Research at the Auke Bay Laboratory On Benthic Habitat

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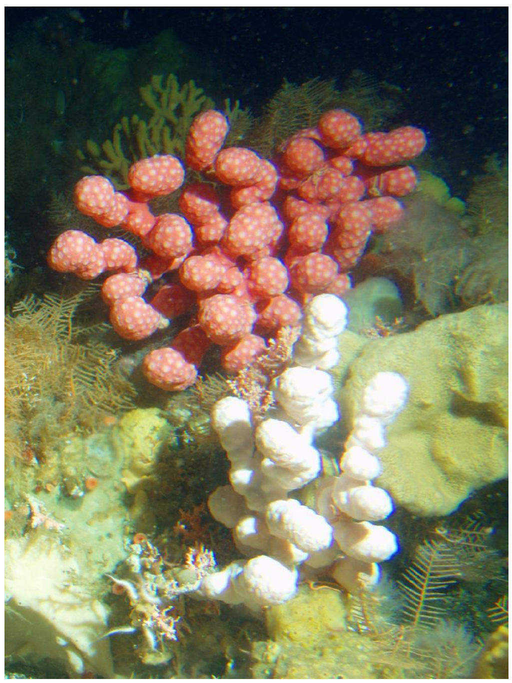

Figure 1. Red and white bubblegum coral are long lived, slow growing, and can reach a height of 5-6 feet in the cold waters off the Aleutian Islands. Photo by Bob Stone.

Introduction

The largest and geologically most complex area of the U.S. coastal zone occurs off Alaska. This region has a wide diversity of benthic habitat types ranging from the extensive soft-sediment areas of the Bering Sea shelf to the complex, high-relief habitats of the Aleutian Islands and portions of the Gulf of Alaska (Fig. 1). These habitats support some of the largest fisheries in the United States. Many Alaska fisheries that target groundfish, crab, and scallops use fishing gear that disturbs benthic habitat. That gear includes bottom trawls, longlines, pots, and dredges.

Since 1996, scientists at the Alaska Fisheries Science Center's (AFSC) Auke Bay Laboratory (ABL) have been conducting research on the effects of fishing gear on benthic habitat. Most of the research has focused on the effects of bottom trawls. The use of bottom trawls is one of the more controversial fishing methods due to documented changes in species composition and diversity and a reduction in habitat complexity associated with this gear type. The ABL studies provide information for developing appropriate measures for minimizing adverse impacts of fishing on habitat, as required in the Magnuson-Stevens Fishery Conservation and Management Act.

Research has focused on 1) understanding the direct effects of bottom trawling on seafloor habitat; 2) understanding the associations of fish and invertebrate species with habitat features that may be affected by fishing gear; and 3) developing analytical tools to assess habitat impacts and evaluate proposed mitigation measures. This article provides an overview of research on benthic habitat conducted by the ABL's Groundfish Assessment Program in collaboration with scientists from several universities and other government agencies.

Effects of bottom trawling on hard bottom habitat

The Sustainable Fisheries Act of 1996 was passed, in part, to ensure long-term protection of essential fish habitat. The act specifically requires the National Marine Fisheries Service (NMFS) to minimize adverse impacts to essential fish habitat by the fisheries it manages. In response, the ABL initiated a

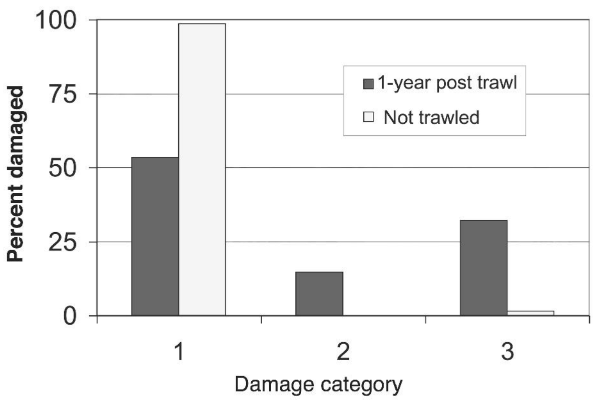

Figure 2. Incidence of damage to sponges in trawled transects in the eastern Gulf of Alaska in 1997, one year post-trawl and in untrawled transects. Values are for mean percentages for each damage category for three trawled and three untrawled transects. Damage category 1 = undamaged; 2 = upright but torn; 3 = lying on the sea floor, torn or intact.

