Effects of Fishing Activities on Benthic Habitat
Proposed Research Plan for the Alaska Region

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The largest fisheries in the continental United States occur in waters off Alaska. The region has five fishery management plans and encompasses the largest shelf and geologically most complex area of the U.S. coastal zone. There is a wide diversity of habitat types in this region ranging from the extensive soft-bottom areas of the Bering Sea shelf to the complex high-relief habitats of the Aleutian Islands and portions of the Gulf of Alaska. Alaskan fisheries that target groundfish, crab, and scallops all use gear that may adversely impact benthic habitat. This gear includes bottom trawls, longlines, pots, and dredges.

Since 1996, the Alaska Fisheries Science Center (AFSC) has been conducting research on the effects of fishing gear on benthic habitat. This research has led to important findings that increase our understanding of fishing gear effects on benthic habitat. Research has focused on 1) understanding the direct effects of bottom trawling on seafloor habitat; 2) the associations of fish and invertebrate species with habitat features that may be affected by fishing gear; 3) the evaluation of technology to determine gear effects and benthic habitat features; and 4) retrospective analyses of spatial and temporal patterns of bottom trawling. Most of the field-oriented studies (i.e., 1-3 above) have focused on small geographic areas in specific habitat types. Research efforts over larger geographic areas and a variety of habitat types will provide fisheries managers the information needed to develop measures for minimizing the adverse impacts of fishing gear, as required in the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

During a three-day workshop held in January 2000 in Juneau, Alaska, research projects were identified and a timetable for completion was drafted. Subsequently, this plan has been revised as research is completed or priorities change. The suite of projects identified takes a comprehensive and scientific approach to the issue of fishing gear effects on habitat. During the initial phase of this research, the focus is on identifying the effects of the various gear types on fish habitat for a range of habitat types, mapping habitat, examining the associations between habitat features and fish utilization, and defining the geological processes that will allow comparison of natural versus gear effects processes. After this initial phase, studies will transition to those that establish the connections between habitat, and fish production and population dynamics. This research will be implemented through collaborative projects with the Alaska Department of Fish and Game, the University of Alaska, and others.

Under theme A "Determine Effects of Fishing Gear on Benthic Habitat" we have identified ten individual projects that fall into three major categories: 1) effects of specific gear on specific habitat, 2) linkage of fishing induced disturbance to population dynamics of commercial and

non-commercial species, and 3) mitigation-related studies. Some of these projects represent continuance and expansion of existing projects and others are new projects. Following each project description is a budget. A summary of the individual projects and time frame for completion is in Table 1.

A. Determine Effects of Fishing on Benthic Habitat

Three experimental approaches are applicable to this general research objective and suitable research sites are generally available in the Bering Sea, the Gulf of Alaska, and Aleutian Islands areas.

(1) *Compare conditions in heavily fished and lightly fished/unfished areas that are in close proximity and otherwise similar.* This approach allows an assessment of long-term (chronic) effects of fishing activity on physical features of the seabed as well as effects on the structure and function of associated benthic invertebrate communities. High quality fishing effort data are required to identify appropriate experimental sites, which may or may not straddle closed area boundaries. Replicated biological sampling with grabs, trawls, and underwater video or submersible observations are needed to characterize relevant population and community-level attributes in the disturbed and undisturbed sites, such as biomass, numbers of individuals, body size, species richness, species diversity, and the physiological states of biostructure, prey, and resident FMP species. Acoustical surveys with multibeam, side scan, or single beam devices, coupled with grab and video groundtruthing, would be the basis for comparison of physical features such as sediment texture and bedforms.

(2) *Compare conditions before and after fishing to identify effects on the benthos. Unfished controls are necessary to evaluate the effects of fishing where existing closures do not provide a necessary contrast in fishing intensity.* Recovery can be examined in unfished controls with continued sampling. Replication with multiple (paired) sites is required to avoid spurious outcomes. Otherwise, longer-lived individuals or species will be underrepresented in the samples, thereby biasing results. In addition to sampling methods and gears described in (1) above, effective contrasts of conditions before and after fishing requires highly accurate positioning of fishing and sampling gear within the disturbed (experimentally fished) and undisturbed (control) sites, especially when destructive sampling methods are used.

