AGENDA D-3
DECEMBER 2006

MEMORANDUM

TO: Council, SSC and AP Members

FROM: Chris Oliver
Executive Director

ESTIMATED TIME
4 HOURS

DATE: November 27, 2006

SUBJECT: Bering Sea Habitat Conservation

ACTION REQUIRED:

Receive report on EBS gear modification research and finalize alternatives for analysis

BACKGROUND:

The Council took action in February 2005 to conserve essential fish habitat (EFH) from potential adverse effects of fishing. EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. The EIS prepared for the action concluded that while fisheries do have long term effects on benthic habitat, these impacts were minimal and had no detrimental effects on fish populations. The Council adopted several new measures to minimize the effects of fishing on EFH in the Aleutian Islands and Gulf of Alaska. The EFH EIS also evaluated a suite of alternatives for the eastern Bering Sea (EBS). Based on that analysis, the Council determined that additional habitat protection measures in the EBS were not needed right away, and that an expanded analysis of potential mitigations measures for the EBS should be conducted prior to taking action.

In December 2005, the Council discussed a framework for alternatives to conserve habitat in the EBS and finalized a problem statement. In June 2006, the Council reviewed two discussion papers that provided background information to assist the Council formulating a reasonable range of alternatives. The Council requested staff to develop a concept paper on an open area approach to allow bottom trawling in areas historically fished. In October, 2006 the Council reviewed the open area approach concept and suggested options for the northern boundary of the proposed open area, based on varying thresholds levels of historic fishing. These are depicted in Item D-3(i). The October Council motion is attached as Item D-3(ii) and the problem statement and revised alternatives are attached as Item D-3(iii). Several issues have been raised by staff regarding options for scientific research (Item D-3(iv)), and the Council may wish to address these issues at this meeting.

The Council will receive a report from Dr. Craig Rose (AFSC) on recent research on gear modification in the Bering Sea to mitigate the effects of bottom trawl fisheries. A report of preliminary results is attached as Item D-3(v).

The Council also requested a discussion paper summarizing current scientific information on three canyon areas (Pribilof Canyon, Pervenets Canyon, and Zhemchug Canyons) and a summary of current research on skate nurseries and the degree of overlap with fisheries. A copy of this paper was sent out in a Council mailing. The Council further requested a review of the HAPC process, and that information is attached as Item D-3(vi).

At this meeting, the Council is scheduled to finalize the alternatives for analysis. Initial review of the analysis is currently scheduled for February, 2007.

Revised

Item D-3 (i)v2
DECEMBER 2006

Bering Sea Open Area Approach:

In June 2006, the Council discussed potential alternatives for the Bering Sea Habitat Conservation analysis. This analysis will tier off of the EFH Environmental Impact Statement (EIS). The range of alternatives being considered includes an open area approach and modifications to bottom trawl gear. The Council tasked staff with developing an open area approach that would utilize fishing data through 2005. In October, 2006 the Council reviewed the open area approach concept and suggested that the Northward boundary of the open area would be configured such that the area south and west of St. Matthew Island is excluded from the open area to conserve blue king crab habitat and suggested further options for modifying the northern boundary of the proposed open area based on varying thresholds levels of historic fishing.

Background on Open Area Approaches:

The premise of the open area approach is that 'the first pass of a trawl is the worst pass (trawling over undisturbed bottom has more habitat impacts than subsequent trawl passes). Thus, constraining trawling to areas that have already been impacted has habitat conservation benefits. Allowing trawling in previously untrawled areas could potentially result in acute local changes to the benthos and overall an increase in the long- term effects indices (LEI). Recall that the LEI were the tool used in the EFH EIS to assess the impacts of fisheries on EFH.

Limiting the trawl fishery to those areas traditionally fished provides a precautionary approach by setting aside relatively pristine areas before they become impacted. This habitat conservation measure mirrors the approach used for protecting terrestrial areas from development (e.g., national parks). The EFH EIS analysis (Chapter 4) discusses potential benefits of prohibiting trawling in the northern Bering Sea areas, particularly to conserve snow crab habitat and habitats used by other species.

The creation of an open area that encompasses historically fished areas would not reduce the effects of fishing that generated the LEI scores. On the other hand, creation of closure areas in areas currently fished may redirect effort into areas with lower catch rates, and in turn may cause more impacts on EFH.

An open area based on older fishing patterns may not adequately represent the distribution of current bottom trawl fisheries, as effort may have expanded northward in response to fish distribution (according to public testimony). This primarily is due to shifts in the ecosystem; a northward shift in response to changing temperatures, atmospheric forcing and compositional changes in the predominant groundfish biomass structure. Recent fishing effort depicts this northern shift in fishing effort particularly in the flatfish fisheries (yellowfin sole, rockfish, flathead sole and other flats). The concern expressed in June 2006 was that the open area described and analyzed in the EFH EIS (Figure 1) does not reflect recent effort in the northern areas (St. Matthew and south of Nunivak Island) or consider reporting area 519 Bogoslof. The original open area was based on bottom trawl effort from 1998-2002.

Current Analysis:

In October, 2006 the Council suggested revisions to the open area approach to define the Northward boundary and to exclude the used by blue king crab near St. Matthew Island. The blue king crab savings area is near St Matthew Island and extends southwest to project juvenile, non-ovigerous female and male blue king crab habitat, and northeast to protect ovigerous females habitat (Figure 2). This area has: (1) been represented in the NMFS and ADF&G surveys to contain juvenile and mature BKC; (2) locations of PSC catch in the rock sole trawl fleet; and (3) observations from the directed crab fishery. Industry comments indicate that increased flatfish trawl effort has been progressing northward on average 20 miles/year. some of this effort is occurring near St. Matthew Island. This crab stock is severely depleted, designated overfished such that the last pot survey found only 5 legal male BKC in the area.

The Council requested the Open Area Approach northward boundary also be modified with based on bottom trawl effort distribution. Three options were developed based on ranges for relatively low to relatively high trawl effort.

Option 1: *Smallest open area.* Northern open boundary based on high effort intensity.
Option 2: *Slightly larger open area.* Northern boundary based on medium effort intensity.
Option 3: *Larger open area.* Northern boundary based on low effort intensity.

To examine the northward boundary options both observer data (1990-2005) and more historic bottom trawl data from 1973-1996 (Fritz et al. 1998) was used. The data set was divided into three separate parameters to represent low, medium, and high trawl intensity. The parameters selected were: high bottom trawl intensity were more than 50 hauls / year, that for medium bottom trawl intensity were more than 15 trawls / year, and that of low bottom trawl intensity was 3 trawls /year. The figures were created using a series of layers in GIS. The previous open area selected by the Council in October 2006 was overlayed with both recent and historic bottom trawl fishing effort as described above. The highest amounts of effort occurred along the 100 m line of the shelf (NMFS report area 513) and the southern portions of the Bering Sea (NMFS report areas 519, 517, 516, 509). A subset of the bottom trawl data was used to better focus intensity calculations for the northern fisheries north of the 58° N latitude line excluding the Bristol Bay Area.

Utilizing an editing tool in ArcGIS the bounds of the previous open area were extended to capture bottom trawl sets that occurred by intensity category on both the historic and observer data. Additional extensions occurred to include the areas specifically near Bogoslof, south of Nunivak Island, and the 10° strip on the south end of the Red King Crab Savings Area. Exclusions were made for the St. Matthew area based on the Council's October, 2006 motion for crab protections. The area for Option 1 high trawl intensity is depicted in Figure 3, Table 1 and captures 87% of the observed catch from 1990-2005. The area for Option 2 medium trawl intensity is depicted in Figure 4, Table 1 and reflects 93% of observed catch. Figure 5 represents Option 3 low trawl intensity and captures 96% of the observed bottom trawls vessel's groundfish catch.

Table 1. Calculations for Area, Effort and Catch of the Northern Boundary Options of the Open Area Approach

	Area Open (km^2)	Observed Catch Inside (mt)	Observed Catch Outside	% of total EBS	Observed Effort Inside	Observed Effort Outside	% of total EBS
Option 1 High Intensity	291,045	4,650,169	670,551	87%	249,397	33,043	88%
Option 2 Medium Intensity	345,800	4,958,350	362,370	93%	263,900	18,540	93%
Option 3 Low Intensity	471,300	5,128,095	192,625	96%	271,624	10,816	96%

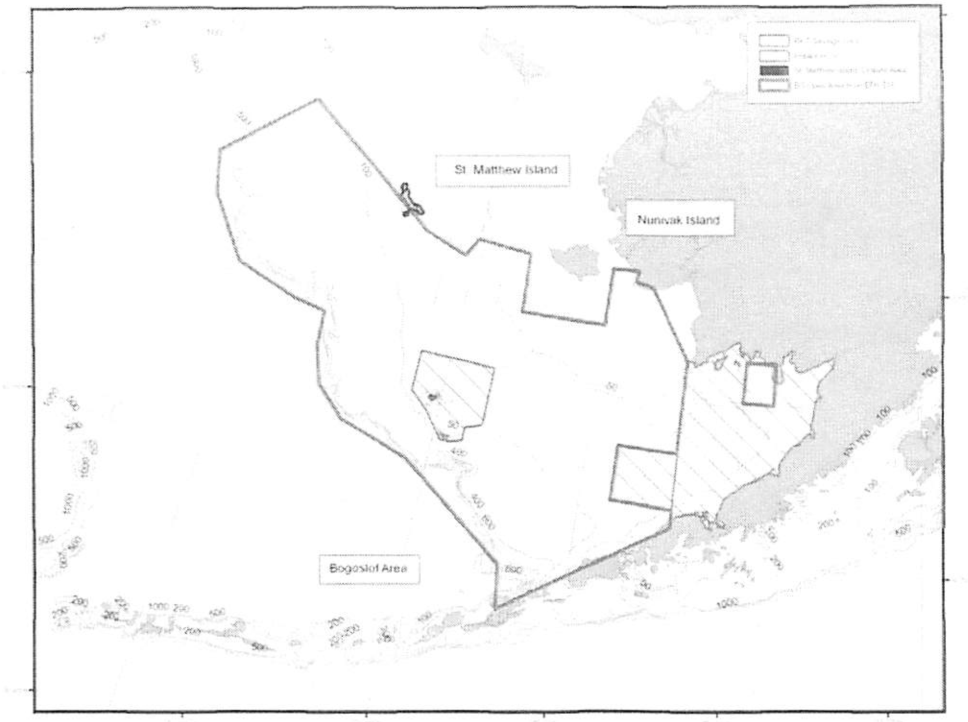

Figure 1. Open area presented in the EFH EIS, without the rotational closures, with other Bering Sea trawl closures areas depicted (Red King Crab Savings Area, Pribilof Island Habitat Conservation Area, and the State of Alaska's St. Matthew Island Closure Area).

