Trawling the North Pacific

Understanding the Effects of Bottom Trawl Fisheries on Alaska's Living Seafloor

Ben Enticknap, Alaska Marine Conservation Council, Fisheries Project Coordinator

"I don't think the problem is mobile gear per se, but too much use of it." - Jeremy Collie (as in Russell 1997)

"Like storms and turbidity currents, it churns and resususpends sediments. But its effects are felt deeper than storm-generated waves, and it occurs more often." - Elliot Norse (1993)

Introduction

The Alaska Marine Conservation Council (AMCC) promotes habitat conservation to sustain fisheries and a healthy ocean ecosystem. We are concerned about the impacts of bottom trawling on seafloor life and believe that trawling is only appropriate in places where its impact on habitat is minimal. It is intuitive to many coastal residents, fishermen, and fisheries managers that dragging large nets across the seafloor, weighted with chains and tires, is going to have negative impacts on benthic habitats and the species that flourish there. This intuition is confirmed by scientists who in the past decade have focused a great deal of research in determining the effects of trawling on seafloor habitats.

This report updates our understanding of the effects of bottom trawling in the North Pacific, including the U.S. Bering Sea, Aleutian Islands, and Gulf of Alaska, by reviewing the literature of fishing effects in the Alaska region and worldwide. This report will also characterize commercial bottom trawling in the North Pacific by reviewing historical fishing effort, fleet composition and gear types, and the habitats that are fished. It is important to understand the different types of trawls used and the extent of their impact on various habitat types. It is important to understand what scientific studies are applicable to our region, and what habitats, if any, can withstand the impacts caused by commercial bottom trawling.

Most research on bottom trawling has been conducted off the coast of Australia, the eastern United States and the North and Irish Seas. Relatively few studies have been conducted in the waters of the North Pacific. However regardless of latitude, reviews of studies worldwide have shown similar impacts caused by trawling, including the removal or damage of benthic animals, the smoothing of the seafloor, and the reduction of habitat complexity (Auster and Langton 1999). A recent report by the National Research Council (2002) declares,

> "Although there are still habitats, gears, and geographic regions that have not been adequately studied and characterized, there is an extensive

> literature on the effects of fishing on the seafloor. It is both possible and necessary to use this existing information to more effectively manage the effects of fishing on habitat."

The debate over the effects of bottom trawling is shifting away from whether or not it reduces marine biological diversity and habitat complexity; research from across the globe clearly indicates this is the case. The debate over bottom trawling is now focused on where and to what degree it is appropriate. Meanwhile as this debate ensues, commercial fishermen in the North Pacific, with some of the highest volume fisheries in the world, are dragging bottom trawls through sensitive soft-bottom habitats, over rocky seamounts, and through forests of corals and sponges.

What is bottom trawling?

The North Pacific (Gulf of Alaska and Aleutian Islands) and Bering Sea are home to a diverse array of commercial fishing fleets, using many different types of fishing gear and vessels. Commercial fishermen use pots, longlines, jigs, seines, gill nets, trolls and trawls, in boats ranging from small skiffs to 350-foot factory trawlers. In the North Pacific and Bering Sea, the otter trawl is the principal bottom trawl used and therefore it will be the primary focus in this report. Bottom trawling is the fishing practice of dragging large nets across the seafloor, weighted with chains, rock-hopper and roller gear, or steel beams.

The National Marine Fisheries Service (NFMS 2001) reports that about 50% of the groundfish trawl catch in the Gulf of Alaska (GOA), 27% of the Bering Sea Aleutian Island (BSAI) trawl catch, and 30% of the overall groundfish trawl catch is caught with bottom trawl gear. Beam trawls are permitted in State managed shrimp fisheries in Southeast Alaska (mainly near the Petersburg and Wrangell area) but they are prohibited in the North Pacific groundfish fisheries (ADF&G 1994). Dredges, another type of mobile bottom gear, are used to catch weathervane scallops near Yakutat, Kodiak and in Cook Inlet. The Bering Sea pollock fishery exclusively uses pelagic trawls since bottom trawls were prohibited in this fishery in 1999 (BSAI Amendment 57). Also, most vessels (90%) fishing for pollock in the Gulf of Alaska use pelagic trawls (NPFMC 2001a). These are not considered bottom trawls because the steel doors used to spread the mouth of the net are designed to stay off the seafloor. However mid-water or "pelagic" trawls often contact the seafloor with their footropes, up to 85% of the duration of the tow (Loverich 2001).

Trawlers target large aggregations of mid-water species, such as pollock and bottom fish like cod, rock sole and yellowfin sole. Trawl vessels tow a large net bag with a wide opening at the mouth. To keep the mouth of the trawl net open, large "doors" - weighing up to 700 pounds and about 6 feet long - fan out the bottom of the net. Bottom trawlers use heavy chains sometimes fixed with rock-hopper or tire gear strung along the base of the net's opening to hold it close to the sea floor, allowing the nets to be dragged through rough and rocky areas that typically create complex habitats (Browning 1980). Rock-hopper gear is used in the Aleutian Island Atka mackerel and rockfish fisheries and by many vessels fishing in the GOA for cod, Pacific ocean perch (POP), rockfish, and Dover and rex sole. Historically all slope rockfish (POP, shortraker/ rougheye rockfish, and "other slope rockfish") in the GOA were fished with bottom trawls. Between 1996 and 1998, 14-20% of Pacific ocean perch were caught with pelagic trawls (NPFMC 2001a).

Trawl Gear

Otter Trawl: a net towed behind a vessel that is held open by two boards (or doors) attached to warps (cable or rope) between the net and the vessel.

Bottom Trawl: In the North Pacific, these are primarily otter trawls whose trawl doors are designed to drag along the seafloor. The footropes are fixed with rolling discs, metal or rubber bobbins that bounce over obstructions.

Rock-hopper gear: Bottom trawl gear designed for fishing over rocky ground. The gear may use 24-inch diameter airplane tires or rubber disks that are greater than 21 inches in diameter, fitted to the footrope of the trawl net. Bobbins are also used that can weigh up to 22 lbs each.

Pelagic Trawls: These otter trawls are designed so that the doors do not contact the seabed. The footrope, made of metal chain, often drags over the seafloor. Performance standards for the BSAI pollock fishery mandate that it is unlawful to have onboard 20 or more crab of any species.

Beam Trawl: A trawl with a fixed net opening, utilizing a wood or metal beam

Footrope: The weighted rope that runs along the bottom of the mouth of the net.

Codend: The rear portion of the net in which the fish collect.

Bridles: The cables that attach the doors to the trawl net.

Scallop Dredge: A dredge-like device designed specifically for taking scallops by dragging and digging into the seabed.

(Garner 1988, Jennings et al. 2001)

Factory trawlers are equipped with on-board processing plants and can measure up to 350 feet in length. Trawl catcher vessel lengths range between 58' to 190'. Catches can be as enormous as 100 tons or more per tow, depending on the fishery, size and horsepower of the vessel (Gunstrom 1994).