(3) *Determine rates of disturbance with repetitive fishing of specific grounds. Incremental and cumulative catch rates can be used to measure the rates of depletion of benthic fauna, changes in community structure, and alteration of seabed properties as a function of fishing intensity.* Similar to (2) above, these sites should have limited or preferably no prior fishing disturbance history in order to obtain a full measure of effects. Once again, careful positioning of fishing and sampling gear is required for meaningful results.

Specific studies:

1. Effects of specific gear on specific habitat

a. Effects of bottom trawling on soft-bottom habitat of the Gulf of Alaska. Extensive trawling occurs over soft-bottom habitats in the Gulf of Alaska. Immediate and long-term changes in soft substrates and associated animal communities will be evaluated through comparisons of adjacent open and closed fishing areas and through intensive trawling experiments. In areas with soft substrates, sea whip colonies are vulnerable to gear damage. Sea whips can be removed, dislodged, or broken by fishing gear. Previous studies conducted by the AFSC on soft-bottom habitat have shown that areas with sea whips appear to have greater productivity (greater biomass and numbers of megafauna) than adjacent areas devoid of sea whips. Because sea whips are believed to be long-lived, recolonization rates may be very slow. Sea whip biological characteristics and their resistance to levels of trawling will be studied. The study will also provide an opportunity to assess recolonization in future years. The study will provide information for evaluating measures to minimize fishing effects such as area closures or gear modifications.

b. Effects of bottom trawling on soft-bottom habitat of the Bering Sea shelf. The relatively recent and well-documented development of large-scale commercial fisheries in the Eastern Bering Sea presents a rather unique opportunity for studying the potential impacts of trawling on benthic habitats. Areas closed to trawling are adjacent to heavily fished areas allowing for comparison of the effects of fishing activities on seabed habitat utilized by nationally important stocks of groundfish and crab. Physical and chemical characterizations of the seabed, in addition to biological assessments, are needed to evaluate fishing effects on these habitats. Current studies in the Bering Sea have identified possible adverse effects of bottom trawls on soft-bottom benthos, including chronic effects on community diversity and on individual megafauna populations. However, interpretation of these findings and effective use for management purposes requires some understanding of the underlying processes. To address this need, a multi-year study is required to investigate acute effects and recovery from bottom trawling. Project findings will address management issues related to the need for and efficacy of bottom trawl prohibitions, as well as operational considerations related to management of closed areas.

c. Effects of scallop dredging on benthic communities. A research program is urgently needed to examine the effects of scallop dredging on the scallop's life history, population dynamics, and associated benthic community and habitat. A scallop dredge is a heavy fishing gear with maximum contact with the seafloor. Worldwide, scallop dredges have been implicated in negative, neutral, and positive effects on benthic animals and habitats depending on local environments. Typically, dredges catch only 5-35% of scallops in their path, so dredge paths are towed repeatedly during intense fishing seasons before vessels move to new fishing areas. In Alaska, the main target species, the weathervane scallop, overlaps in geographic distribution and habitat with a number of other important commercial species, including Tanner crabs whose stocks are depressed and/or "overfished" throughout Alaska. In Alaska, large areas of the coast are permanently closed to scallop dredging without evaluation of potential effects. We propose a multi-agency program with industry cooperation to study the biological and physical effects of

scallop dredging in Alaska. A carefully planned research program was developed by internationally acclaimed scientists during a workshop in Kodiak sponsored by the Alaska Department of Fish and Game, and the University of Alaska during June 10-12, 1999. A set of integrated field and laboratory projects will focus on process-oriented research directed at individual, population, and community levels.