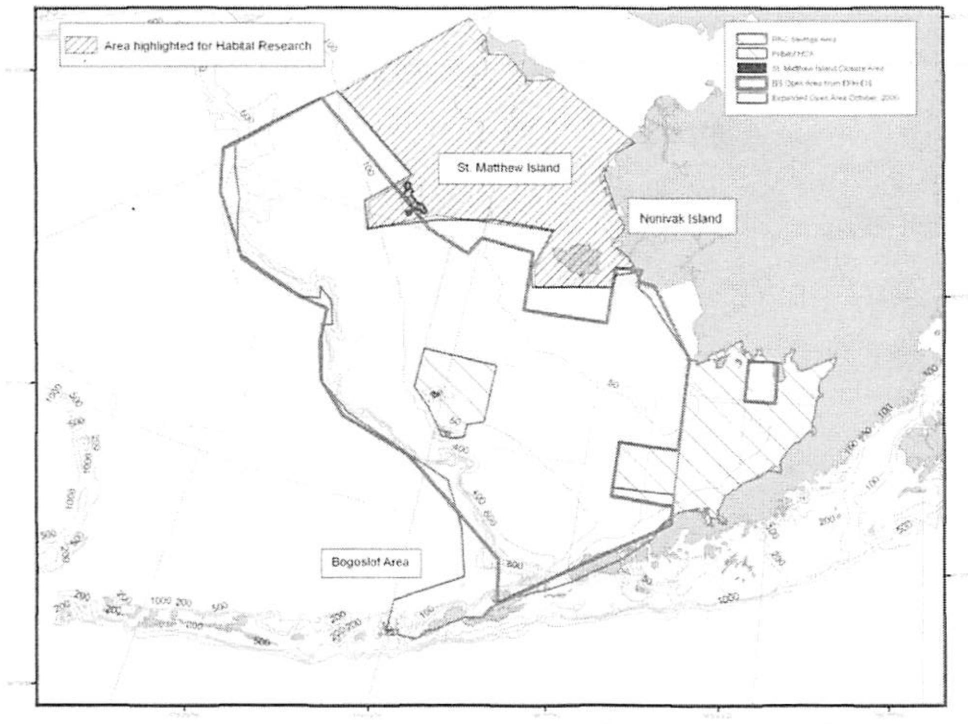

Figure 2. Open area approach adopted October 2006 contrasted with that of the EFH EIS (NOAA, 2005), with other Bering Sea trawl closures areas depicted (Red King Crab Savings Area, Pribilof Island Habitat Conservation Area, and the State of Alaska's St. Matthew Island Closure Area).

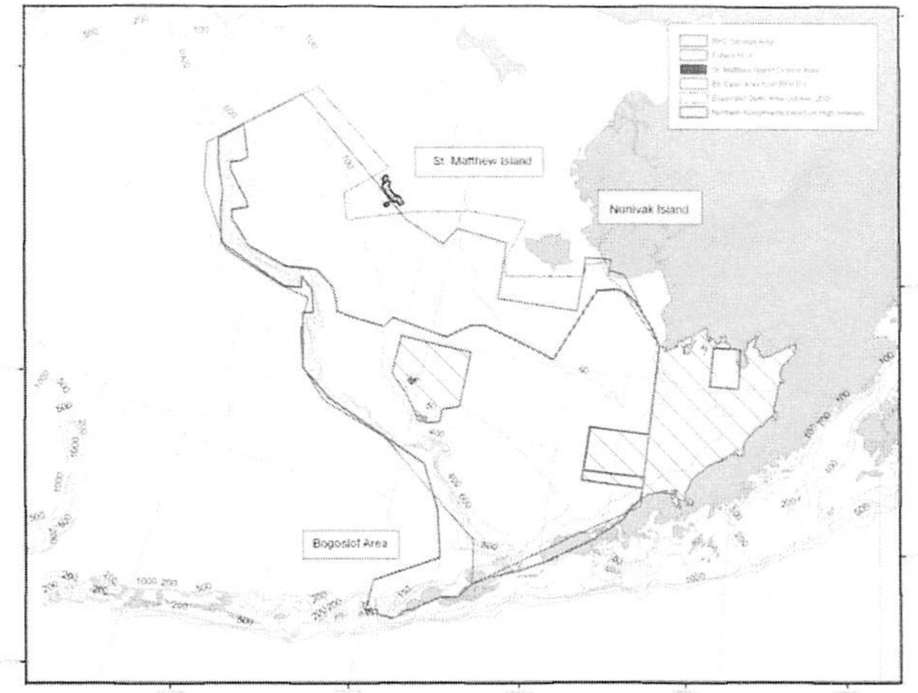

Figure 3. Modified northern boundary Option 1 based on high fishing intensity contrasted with Open area approach adopted October 2006, and the EFH EIS (NOAA, 2005) depicted with other Bering Sea trawl closures areas.

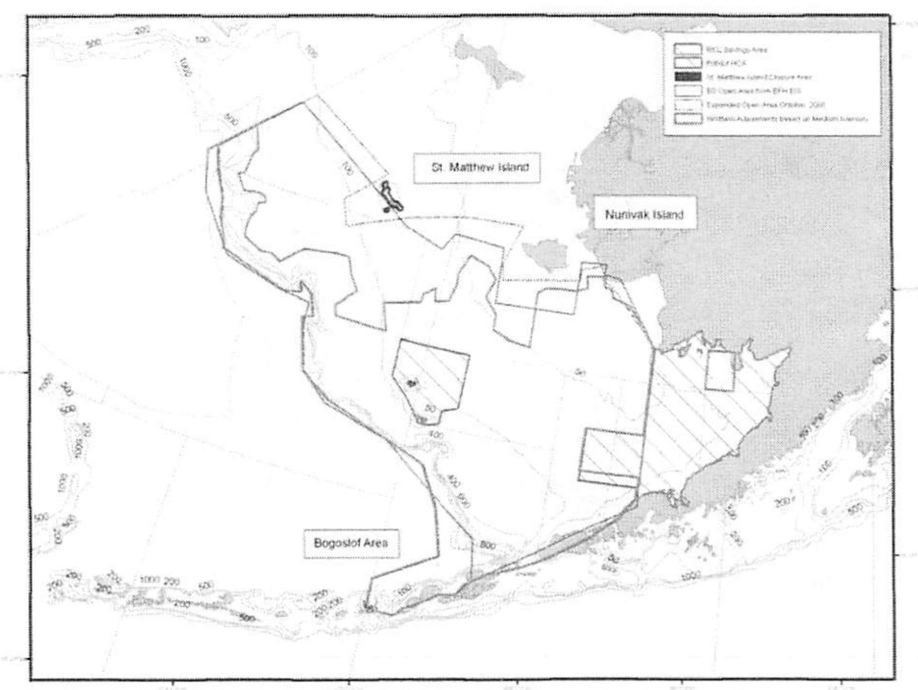

Figure 4 Modified northern boundary Option 2 based on medium fishing intensity contrasted with Open area approach adopted October 2006, and the EFH EIS (NOAA, 2005) with other Bering Sea trawl closures areas.

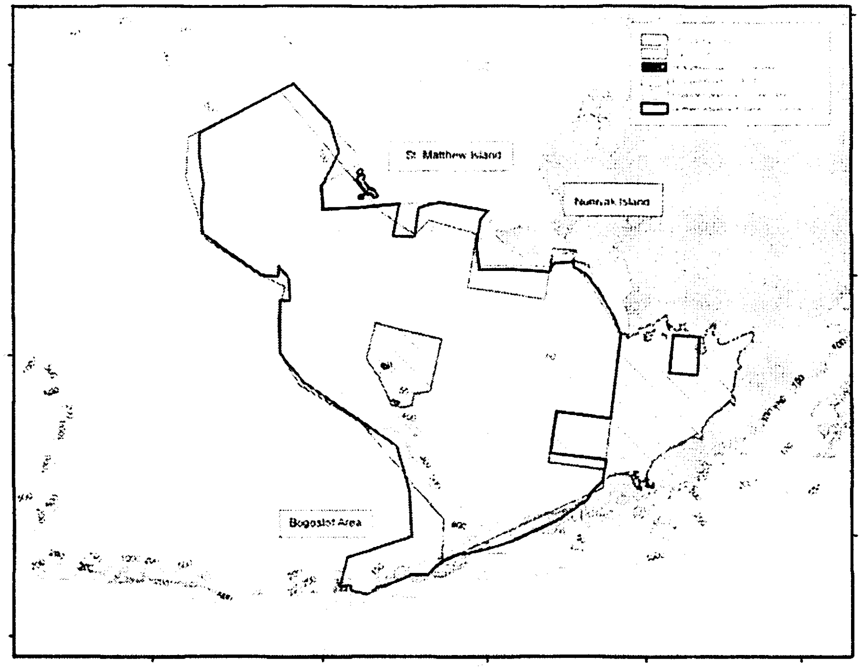

Figure 5 Modified northern boundary Option 3 based on low fishing intensity contrasted with Open area approach adopted October 2006, and the EFH EIS (NOAA, 2005) with other Bering Sea trawl closures areas.

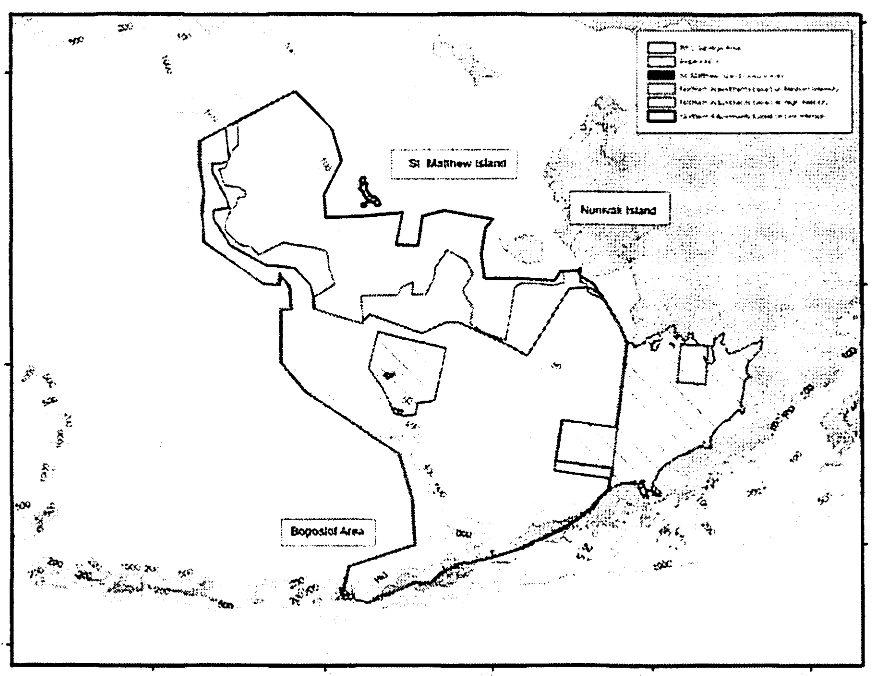

Figure 6. Comparison of the three options for a modified northern boundary with other Bering Sea trawl closures areas depicted (Red King Crab Savings Area, Pribilof Island Habitat Conservation Area, and the State of Alaska's St. Matthew Island Closure Area).