Technological advances are allowing fishermen to work with improved efficiency. Electronics have become more sophisticated, nets are larger and fishing boats stay out at sea for prolonged periods of time. Advancements in trawl technology and efficiency have also allowed fishermen to trawl areas of the seabed that were once considered too deep or rough to fish with mobile gear (NRC 2002).

The Effects of Bottom Trawling on Marine Habitats

Direct physical effects of bottom trawls on living seafloor communities include damage and mortality of target and nontarget species (species with no commercial value such as clams, corals and urchins) (Norse 1993). Indirectly, bottom trawls affect marine animals and their associated habitat by resuspending sediments, toxins, and nutrients into the water column by scraping and plowing 1cm – 30cm into the seafloor (Vining, Witherell, Heifetz 1997: Dayton et al. 1995). Bottom trawls can alter the physical structures of the seafloor by scraping, plowing, smoothing sand ripples, removing stones and turning over boulders (Auster and Langton 1999, Schwinghamer 1998). Delayed effects on the seafloor include post-fishing mortality of the benthic sea life and long-term changes of the community structure (Collie et al, 1997, Jones 1992).

When trawl gear is dragged along the seafloor, sediments are kicked up behind the net. Sediment suspension can reduce the light available for photosynthetic species and bury benthic organisms. Repetitive trawling reduces the abundance of organic matter at the surface of the sediments and flattens sand waves (Schwinghamer 1998). "Like storms and turbidity currents, it (bottom trawling) churns and resususpends sediments. But its effects are felt deeper than storm-generated waves, and it occurs more often" (Norse 1993).

Infauna and **epifauna**:
Infauna are animals living entirely within the sediment and **epifauna** are animals living on, protruding from, anchored in, or attached to, the substratum. Both groups are known as benthic fauna, bottom-living fauna or benthos. Pelagic fauna are animals that live in the water column (Jennings et al. 2001a).

While sediment suspension may create anaerobic conditions for some benthic communities, it may also stimulate primary production by increasing nutrient levels in the water column (Pilskaln 1998). In areas where natural upwelling occurs, it is difficult to determine if trawling or natural upwelling is responsible for increasing nutrient. The effects of sediment suspension are site-specific and are dependent on sediment grain size and hydrologic conditions. Areas that experience high amounts of natural disturbances are less affected than more stable seafloor communities that experience few natural disturbances from storms or strong tides (Hall 1994, Kaiser 1998, Collie 2000). Although Hall (1999) stresses that, "while it is important to appreciate a range of natural variation in disturbance from wind, currents and waves to put fishing in context, the fact that the natural range is large in itself, gives no basis for arguing that the additional perturbation imposed by fishing is inconsequential." Kaiser (1998) states, "Presumably, the scale and frequency of physical disturbance events can increase to a point where lasting ecological effects are observed even against the background of natural disturbance."

In a review of scientific literature on fishing effects, Collie (2000) found that fauna in stable gravel, mud and biogenic sediments were more adversely affected than in less consolidated coarse sediments (e.g. sand). Studies in the North Pacific clearly corroborate this finding (Freese 1999, McConnaughey 2000). When ranking the impacts of mobile gear on habitat, Collie found that inter-tidal dredging and scallop dredging had a greater adverse effect on benthic animals than otter trawling. Prena (1999) found that otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland (120 – 146m deep) produced a detectable change on benthic habitat and communities, with a significant reduction in the biomass of large epifauna.

A Description of the Eastern Bering Sea

The Bering Sea ecosystem is one of the most biologically productive areas of the world (NMFS 2001). Some of its unique physical features include a broad continental shelf, comprising 44% of the Bering Sea, and pack ice that covers most of the eastern and northern areas of the continental shelf during winter and spring (NMFS 2001). Phytoplankton blooms along the ice edge account for 10 to 65% of the total annual primary production (NMFS 2001).

Benthic substrates on the continental shelf show considerable variability on a local scale. However, a sediment pattern is evident as one moves from the nearshore to the continental slope. Sediments of the inner shelf (0-50m deep) in the east and southeast are often sandy gravel that then turns to plain sand farther offshore (NMFS 2001). The middle shelf (50-100m deep) and outer shelf (100-200m deep) seafloor is predominately a more stable muddy sand.

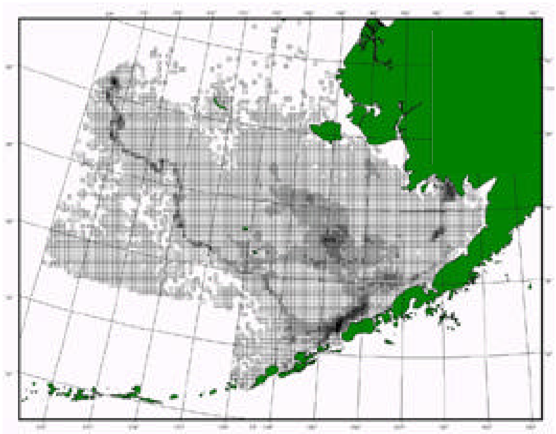
But the Bering Sea seafloor is not just made up of sand and gravel. The seafloor is rich with life, including communities of soft corals, hydroids, sea pens, tubeworms, tunicates, and sponges. These sedentary benthic organisms help create diverse communities by providing structural habitat (McConnaughey 2000). For example, juvenile red king crabs have been found in close association with mats of tubeworms, north of the Alaska Peninsula (NPFMC 2000a). Living substrates are an important component of the habitat essential to crab species in the Bering Sea.

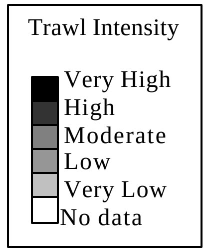
A Description of the Gulf of Alaska and the Aleutian Islands

The Gulf of Alaska (GOA) and Aleutian Island (AI) substrates are distinctly different from the Bering Sea. The GOA is a much more open marine system than the eastern Bering Sea which is partially enclosed by the Aleutians, Russia, and Alaska. The GOA continental shelf is less than 25% the size of the eastern Bering Sea shelf (NMFS 2001). The GOA also has relatively weaker currents and tidal actions near the seafloor. The result of this is an array of benthic substrates such as gravely sand, silty-mud, and areas of hard bedrock (NMFS 2001). The western GOA shelf consists of many banks and reefs with coarse, rocky bottoms and patchy bottom sediments. In the area around Kodiak Island, the shelf is made up of flat, shallow banks cut by deep gullies. The substrate in the western Aleutians is predominately bedrock outcrops and coarse sediment with some sandy bottoms (NMFS 2001). The AI shelf is extremely narrow and on the Gulf side, the shelf edge drops off into some of the deepest waters of the world, the Aleutian Trench.