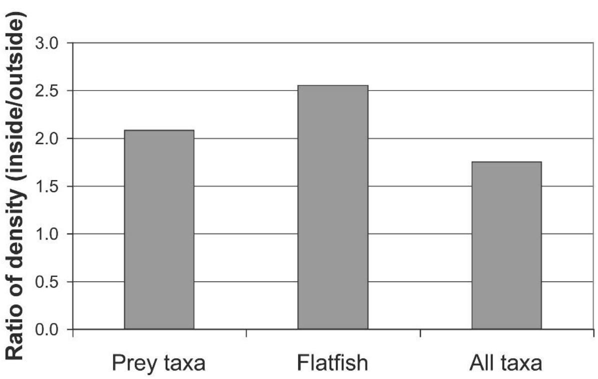

Figure 3. Ratio of density of epibenthic fauna inside and outside of sea whip groves at a site in the central Gulf of Alaska.

study in 1996 to determine the effects of bottom trawling in hard-bottom (boulder, cobble, and pebble) habitat in the Gulf of Alaska. Eight sites, 200-275 m deep, were trawled with bottom trawl gear similar to that used over rough bottom in the rockfish fishery. From the submersible *Delta*, ABL scientists videotaped each trawl path and a nearby reference transect. Results of the study showed that a single pass of a trawl can displace boulders and remove or damage large epifaunal invertebrates such as sponges, which provide three-dimensional relief on the seafloor.

In an area studied off Southeast Alaska, sponges accounted for most of the invertebrate biomass because of their large size and population density. Determining the capability of damaged sponge communities to regenerate has important implications for understanding the long-term impacts of bottom trawling. Thus, in 1997, ABL researchers returned to the Southeast Alaska study area one year after trawling. Furrows in the seafloor caused by trawling were still prominent and showed no evidence of backfilling. Unlike sponges in warm, shallow waters, sponge communities in the eastern Gulf of Alaska are slow to regenerate. No new colonization of sponges was apparent in any of the trawl paths, and none of the damaged sponges showed any signs of repair or regrowth (Fig. 2).

The study lasted only a year, and recovery rates for some species may be in excess of several years; thus, actual long-term recovery rates are not known at this point. Because of the complex habitat and the demonstrated vulnerability of sponges to trawling, further studies are needed to ascertain the importance of sponges as habitat for commercially important species and to determine long-term effects of trawling on recovery rates of sponges.

Effects of bottom trawling on soft-bottom habitat

In April 1987, the North Pacific Fishery Management Council closed two areas around Kodiak Island, Alaska, to bottom trawling and scallop dredging (Type 1 Areas). These areas were designated as important rearing habitat and migratory corridors for juvenile and molting crabs. The closures are intended to assist rebuilding of severely depressed Tanner and red king crab stocks. In addition to crab resources, the closed areas and areas immediately adjacent to them have rich stocks of groundfish including flathead sole, butter sole, Pacific halibut, arrowtooth flounder, Pacific cod, walleye pollock, and several species of rockfish. Because bottom trawling occurs immediately adjacent to the closed areas, the closures provided a rare opportunity to study the effects of an active bottom trawl fishery on soft bottom, low-relief marine habitat.

In 1998 and 1999, studies were initiated to determine the effects of bottom trawling on these soft-bottom habitats. The goal was to determine if bottom trawling in some of the more heavily trawled areas of the Gulf of Alaska has chronically altered soft-bottom marine communities. Direct comparisons were possible between areas that were consistently trawled each year and areas where bottom trawling had been prohibited for 11 to 12 years. Continuous video footage of the seafloor was recorded from the *Delta* at two sites that were bisected by the boundary between open and closed areas. Completed analyses indicate that 1) trawling intensity, although high for the Gulf of Alaska, is relatively low compared to other areas worldwide; 2) effects on the sedimentary and biogeochemical features of the infauna community from present levels of bottom trawling were minor and no clear patterns were detectible; and 3) effects on epifauna include decreases in richness and abundance of prey species and species with low mobility. In addition, a relationship between epifaunal biomass and sea whip abundance was apparent (Fig. 3). This relationship indicates that sea whip habitat may have increased productivity over other habitat types.

Sea whips are highly visible and changes in their abundance can be readily quantified (Fig. 4). Sea whip groves provide vertical relief to otherwise homogeneous soft-bottom habitat and may be particularly vulnerable to trawling because sea whips can be removed, dislodged, or broken by bottom fishing gear. Furthermore, because sea whips are generally believed to be long-lived, recolonization rates may be very slow.

