The North Pacific Research Board (NPRB) was established by Congress in 1997 to develop a comprehensive science program of the highest caliber that provides a better understanding of the North Pacific, Bering Sea, and Arctic Ocean ecosystems and their fisheries.

The NPRB carries out science planning, prioritizes pressing fishery management and ecosystem information needs, coordinates with other ocean science programs, competitively selects research projects, and communicates research results to diverse audiences.

Since its founding, the North Pacific Research Board has developed a comprehensive program of marine research. The Science Plan, developed with guidance from the National Research Council of the U.S. National Academies of Sciences, serves as the foundation for annual requests for proposals organized by major research themes, including:

- Lower Trophic Level Productivity
- Fish Habitat
- Fish and Invertebrates
- Marine Mammals
- Seabirds
- Humans
- Other Prominent Issues
- Integrated Ecosystem Research
- Other Research and Partnerships

The annual requests for proposals result in the majority of the funded projects, which are numbered by the year they were funded (e.g., #201 funded in 2002). The Board also supports integrated ecosystem research programs that look in-depth at Alaska’s major ocean ecosystems, with a program ongoing in the Bering Sea and in development for the Gulf of Alaska.

This research summary describes research funded from 2002 through 2008.
Maintaining healthy habitats is essential to ecosystem-based management. According to the National Research Council, the lack of basic information on the distribution and habitat use of most early life stages of fish and the ecosystems that support them could pose a major constraint to managing fisheries.

Our national fisheries legislation calls for scientists and resource managers to identify essential fish habitat (EFH) and implement measures to protect it. In characterizing essential fish habitat, researchers need to study more than just where fish live, but answer the more complex questions of how fish production relates to a particular type and extent of habitat. The Board is helping fishery managers and the North Pacific Fishery Management Council address this very daunting challenge by funding a variety of fish habitat-related studies. They fall under three broad topics:

- ecosystem functions of habitat,
- habitat mapping, and
- fishing effects.

The Board’s Science Plan suggests a mix of research focusing on how fish relate to habitat, comparisons of fished and unfished habitat to determine impacts and recovery, gear mitigation research, and advances in technology that would enable efficient mapping and characterization of the seafloor. Through 2008, the Board supported 15 habitat-related projects for just under $3.5 million, of which 12 projects have been completed.
## FISH HABITAT PROJECTS

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Some of Alaska’s marine habitats are home to a diverse assemblage of species, such as corals and sponges, and may or may not support species of commercial interest. Regardless, as a hub of biodiversity, we need to know where they are, their role in the ecosystem, and whether they need to be protected.

Investigations of this nature address the “marine ecosystems information needs” priority in NPRB’s enabling legislation. Yet we also need to shed light on how fish depend on particular types of habitat so resource managers may use the information for sustainable fisheries management. And managers need to know more than the rudimentary presence or absence of particular fish species. They must also consider growth, reproduction and survival rates, and to the extent possible, production rates as they relate to different types of habitats.

Our ultimate goal in funding this research is to determine which habitats are necessary to maintain fish production consistent with a sustainable fishery and the managed species’ contribution to a healthy ecosystem. Ecosystem functions of habitat include:

- fish-habitat relationships
- ecological value of habitat types
- the role of benthic invertebrates
- identification of potential refugia
- vulnerability of habitat to natural disturbances
- identification of important nursery areas, and
- linking habitat to species population dynamics.

NPRB focused most of its fish habitat research on the ecosystem functions of habitat, funding 12 studies of which nine have been completed through 2008.

**Shelter for Young Pacific Ocean Perch in the Aleutians**

**Project 416**

Using sonar groundtruthed with underwater video, Project 416 examined the ecological value of habitat to juvenile Pacific ocean perch at five study sites in the Aleutian Islands. Researchers found juveniles mainly in mixed sand and boulder substrate, to the exclusion of most other habitats, and usually within one body length of boulders, corals, sponges, or other complex structures. The study also looked at the condition of the fish and why it varied between sites, perhaps due to differences in prey quality, predator abundance, and/or habitat quality, possibly as mediated through the abundance of zooplankton, especially large copepods. Scientists concluded that climate forcing and its effects on wind forcing could influence the intensity of upwelling in different areas, affecting zooplankton production and quality, which could in turn affect the condition of juvenile Pacific ocean perch. Also, the amount and type of habitat available to juveniles could influence their ability to avoid predators.