Bottom Trawl Effort in the Gulf of Alaska and Bering Sea/ Aleutian Islands

An important component in understanding the effects of trawling on marine habitats is documenting the spatial extent and intensity of fishing effort. The NMFS observer program has been documenting fishing effort since about 1973, allowing NMFS to make a fairly comprehensive determination of historical effort. However most of the data is limited to the number of trawl tows within large, 25km^2 blocks. New developments in technology, like Vessel Monitoring Systems (VMS) will allow NMFS to more precisely track where fishing effort occurs.





From the period of 1973-1997, NMFS observers documented 412,040 bottom trawl tows in the Bering Sea (NMFS 2001a). Throughout this time period, bottom trawling has impacted most all of the Bering Sea, but the intensity of the impact varies throughout the region (NMFS 2001).

Historic Trawl Intensity in the Bering Sea (1973-1997) NMFS 2001. (This map does not show trawling in the Aleutian Islands management district or Gulf of Alaska)

The highest concentrations of fishing effort in the Bering Sea are located along the shelf edge, north of the Alaska Peninsula near Unimak Island, and Togiak Bay. Bottom trawls in this region are targeting primarily Pacific cod and flatfish.

In the Gulf of Alaska, the greatest bottom trawl effort has occurred in the Kodiak Island region. Trawl fisheries in this area target primarily Pacific ocean perch, Pacific cod and flatfish. Based on observed bottom trawl effort and estimates of unobserved effort, NMFS estimates that from 1990 to 1998 there were approximately 116,288 tows in the Gulf of Alaska and 41,015 tows in the Aleutian Islands. In the Aleutian Islands, the greatest bottom trawl effort has occurred in the Atka mackerel and Pacific ocean perch fisheries (NMFS 2001).

Estimates of the total area swept by bottom trawl gear in 1998 – 2000 include 53,931 km^2 in the Bering Sea, 10,201 km^2 in the Aleutians, and 17,562 km^2 in the Gulf of Alaska (NRC 2002). The sum of these trawled sites (1998 – 2000) equates to an area greater than the state of South Carolina, yet these disturbances are not occurring in a consolidated block but spread throughout the Bering Sea, Aleutians and the Gulf of Alaska, year after year.

The NRC reports a significant decline in the number of observed bottom trawl tows from the early 1990's to 2000, due to management closures to bottom trawls and the increased use of pelagic trawls. However, it is unclear if there would be an observed decline in trawl tows if pelagic trawls were included in these effort estimates. In addition, bottom trawl vessels less than 60 feet in length are unobserved. The use of bottom trawls is prohibited in a number of areas in the North Pacific such as the Gulf of Alaska (E. of 140^0), the Nearshore Bristol Bay Closure Area, the Pribilof Islands Conservation Area, Type I Kodiak King Crab Protection Zones, and inside state waters throughout most of the Gulf of Alaska (Figures 2-3). The total area closed to trawling in federal waters off Alaska is approximately 310,500 km^2 (NRC 2002).

Trawl Research in the Bering Sea

Seafloor communities of the Bering Sea are dynamic environments that provide habitat for a wide range of both commercial and non-commercially valuable species. To better understand the effects of trawling on these complex habitats, R.A. McConnaughey of the National Marine Fisheries Service led an experiment to examine biological diversity in heavily trawled versus unfished sites in the eastern Bering Sea. In "An examination of chronic trawling effects on soft-bottom benthos of the eastern Bering Sea," McConnaughey (2000) systematically sampled seafloor organisms in the Crab and Halibut Protection Zone 1 (also known as area 512) - a site north of the Alaska Peninsula that has had a series of trawl prohibitions since 1959. Similarly, adjacent areas that have experienced chronic trawling for yellowfin sole were also sampled. The area studied is relatively shallow (44-52m) with a sandy substrate and rich communities of invertebrates.

The results of his analysis showed that long-lived attached or non-mobile organisms were significantly patchier in the heavily fished areas (sponges, anemones, soft corals, stalked tunicates). Biomass of stalked, encrusting and attached organisms was higher in the unfished areas. Also, structural complexity of the habitat was enhanced in the unfished areas by an abundance of "biogenic substrate" (such as empty snail and clam shells). McConnaughey summarized his conclusions by stating, "Overall, structural complexity and diversity are reduced by trawling. Finally, bottom trawls directly affect physical properties of the seafloor, by increasing turbidity and by altering grain-size distributions, sediment porosity, and chemical exchange processes."

Eloise Brown of the University of Alaska, Fairbanks has been conducting research on experimental flatfish trawling in the Bering Sea and the potential for long-term changes in sediment composition and structure (Brown 2001). Brown's study was conducted in and around the Round Island 12-mile closure in Bristol Bay. Trawling has been prohibited in the 12 miles around Round Island since 1992, in an effort to increase protection for walrus habitat. This area ranges from 16 – 30 meters in depth and is a structurally featureless area comprised of mostly fine sand with a little mud. The research team conducted experimental trawl tows using a 132-foot commercial trawler inside the closed area and in adjacent areas open to trawling (1 April – 15 June). This study looked for changes in the distribution of chemical properties in the seafloor after trawling. Brown was also trying to determine if trawling effects were measurable over natural disturbances such as tides and storms.

Although the results of this research have not yet been published, Brown reported her initial findings to the National Research Council symposium on the effects of bottom trawling, in Anchorage, Alaska June 2001. Initial tests showed no significant difference in sediment composition in the experimental and control sites. She also looked at more sensitive indices of change, such as concentrations of chlorophyll in the top layers of sand. Chlorophyll is an important component for the production of phytoplankton, the base of the biological food chain (Castro and Huber 1997). Brown was interested in whether chlorophyll concentrations in the top layers of sand were different in the trawled and untrawled sites. She found that chlorophyll concentrations in the top layers of sand at the trawled sites were patchier and more variable relative to the control areas. There appeared to be some patchy disturbance and some form of mixing of the sediments but the differences were not statistically significant.

There are important differences in the study sites used by McConnaughey and Brown that affect the outcome of their experiments. Although tidal currents would be felt at the Alaska Peninsula site, the area studied by McConnaughey is deeper and potentially less affected by tides or storms. The shallow waters of the Round Island experiment are routinely disturbed by storm-generated waves and strong tides. The organisms living in this habitat are likely to be more adapted to disturbances than at McConnaughey's deeper study site. Also, the substrate near Round Island is predominantly fine sand with little habitat complexity. The site north of the Alaska Peninsula was reported to be rich with invertebrates and organisms like sponges and anemones that create a living seafloor habitat, and thus are more susceptible to direct damage from trawling.