In 2001, the ABL began investigations of the immediate effects of intensive bottom trawling on Gulf of Alaska soft-bottom habitat and, in particular, on an area colonized by sea whips. Sea whip biological characteristics and their resistance to two levels of trawling were studied. Within the study site, at least two species of sea whips (*Halipteris* sp. and *Protoptilum* sp.) were present with densities of up to 16 individuals per square meter.

The study plan consisted of three phases. In Phase 1 before trawling, baseline data were collected from a control (untrawled) and two treatment corridors. The *Delta* submersible was used to collect *in situ* videographic documentation of the seafloor along predetermined transects within the study corridors. Additionally, a bottom sampler was deployed from the submersible tender vessel to collect sediment samples from each corridor.

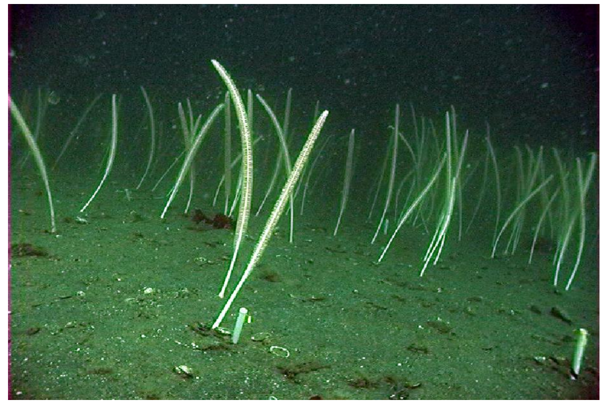

Figure 4. A sea whip grove in the eastern Gulf of Alaska. Photo by Pat Malecha.

During Phase 2, a commercial trawler made a single trawl pass in one corridor of the study area and repetitively trawled (six trawl passes) a second corridor. The control corridor was left untrawled. Phase 3 repeated the videographic and sediment sampling following the trawling phase. A scientist on board the *Delta* observed the seafloor and vocally recorded identification of biota and evidence of trawling, including damaged or dislodged biota and marks on the seafloor from the various components of the bottom trawl, such as trawl door furrows and ground gear striations.

Without clear evidence of trawling (e.g., trawl tracks) in the habitat studied in 1998 and 1999 and because of the patchy distribution of the most obvious sessile organisms (sea whips), quantifying immediate changes to the seafloor from trawling has been difficult. Investigations in 2001 allowed quantification of effects resulting from known levels of trawling. The experimental trawling allowed testing of hypotheses concerning the observed 1998-99 sediment, infauna, and epifauna changes. Analysis of the 2001 data is ongoing and will identify immediate bottom trawling impacts to sea whips including the percentage of sea whips damaged and dislodged.

Because the long-term fate of damaged and dislodged sea whips is unknown, scientists initiated new studies in 2003 to investigate long-term impacts of bottom trawls to sea whips. Large (1-2 m) sea whips

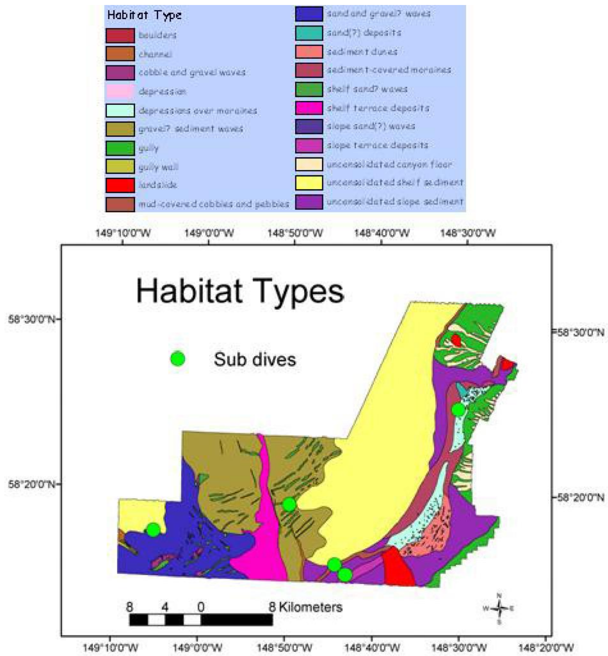

Figure 5. Habitat classification chart of the Portlock Bank site in the central Gulf

of the genus *Halipteris* were tagged with identification markers and observed *in situ* at a study site in Auke Bay. Videographic documentation of tagged sea whips was performed approximately weekly for 4 months and will continue at longer intervals for up to a year or more. Small (<30 cm) sea whips of the genus *Protoptilum* were collected near Kodiak Island and are being observed in laboratory aquaria. The purpose of these studies is to simulate disturbances caused by fishing gear and document the ability of sea whips to 1) survive after having their internal skeleton broken or flesh torn and 2) rebury themselves after being dislodged.