Map of islands of Four Mountains and Samalga Pass area showing three of the five sites (black strips) where acoustic mapping was completed.
The Central Gulf of Alaska around Kodiak has supported a commercial flatfish fishery for many years, beginning with foreign fisheries that worked the area starting in the early 1960s. South of Kodiak, emergent structures created by polychaete tube worms dominate the low-relief benthic region. This tube worm habitat provides a nursery area for age-0 juvenile flatfish, particularly northern rock sole and Pacific halibut, which are both commercially important species. Project 301 set out to evaluate these emergent structures to better estimate the distribution and abundance of juvenile flatfishes around Kodiak.

Using video camera sleds, researchers assessed fish densities, habitat features, and fish-habitat associations on a fine spatial scale. They found juvenile flatfish associated with low to moderate worm tube densities, where fish may aggregate to feed on the worms or associated fauna. The structural complexity created by the tubes may also reduce the predation threat for flatfish. Yet when worm tube densities were too high and created a continuous turf, juvenile flatfish were nearly absent because they could not bury themselves and thus were more vulnerable to predation. If shell material was added to the seafloor to enhance structural complexity, juveniles were attracted only when larger adult flatfish were scarce.

Scientists concluded that differential predation pressure may make two seemingly similar areas of seafloor vastly different in quality as perceived by juvenile flatfish. The study also showed how species react to predation pressure. Rock sole minimize activity and bury themselves, while English sole become more active to avoid predation. Pacific halibut had an intermediate reaction. Knowing how individual species relate to different habitat types, and the vulnerability or resilience of particular bottom types helps managers make better decisions on how to protect it. Fishing impacts on these habitat types are being studied under Project 710.

Scientists are also studying flatfish habitat in the Eastern Bering Sea under Project 709. That retrospective study examines the spatial distribution of yellowfin sole, Alaska plaice, and arrowtooth flounder on the eastern Bering Sea shelf over 25 years, from 1982 to 2005. In this ongoing study, researchers expect to analyze fish distributions relative to small-scale environmental features, climatic indices, demographic state of the population, and human harvest activities.
AT THE HEAD OF BERING CANYON, NEAR WHERE THE shallow shelf meets the slope at 150 meters, Alaska skates deposit eggs in a highly productive nursery covering about one to two square kilometers. Project 415 set out to study this relatively flat, sandy, muddy bottom habitat that had no detectable abiotic or biotic structure or diversity, yet which supported more than 500,000 skate eggs per square kilometer.

Skates reproduce in Alaska throughout the year, peaking in fall and winter. Embryos develop slowly, hatching more than 3.5 years after being deposited in the nursery. Skate survival is a gamble—gastropods, particularly the Oregon triton, cruise the nurseries preying on the egg cases, while Pacific cod and halibut feed on newly hatched skates.

Skate nurseries seem to be located in highly productive upwelling areas near canyons. Having a ready supply of food allows skates to remain within the nursery site and minimize foraging excursions during reproductive cycles. Currents supply oxygen and remove metabolic wastes from the egg cases. The shelf-slope interface may provide the delicate balance of these critical elements that ensure the highest production and survival of adults and developing offspring.

Sensitive to disturbances, these nursery sites are important habitat for successful skate reproduction, the study concluded, and may need to be protected from disturbance by fishing activities. Project 808 continues work on skate nursery sites in the eastern Bering Sea, gathering detailed information on nursery habitat and benthic associations and providing annual production estimates for each site. These estimates will be used to develop a model that predicts the importance of each site and its relative contribution to the estimated young-of-the-year population for the Alaska skate.
Rocky Reef Habitat for Yelloweye and Lingcod
Project 616

THE CHISWELL RIDGE SOUTH OF SEWARD, ALASKA supports high densities of yelloweye rockfish and lingcod. Project 616 estimated the density and abundance of these species based on new habitat delineations and compared those to previous estimates. More precise mapping of rocky reef habitat and evaluating the associated fish densities demonstrated that abundance estimates should be decreased by about 48% for the southern Chiswell area, compared to earlier estimates. Applying these new estimates would require more conservative management, especially considering the low inherent productivity of yelloweye rockfish populations. *(For more about the habitat mapping aspect of this study, see page 14: Mapping the Chiswell Ridge in the Gulf of Alaska)*

Home Ranges for Copper Rockfish and Lingcod in Prince William Sound
Project 729

FURTHER NORTH AND EAST, IN PRINCE WILLIAM SOUND, Project 729 studied residency and movements of copper rockfish and lingcod in nearshore areas using acoustic telemetry. Researchers surgically implanted acoustic transmitters in 45 fish captured in three habitats: artificial reef, low-relief natural reef, and patch high-relief rock reef. The homing experiment demonstrated that rockfish have the ability to return to capture sites following a four kilometer displacement. Rockfish and lingcod appear to exhibit very high site fidelity and long periods of residence at the sites studied. Fish on the artificial reef moved least, while those in low-relief natural reef areas maintained the largest home range. The artificial reef also attracted fish from the other habitats and appears to have the potential to provide refuge habitat in the event of physical disturbances such as oil spills and coastal development.