Trawl Research in the Gulf of Alaska

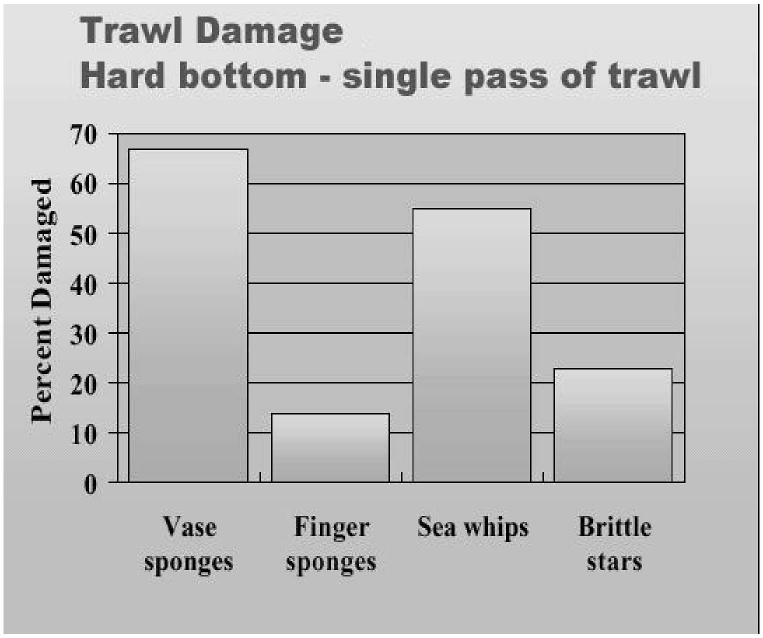
While Brown noticed little change after trawling at her study site, NMFS researchers found evidence of habitat damage seven years after a single trawl passage off of Dixon Entrance. In 1990, a single pass of a research trawl at a depth of 365m removed over 2,000 pounds of *Primnoa* red tree coral (Krieger 2001). The trawl used was a Nor'eastern otter trawl fixed with rubber bobbin roller gear, with a spread of 13 to 18 meters from wingtip to wingtip.

Using a manned submersible, researchers observed the trawled area in 1997. They found colonies of corals that were still damaged, missing up to 99% of their branches. The NMFS researchers estimated that 27% of the corals in the net path were detached. The corals that were detached by the passing trawl but remained on the seafloor were missing 50-90% of their polyps. The corals were most likely dying because they were no longer oriented correctly to the current and could not feed effectively (Krieger 2001).

In 1996 Lincoln Freese and his colleagues began a study of bottom trawling on a hard-bottom (pebble, cobble, and boulder) seafloor habitat east of Sitka (Freese et al. 1999). This study area had been exposed to either no or little trawling since the 1970s. Freese confirmed that this was a relatively pristine habitat by diving on the site with a submersible before experimental trawling began.

The researchers used a 42.5m commercial trawl vessel, equipped with a Nor'eastern bottom trawl fitted with .45m rock hopper discs and bobbins and 0.6m tires. Freese reported that this bottom trawl is similar to those used in the commercial rockfish fishery in the Aleutian Islands.

Eight sites at depths between 206 to 274 meters were trawled one time for a short duration, and then compared to eight control sites. After trawling, researchers viewed the study area from a submersible to document the fishing effects. This study found that a significant number of boulders were displaced and epifauna were removed or damaged. 67% of erect sponges (morel, vase, and finger sponges) were damaged. They documented that 55% of the sea whips, *Stylea sp*., were broken or pulled out of the seafloor and there was no observed damage to anemones.



(NMFS – Auke Bay Lab)

A year after bottom trawling in the study site, researchers returned to the area to document recovery. They noted that trawl tracks from the doors were still identifiable and little filling of the tracks had occurred. When examining the sponges they found that, "None of the 115 damaged sponges in the trawl path showed signs of repair or re-growth." Freese concluded that, "Unlike sponge communities in warm shallow waters, sponge communities in the Gulf of Alaska do not appear to have the ability to quickly return to pre-trawl population levels, nor do individual sponges appear to have the ability to quickly recover from wounds suffered from trawl gear" (NPFMC 2000b).

Robert Stone (NFMS) researched the seafloor habitat in trawled areas near Kodiak Island and compared these to nearby areas that have been closed to bottom trawling (NPFMC 2000b). The year round closures (Type I areas) to bottom trawling and scallop dredging were implemented in April of 1987 to protect concentrations of king crab. This study examined differences in epifauna (species living on top of the seafloor) and infauna (species living in the seafloor) in terms of composition, diversity and abundance, along with substrate characteristics such as total organic carbon levels and grain-size composition (NPFMC 2000b).

Stone studied three sites that bisected the boundaries of the closed areas. However, these closed areas do not function as true controls since state and federal researchers conduct trawl surveys inside the Type I areas (Stone pers comm). Although all the sites are near Kodiak Island, each site has markedly different characteristics in terms of current flow and sediment composition. Stone noted that in Chiniak Gully, where trawl intensity is relatively high, impacts by trawl doors leave little trace in the sandy-mud sediments. However just south of Kodiak near the Trinity Islands where there is both less current and trawl effort, bottom trawls leave noticeable scours in the sediments (Stone pers comm).

Initial examinations found that infauna composition; abundance and diversity were similar in the trawled and closed areas, while organic carbon levels were higher in the trawled zone of one of the three study sites. At one of the sites there was a clear difference in the substrate type between the trawled and untrawled zones. Although Stone has not finalized research on epifauna composition, his initial analyses of trawling in the Kodiak region are that:

> 1) Trawling intensity, although high for the GOA, is relatively low compared to other areas worldwide, and 2) effects on the sedimentary and biogeochemical features of the seafloor and infauna community structure from present levels of bottom trawling were minor and no clear patterns were detectible (NMFS 2002 web-page).

The **sea whip** is commonly found on soft bottoms below 75 feet where they often form large fields. They are a type of feathery gorgonian coral and considered to be long lived with a slow recolonization rate. They provide vertical structure to an otherwise low relief habitat.

Stone is presently continuing research of trawl effects on the soft-bottom benthos near Kodiak, examining the effects of trawling on sea whip habitat. He reports that a clear relationship exists between total epifaunal biomass and sea whip abundance, indicating that sea whip habitat may increase productivity (NFMS 2002 web-page). Simon Thrush corroborates this statement when describing the removal of epifauna and disturbance of soft-sediments by trawling and dredging in New Zealand. His research indicates that the removal of habitat structure in relatively low-structure soft-sediment systems significantly decreases the areas' biodiversity, and ultimately that of the greater marine ecosystem (Thrush et al. 2001).