Mapping of habitat features of major fishing grounds

Knowledge of existing habitat is basic to minimizing the adverse impacts of commercial fishing on essential fish habitat. However, very few areas of the continental shelf and continental slope where major fisheries occur have been adequately described. Without sufficient geophysical and biological data, regulatory measures adopted to minimize impacts on vulnerable habitat may be ineffective or unnecessarily restrictive. Habitat mapping along with direct *in situ* observations is a way of obtaining such information.

In 2001, the ABL initiated a study to map limited areas of Alaska's fishing grounds in the U.S. Exclusive Economic Zone (EEZ) for habitat characterization, using state-of-the-art technology. In 2001 and 2002, about 1,600 km^2 of seafloor were mapped using a high-resolution multibeam echosounder that includes coregistered backscatter data. The mapped areas covered 500 km^2 off Yakutat, 900 km^2 on Portlock Bank northeast of Kodiak, and 200 km^2 off Cape Ommaney, Baranof Island. Survey depths ranged from about 50 m to 750 m. During 2003, additional areas were mapped in the central Aleutian Islands and in the vicinity of Albatross Bank, southwest of Kodiak Island in the Gulf of Alaska in cooperation with NOAA's National Ocean Service.

The Yakutat site is characterized as a formerly glaciated area of irregular seabed with mixed sediments (mostly sand, mud, and gravel) and high-relief areas consisting mostly of boulders. Analysis of the multibeam and backscatter data for Portlock Bank indicated at least a dozen macro- or meso-habitats (Fig. 5). The habitats are the result of past glaciation and are being modified into moderate relief features, between 1 cm and 1 m. Submarine gullies notch the

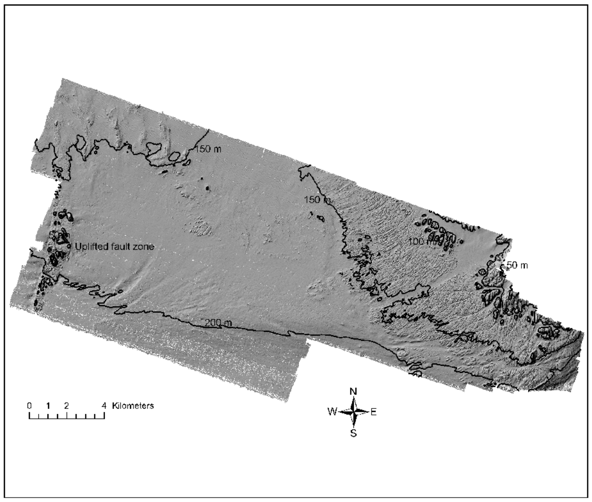

Figure 6. Multibeam bathymetric chart of the Cape Ommaney site off Baranof Island in Southeast Alaska. Uplifted fault zone of a series of pinnacles is noted.

upper slope and provide steep relief with alternating mud-covered and consolidated sediment exposures. The Cape Ommaney site ranged in depth from about 50 m to 300 m (Fig. 6). The site is characterized as an irregular seabed with mixed sediments (mostly sand and gravel) and high-relief rocky outcrops and pinnacles. The habitat at the Cape Ommaney site is the result of past glaciation and plate tectonics highlighted by the presence of an uplifted fault zone.

At the Cape Ommaney and Portlock Bank sites, mapping was complemented by observation dives using the *Delta*. The uplifted fault zone was the focus of the *Delta* dives at the Cape Ommaney site (Fig.7). The ridge is made up of a series of pinnacles, with substrate of primarily bedrock and large boulders. The epifaunal community is rich and diverse, much more so than in the surrounding low-relief habitat. The largest epifauna were gorgonian red tree coral colonies and several species of sponges. There were also numerous species of fish, in abundant numbers, including several species of rockfish. Rockfish were often associated with gorgonian coral colonies and at least one species of sponge. We were especially interested to find a pod of several hundred juvenile golden king crab located on acorn barnacle shell fragments along a sloping ledge of one of the pinnacles. We believe this is the first documented observation of juveniles of this species in their natural habitat. Water currents at the site are generally variable in direction and strength depending on location. Numerous sections of derelict longline gear were observed on certain areas of the pinnacle, and some damage to red tree corals was evident.