d. Effects of longline and pot gear on sensitive habitats. Considerable attention and some research has been directed at the effects of bottom trawling on benthic habitat. However, large-scale fisheries that target crab, sablefish, rockfish, and Pacific cod use longline or pot gear. These gears can have an impact on certain sensitive habitat as evidenced by limited underwater observations. The actual capture of gorgonian and stony corals, as examples, has been verified by commercial fisheries observers and NMFS surveys. Damage can be caused to corals, sponges, and some other sessile organisms by hooking, by crushing and plowing by pots and anchors, and from shearing by groundlines upon retrieval. On the other hand, a large proportion of this gear is set on soft substrate where effects are considered negligible. Estimating cumulative effects for a variety of substrates and the behavior of gear in contact with the bottom are two topics that require study. These studies will involve underwater observation of longline and pot deployment and retrieval with remote and manned submersibles.

e. Effects of fishing on hard-bottom habitat of the Aleutian Islands. The narrow shelf areas of the Aleutian Islands, characterized by swift currents and very irregular terrain, support a very diverse and lush community of benthic organisms, including commercially important fish and shellfish. The taxonomy, life history, and ecology of many of the invertebrate species are poorly known. Initial studies in the Aleutian Islands focused on the Seguam Pass area, where a trawl fishery for Atka mackerel has operated over the past two decades. This research identified six distinct bottom habitats and documented potential impacts from the historical trawl fishery. This study also considered potential recolonization of coral following trawl closures established to protect sea lion foraging areas. Additional work is needed to investigate impacts from other fisheries (e.g. cod, halibut, crab, and rockfish) and gears types that occur in other key areas of the Aleutians. Because of limited habitat data, extreme tides and currents, and overall high biodiversity throughout the Aleutian Archipelago, research in the area is challenging. More exploratory studies will be the basis for development of specific research hypotheses that will emerge as more knowledge and experience is gained in the region.

f. Impacts of fishing on crab resources and habitat. Crab populations that support major commercial fisheries are perceived to be highly vulnerable to bottom trawling, given crab life cycles and behavioral patterns. Over the past 30 years, crab stocks have undergone significant fluctuations in abundance and currently are at very low levels. Juvenile crab, particularly juvenile king crab, are dependent on a variety of epibenthic organisms which are themselves vulnerable to bottom trawls. Also, large pods of juvenile king crab and female Tanner crab form during the mating season in very localized areas, and substantial numbers could be removed or injured if bottom trawling were to occur at these locations. Fishery management regulations for crab and groundfish have been directed at protecting the productivity of the crab resources in order to expedite their recovery. Large areas have been closed to bottom trawling and restrictive

bycatch limits for crab have been imposed. However, because of interactions with other fisheries, effective use of these measures requires a clear understanding of factors affecting spatial and temporal patterns of crab distribution. In particular, podding behavior must be thoroughly investigated so that protective time and area closures can be accurately devised not only to reduce unintended mortality but also to minimize consequences for trawl fisheries. Similarly, research is needed to observe and document species associations that are critical to juvenile growth and survival. Furthermore, impacts of lost crab pots on eastern Bering Sea habitats must be investigated. In some years, tens of thousands of crab pots are lost due to rapidly moving ice flows. Derelict crab pots may alter habitat by adding hard structure to an otherwise flat and featureless soft bottom. Traditional dump sites for trawl-caught derelict pots would serve as natural laboratories for documenting effects on the benthos, and controlled laboratory and/or *in situ* field studies would subsequently evaluate long-term impacts on productivity.

g. Effects of bottom trawling on shelf break and upper continental slope habitats. Some of the highest density of bottom trawl effort occurs in the narrow zone that constitutes the upper continental slope and shelf break. This zone is a geologically unique area used by species of high commercial value such as sablefish, shortraker and rougheye rockfish, and Pacific ocean perch. Studies are needed to understand how bottom trawls affect the habitat that constitute this zone. These studies will focus on determining effects of bottom trawling in this zone and identification of habitat types that are sensitive to fishing-induced disturbance.