The Link Between Bycatch and Habitat

Marine life hauled on board fishing vessels and then tossed back to sea as bycatch, dead or dying, are members of a diverse ecological community. When parts of the seafloor habitat are crushed, upended, or removed by fishing gear, the habitat is changed and can no longer support all the species that once lived there in their former abundance. It is clear that bottom trawling impacts sensitive seafloor habitats and the associated ecological communities. This impact is also evident when reviewing NMFS bycatch data. For example in 1997 – 1999 the observed bycatch of corals in the BSAI Pacific cod bottom trawl fishery was 8,444 lbs. This fishery also

Bycatch in the North Pacific: Every year hundreds of millions of pounds of marine life are caught and discarded as bycatch. For example, in 1999 trawl (including pelagic trawl) vessels accounted for 89% (~245 million pounds) of the bycatch in the Bering Sea and Aleutian Island groundfish fisheries and 82% (~ 43.6 million pounds) in the GOA groundfish fisheries (FIS 2000).

took 487 lbs of sea whips and 159,352 lbs of sponges. In the Aleutian Island Pacific ocean perch bottom trawl fishery, 40,823 lbs of corals and 149,211 lbs of sponges were caught from 1997 to 1999 (NMFS 2001).

Bycatch is not always visible from the deck of a fishing boat. Many fish and other ocean species may not actually be caught in fishing gear, but may be crushed by the heavy doors of an otter trawl or killed or stunned after passing through the mesh of a trawl net. Unobserved mortality of target and non-target species needs to be better accounted for.

An interesting story of the disappearance of corals has been unfolding in the Aleutians. Spurred by the sensitivity of corals to disturbance, NMFS is currently examining the distribution of Gorgonian corals in the Seguam Pass area of the Aleutians. The Atka mackerel fishery in Seguam Pass had historically high rates of coral bycatch, but now corals are caught less frequently (NMFS 2001).

Similarly, on the northwest Australian shelf, trawl data showed that bycatch of sponges and corals fell during the development of a trawl fishery (Sainsbury 1987 as in Auster 1996). Over time, fauna normally associated with sparse sandy habitats increased in catch while fauna associated with dense habitats decreased. Species that show the greatest decline in areas routinely trawled tend to be those that are slow growing, low in fecundity, and physically vulnerable to damage by fishing gear (Kaiser 1998b).

This information leads us to the conclusion that trawling is changing the biological community structure by damaging sensitive habitats. Bottom trawling is devastating sensitive habitats such as slow growing deep-water corals and sponges. These species are considered bycatch, an ecological cost, justified by the economic profit gained by the catch of the target species. But as the bycatch of sensitive species continues, we will lose the biological diversity supported by sensitive habitats, and create a seafloor community dominated by species that thrive off periodic disturbance, resulting in human-induced alteration of the ocean's ecological communities.

Conclusion

After reviewing the scientific literature of bottom trawling effects in both the North Pacific, and around the world, it is apparent that trawling negatively affects seafloor habitats and alters the composition of species that can live there. However, the effects on habitat and the ability of the habitat to recover is dependent on a number of variables:

> "1) Type of gear employed, 2) depth of penetration of the gear into the sediment, 3) water depth, 4) nature of the substrate (rocky, mud, sand, pebble, etc.), 5) kind of benthic fauna being impacted (epibenthic, infauna, emergent fauna), 6) frequency of the area being fished, 7) weight of the gear on the seabed, 8) towing speed, 9) strength of the tides and currents, and 10) time of year. Intensive and repeated trawling in the same area

> may lead to long-term changes in both benthic habitat and communities" (DeAlterus, J., *et al.*, 1999).

Shallow water habitats that are exposed to natural disturbances such as strong tides and storm generated waves, with little sensitive epifauna, may be able to sustain some levels of additional anthropogenic disturbance. It is important that the fishing effort does not create a disturbance level that exceeds that of natural disturbances. Collie (2000) speculates that shallow water sandy habitats (<60m) can recover from a disturbance in approximately 100 days, suggesting that this habitat type could sustain 2 to 3 incidences of physical disturbance per year. Bering Sea trawl effort data shows that some areas were trawled up to 78 to 176 times in 1999-2000. More commonly, sites in the Bering Sea shelf were trawled between 11 and 77 times in this two-year time frame (Figure 4).

Recognizing the importance of habitat to the health of fish species and the coastal communities and commercial fisheries that rely on them, Congress amended the Magnuson-Stevens Act to ensure the designation and protection of "essential fish habitat" (EFH). The Magnuson-Stevens Act describes EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

Here in the North Pacific, federal fisheries managers are working to find appropriate methods to designate essential fish habitat and ways to reduce damage from fishing gear to habitat. The North Pacific Fishery Management Council (NPFMC) has approved a range of alternatives to be analyzed in an environmental impact statement (EIS) for the designation of EFH and Habitat Areas of Particular Concern (HAPC). HAPCs can be types of habitat like corals, or specific sites like the Sitka Pinnacles. These habitats may be given elevated importance based on their significant ecological function, rarity, or sensitivity to human disturbance.

In the past the NPFMC and state Board of Fish have taken a number of steps to protect benthic habitat from bottom trawl gear including the Bristol Bay Crab Protection Zone, the Pribilof Islands Habitat Conservation Area, the Southeast Alaska (E. of 140^{o}) Trawl Closure, and selected state waters. These areas all provide year round protection from bottom trawling, while allowing the use of other commercial gear types.

Many different management tools can be used to protect habitat. The appropriate tools should be considered based on the vulnerability and sensitivity of the site to a disturbance. Tools being considered for the protection of essential fish habitat include a harvest prohibition for HAPC biota, gear restrictions, gear conversions, areas of limited effort, rationalization (minimizing impacts by slowing down the pace of fishing), and habitat conservation areas.

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Figure 1.