Six sites were surveyed with the *Delta* on Portlock Bank (Fig. 8). Two were relatively flat sites on the north end of the bank, one lightly fished and the other in an area fished for Pacific ocean perch. Two were sloping sites along the eastern slope edge, and two sites were toward the middle of the bank, one fished for flatfish, the other lightly fished. We observed little evidence of trawling on the low-relief grounds of the continental shelf, where perhaps the level bottom did not induce gouging by trawl doors and where there was a lack of boulders to be turned over or dragged. The most common epifauna were crinoids, small nonburrowing sea anemones, glass sponges, stylasterid corals, and brittlestars (Fig. 9). Occasional large boulders located in depressions were the only anomaly in the otherwise flat seafloor. The glass sponges and stylasterid corals attached to these boulders were larger than were typically observed on the low-relief grounds. In contrast, there was evidence of boulders turned over or dragged by trawling in the areas of the upper slope. The substrate

Figure 7. Red tree coral and boulder habitat of the uplifted fault zone of the Cape Ommaney mapping site. Note the yelloweye rockfish in the foreground and an unidentified dark rockfish nestled underneath coral in the upper left corner. Photo by Linc Freese.

was mostly small boulders, cobble, and gravel. In summary, for this very limited sample of the outer Portlock Bank, there was very little high-relief benthic habitat that would be at risk to further fishing. No large corals and very few large sponges were seen.

Coral and sponge habitat of the Aleutian Islands

At the First International Symposium on Deep Sea Corals in Halifax, Nova Scotia in 2000, a conclave of scientists concluded that deep sea corals were in desperate need of research and conservation. Many species of deep sea corals are strikingly beautiful, may form large groves, are sensitive to human-induced and natural change, and are believed to live hundreds if not thousands of years. Previous studies in the Gulf of Alaska indicated that deep-sea corals likely provide important habitat and refuge for a variety of fishes and invertebrates. Summaries of trawl survey data and recently acquired fisheries bycatch specimens have suggested that the Aleutian Islands may harbor the highest abundance and diversity of temperate water corals in the world. Fishery observer records also document a wide distribution of corals in the Aleutian Islands.

In response to these observations, the ABL Groundfish Program initiated a pilot research program in 2002 to examine corals and associated communities in the Aleutian Islands region. In July 2002, the submersible *Delta* was used to explore coral habitat near the Andreanof Islands in the central Aleutian Islands and on Petrel Bank in the Bering Sea. This was the first and only directed exploration of coral communities in the Aleutian Islands since the surveys conducted by the research vessel *Albatross* nearly a century ago. Submersible observations confirmed that coral was widely distributed in that region; corals and sponges were found at 30 of 31 dive sites investigated. Disturbance to epifauna, likely fishery induced, was observed at most dive sites. Percent of the seafloor covered with corals ranged from approximately 5% on some low-relief pebble substrate to 100% coverage on high-relief bedrock outcrops. Unique coral habitat consisting of high-density gardens of corals, sponges, and other sessile invertebrates was found at five sites between

Figure 9. A glass sponge and gravid rockfish. Photo by Pat Malecha.