2. Linkage of fishing-induced disturbance to population dynamics

a. Laboratory and field studies. In instances where fishing gear has measurable effects on the sea floor, follow-up research is required to quantify the biological responses. Overall productivity could change as a result of gear induced disturbances. Individual rates of growth, survival, settlement, and reproduction could also be affected. Except in instances where change is inherently unacceptable, it is paramount to know whether these changes are positive or negative in nature. The ecological relationships in affected areas will be extremely complex. Variation in the responses of different taxa, life history stages and even individuals can be expected. Thus, only the dominant linkages will be understood or practical to investigate, at least initially. Controlled experiments over the range of observed impacts will be required. Specific hypotheses will be designed in laboratory and field settings as dictated by the needs for specific environmental conditions or variability, treatment groups, controls, and statistical replication. Experimental work will be conducted in seawater laboratories or *in situ* at selected sites in the Bering Sea, Gulf of Alaska, or Aleutian Islands. These sites may require protection from further human disturbances throughout the experimental period.

b. Modeling. An understanding of the natural processes of seabed disturbance (storms, erosion, deposition, bioturbation, landslides, etc.) is required for comparison with the disturbance effects of fishing gear. Once disturbed naturally or with fishing gear, does the habitat return to the original undisturbed state or to some new equilibrium condition? Models of natural seabed sediment dynamics and seafloor geologic and biologic disturbance will be developed and applied to different physical and biological settings to allow comparison with fishing gear disturbance.

Because potential management decisions are typically evaluated with respect to their effect on the population attributes (stock size, recruitment, etc.) of specific stocks, it is necessary to consider the linkage between fishing-induced disturbances and population dynamics. This process would minimally require information on the critical life history stages where substantial mortality takes place, the habitats associated with those critical life history stages, and how changes in habitat quality affect mortality rates and other vital population parameters. The field projects identified in the other parts of this initiative should provide the basic information to guide modeling efforts.

3. Mitigation-related studies

a. Evaluation of mitigation measures and impacts with research closures. The MSFCMA mandates the protection of essential fish habitat of the nation's fishery resources. As the regulatory agency for federally managed fisheries, the NMFS is particularly responsible for adverse effects to essential fish habitat (EFH) due to fishing activities. As a result of that responsibility, NMFS is in the process of determining alternative measures to minimize to the extent practicable the adverse effects to EFH. Due to a considerable lack of available information, there is a great deal of uncertainty about the type and extent of measures that would actually be necessary or effective. The EFH Final Rule instructs that establishment of research closures be considered to evaluate the impacts of fishing activities. This research plan is an attempt to design and utilize research closures as a method to obtain information needed to protect habitat in a practicable manner. We will first provide a design to be implemented under baseline conditions, then attempt to modify the design as needed for the various minimization alternatives being considered.

The long-term goal of this research is to understand effects of fishing on habitat and validate whether adopted minimization measures are necessary and effective. Objectives are to determine whether fishing reduces or alters benthic habitat and whether such alterations effect the shelter, food, species composition, and ultimately the productivity, or maximum sustainable yield of important fishery management plan (FMP) species. Specific objectives of the research closures would be to compare, under contrasting (fished versus unfished) levels of fishing, information such as habitat condition, the abundance, composition, and size of habitat forming organisms, and possibly the local abundance of fish and prey. These research closures are not expected to be able to demonstrate differences in stock productivity due to fishing impacts on habitat, but are a first step in seeing whether habitat features that provide shelter, prey, and other functions are altered.

b. Reducing fishing gear effects through gear modification. The modification of fishing gear has potential to substantially reduce seafloor effects. Fishing gear research has greatly improved both the effectiveness and the selectivity of fish harvests, and similar success is likely if efforts are turned toward reducing seafloor effects. Some promising concepts are already apparent (i.e., fishing trawl doors off-bottom and using lighter groundgear) while others would emerge from focused research and development. Since gear effects are habitat and community specific, appropriate gear modifications are likely to vary between fisheries and locations. Failing to develop such options would exclude an entire class of mitigation possibilities.