Bering Sea Habitat Conservation Open Area Approach
Council Motion October 10/08/06 3:20pm

The Council tasks staff to evaluate a modified open area approach under Option 1 of both Alternatives 2 & 4 and evaluate two additional options as follows:

Alternatives 2 & 4 Revised Option 1: Include the areas north of Bogoslof, south of Nunivak Island and the 10 minute strip in the Red King Crab Savings Area in the open area, and redefine the Northward boundary[1] of the proposed Bering Sea Open Area to include Blue King Crab Savings Area near St. Matthew Island (see attached map).

Alternatives 2 & 4, new Option 2: In order to fish (with bottom trawl gear) in the Closed Area north of the Open Area boundary an Exempted Fishery Permit is required.

Alternative 4, new Option 3: For the region north of the historically fished area, research openings will be established to assess the impact of bottom trawling on benthic habitat and organisms-particularly C. opilio crab. The area opened shall be established across bottom contours so as to include representative habitat types.

Alternative 3: Include a new Option 1 that would establish habitat research areas in the Bering Sea to assess the impact of bottom trawling on benthic habitat and organisms particularly *C. opilio*. The research areas shall be established across bottom contours so as to include representative habitats and should focus on assessing habitat impacts of trawling by adopting a statistical design of open and closed areas. The habitat research areas would be located in the northern portion of the BS, that has not had much fishing in the between St. Matthew and St. Lawrence Islands and would be similar to that in Alternative 4.

Further:

1) The Council tasks staff to present better depiction of the maps to include the bathymetry of the slope.
2) The Council, in response to the SSC and public comment, tasks staff with drafting a white paper to discuss current scientific information on three canyons within the EBS including, Pribilof canyon, Middle canyon and Zhemchug Canyon
3) The Council tasks staff to bring forth a summary of current research on Skate nurseries and the degree of overlap of fisheries in the EBS.
4) Lastly, staff should bring forward as part of the discussion information a draft schedule for the next HAPC process.
5) Request Council staff provide more than 1 option for the northern boundary of the open area under Alternatives 2 & 4 based on varying threshold levels, staff would determine approach based on ranges for relatively low to relatively high trawl effort

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The redesignation of the northward boundary, defined in the staff discussion paper (AGENDA D-4 (b) October 2006, Figure 5), is near St Matthew Island and extends southwest to project juvenile, non-ovigerous female and male blue king crab habitat, and northeast to protect ovigerous females habitat. This area has: (1) been represented in the NMFS and ADF&G surveys to contain juvenile and mature BKC; (2) locations of PSC catch in the rock sole trawl fleet; and (3) observations from the directed crab fishery. Industry comments indicate that increased flatfish trawl effort has been progressing northward on average 20 miles/year, some of this effort is occurring near St. Matthew Island. This crab stock is severely depleted, designated overfished such that the last pot survey found only 5 legal male BKC in the area.

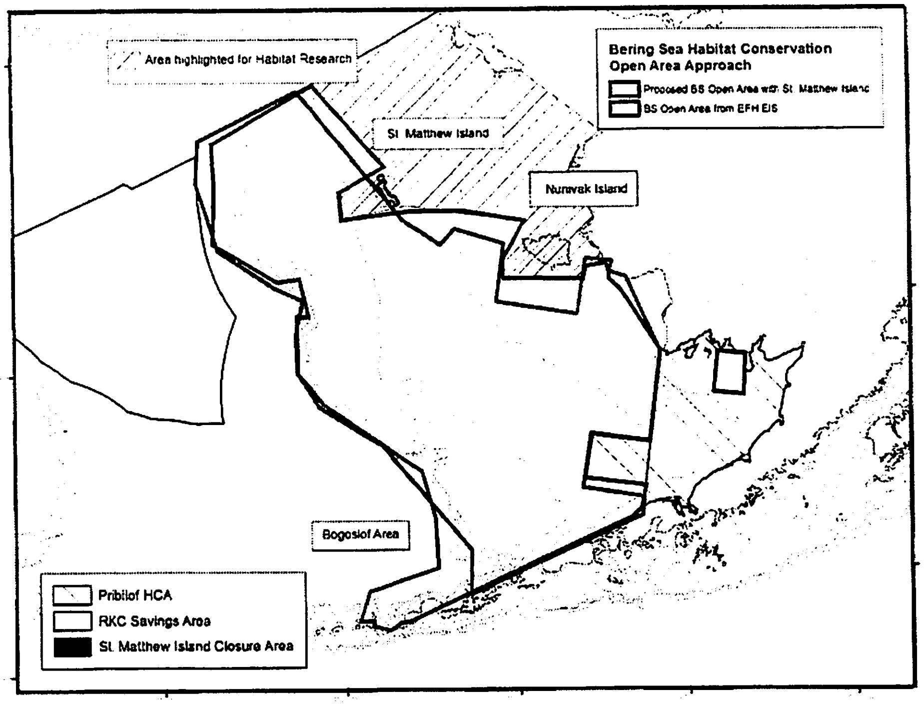


Figure 1. Alternatives 2 & 4 Current Option 1: Open area approach October 2006 contrasted with that of the EFH EIS (NOAA, 2005) further modifications will be presented in December 2006.

AGENDA D-3(iii)
DECEMBER 2006

Bering Sea Habitat Conservation Alternatives
DRAFT Revisions based on October 2006 Council motion

> Problem Statement: Bering Sea EFH:
>
> The Council intends to evaluate potential new fishery management measures to protect Essential Fish Habitat (EFH) in the Bering Sea. The analysis will tier off of the 2005 EFH Environmental Impact Statement and will consider as alternatives open and closed areas and gear modifications. The purpose of the analysis is to consider practicable and precautionary management measures to reduce the potential adverse effects of fishing on EFH and to support the continued productivity of managed fish species.

Alternative 1: **Status quo**. No additional measures would be taken to conserve benthic habitat.

Alternative 2: **Open area approach.** This alternative would prohibit trawling with bottom trawl gear outside of a designated 'open area'. The open area would be designated by utilizing fishing effort data through 2005 to define the open area. The designated open area would include the areas north of Bogoslof and south of Nunivak Island. The 10 minute strip in the Red King Crab Savings Area would remain open pursuant to current regulations. The Northward boundary of the open area would be configured such that the area south and west of St. Matthew Island is excluded from the open area to conserve blue king crab habitat. There are three options for establishing the northward boundary of the open area, based on bottom trawl effort distribution. There is also one option that would require an Exempted Fishing Permit to fish outside of the designated open area.

Option 1: *Smallest open area*. Northern open boundary based on high effort intensity.
Option 2: *Slightly larger open area*. Northern boundary based on medium effort intensity.
Option 3: *Larger open area*. Northern boundary based on low effort intensity.
Option 4: *Require Exempted Fishing Permit*. Bottom trawling in the closed areas north of the open area boundary would only be authorized under an Exempted Fishing Permit.

Alternative 3: **Gear modifications.** This alternative would require gear modifications for all bottom trawl gear used in flatfish target fisheries. Specifically, this alternative would require discs on bottom trawl sweeps to reduce seafloor contact and/or increase clearance between the gear and substrate.

Option 1: *Gear modification and research closures*. Areas would be closed to bottom trawling in the northern Bering Sea to research the impact of bottom trawling on benthic habitat and organisms, particularly *C. opilio*. The research areas would be located in areas that have not had much fishing effort between St. Matthew and St. Lawrence Islands. The research areas shall be established across bottom contours so as to include representative habitats and should focus on assessing habitat impacts of trawling by adopting a statistical design of open and closed areas.

Alternative 4: **Open area approach and gear modifications.** This alternative would prohibit trawling with bottom trawl gear outside of a designated 'open area' (described in Alternative 2) and require gear modifications on all bottom flatfish trawl gear. The open area options are identical to Alternative 2. There is also one option that would require an Exempted Fishing Permit to fish outside of the designated open area, and one option that establishes special open areas for research.

Option 1: *Smallest open area.* Northern open boundary based on high effort intensity.
Option 2: *Slightly larger open area.* Northern boundary based on medium effort intensity.
Option 3: *Larger open area.* Northern boundary based on low effort intensity.
Option 4: *Require Exempted Fishing Permit.* Bottom trawling in the closed areas north of the open area boundary would only be authorized under an Exempted Fishing Permit.
Option 5: *Special Open Areas for Research.* Special open areas to the north of the Northern open area boundary will be established for the purpose of conducting research to assess the impact of bottom trawling on benthic habitat and organisms, particularly *C. opilio*. The research areas shall be established across bottom contours so as to include representative habitat types.

AGENDA D-3(iv)
DECEMBER 2006

Discussion of research and exempted fishing permit (EFPs) under BS Habitat Conservation Alternatives:

NMFS and Council staff have discussed the alternatives for the Bering Sea Habitat Conservation measures, as modified by the Council's October 2006 motion, and identified the following issues that would complicate an analysis of some of the particular options. The Council should address these issues prior to finalizing a range of alternatives for analysis at the December meeting.

Alternatives 2 and 4 include options to allow bottom fishing in the closed area under an exempted fishing permit (EFP). In addition, Alternative 4 includes an option that would allow special open areas extending across bottom contours to the north of the Northern open area boundary for the purpose of conducting research on the impact of bottom trawling on benthic habitat and organisms, particularly *C. opilio*.

The Alaska groundfish fisheries regulations at 50 CFR 679.6 and 50 CFR 600.745 currently allow an exempted fishing permit (EFP) to be issued to allow fishing activity that would otherwise be prohibited under 50 CFR part 679. Thus, the options for EFPs under Alternatives 2 and 4 are unnecessary. The process for issuing an EFP involves the applicant working with the Alaska Fisheries Science Center (AFSC) to develop an experimental design, environmental review of the proposed study, consultation with the Council, and identification of the exemptions necessary to complete the study. The impacts of an EFP are dependent on the details of the study and the specific exemptions. Because current regulations already provide for the use of EFPs to fish in a manner not otherwise allowed, the EFP option under Alternative 2 and 4 would require no action. Because the details of such an EFP are not currently known and each EFP is required to be processed in the manner described in 50 CFR 679.6, it is not possible to evaluate the environmental effects under the EFP option at this time. NMFS recommends removing this option from the analysis and deferring any EFP analysis to when an application for an EFP is received.

Research fishing is not considered "fishing" under the Magnuson-Steven Fishery Conservation and Management Act. Research fishing is usually conducted under a Scientific Research Permit (SRP) (for NMFS or NMFS- controlled vessels) issued by the Regional Administrator or a Letter of Acknowledgement (for foreign vessels or vessels of opportunity) issued by the AFSC Director (50 CFR 600.745) after review of the research plan. The researcher is encouraged (and in some cases required as a condition of the permit) to carry their research plan and the LOA or SRP on board during their research activities. As with the EFP, regulations currently exist that provide for research fishing activities; and therefore, no regulatory action would be required to implement "research" in the proposed closed area under option 5 to Alternative 4.