Forage Fish in Nearshore Habitats
Project 642

A SECOND PRINCE WILLIAM SOUND STUDY, PROJECT 642, examined seasonal distribution, habitat use, and energy density of forage fish in the nearshore areas of eel grass beds, bedrock outcrops, and kelp. Scientists most frequently encountered Pacific herring, saffron cod, pink salmon juveniles, and capelin, which used the nearshore habitat for about six months. Pink salmon were most abundant in spring, herring in summer and capelin in fall. These areas serve as nursery habitat and are particularly susceptible to oil spills or other shoreline disturbances.
The main objective of this project was to determine if, and under what conditions, the larvae of blue crab, once the basis of thriving commercial fisheries around the Pribilofs and St. Mathews Island, could be cultivated at the National Marine Fisheries Service lab in Kodiak. The longer-term goal, through subsequent research, would be to use laboratory experiments to help characterize essential fish habitat for declining or depleted crab species.

Researchers tested the effects of diet, temperature, and rearing density, but density did not appear to have a significant effect on survival. A diet of Artemia nauplii plus diatoms produced significantly higher survival and the colder the temperature, the longer it took for the first juvenile crab stage to develop. Results showed that blue king crab larvae can be cultivated with high survival. Using the proper diet, and that swimming larvae need to feed, but settling larvae do not feed. These results may be used to produce larger numbers of juvenile crab for laboratory research and stock enhancement.

In a warming Bering Sea, earlier hatching by king crab could put them out of synchrony with plankton blooms, resulting in poor survival and small, weak subsequent year-class survival. Laboratory data from this study showed that crabs may be able to compensate somewhat for changing temperature regimes by adjusting development rates, allowing limited reproductive success in years of warm conditions, thus preventing complete reproductive failure.
FEATURE PROJECT

FISH HABITAT :: Ecosystem Functions of Habitats

Biodiversity in Aleutian Coral Gardens

Project 304

PROJECT 304 EXAMINED DEEPSEA CORAL DISTRIBUTION AND HABITAT IN the central Aleutian Islands. Funded at $1.3 million, this was the largest individual study ever supported by the Board. While primarily a mapping study using submersibles, scientists also wanted to assess the importance of coral and sponge habitat for commercially important species of fish, crab, and octopus, as well as assess any impacts of fishing gear.

Associated Species

The study found that 64-72% of commercially important fish species in the Aleutians were associated with corals or sponges. Juvenile rockfish were the most abundant fish, followed by grenadiers and Pacific ocean perch. Crabs were not as abundant as fishes and among the eight species identified, deepsea Tanner crabs were the most abundant. Most shallow-water fishery management plan species (those living at depths of less than 1,000 meters) appear to frequently associate with sedentary, structure-providing invertebrates, such as hydroids, actiniarians, bryozoans, and tunicates, and there is evidence that their presence may be essential to some species.
Mapping Corals and Sponges
Scientists mapped 17 sites with dual frequency multibeam sonar systems, covering 2,600 square kilometers down to depths of 3,800 meters, coupled with visual observations to 2,950 meters. They collected biological information and developed a predictive model to relate coral and sponge distribution to environmental characteristics. They also used bathymetry and backscatter data, combined with geologic interpretation, to create habitat classification maps.

The new data showed details of the substrate variations within sites, proportions of different types of substrates, and the interplay between substrates and geologic and oceanographic processes. Habitats dominated by bedrock and cobble supported the highest densities of corals, while coral and sponge diversity increased from deep to shallow water. For predictive modeling, explanatory variables included depth, slope, and roughness, with depth and slope being the most important factors. Models of coral and sponge presence or absence were more successful to the north of the Aleutian archipelago than to the south. The study reported over 60 sponge species that had not been known previously in the Aleutians, and more than 25 new species that are being formally described.