Diagram of an Otter Trawl with description of roller and rock hopper gear

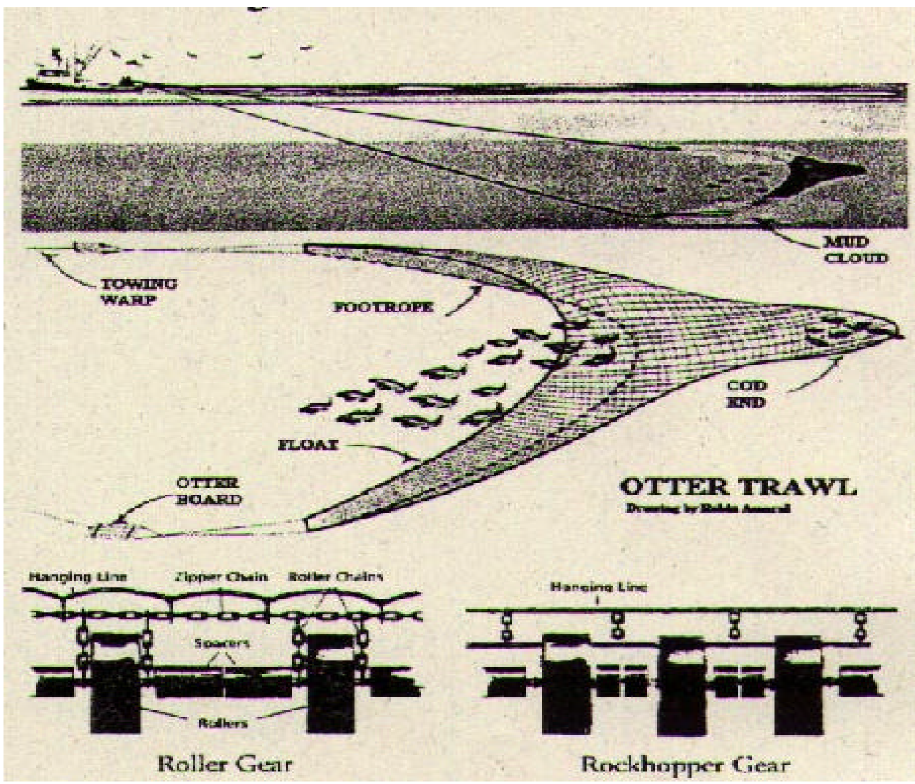


Figure 2. **Trawl Closures: Bering Sea/ Aleutian Islands**

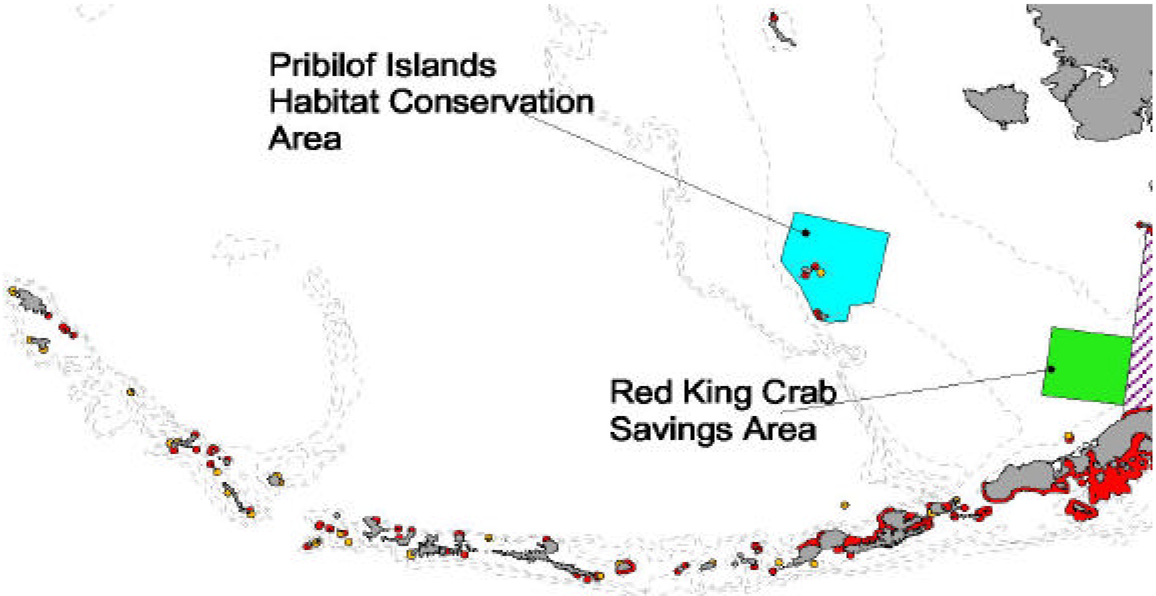
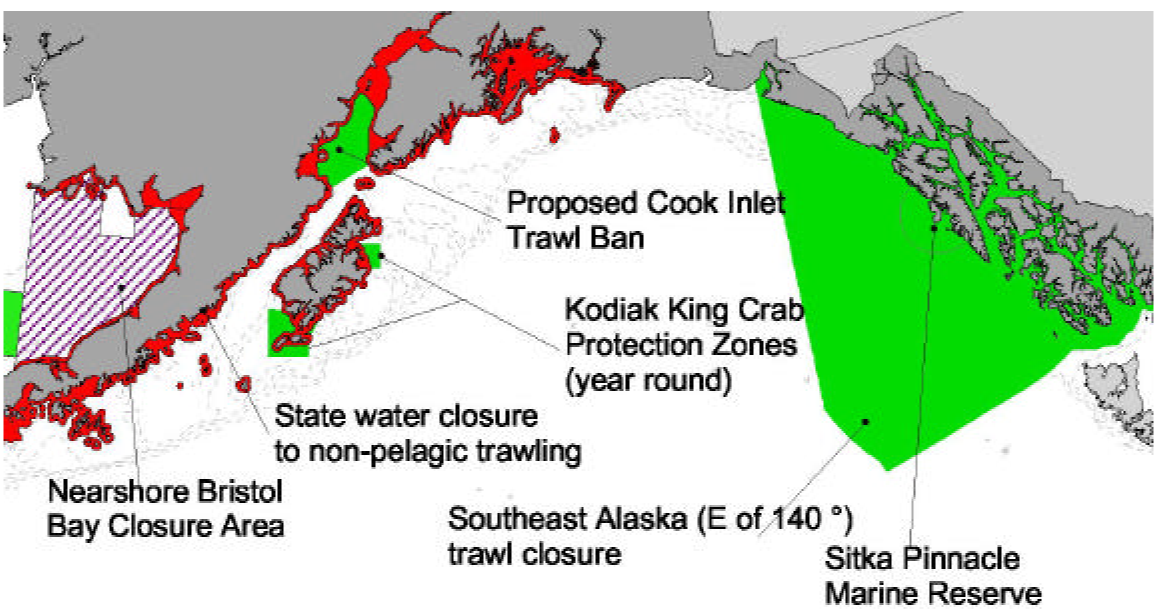


Figure 3. **Trawl Closures: Bering Sea/ Gulf of Alaska**



Maps from North Pacific Fishery Management Council (2001)