In order to evaluate the potential effects of providing a research area under option 5 to Alternative 4, the details of where, when, and how would need to be clearly described. Placing such details in regulations would prevent flexibility in the future in designing studies based on the best available science. If a research option including provisions in regulations is desired, the Council should work closely with the AFSC to develop the details of the research plan to ensure the regulations provide the flexibility needed to perform the research.

If the Council determines that the research option should be pursued, it could either delay the Bering Sea Habitat Conservation analysis until the details of the research design and regulatory provisions can be developed, or close the areas north of the northern boundary to the extent possible to all fishing until completion of a separate action to open the area under a research plan. NMFS cannot prohibit research fishing in an area. This would be necessary to prevent most fishing activities that may undermine the research plan developed under option 5 to Alternative 4.

Development and evaluation of trawl groundgear modifications to reduce damage to living structure in soft bottom areas. (Preliminary Results)

Craig S. Rose – Alaska Fisheries Science Center, NMFS

Summary – Simple modifications to trawl sweeps (Figure 1) were tested for their effectiveness at reducing effects on sessile seafloor animals on unconsolidated (sand – mud) substrates. The modifications support most of the sweeps 2 – 4 inches above the substrate, allowing space for animals to pass beneath. These were effective in reducing effects to basketstars and sea whips and did not substantially reduce catches of target flatfish until the space was increased to 4 inches.

Introduction

Scientists from the RACE Division's Conservation Engineering project have been working with the fishing industry to modify groundfish trawls to reduce their effects on the seafloor environment. We have initially focusing on areas with soft-bottom (sand – mud) substrates where most groundfish fishing occurs. In those areas, the seafloor features considered most likely to be both significant habitat elements and be vulnerable to fishing are the sessile invertebrates, such as anemones, ascidians, sponge and basketstars. Because they have relatively low profiles and flexible bodies, trawl modifications that create more space between the trawl and the seafloor are being evaluated as a way to reduce damage to these animals.

Do changes to trawl sweeps that reduce seafloor contact affect the degree of damage to structure-forming invertebrates?

From May 23 - June 7, RACE scientists compared the effects of conventional and modified sweeps (herding cables ahead of the trawl net) the on sessile invertebrates at four study sites on the eastern Bering Sea shelf (Figure 2). We selected sites with high abundances of such animals as well as a variety of the most common types. A site about 60 nautical miles west of St. Paul Island (A) was dominated by sea whips and basketstars. Sites 45 nm east of St. Paul (B) and 100 nm west of Cape Newenham (C) had mostly ascidians (*Halocynthia*, *Boltenia* and *Styela*). Finally, sponge dominated the sessile seafloor fauna at a site 60 nm NNE of Port Moller (D).

At each site, experimental trawling created parallel tracks of four types of modified sweeps and two types of conventional sweeps. Conventional sweeps had the same diameter throughout, of either 2-inch diameter combination rope (rope including interwoven steel and fiber element, with the softer fiber on the outside) or 3-inch disks strung over steel cable, causing more continuous seafloor contact (Figure 3). Modified sweeps had clusters of cluster of 6 inch, 8 inch or 10 inch diameter disks secured at 30-foot (9.1 m) intervals, lifting the sweep cables above the seafloor. Modification included all diameters of disk clusters on combination rope and 8-inch clusters on disk and cable sweeps. Three sets of two trawl tows each were made in opposite directions on parallel tracks, each with two types of sweeps, resulting in 12 parallel sweep tracks. The exception to this was Site C, where time limitations restricted towing to a single trawl track with only bare combination rope and combination wire with 8-inch disk cluster sweeps.

A seafloor sled (Figure 4) with both sonar and video sensors was then towed across the parallel trawl tracks at several points to compare the condition of seafloor animals in areas affected by these different gears and in control areas between tracks. An acoustic camera (DIDSON) provided an image of seafloor terrain on which trawl marks could be consistently identified, making it possible to discern which part of which trawl track the sled was in or whether it was between tracks. A video camera with strobed lights was then used to assess the condition and abundance of seafloor invertebrates associated with each area.

The imagery from these sensors was analyzed to estimate the relative effects of the alternative sweep designs on the principal structure-forming invertebrates at each site. Counts and condition evaluations were made for each crossing of a sweep track as well as for a swath of equal length from the seafloor on the other side of the adjacent door track, an area outside of the swath of the trawl system. Examples of the video from each site, including unaffected seafloor and those affected by conventional (combination rope) and modified (8-inch clusters on combination rope) gears, can be viewed at: http://www.afsc.noaa.gov/RACE/midwater/seafloor_videos.htm.

At this time, we have only completed analysis on the basketstars and sea whips from Site A. These are the two animals with the most vertical structure and have the clearest effects from sweep contact of all of the animals studied. Basketstars react to disturbance by curling their legs into a tight cluster. In their normal posture, they have upper legs spread to filter the water and lower legs braced against the substrate. Disturbance classes included 1) normal posture with all legs extended, 2) an intermediate level of disturbance where bracing legs are out, but filtering legs withdrawn 3) animals with all legs drawn in and 4) parts of basketstars (legs) lying separately on the seafloor. The proportions of these classes associated with each sweep type and the control areas are presented in Figure 5. The pattern is consistent with a reduction of effects from the conventional combination sweeps to those with larger disk cluster (more space beneath sweep), though the change is clearer when only the more severe effects are considered (25% vs. 40% damaged) than when the intermediate effects are included (41% vs. 46% damaged). Both types of rubber-over-cable footropes had larger effect rates than those with combination rope (roughly 65 –55% damaged for more severe and with intermediate included) and there was little difference when due to adding the larger disks. Notice that some of the animals in the control areas were not in the normal posture as basketstars do sometimes retract arms to retrieve collected food.

Sea whips were classified into 3 groups: 1) normal (vertical) posture, 2) laying flat on the substrate and 3) broken or otherwise visibly damaged. Some bare sea whip rods were also present, but these were not counted, as they were clearly remnants of animals that were dead long before the experimental trawling. While the proportion of normal postures was much higher for sea whips than for basketstars, the pattern of effects was similar (Figure 6). The conventional sweeps of both kinds showed 16-17% damage, while the reduction of that rate was approximately proportional to disk cluster diameter for the modified sweeps. Smallest effects were seem for the combination rope with 8 and 10 inch disk clusters with only 8-9% affected. The vast majority of affected sea whips were flattened on the seafloor with no apparent damage. Research by Malecha and Stone (in a poster by these AFSC Auke Bay scientists at: http://www.afsc.noaa.gov/ABL/MarFish/pdfs/Whip_Poster.pdf) indicates that some of these are capable of righting themselves, though they are more vulnerable to some forms of predation while down.

Analysis for the sponge encountered at Site D should be completed for the NPFMC December meeting. Because damage of these amorphous animals is difficult to classify, the analysis is based on size composition of the sponge colonies, detecting breakage.

The purpose of this study was to test for a reduction in the effects of trawl sweeps on sessile invertebrates when the sweeps are elevated off of the seafloor. Even though all sites have not been analyzed and the effects seen are not directly interpretable as mortalities, the results to date show a consistent pattern of reduced effects with the space created below the sweeps. Differences between the 8-inch and 10-inch modifications were minimal, perhaps indicating that further height would not further reduce effects.

Do changes to trawl sweeps that reduce seafloor contact affect the capture of flatfish?

From September 6 – 23, AFSC scientists conducted experiments aboard the F/V Cape Horn to determine whether modifications to raise 97% of the trawl sweeps inches above the seafloor affect how well they herd fish into the trawl. The Cape Horn is the only vessel in the Alaska groundfish fleet that uses a twin trawl, two matched trawl systems fished side-by-side (Figure 7). This allowed catches from identical trawls, except for the sweep modifications, to be compared to determine how the modifications affected catch rates.

Clusters of disks (6 inch, 8 inch and 10 inch diameters) were placed at 30 foot intervals along 300 foot-long, combination-rope sweeps (2 inch diameter), which were fished ahead of one trawl, while sweeps without the disks were fished ahead of that trawl's twin. The catches were processed separately, with the primary commercial species sorted and then weighed on a motion-compensated flow scale. Thus the catch for each of these species from each net was directly measured instead of being estimated from the total catch weight and a sample of the species composition. Length samples of each species were taken to test for any selectivity by size.

Initial analyses (Figure 8) indicated that:

1) Using the 6 and 8-inch disks did not significantly change flatfish catch rates.
2) Ten inch disks reduced flatfish catch rates 5-10%.
3) Roundfish catches, while more variable, tended to increase with the disks.

Discussion –
The tested modifications were effective at reducing the effects of trawl sweeps on sessile seafloor animals that are considered the most vulnerable habitat feature in the sand – mud habitats of the eastern Bering Sea shelf. The 8-inch disk clusters, creating up to 3 inches of opening under the sweeps, seems the best configuration; having no greater effects than the 10-inch disk clusters with no significant loss of target catch.

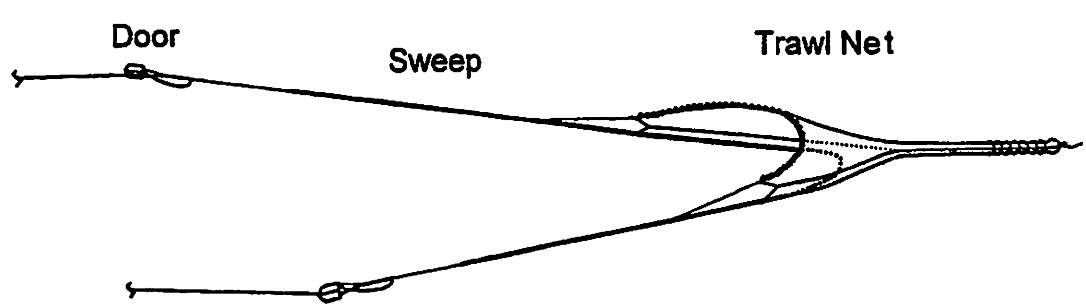


Figure 1 – Relative positions of doors, sweeps and trawl in an otter trawl system. Length of sweep varies with target species and seafloor. For most Bering Sea sole trawls sweeps are so long (up to 1500 feet) that they sweep 90% of the area covered between the doors.

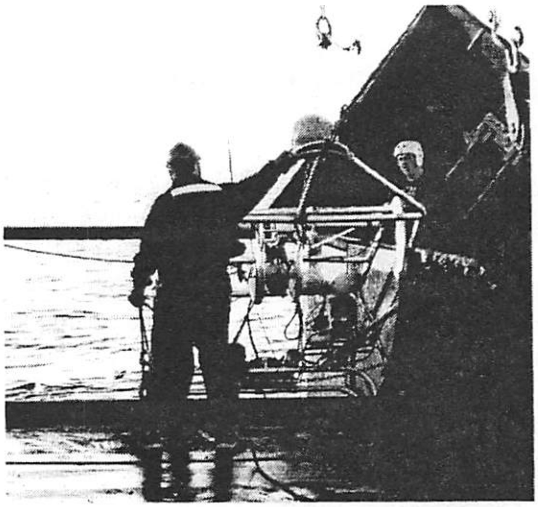


Figure 2 – Seafloor camera/sonar sled.