Assessing the Impact of Fishing Gear
Scientists examined video footage of the seafloor for damage and disturbance in relation to observed fishing intensity in the central Aleutian Islands. They classified corals and sponges as damaged if skeletons were broken, if organisms had missing or broken branches, were torn or had other evidence of injury, were detached from the seafloor, or were attached but overturned and lying in contact with the seafloor. Overall, 11% of the corals and 21% of the sponges were damaged. Disturbance was widespread and evident on most video transects, with the most damage in heavily trawled areas. This study helped provide significant background information to the North Pacific Fishery Management Council when it approved closing large areas to trawling to protect the coldwater coral and sponge habitats in the Aleutians.
Fish habitat :: habitat Mapping

Seafloor Habitat Changes in Norton Sound
Project 604

TO THE NORTH IN NORTON SOUND, PROJECT 604 INVOLVED A RETROSPECTIVE analysis of trawl survey data from 1976 to 2006 to examine changes in distribution and abundance of benthic fauna and demersal fishes in response to climate change. Instead of collecting new data, the investigators constructed a geographical information system database and used it to analyze changes in abundance and distribution of selected dominant benthic species, species richness, and diversity. Over the study period, overall trawl catches grew exponentially by 370%, driven primarily by one sea star, Asterias amurensis, which accounted for 70% of the total catch. Catches increased for some 13 other species as well, although the composition of dominant species remained unchanged. Researchers looked at a variety of environmental factors to explain the variability in species biomasses. Significant correlations were identified with east-west gradients across Norton Sound, incident solar radiation, duration of ice-free waters, and a large-scale climate index called the Pacific-North American Index.

Red king crab, the species of greatest interest, were negatively related to near-bottom water temperatures. Neither the crab population nor the average bottom temperatures showed any trend during the study. The study concluded that physical forcings are transmitted unevenly through the benthic community and other higher-order interactions need to be considered to explain red king crab population dynamics.

Habitat Mapping

MAPPING NORTHERN MARINE ECOSYSTEMS FOR ESSENTIAL FISH HABITAT.

Once we know that an undersea habitat is important for biodiversity or fish production, we need to know its location and extent for delineating truly essential fish habitat.

Much of Alaska’s continental shelf, especially in the Bering Sea, is characterized by broad regions of sand and silt, with little topographic relief. Resource managers include these areas in EFH designations under “fish presence/absence criteria,” and we know that large populations of walleye pollock, Pacific cod, and other pan-shelf species reside there. But often the more critical habitat areas have harder substrates that support epifaunal structures where fish hide, feed, grow, and reproduce. Hard substrates also may support coldwater coral and sponge gardens that not only provide refuges for fish, but contribute to the biodiversity of these northern marine ecosystems.

Ship time and fuel costs are so high when mapping bottom habitat that very limited fish habitat mapping has been accomplished in the Bering Sea, the Aleutians, or the Gulf of Alaska. NPRB has helped in that regard by supporting several mapping studies.

Locations of trawl survey stations in Norton Sound. Stations in the boxed area were continuously surveyed from 1976 to 2006 by NMFS (1976-1991) and ADF&G (1996-2006). Stations outside the boxed area were surveyed when additional time was available.
A second mapping project in the Aleutians examined preferred substrate characteristics for Pacific ocean perch. Project 416 mapped five sites using sidescan and multibeam sonar, groundtruthed by video observations. Indices of reflectivity, complexity, roughness, slope, and relative height were related to fish densities. A substrate classification tree was used to classify bottom types from acoustic data.

The study found that bottom reflectivity and roughness were the most important features of the acoustic data for determining correct substrate classification. One of the most important findings identified characteristics of nursery habitats utilized by juveniles. Isolated from adult populations, young ocean perch used only specific habitat types within the nurseries, with most found in mixed sand and boulder fields. Juveniles appeared to be using these complex habitats and the associated epibenthic invertebrates for shelter. Sponge and coral were common on all hard substrates and prevalent on boulders in areas occupied by juvenile ocean perch.

Researchers drew two important conclusions from the mapping study: all substrate types must be groundtruthed, for example, using underwater video or by sediment grab; and they need a relatively large sample size of more than 100 observations to correctly parameterize the classification tree and get accurate maps of the seafloor.