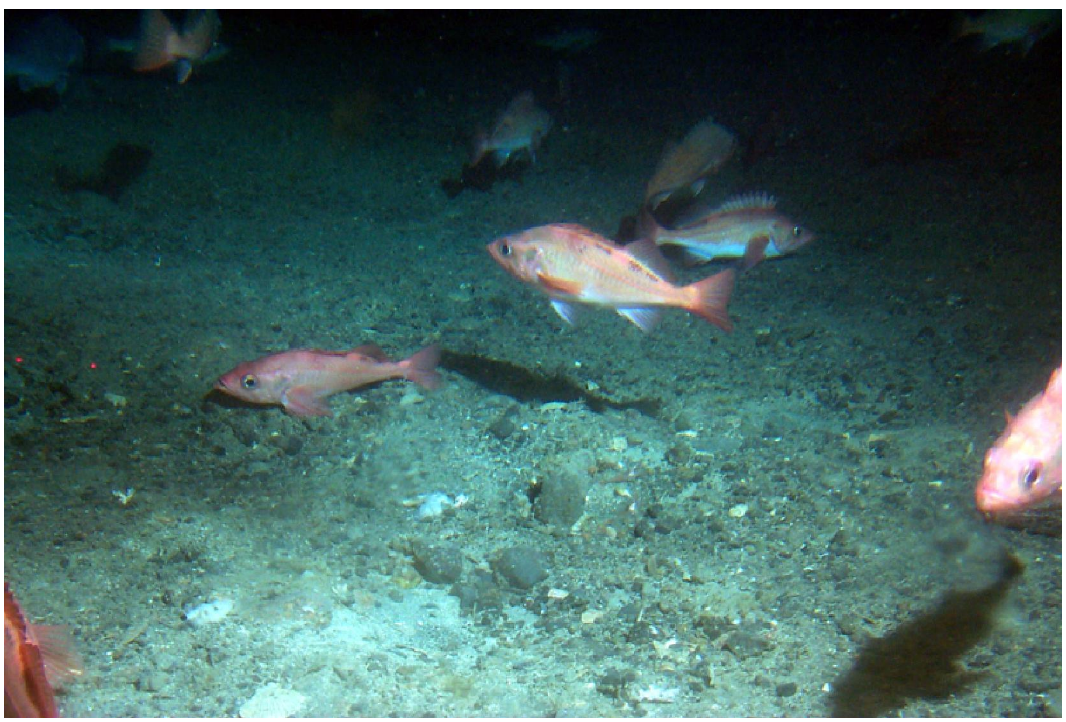

Figure 8. Pacific ocean perch over sediment-covered glacial moraine with occasional cobbles and boulders on the upper continental slope of Portlock Bank. Photo by Pat Malecha.

150 and 350 m in depth (Fig. 10). These gardens were similar in structural complexity to tropical coral reefs and shared several important characteristics with tropical reefs, including complex vertical relief and high taxonomic diversity. These dense aggregations appeared to be particularly sensitive to bottom disturbance and had not been previously documented in the North Pacific Ocean or the Bering Sea. Underwater video footage of the coral habitat is available for viewing on the ABL web site at http://www.afsc.noaa.gov/abl/MarFish/coral_gardens_video.htm

With supplemental funding provided by the North Pacific Research Board (NPRB), ABL coral research expanded in 2003. The goal of the expanded research is to provide information on corals and sponges in the Aleutian Islands region necessary for making critical fishery management decisions to protect habitats. This research focuses on the 500-km long section of the central Aleutian Islands between Seguam Pass (174°W long.) and Petrel Bank (180°W long.) The research has several objectives.

The first objective is to assess the distribution and abundance of corals and sponges in the central Aleutians with respect to major environmental factors and construct a predictive model based on the assessment. This will allow us to determine whether there are predictable relationships between the occurrence of corals and sponges and environmental characteristics, including substrate type, depth, slope angle, seafloor roughness, and currents. The approach is to map the seafloor in a representative sample of a large and significant section of the Aleutian Archipelago (Fig.11) and directly observe the distribution and abundance of corals and sponges in these habitats. The data collected will allow us to construct a predictive model of where corals and sponges are likely to occur for areas where direct observations have not been made.

The second objective of the study is to assess the importance of corals and sponges as habitat for commercially important fishes and invertebrates. Through observations with a submarine and remotely operated vehicles, and detailed mapping of fine-scale distribution of coral and megafauna, we will describe associations. Coral habitat is more at risk to damage from fishing gear if targeted species are predictably associated with it. These data are important in examining how coral habitat will be affected by specific gear types.

The third objective is to assess the extent of fishing gear impacts on coral and sponge habitats. This objective addresses whether damaged corals and sponges are more frequent in heavily fished areas than in areas with little or no fishing. Our approach is based on our observations in the central Aleutian Islands in 2002—that disturbances to coral habitat, including those due to bottom fishing gear, are recognizable *in situ* as discontinuities in coral patches where coral and sponge fragments have accumulated and the seafloor (substrate) has been scarred or otherwise modified. While it may be difficult to determine if any particular disturbance is due to fishing gear, the extent of the disturbances can be quantified and compared between areas with and without intensive fishing.