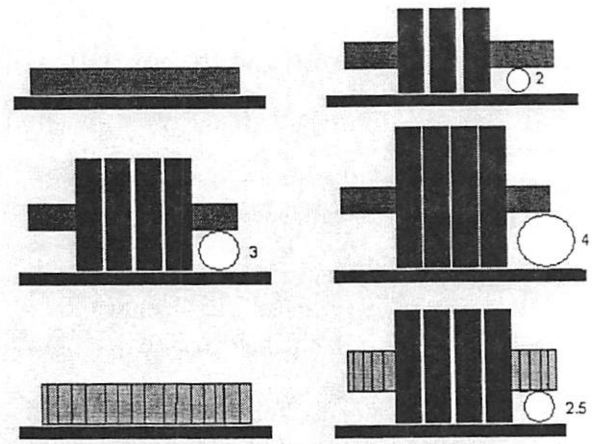


Figure 3. Sweep modifications tested for reduction of effects on sessile animals.

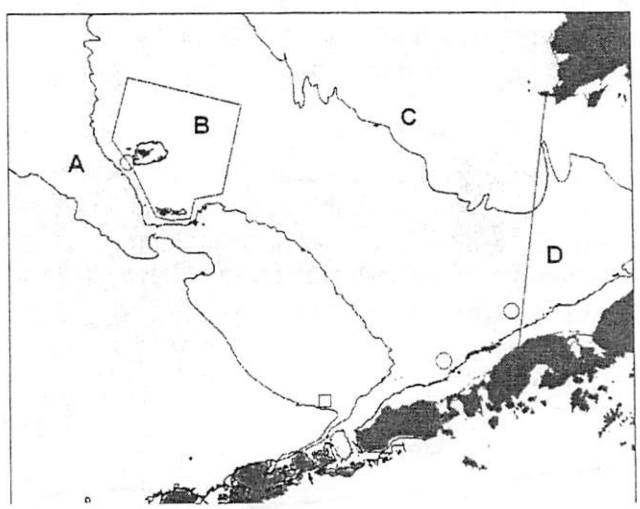


Figure 4 – Sites of studies of sweep modifications to reduce trawl effects on sessile animals

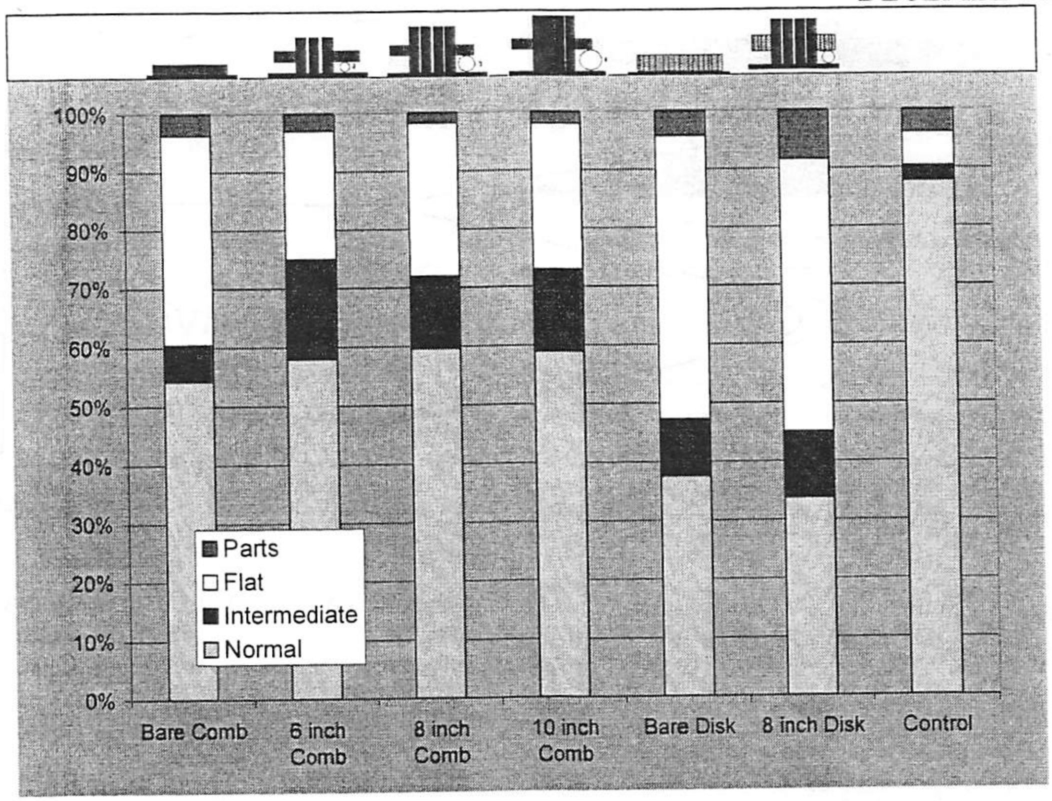


Figure 5 – Percent of basketstars in different condition categories after exposure to trawl sweep modifications.

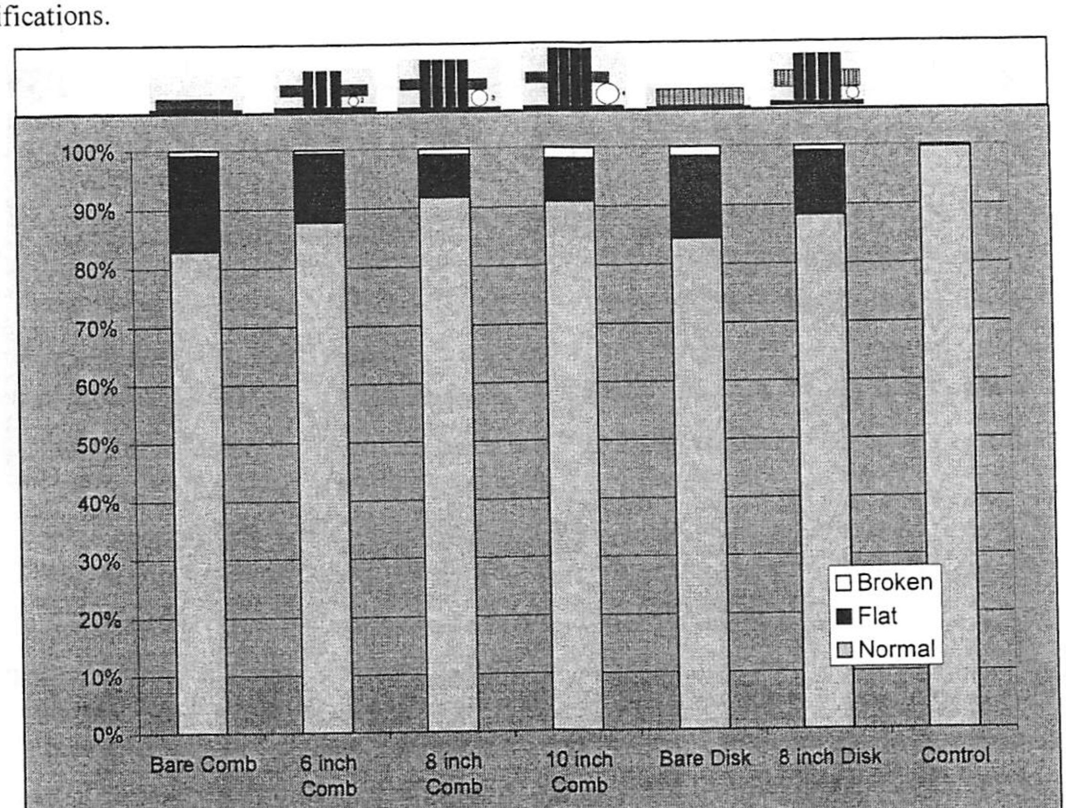


Figure 6 – Percent of sea whips in different condition categories after exposure to trawl sweep modifications.

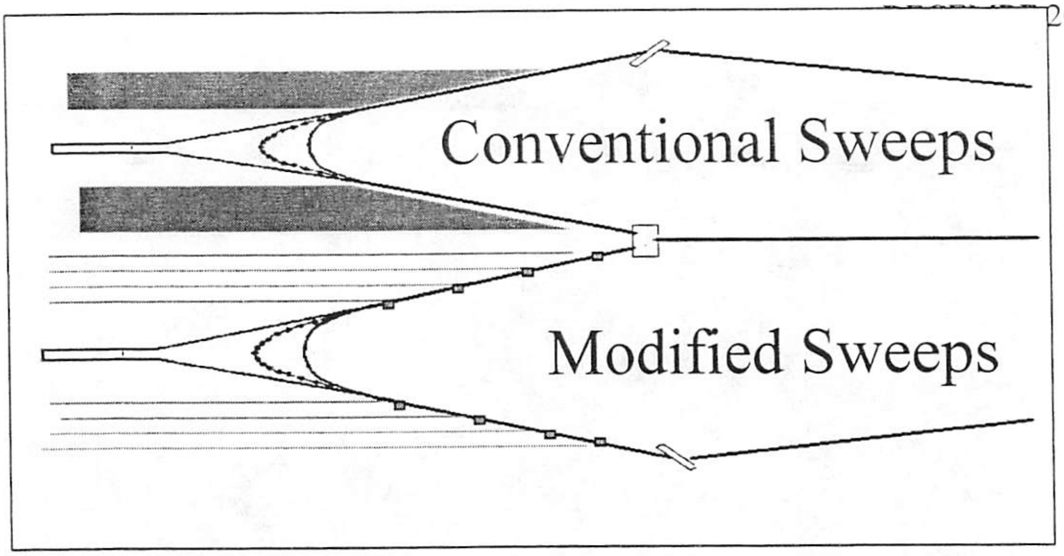


Figure 7 – Schematic of a twin trawl system, showing the concept of reducing bottom contact area of sweeps by limiting contact to disk clusters.