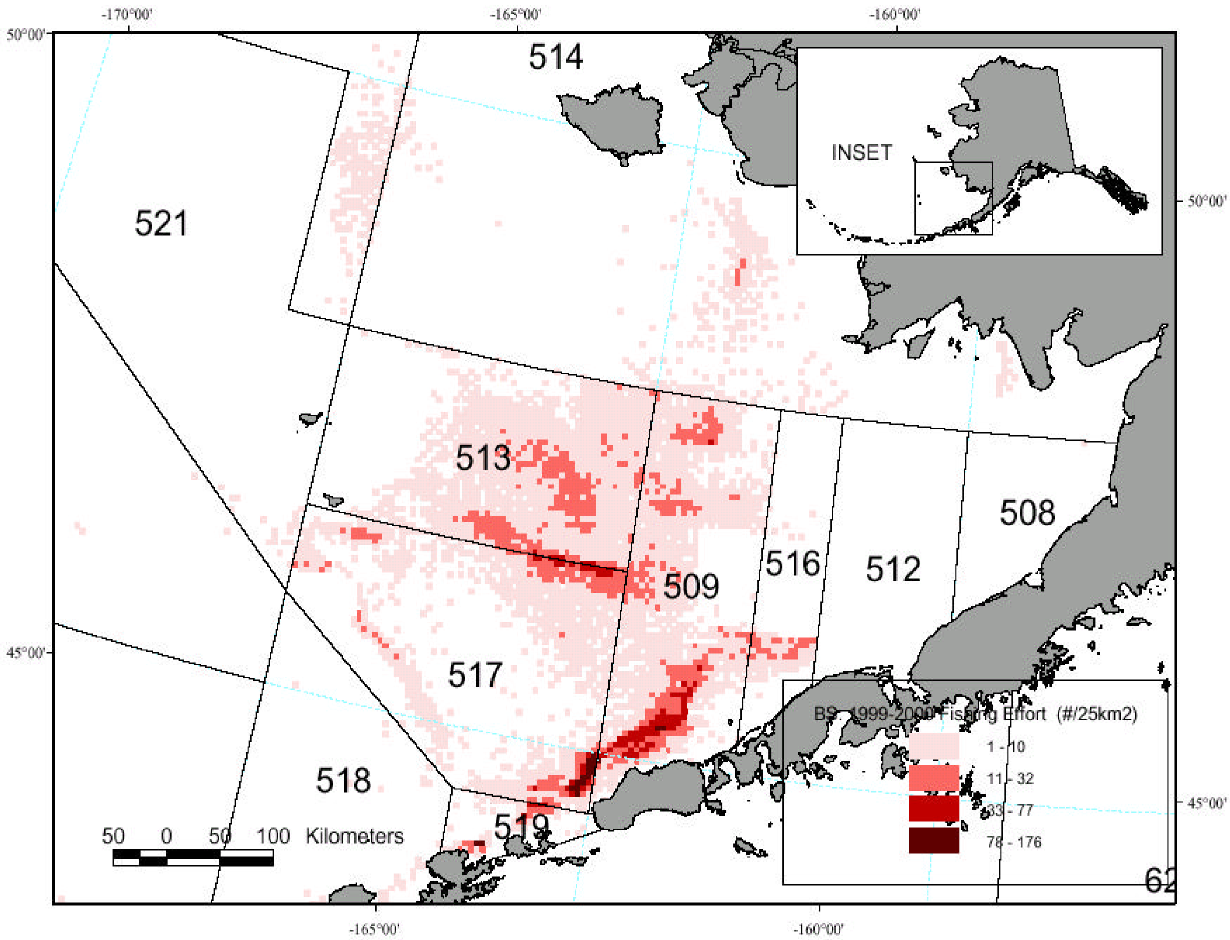


Figure 4.

Bering Sea: 1999-2000: Number of Bottom Trawl Tows/ 25km^2

(NPFMC 2001)

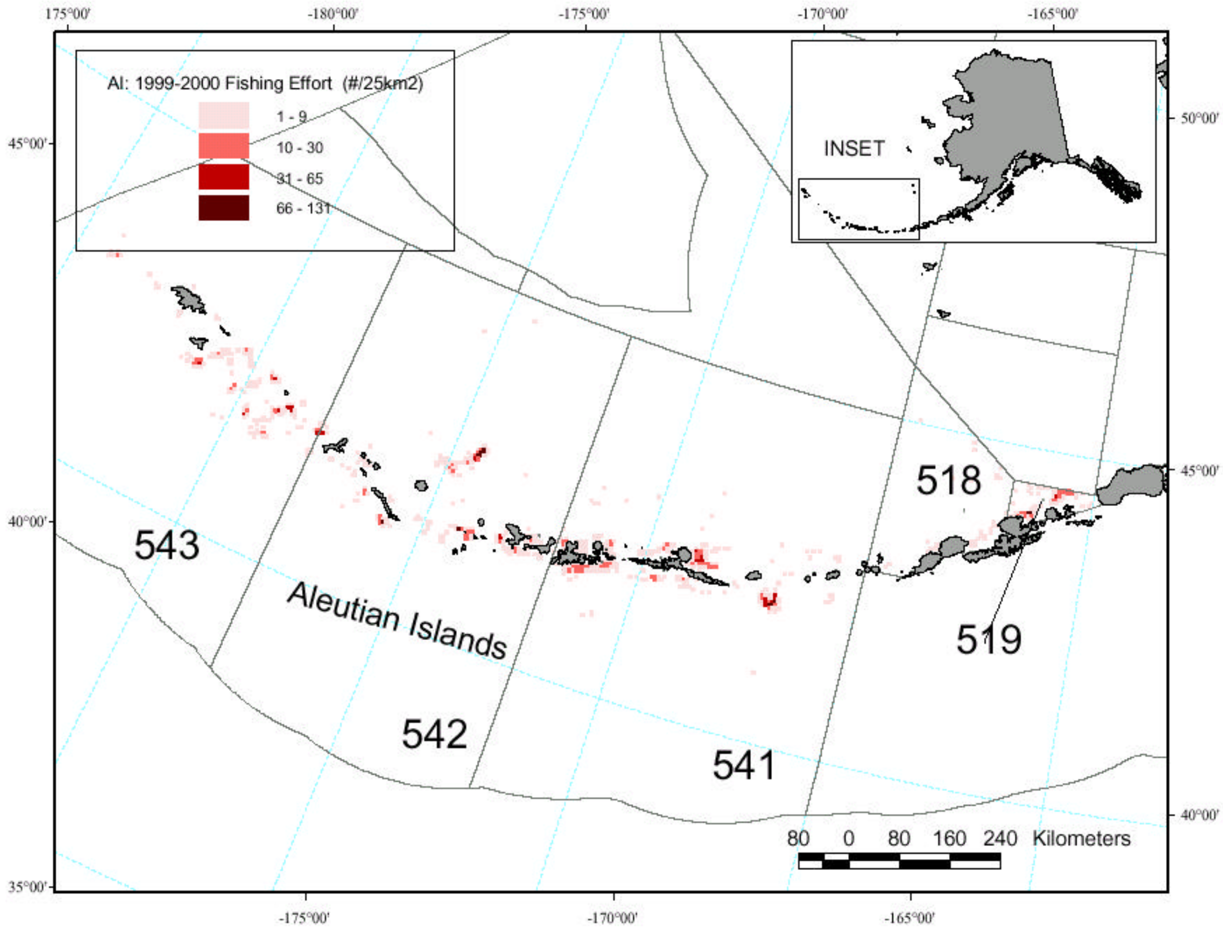


Figure 5.