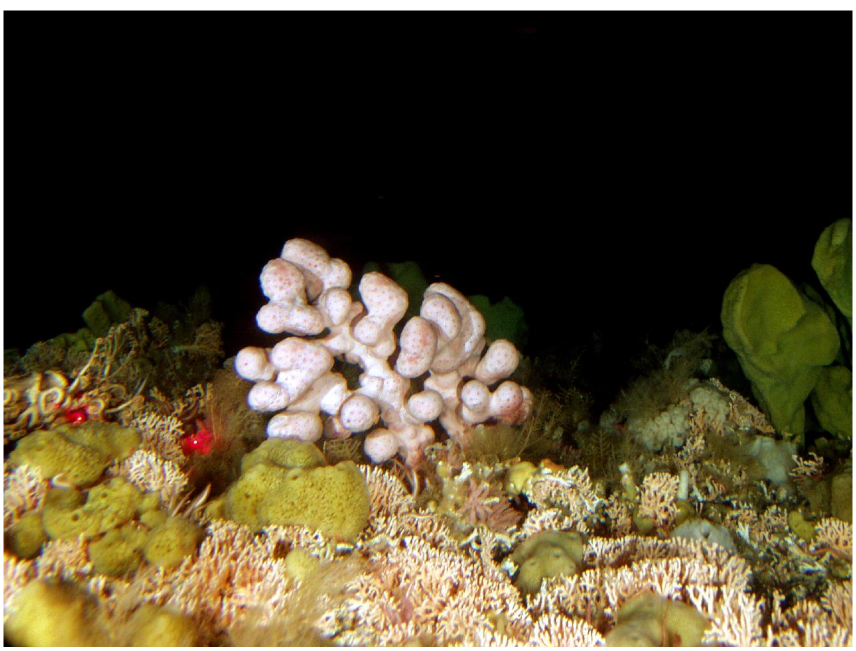

Figure 10. Coral and sponge garden habitat of the Aleutian Islands. See also underwater video on the AFSC web site. Photo by Bob Stone.

The fourth objective is to collect soft corals (order

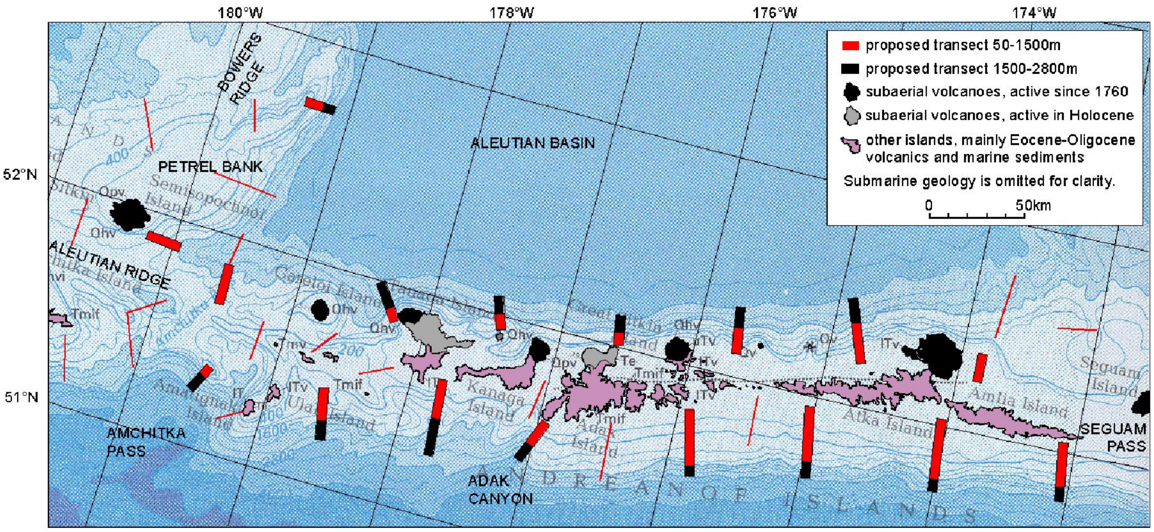

Figure 11. Chart of central Aleutian Islands showing locations of planned mapping transects. Narrow transects (—) denote extra mapping sites, if time permits.

Alcyonacea), stony corals (order Scleractinia), hydrocorals (order Stylasterina), gorgonians (order Gorgonacea), and black corals (order Antipatharia) to describe new species, aid in taxonomic revisions presently under way, and determine the reproductive schedule and larval dynamics of gorgonians and hydrocorals. Given the lack of biological exploration in this region, we anticipate discovering new species and range extensions from more southerly waters. Sequences of DNA will be incorporated into a genetic database, which may allow for rapid identification of corals in the future by means of simple genetic markers. Histological examination of gonads will provide information about the reproductive timing and the mode of larval dispersal. These data will help provide timely insights into the capability of these species to recolonize areas. Such information has important implications for the design of marine protected areas.