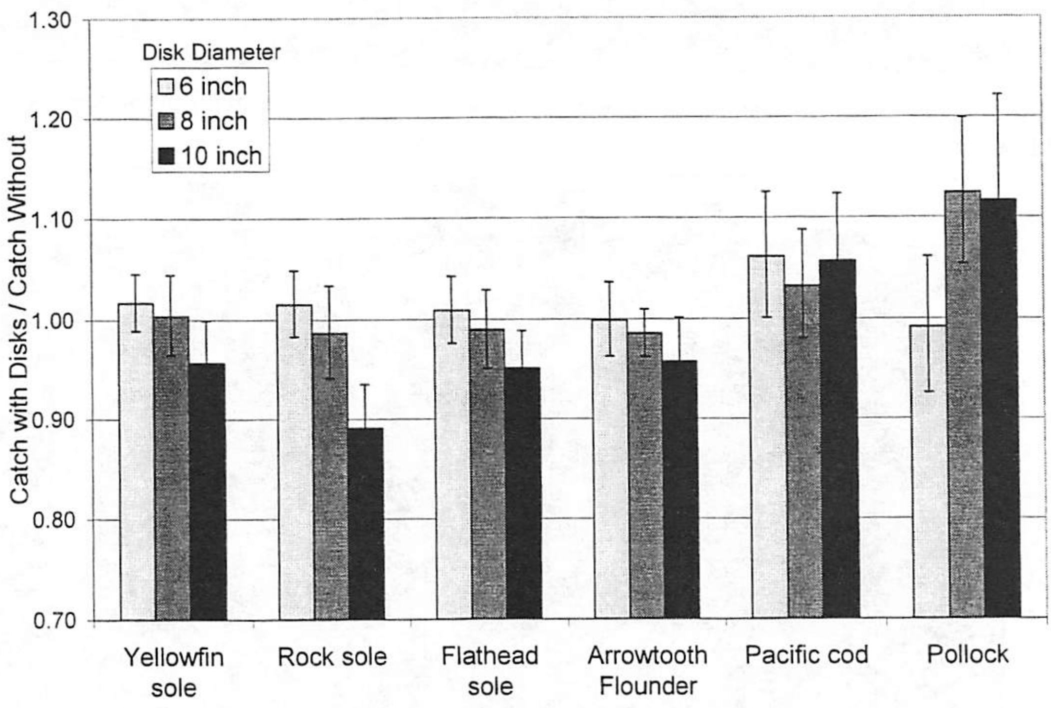


Figure 8 – Preliminary analysis of the proportional change in catch rates when trawl sweeps had disk clusters (6, 8 and 10 inch diameters) installed at 30 foot intervals.

Habitat Areas of Particular Concern (HAPC)

Review HAPC process and identify priorities.

Background

The Council established a process for identifying Habitat Areas of Particular Concern (HAPC) as part of the April 2005 Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska (EFH EIS). HAPCs are an important tool for the Councils to identify rare, sensitive, or vulnerable habitats. Two important HAPC decisions came from the EFH EIS. First, HAPC identification changed from broadly described habitats (living substrates in shallow and deep marine waters and freshwater anadromous fish streams) to HAPCs identified as specific habitat sites (15 seamounts, several sites for Gulf of Alaska corals, and Bowers Ridge). Second, a public nomination proposal and scientific review process was developed. As part of that process, the Council may undertake a HAPC proposal process once every three years or by discretion, should the Council wish to initiate the HAPC process.

HAPC Process Overview

To begin the HAPC process, the Council identifies a management priority or priorities. The priority focuses the HAPC process to address a specific management goal. For the 2004 HAPC process, the Council set a priority to conserve named seamounts on the NOAA Charts and areas where long lived, sensitive habitat forming structure (corals) are associated with rockfish. The Council received 23 HAPC proposals from six different organizations. After an initial screening by staff, the proposals were reviewed by the Plan Teams and underwent an initial review to consider management, enforcement, and socioeconomic issues. Ultimately the Council identified a range of alternatives, staff completed an analysis, and the Council established several new HAPCs.

HAPC Process Steps Outline

- Call for Proposals
- Evaluation of Proposals
- Draft Alternatives and Analysis
- Draft NEPA document
- Final NEPA document
- FMP Amendment and Rulemaking (if needed)

HAPC Timeline

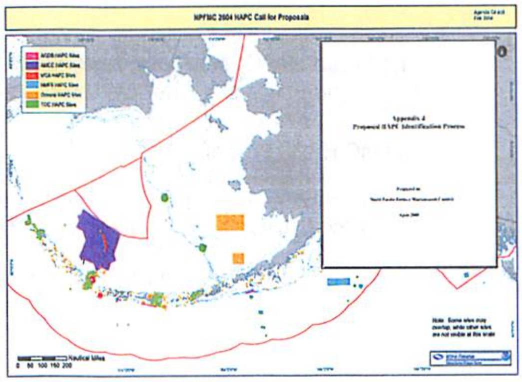
Should the Council decide to consider new HAPCs, the process needs to fit within the Council schedule and Plan Team availability.

Example Timeline

February	Council Identifies HAPC Priorities FR Notice to Initiate Call for HAPC Proposals
April	Comment Period Closes
June	Council review and decision as to which ideas should be forwarded for Plan Team review.
September	Plan Team Review Preliminary Enforcement and Socioeconomic Reviews
October	Council Identifies HAPC Alternatives for Analysis
February	Initial Review
April	Final Review

Habitat Areas of Particular Concern (HAPC)

1. HAPC Overview
2. HAPC Process
3. 2004 HAPC Proposals
4. 2004 Bering Sea Proposals
5. Consideration Points
6. Timelines



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Councils & HAPC's

- "... HAPCs offer a powerful tool for NMFS and the Councils to identify priority areas within EFH for conservation" (NMFS EFH Memorandum; 10/30/06).
- Nationally, Councils have consistently used the four HAPC considerations (50 CFR 600.815(a)(8)) as an underlying basis for identifying HAPCs.
  - the importance of the ecological function provided by the habitat;
  - the extent to which the habitat is sensitive to human-induced environmental degradation;
  - whether and to what extent development activities are or will be stressing the habitat; and
  - the rarity of the habitat type.
- However, each Council has approached the designation process differently.
  - For example, some Councils designated discrete geographic areas as HAPCs, while others designated habitat types as HAPCs (e.g. estuaries) without specifying geographic boundaries.
- NPFMC chose to identify HAPC as sites.

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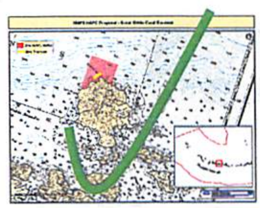
HAPC - Alaska Region

- The broad HAPCs originally designated in 1999 (living substrates and anadromous fish streams) were replaced by HAPC sites in 2005.
- NPFMC HAPC Process
  - The process may occur on a 3 year schedule or on a schedule established by the Council, if additional habitat protection is warranted.
  - Process will be initiated when the Council sets priorities and issues a request for HAPC proposals.



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HAPC Process - Steps

- Call for Proposals
- Evaluation of Proposals
- Draft Alternatives and Analysis
- Draft NEPA document
- Final NEPA document
- FMP Amendment and Rulemaking (if needed)

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HAPC Process - Overview

- Council Identifies HAPC Priority
  - Council identifies priority management issue or issues.
  - Criteria to evaluate the HAPC proposals will be reviewed by the Council and the Scientific and Statistical Committee (SSC) prior to the request for proposals.
- Call for HAPC Proposals Initiated.
  - A Call for Proposals is:
    - Announced during a Council meeting;
    - Published in the Federal Register:
    - Advertised in the Council newsletter.
  - Scientific and technical information such as habitat, fishery distributions, and economic data is made available simultaneously.
- Any member of the public (NGOs, industry, local communities, government agencies, scientific and educational institutions) may nominate a site for designation as a HAPC by submitting a proposal.

HAPC Proposal Contents

- Name, address, and affiliation.
- Title for the HAPC proposal.
- Brief, concise description.
- Identify the habitat and FMP species that the HAPC proposal is intended to protect.
- Statement of purpose and need.
- Describe whether and how the proposed HAPC addresses the four considerations set out in the final EFH regulations.
- Define the specific objectives.
- Propose solutions to achieve these objectives.
- Establish methods of measuring progress towards those objectives.
- Define expected benefits of the proposed HAPC; provide supporting information/data, if possible.
- Identify the fisheries, sectors, stakeholders, and communities to be affected by establishing the proposed HAPC [Who would benefit from the proposal; who would it harm?] and any information you can provide on socioeconomic costs.
- Clear geographic delineation for the proposed HAPC (written latitude and longitude reference point and delineation on an appropriately scaled NOAA chart).
- Best available information and sources of such information to support the objectives for the proposed HAPC (citations for common information or copies of uncommon information).

HAPC – Initial Proposal Review

- Initial Proposal Screening
  - Council staff screen proposals to determine consistency with priorities, HAPC criteria, and general adequacy.
  - Staff present a preliminary report of the screening results to the Council.
  - The Council determines which of the proposals will be forwarded for the next review step: scientific, socioeconomic, and enforcement review.
- Proposal Modifications during Review
  - The Council may modify proposed HAPC sites and management measures and request additional stakeholder input and technical review before designating a site as HAPC.

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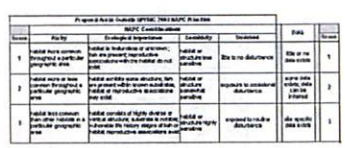
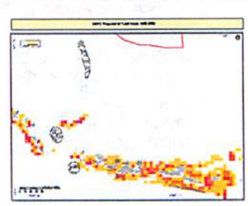
HAPC – Plan Team (Scientific) Review

The Council refers selected proposals to the plan teams. Plan teams evaluate the proposals for ecological merit.

To Facilitate Review & Provide Consistency:

- Tables and forms assist in review to decide whether areas meet the regulatory considerations and the Council's priorities.
- GIS analysis depicts each HAPC proposal area along with sorted abundance/presence, fishing effort, bycatch, etc…





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HAPC – Additional Reviews

- Socioeconomic Review
  - The Magnuson-Stevens Act states that EFH measures are to minimize impacts on EFH "to the extent practicable," thus, socio-economic considerations have to be balanced against expected ecological benefits at the earliest point in the development of measures.
  - Identifies which fishing communities have potential to be affected and the effects on those communities such as employment, fishing and processing sectors earnings, and related infrastructure, to the extent that such information is readily available to the public.

- Management and Enforcement Review
  - HAPC Requirements
  - Scale, Location, and Restrictions
  - Collaboration with fisherman, NOAA ENF, and vessel observers to identify realistic solutions.

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HAPC - Council Assessment and Selection

- Staff will provide the Council with a summary of the ecological, socioeconomic, and enforcement reviews.
- The Council will select which proposal or proposals will go forward for analysis for possible HAPC designation.
- The Council may modify the proposed HAPC sites and management measures.
- The Council may obtain additional technical reviews as needed from scientific, socioeconomic, and management experts.
- The Council may set up a stakeholder process, as appropriate, to obtain additional input on proposals.

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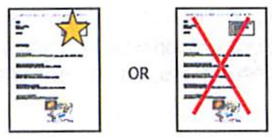
HAPC – Outcomes

Each proposal received and/or considered by the Council has one of three possible outcomes:

1. The proposal can be accepted.
2. The proposal can be used to identify an area or topic requiring more research.
   - Council would initiate request to NMFS or other.
3. The proposal can be rejected.