**Identifying Nearshore Habitat in Northern Bristol Bay**

Project 201 demonstrated the efficacy of combining sidescan sonar with towed seabed video imagery to delineate three different habitat associations close to shore in northern Bristol Bay. Researchers identified the following habitats:

- eelgrass with sandy gravels
- bladed kelps and filamentous red algae with sandy gravels
- coraline algae, green urchins and bryozoans with bouldery/cobbly sandy gravel

High-frequency (390 kHz) sidescan sonar worked best in mapping eelgrass beds, with sufficient precision, groundtruthed by visual data, to monitor longer-term changes in eelgrass distribution. The approach did not work as well in other habitats, especially those that were particularly heterogeneous.
The results of the study revealed a 47.5% decrease in estimated fish abundance based on a much lower estimate of rocky reef area than shown previously in historical NOAA data. With the decrease in available habitat, the estimated abundance of lingcod remained higher on the southern Chiswell Ridge, but yelloweye rockfish were estimated to be more abundant in the northern ridge area. Given the low inherent productivity of yelloweye rockfish populations, it is important that management remains conservative, and that population estimates are as accurate as possible. (For more about the ecosystem function aspect of this study, see page 8: Rocky reef habitat for yelloweye and lingcod)

Since habitat mapping is very expensive, the board wanted to understand which technologies would be most effective and affordable for a given purpose. Project 615 gathered together experts in various aspects of marine habitat mapping to identify key issues, evaluate available technologies and techniques as well as those in development, and present results in a form that could be used to educate managers and other interested parties. The workshop produced a comprehensive report discussing available technologies, their capabilities, and how they might be used in the development of effective mapping programs. Researchers reviewed remote sensing technologies and their applications, including a variety of sonar mapping systems, mapping AUVs, small-boat surveys in shallow water, airborne Lidar (light detection and ranging) bathymetry, and sub-bottom profiling. Visual scale technologies included towed video sleds, small ROVs, the imaging AUV SeaBED, manned submersible Delta, and methods of quantitative video analysis. Participants discussed habitat classification schemes and provided case histories for major habitat mapping programs in other regions. Workshop results were summarized in a CD available through Sea Grant and NPRB.
Fishing Effects

ONE OF THE MORE DIFFICULT ISSUES FOR FISHERIES MANAGERS IS MITIGATING FISHING GEAR IMPACTS ON BENTHIC HABITATS CRITICAL FOR SPECIES SURVIVAL.

All of the regional fishery management councils need this information for developing environmental impact statements and assessments for proposed regulations. Research to support this effort should examine:

• the magnitude and disturbance rates of repetitive fishing
• vulnerability and resilience of certain habitat types to fishing disturbances
• recovery rates of benthic habitat
• how fishing gear may be modified to reduce its impacts on habitat

The councils also need to determine if certain areas should be closed to protect fish stocks or special faunal assemblages such as corals and sponges. And if the case for a closure is made, what are the economic consequences for the fisheries?

Conclusively determining whether observed changes in habitat are due to fishing is difficult. As a result, few studies have come forward to tackle this problem. New studies to do so involve a combination of field work, laboratory experiments, and modeling.

Fishing Effects near Round Island
Project 201

PROJECT 201 CARRIED OUT A PILOT STUDY TO MAP AND CLASSIFY NEARSHORE habitat in northern Bristol Bay using acoustic and visual techniques. They set out to compare two offshore habitats near Round Island, one trawled and one untrawled, during the yellowfin sole fishery. While researchers accomplished much of the nearshore mapping work, rough seas and very poor visibility severely limited acquisition of seafloor video data at the offshore sites, preventing the study from completing the fishing effects component.

Impacts of Trawls on Flatfish Habitat off Kodiak Island
Project 710

ANOTHER STUDY EXAMINES POTENTIAL TRAWL IMPACTS on ecological processes controlling habitat quality in juvenile flatfish nurseries around Kodiak Island. Project 710 builds on Project 301, which examined worm tube habitat for juvenile flatfish nurseries. It uses controlled field experimentation to examine trawl impacts upon structural components of flatfish habitat and measures the changes in juvenile flatfish spatial distribution in response to that disturbance. The goal is to quantify juvenile flatfish distributional response to trawl disturbance as well as compare feeding and vulnerability to predation in disturbed versus undisturbed areas of seafloor characterized by a range of worm tube densities.
FISH HABITAT
Oases of Ocean Life

2002-2008 RESEARCH SUMMARY

NORTH PACIFIC RESEARCH BOARD

Mission
NPRB supports research to build a clear understanding of the North Pacific, Bering Sea, and Arctic Ocean ecosystems that enables effective management and sustainable use of marine resources.

Fish Habitat is one in a series of publications produced by the North Pacific Research Board in support the 2005 Science Plan developed with guidance from the National Research Council of the U.S. National Academies of Sciences.

Find out more by visiting our website at nprb.org

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