Fieldwork for this expanded research began in June 2003. Seafloor mapping operations were successfully conducted during a 22-day cruise on the research vessel *Davidson* when multibeam bathymetry and backscatter surveys of 17 representative sites were completed. Wherever possible, the sites were mapped from 50 m to 3,000 m water depth. Subsequent to the mapping the *Delta* was used to visit 10 of the sites and collect video of the seafloor on 22 strip transects in water shallower than 365 m (the depth limit of the *Delta*). Corals and sponges were widely distributed over the 23 km of seafloor observed (found at 21 of 22 transects) and at densities varying from 0% on low-relief pebble substrate to 100% coverage in coral gardens. Disturbance to epifauna, likely anthropogenically induced, was observed at seven dive sites and appeared to be more evident in areas with high fishing effort. Sixty-six coral specimens were collected for molecular and morphological taxonomic identification and studies on reproduction. Scientists will use the *Delta* in 2004, with funding provided by NPRB, to complete observations at the six sites not visited in 2003. Also in 2004, with funding provided by the National Underwater Research Program (NURP), the remotely operated vehicle *Jason II* will be used to collect video and specimens in water deeper than 365 m.

Habitat impacts model

In response to the need for a tool to quantify potential impacts to benthic habitat, a mathematical model was developed, and has thus far been applied within the framework of supplemental environmental impact statements being prepared by NMFS scientists and the North Pacific Fishery Management Council. The model comprises equations that incorporate basic factors determining impacts of fishing on habitat. Given values, either estimated or assumed, of 1) fishing intensity, where f = absolute effort in area swept per year ÷ area size, 2) sensitivity of habitat to fishing effort, q_H, and 3) habitat recovery rate a, the model predicts a value of equilibrium (i.e., long-term) habitat level, H_{eq}, as a proportion of the unfished level, H_0.

The full equation is:

$$H_{eq} = H_0 \,] \, a\, S/(I + a\, S),$$

where H_0 = unfished habitat level, $I = f\, q_H$, and $S = e^{-I}$. Habitat impact or effect level, E, for the given effort, sensitivity, and recovery rates, would be 1- H_{eq}. Letting H_0 = 1.0, then

$$E = I/(I + a\, S).$$

Habitat is defined as any feature of the seafloor that could be impacted by fishing gear. Initially, application of the model focused on the impact to biostructure habitat features, where biostructure is living habitat provided by organisms such as corals, tunicates, and sponges; however, other substrate types such as sand and mud have been added.

The habitat sensitivity rate, q_h, is the proportion of habitat in the path of the fishing gear that is impacted by one pass of the gear. Sensitivity of a particular habitat feature varies greatly depending on its physical characteristics and the characteristics of the fishing gear. Because of the lack of information for many benthic species, sensitivity may be difficult to determine. Also, certain features of the gear may make the gear more or less damaging to different organisms.

Recovery rate, a, reflects the rate of change of impacted habitat back to unimpacted habitat, H_0. In the absence of further impacts, it is assumed that impacted habitat would decrease exponentially until all habitat was in the unfished condition. The recovery time can be thought of as the average amount of time the impacted habitat stays in the impacted state, which would equal 1/a (in the absence of further impacts). The recovery rate includes any recruitment required to initiate recovery and the growth needed to reach a size that is necessary to provide habitat function.

Because fishing intensity is the absolute effort in area swept per year divided by area size, a geographic perspective of impact is attained by using estimated fishing effort for each 25 km^2 block within the EEZ. For the given values of sensitivity, q_h, recovery rate, a, and bottom fishing intensity, f, estimated for each 5 km^2 block, habitat impact, $E_i = I_i/(I_i + aS_i)$, can be calculated for the block represented by the I parameter. Larger values of E equate with more impacts. Results for a region can be presented in a single value as a mean impact, as a frequency distribution of impacts for each block, and as the geographic distribution of the impacts.

Conclusion

The research conducted at the Auke Bay Laboratory has led to important findings that increase our understanding of fishing gear effects on benthic habitat. Many of the field-oriented studies have focused on small geographic areas in specific habitat types. During this initial phase of research, the focus has been on identifying the effects of bottom trawling, mapping habitat, examining the associations between habitat features and fish utilization, and defining the geological processes that may allow comparison of natural processes with gear effects. The development of a mathematical model on fisheries impacts has led to identification of which processes (e.g., habitat sensitivity and recovery rates) are important to evaluation of gear impacts within a fishery management context. As research continues, focus should be on understanding these processes and expanding efforts to other gear types and habitats. Ultimately, the goal of this research is to determine whether fishing affects benthic habitat to the extent that the shelter, food, species composition, and productivity of important species is altered.

Research on effects of gear on benthic habitat is also being conducted by scientists in the AFSC's Resource Assessment and Conservation Engineering Division and is available on the web at http://www.afsc.noaa.gov/abl/MarFish/geareffects.htm.