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2004 HAPC Proposals

23 HAPC Proposals were received from 6 different groups:
[Alaska Marine Conservation Council, The Ocean Conservancy, Oceana, Marine Conservation Alliance, Alaska Groundfish Data Bank, and NMFS]

DEC 2003	Council Identifies HAPC Priorities Initiate Call for Proposals
JAN 2004	Proposals Received
MAR 2004	Plan Team Review Preliminary Enforcement and Socioeconomic Reviews
APR 2004	Council Motion – Process Council finalizes HAPC Alternatives
JUN 2004	HAPC Analysis
FEB 2005	Final EFH/HAPC motion (Adopt sites process)
APR 2006	HAPC EA/RIR for specific sites

Table 2. Summary of Plan Teams' classification by group. NOTE: see Plan Teams' concerns in introduction for a discussion on problems with interpreting this table.

Plan Team Group	Proposal Area	Name of Proposer	Proposal Number	Rarity Global (Y/N)	Rarity Local	Ecological Importance	Sensitivity	Stressed	Total
A	AI Pinnacles	Oceana	3	N	2	NA	NA	NA	NA
A	GOA Pinnacles	Oceana	2	N	2	NA	NA	NA	NA
A	Kodiak 8 fathom pinnacle	NMFS	23	Y	3	2	2	R	NA
B	BS Zemchug and Pribilof Canyons	TOC	20	N	3	2	2	R	NA
B	GOA Prince William Sound Deep Water Canyon	TOC	21	N	2	2	2	R	NA
C	GOA Albatross Rockfish	AAG	6	CY	2	2	2	O	NA
C	GOA Middleton Island	AAG	7	CY	2	2	2	O	NA
C	GOA Sanak Island	AAG	5	CY	2	2	2	O	NA
C	GOA Primnoa Forrest	NMFS	8	Y	2	3	3	O	NA
D	AI Adak Canyon	AMCC	9	Y	2	3	3	O	NA
D	AI South Amlia Atka	MCA	15	Y	2	3	3	R	NA
D	AI Adak and Kanaga	MCA	16	Y	2	3	3	R	NA
D	AI Amatignak/Ulak	MCA	17	Y	2	3	3	R	NA
E	AI Bowers Ridge	AMCC	10	Y	2	NA	NA	L	NA
E	AI Semisopochnoi	MCA	18	Y	2	3	3	R/O	NA
E	AI Coral Gardens	NMFS	19	Y	3	3	3	R	NA
F	AI Marine Reserve	TOC	12	Y	3	3	3	R	NA
F	AI Core bottom trawl area	Oceana	14	Y	3	NA	NA	R	NA
G	AI Coral and Sponge	TOC	11	Y	3	3	3	R	NA
G	AI corals gardens	Oceana	13	Y	3	3	3	R	NA
H	BS- Soft coral	Oceana	22	Y	2	2	3	R	NA

Legend:
L = Low level of fishing
O = Occasionally fished
R = Routinely fished
CY = Conditionally yes
Y = Yes
W = Weak information
NA = Not available, see qualitative comments

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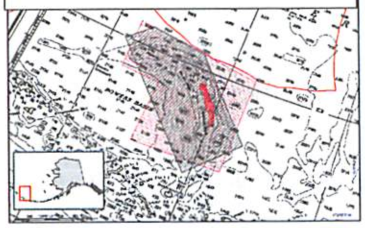
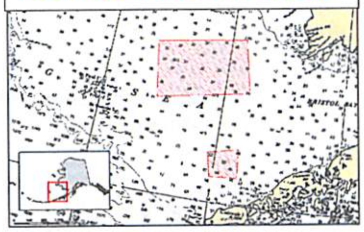
2004 Bering Sea HAPC Sites

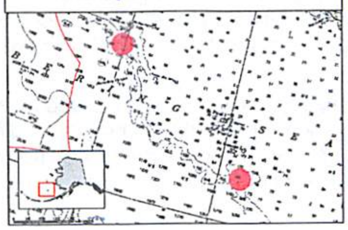
BS Bowers Ridge – Designated



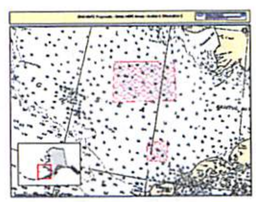
BS Soft Coral Areas – not selected



BS Canyons – not selected



2004 BS HAPC – Bering Sea Soft Coral Areas



Oceana proposal to create two HAPC's in the Bering Sea to protect soft corals (*Gersemia* sp.).

1. Northern area encompasses 8,800 km2 and east of the Pribilof Islands.
2. Southern area encompasses 2,000 km2 and east of the Pribilof Islands.

- The areas would be used for studies to evaluate the effects of fishing gear on the soft coral habitat and ecology.
- Southern site appears to have large amounts of coral/bryozoa catch according to NMFS observer data. Although it is not known if this is large relative to what may be available.
- The soft corals provide low relief structure which may promote ecological diversity.

2004 BS HAPC - Bering Sea Soft Coral Areas (continued)

Enforcement Comment

- The proposed management areas are generally within the routing of current patrol missions of USCG aircraft.
- Costs to conduct on scene patrol of these proposed management area over existing levels would be high.
- Given the relatively high amounts of past bottom trawl fishing occurring in these proposed areas, if fishing closures were implemented, the threat of violations of these management measures is believed to be increased.
- Given the size of the area required to be covered by enforcement resources, and the increased potential for unlawful fishing, modifications of observer coverage levels and/or observer reporting mechanisms could be an effective deterrent tool, and could serve as a valuable compliance-monitoring tool.

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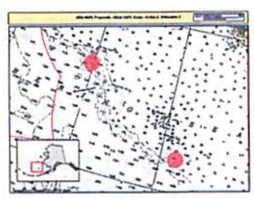
2004 BS HAPC - Zhemchug & Pribilof Canyons

Plan Team Review Comment



- Zemchug canyon appears to have higher biodiversity than Pribilof. However, both are considered to be in the "green belt."
- The "Mushroom area" experiences fishing pressure. Zemchug canyon may be less susceptible to disturbance than the Pribilof canyon. It was noted that there is limited data on coral bycatch in this region.
- Golden king crab and other crab species occur in both canyons. The importance of these areas on these species' life histories is unknown.
- Team discussed how canyons qualify as being "rare." For the Eastern Bering Sea, there are only two and it was noted that worldwide, canyons such as these are relatively uncommon.
- Areas are routinely fished. Longline fisheries routinely operate in Zemchug canyon as do snow crab fisheries (fish down to 150 fathoms).
- Discussion to rate ecological importance centered on the highly diverse vertical structure and prey base. The proposed management measures (e.g., 15 mile radius no-take zone) were also considered important to provide protection of the midwater zone.

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2004 BS HAPC - Zhemchug & Pribilof Canyons (continued)

Enforcement Comment

- On scene enforcement would likely be conducted principally by USCG patrol aircraft and USCG surface patrol vessels.
- The proposed areas are generally within the routing of current low frequency patrol missions of USCG aircraft.
- Costs to increase on scene patrol of these proposed management areas would be high.
- Subsistence mammal hunting activities would not be expected to pose any enforcement concerns.
- To the degree subsistence fishing for halibut or other bottom species would be allowed, this could possibly serve as a cover for other prohibited commercial fishing, (specifically sablefish longline fishing). This threat is considered very low. However, given the proximity of the proposed Pribilof Canyon management area to traditional subsistence fishing activities at St. Paul Island, combined with the depth of the waters in the proposed management area generally being beyond the depth of legitimate subsistence halibut fishing activities, it is recommended subsistence fishing also be prohibited in the proposed areas.

North Pacific Fishery Management Council   NOAA Fisheries

HAPC Proposals – Future Consideration Points

- Acknowledge that public input is necessary to propose HAPC areas, but public may not have all the necessary information or expertise to fully submit a stand-alone HAPC.
- Uncertainty may arise because the public may not have access to or be fully aware of all relevant scientific information.
- Accept proposals at face value for ideas. Do not evaluate each proposal for merits as a stand-alone.

  Rather, where proposals suggest similar ideas or overlap, assemble the common traits and differences. Then, evaluate the overall concept. The evaluation of specific details within each proposal may lose sight of the overall intent of the HAPC public process.

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HAPC – December 2006 Council Decision

Council options:

1. Take No Action
   (Council could initiate a HAPC process at anytime; it's discretion.)

Or

2. Initiate the HAPC Process and Identify Priorities

   Timeline Options:

   a. Begin 3 years after initiating the 2004 HAPC Process
      2006 - Call for HAPCs
      2007 - HAPC Process Complete

   b. Begin 3 years after FMP amendments include HAPC measures
      2008 - Call for HAPCs
      2009 - HAPC Process Complete

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HAPC Timeline for Option 2a– 2006 HAPC Call

- Should Council decide HAPC action is necessary, the process needs to fit within the Council schedule and Plan Team availability.
- Abbreviated timeline could accommodate a narrowly-focused HAPC priority.

Example

DEC 2006	Council Identifies HAPC Priorities FR Notice to Initiate Call for HAPC Proposals.
FEB - MAR 2007	Comment Period Closes Summarize proposals received
APR 2007	Initial HAPC Proposals Summary to Council Council decision as to which ideas should be forwarded for Plan Team review
MAY 2007	Plan Team Review Preliminary Enforcement and Socioeconomic Reviews
JUN 2007	Review Summaries (Plan Team, ENF, Socio-Eco) presented to Council Council finalizes HAPC Alternative for analysis
AUG – SEP 2007	HAPC Analysis
OCT 2007	Initial Review
DEC 2007	Final Review

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HAPC Timeline for Option 2b – 2008 HAPC Call

- Should Council decide HAPC action is necessary, the process needs to fit within the Council schedule and Plan Team availability.
- Longer timeline accommodates more detailed analysis and review of a broader call for HAPC priorities.

