage to sponges over time is probably the result of delayed mortality of damaged specimens.

It is worth noting that the type of damage sustained by sponges varies according to species, probably because of differences in skeletal structure and substrate preference. Sponges with elastic skeletons that are usually attached to large boulders, such as basket sponges, would be more likely to sustain tears or be severed from their bases by the trawl. More rigid species, such as *Geodia*, often found attached to cobbles, would probably be either crushed or rolled over; and glass sponges, flexible but usually associated with finer substrates and attached by tufts of spicules extending into the substrate (Brusca and Brusca, 1990), would be pulled from the substrate in their entirety.

Little information is available regarding the recovery of sponges after damage by trawling. Van Dolah et al. (1987) conducted an experimental trawling study on hard-bottom habitat off the southeastern U.S. coast. The results of that study generally agree with the findings of Freese et al. (1999), in that sponges in trawl paths suffered an immediate post-trawl reduction in density and increased incidence of damage to individual specimens. After 1 year, however, numbers of sponges in those trawl paths equaled or exceeded pre-trawl densities, and individual sponges that had been damaged by the trawl could not be relocated because wounds had healed and severed parts had regenerated. In addition, no moribund or necrotized sponge was noted. Those findings contrast sharply with the results of this study and indicate that reductions in habitat complexity due to removal of sponges by trawling activity in deep, cold-water habitats such as are found in the GOA may be much more persistent than in shallower, warmer waters due to faster growth rates in shallower, warmer waters.

The 1996 Magnuson-Stevens Fishery Conservation and Management Act requires that regional fishery management councils identify and take measures to protect EFH for managed species. The Act defines EFH as “waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” Substrate, as defined in the Act, includes sediment, hard bottom, structures, and associated biological communities. The North Pacific Fishery Management Council has designated living substrates in deep waters as habitat areas of particular concern (HAPC) because such areas provide high micro-habitat diversity and are considered readily impacted by fishing activities (NPFMC, 2000). Seafloor habitat with high population densities of large sponges could qualify as HAPC. I found that such habitat is extremely vulnerable to commercial trawling in the short-term (1 year), suffering immediate declines through direct removal of sponges and further reductions in population densities of sponges due to delayed mortality.

Unlike sponge communities in warm, shallow waters, sponge communities in the GOA do not appear to have the ability to return to pre-trawl population levels after 1 year, nor do individual sponges appear to have the ability to recover quickly from wounds suffered from trawl gear. However, this study covers only a 1 year period, and recovery rates for some species may be in excess of several years; thus, actual long-term recovery rates are indeterminate at this point. Little is known concerning the biogeography or community associations of sponges in deep waters in the GOA. However, because of the complex habitat that they provide and because of the demonstrated vulnerability of sponge communities to trawling, further studies should be carried out to document the geographic distribution and abundance of these organisms in the GOA, to ascertain the relative importance of sponges as habitat for commercially important species, and to determine long-term effects of trawling on recovery rates of sponges.

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