Aleutian Islands: 1999-2000: Number of Bottom Trawl Tows/ 25km^2

(NPFMC 2001)

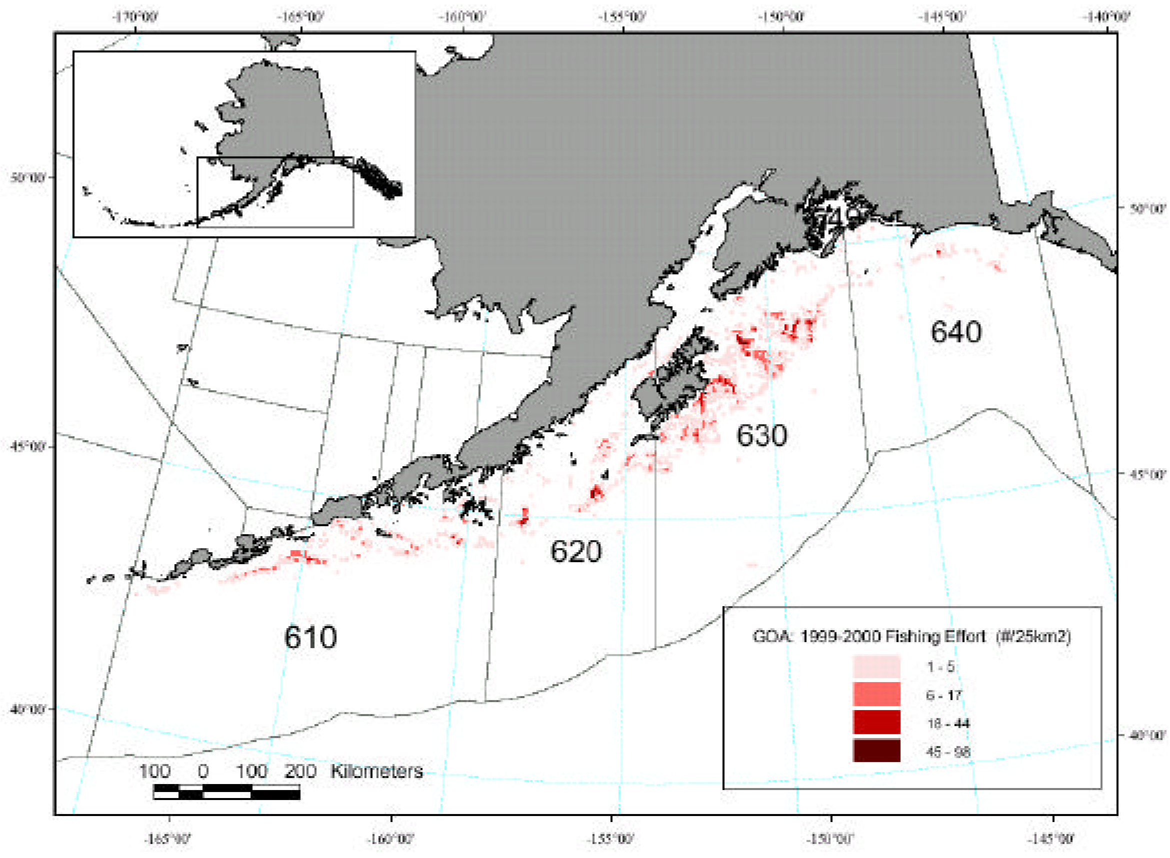


Figure 6.

Gulf of Alaska: 1999-2000: Number of Bottom Trawl Tows/ 25km^2

(NPFMC 2001)

Table 1.

Number of Trawl Vessels that caught groundfish by year, area, target, and vessel type: CV = Catcher Vessel, CP = Catcher Processor

Target/Year	GOA			BSAI			All Alaska		
Pollock	**CV**	**CP**	**Total**	**CV**	**CP**	**Total**	**CV**	**CP**	**Total**
1996	93	4	97	117	41	158	157	41	198
1997	119	6	125	104	35	139	171	36	207
1998	120	2	122	99	38	137	167	39	206
1999	112	0	112	114	17	131	160	17	177
2000	82	0	82	102	16	118	163	16	179
Pacific cod									
1996	108	16	124	107	39	146	190	41	231
1997	133	9	142	82	41	123	182	43	225
1998	117	13	130	85	36	121	171	36	207
1999	106	9	115	81	26	107	170	27	197
2000	95	6	101	84	27	111	173	27	200
Flatfish									
1996	51	19	70	12	38	50	62	41	103
1997	48	15	63	12	33	45	59	34	93
1998	37	14	51	8	30	38	45	30	75
1999	29	11	40	2	29	31	31	29	60
2000	29	11	50	5	29	34	44	30	74
Rockfish									
1996	29	17	46	0	15	15	29	21	50
1997	23	17	40	0	10	10	23	17	40
1998	26	14	40	0	8	8	26	17	43
1999	28	12	40	1	13	14	29	17	46
2000	32	11	43	0	6	6	32	12	44
Atka mack.									
1996	0	9	9	0	17	17	0	18	18
1997	0	0	0	0	12	12	0	12	12
1998	0	0	0	0	14	14	0	14	14
1999	0	0	0	0	17	17	0	17	17
2000	0	0	0	0	12	12	0	12	12
All groundfish									
1996	160	38	198	129	62	191	213	63	276
1997	173	32	205	108	59	167	201	60	261
1998	167	24	191	115	51	166	205	51	256
1999	154	18	172	126	40	166	202	40	242
2000	122	18	140	117	39	156	207	40	247

Table 2.

Mean vessel length (feet) of factory trawls in the Gulf of Alaska

	<124	124-164	165-234	235-259	>260
1996	109	147	204	241	271
1997	103	149	207	238	303
1998	114	155	213	238	-
1999	113	155	207	238	287
2000	111	152	205	238	295

Table 3.

Mean vessel length (feet) factory trawlers in the Bering Sea and Aleutian Islands

	<124	124-164	165-234	235-259	>260
1996	111	149	204	241	302
1997	107	149	206	241	302
1998	115	152	211	241	302
1999	114	152	207	245	306
2000	116	152	204	245	308

Table 4.

Mean vessel length (feet) of factory trawlers in All Alaska

	<124	124-164	165-234	235-259	>260
1996	108	149	204	241	302
1997	107	149	206	241	302
1998	115	152	211	241	302
1999	114	152	207	245	306
2000	114	152	204	245	308

Table 5.

Number of factory trawl vessels in the Gulf of Alaska by year and vessel size.

	<124	124-164	165-234	235-259	>260
1996	9	4	19	4	2
1997	10	3	16	1	2
1998	7	2	14	1	0
1999	6	2	7	1	2
2000	4	4	8	1	1

Table 6.

Number of factory trawl vessels fishing in the Bering Sea/ Aleutian Islands by year and vessel size

	<124	124-164	165-234	235-259	>260
1996	9	5	23	7	18
1997	12	5	21	5	16
1998	8	4	18	5	16
1999	9	4	10	3	14
2000	8	4	11	3	13

Table 7.

Number of factory trawl vessels fishing for groundfish in All Alaska by year and vessel size.

	<124	124-164	165-234	235-259	>260
1996	10	5	23	7	18
1997	13	5	21	5	16
1998	8	4	18	5	16
1999	9	4	10	3	14
2000	9	4	11	3	13

Tables adapted from: NPFMC 2001b