A survey of fishing gears and the ecosystems where they operate will be examined for situations where modifications could have greatest effect. Development of seafloor-friendly gear will start by identifying which parts of the fishing gear generate adverse effects and what characteristics of those components can be changed to make those effects less severe. From this information, appropriate modifications will be developed and tested. Methods will be developed to quantify component-specific effects to allow measurement of the resulting improvements. Expected is that most improvements will involve some reduction in catch rates. Measuring such losses will also be a component of testing. To maximize the relevance and acceptance of the resulting gears, this project will be conducted in cooperation with the fishers and fishing gear designers.

B. Spatial Extent of Fishing Induced Disturbance

1. Habitat evaluation in current FMP fisheries. Of urgent immediate need is the examination benthic habitat in the vicinity of major FMP bottom trawl fisheries. Currently, NMFS is the defendent in a lawsuit that claims NMFS violated EFH provisions in the Magnuson-Stevens Act. The lawsuit expresses concern that "In the North Pacific, bottom trawling and other fishing activities harm EFH in various ways," and cites evidence that bottom trawls will damage benthic marine life, such as sponges and sea whips. The suit claims practicable measures to minimize adverse impacts were not adopted and proposes that NMFS prepares assessments of measures that could be taken to protect EFH from fishing effects. As very little is actually known about the bottom habitat where major FMP bottom trawl fisheries currently occur, particularly in the Gulf of Alaska, there is little information to assess the necessity and effectiveness of any measures that may be proposed. While a variety of measures, such as further area closures, can be proposed without any information, ideally measures should be chosen that have a high likelihood of being effective while retaining benefits of the fishery.

Observations of the Alaska sea floor have been made with manned submersibles and ROVs; these observations have covered only limited areas. Because the costs and logistic limitations of manned submersible observations necessary to survey the fishery area would be prohibitive, the AFSC has been developing remote-camera devices which would be less prohibitive in cost and logistics. The initial phase of this study would sample current heavily-fished grounds to see where and to what extent different habitat types occur. Habitat types that are physically vulnerable to fishing may be of particular concern. Subsequent phases of the study would provide ground truth information on habitat type to complement NOAA/USGS mapping efforts (see 2, below). Later phases of the study would be to survey fishing grounds to evaluate any measures that may have been adopted to protect EFH.

2. Mapping of habitat features of major fishing grounds. Little of the continental shelf and slope of the Alaska EEZ has been adequately characterized. This project proposes to target limited areas of the Alaska EEZ for geomorphic/geologic mapping using state-of-the-art technology. These areas would correspond with areas most at risk to FMP fishing activities. The NMFS will determine the essential benthic ecological characteristics from ground truth surveys

to allow useful habitat characterization and classification. Geological aspects will include assessing sediment dynamics to allow comparison of natural processes versus gear impact processes. High-resolution multibeam systems that include coregistered calibrated backscatter are capable of mapping the continental shelf at spatial resolutions of less than 4 m. The deeper water depths of the upper continental slope can now be mapped at spatial resolutions of about 8 m. Together, accurate, high-resolution bathymetry and backscatter provide quantitative insights into the geology and distribution of the surficial sediments and rock outcrops of benthic habitats. The bathymetry and calibrated backscatter can be combined with accurately georeferenced groundtruth sediment, biota and rock samples to predict the sediment types and habitats in zones where no groundtruth exists.

3. Retrospective analysis of seafloor geologic and biologic character. An analysis of existing data sets can improve current management practices and guide future field studies. These analyses consist of identification of the spatial and temporal occurrence of target fisheries (defined by species composition), and identification of species assemblages using cluster analysis. The data available for this analysis include those collected from the NMFS observer program and the NMFS surveys. The identification of target fisheries builds upon the previous analyses of bottom trawl effort in Alaska and would be extended to include other gear types. This study will also provide large regional perspective and retrospective of the character of the shelf and upper slope sediments and outcrops, based on existing geological and biological data collected by the USGS and others. The identification of fish/invertebrate assemblages provides key information that, when combined with geological characteristics, reveals which habitats have particular biological significance. In cooperation with the USGS, maps and databases summarizing the present state of knowledge of the sea floor off Alaska will be produced and maintained. These products would form the basis for extrapolating site-specific (postage stamp) studies and for targeting priority areas for high resolution habitat mapping and groundtruthing.

4. Quantify abundance of habitat types over large geographic areas. Essential for both fisheries managers and researchers are estimates of the amount of specific habitats by management area. Interagency consultations and evaluation of management alternatives require this information in order to evaluate habitat effects of permitted actions. However, given the immense shelf and upper slope areas of the Gulf of Alaska and the Aleutian Archipelago, a long-term, multi-year study is required. High-resolution multibeam systems can cover relatively large areas of the continental shelf (>20 km^2/hr), collecting georeferenced bathymetry and backscatter. The initial effort for this task will be to design an approach to improve the ability to quantify habitat abundance over large areas. High-resolution habitat studies over large geographic regions are currently difficult with today's technological and funding limitations. The project will involve extensive acoustic and video transects that can map depth, substrate type, and benthic organisms. Currently available mapping databases will be used where practicable. The project will also tie into projects that intensively map small areas of high priority, such as intensively fished grounds and dense coral and sponge habitats. From this project will come area estimates by habitat type, improved description of fish and shellfish habitats, and a general overlay of habitats throughout the Gulf of Alaska and Aleutian Island areas.

5. Characterization of benthic habitat in HAPCs. Recently adopted amendments to FMPs in Alaska address areas of the marine environment that provide habitat necessary for completion of part or all of a managed species' life history cycle. Essential fish habitat that is especially sensitive to human-induced impacts (such as fishing) may be further classified as a habitat area of particular concern (HAPC). Identified, or currently proposed, HAPCs in Alaska include living substrates in shallow or deep waters, seamounts or pinnacles, and the continental shelf break. All three habitat types are characterized by a high degree of biological productivity, and living substrates also provide areas of high microhabitat diversity. Deep-water corals have been classified as an HAPC. Trawl surveys by NMFS scientists have identified several sites in Alaska that may harbor colonies of deep-water gorgonian coral. Gorgonians such as red-tree coral (*Primnoa* sp.) colonies provide complex benthic habitat, and may be ancient and extremely slow growing. This slow growth, coupled with their arborescent nature, makes them highly susceptible to damage by commercial fishing activities. The goal of this study is to use geomorphic and geologic mapping tools along with a research submersible or towed video imaging system to survey particular locations that are being considered for protection as HAPCs by the North Pacific Fishery Management Council. Investigators will initially assess abundance and distribution of red-tree and other gorgonian coral, identify fish and invertebrate species associated with the colonies, document evidence of damage (if any) to the colonies from human and non-human influences, and ascertain substrate morphology and composition in areas of coral abundance. Research in outlying years will focus on characterizing and linking physical and biological aspects of the seabed on seamounts and pinnacles, and along the continental shelf break.

Table 1. Summary of projects and timetable for completion for Alaska studies.

Projects	Year			
	2003	2004	2005	> 2005
A. Effects of fishing on benthic habitat				
1. Effects of specific gear on specific habitat				
a. Gulf of Alaska soft-bottom	x	x	x	
b. Bering Sea soft-bottom	x	x		
c. Scallop dredging	x	x	x	
d. Longline and pot gear	x	x	x	
e. Hard-bottom, Aleutians	x	x	x	x
f. Crab habitat	x	x	x	x
g. Shelf break and upper slope	x	x	x	
2. Linkage to population dynamics				
a. Laboratory and field studies	x	x	x	x
b. Modeling	x	x	x	x
3. Mitigation-related studies				
a. Research closures		x	x	x
b. Trawl gear design	x	x	x	x
B. Spatial extent of fishing-induced disturbance				
1. Habitat evaluation FMP	x	x	x	
2. Habitat mapping fishing grounds	x	x	x	x
3. Retrospective	x			
4. Habitat types large geographic areas	x	x	x	x
5. HAPC	x	x	x	x