Example

JUN 2008	Council Identifies HAPC Priorities Call for HAPC Proposals initiated by FR Notice
AUG 2008	Comment Period Closes
OCT 2008	Initial HAPC Proposals Summary to Council Council decision as to which ideas should be forwarded for Plan Team review
NOV – MAR 2009	Plan Team Review of HAPC ideas Preliminary Enforcement and Socioeconomic Reviews
APR 2009	Plan Team, ENF, Socio-Eco Review Summaries to Council Council finalizes HAPC Alternatives for Analysis
MAY - SEPT 2009	HAPC analysis
OCT 2009	Initial Review
DEC 2009	Final Review

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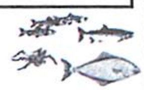

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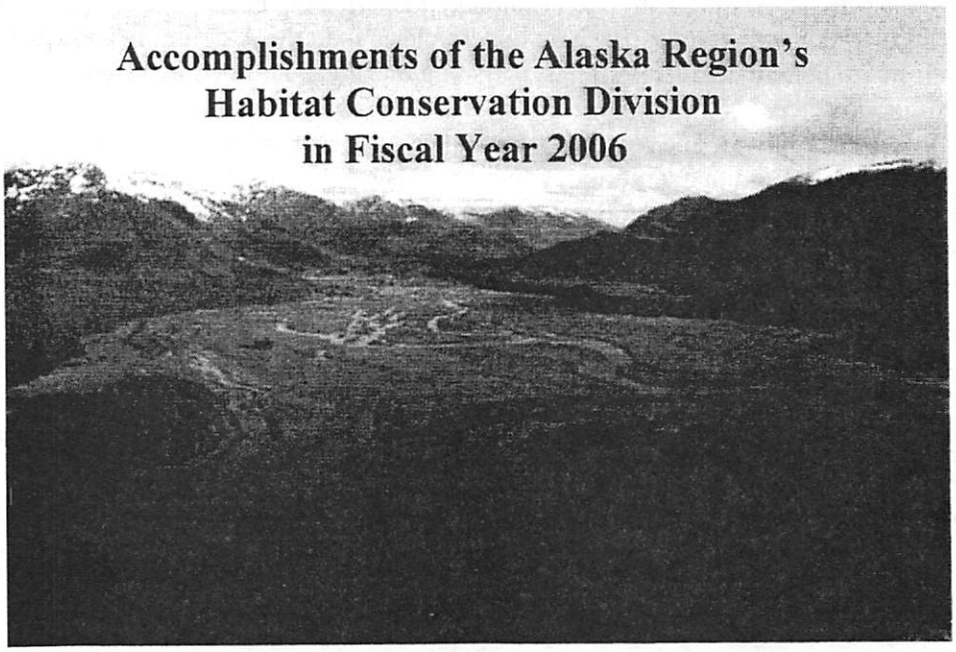
National Marine Fisheries Service

Accomplishments of the Alaska Region's Habitat Conservation Division in Fiscal Year 2006



This report provides highlights of Habitat Conservation Division (HCD) activities in support of the sustainable management of living marine resources from October 1, 2005 through September 30, 2006.

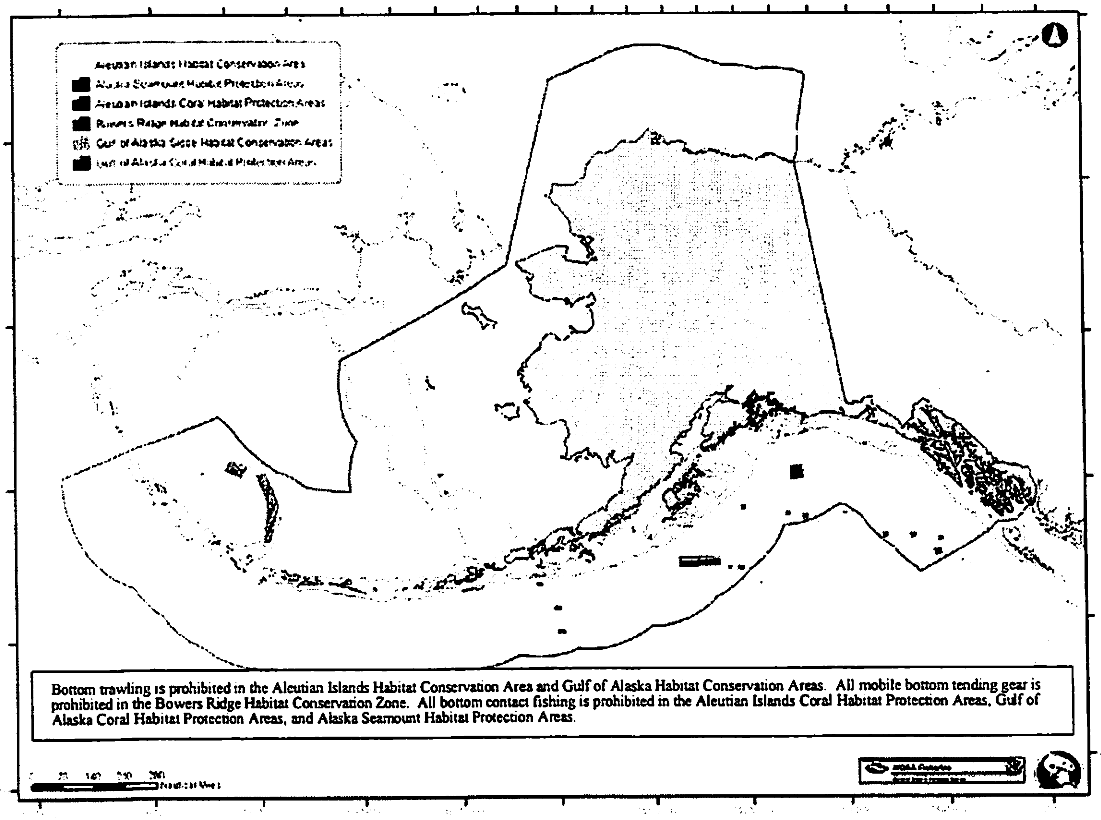
HCD carries out NOAA Fisheries' statutory responsibilities for habitat conservation in Alaska under the Magnuson-Stevens Fishery Conservation and Management Act, Fish and Wildlife Coordination Act, National Environmental Policy Act, Federal Power Act, and other laws. HCD has two principal programs: identification and conservation of Essential Fish Habitat (EFH) through fishery management, and environmental review of non-fishing activities to minimize impacts to EFH or other habitats for living marine resources. HCD also supports habitat restoration projects in conjunction with the NOAA Restoration Center.

HCD has staff located in the Alaska Regional Office in Juneau and a field office in Anchorage. HCD coordinates extensively with other groups to facilitate habitat conservation. Within NOAA, such organizations include the Sustainable Fisheries Division and Protected Resources Division in the NOAA Fisheries Alaska Regional Office; the Alaska Fisheries Science Center; NOAA Fisheries Office of Habitat Conservation; NOAA General Counsel; and NOAA Ocean Service's Office of Response and Restoration. HCD also works in close partnership with other agencies and organizations, including the North Pacific Fishery Management Council; Army Corps of Engineers; Environmental Protection Agency; U.S. Fish and Wildlife Service; Minerals Management Service; U.S. Forest Service; Bureau of Land Management; Federal Energy Regulatory Commission; Alaska Department of Fish and Game; Alaska Department of Natural Resources; Alaska Department of Transportation and Public Facilities; and a variety of industry and conservation groups.

Essential Fish Habitat and Fishery Management

EFH Protection Measures for the Gulf of Alaska and Aleutian Islands

HCD worked in partnership with the Sustainable Fisheries Division to develop proposed and final regulations to implement extensive new fishery closures in the Aleutian Islands and Gulf of Alaska to minimize potential adverse effects of fishing on EFH. The closures stemmed from the 2005 *Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska* (EIS), and received a great deal of positive media attention. The EIS analysis found no indication that bottom trawling or other fishing in Alaska reduce the capacity of seafloor habitats to support healthy populations of managed species, yet precautionary measures may be warranted due to scientific uncertainty. The new closed areas to protect EFH were supported by the fishing industry, conservation groups, and other stakeholders. The final regulations took effect July 28, 2006. (See map below.)



EFH Protection Measures for the Bering Sea

HCD assisted the North Pacific Fishery Management Council with work related to a new analysis of habitat conservation measures for Bering Sea fisheries. HCD provided guidance to Council staff on the development of a range of alternatives for analysis, arranged for a contractor to undertake the socioeconomic analysis of proposed habitat conservation measures, and provided staff support for the Environmental Assessment that will be completed in 2007.

Ecosystem Approaches to Management

HCD provided support in several capacities for the North Pacific Fishery Management Council's initiatives to implement ecosystem approaches to management. HCD represented the Regional Administrator on the Council's Ecosystem Committee and served on a team that will help the Council develop a Fishery Ecosystem Plan for the Aleutian Islands. The Fishery Ecosystem Plan will inform future fishery management decisions by taking fuller account of habitat and ecosystem processes. HCD also represented the Regional Administrator on the Alaska Marine Ecosystem Forum, a newly formed group of 14 federal and state agencies that have jurisdiction over various activities that can affect the marine ecosystem. The purpose of the forum is to coordinate and share information to promote the sustainable management of Alaska's marine ecosystems.

Other Fishery Management Actions

HCD staff advised and assisted staff from the Sustainable Fisheries Division regarding a number of other fishery management actions during FY06. HCD contributed to the EIS for the annual harvest specifications for the groundfish fisheries to evaluate potential effects on habitat, and completed an EFH consultation. HCD staff also reviewed analyses and draft decision memoranda for a variety of regulatory amendments, and recommended modifications in some cases to ensure the analyses clearly reflected consideration of effects on EFH.

EFH Informational Workshops

HCD held EFH workshops in Anchorage and Juneau to inform partners and stakeholders about recent updates to the EFH descriptions, Habitat Areas of Particular Concern, and EFH conservation areas in Alaska. The workshops also included an overview of the interagency EFH consultation process as a refresher for federal and state action agencies to help improve compliance with statutory and regulatory requirements.

Environmental Review to Minimize Habitat Loss

Major New Developments in Upper Cook Inlet

HCD played a key role in the environmental review of three large projects in Upper Cook Inlet: the Port of Anchorage expansion, proposed Knik Arm bridge, and proposed Cook Inlet ferry. Studies requested by HCD have shown extensive use of the Knik Arm area by over 20 species of fish including all 5 species of salmon. NOAA Fisheries' comment letter on the Port of Anchorage expansion raised numerous issues that were then picked up by other agencies, mostly related to alleviating impacts on habitat for salmon and beluga whales. HCD continues to work with other federal and state agencies and project proponents to minimize the impacts of these large projects on living marine resources and identify suitable compensatory mitigation.

Auke Nu Cove Commercial Development

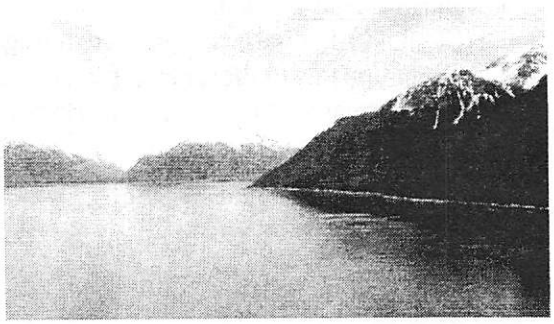
HCD persuaded the City and Borough of Juneau to redesign a proposed landing facility for commercial fishing vessels to minimize direct and indirect impacts to ecologically valuable habitat, and to protect the remaining intertidal habitat in the adjacent cove through a conservation easement. NOAA Fisheries was the only agency to object to a proposed Corps of Engineers permit for the facility located at Auke Nu Cove. The project as originally proposed would have significantly degraded productive eelgrass and other intertidal and subtidal habitats. Through negotiations with the applicant, the project was redesigned to reduce environmental impacts while still achieving the basic project purpose. The applicant and HCD staff will also jointly complete experimental transplantation of eelgrass from the project site to a nearby site.

Haines Highway Project

HCD staff assisted the Alaska Department of Transportation with the monitoring of a major mitigation project associated with the Haines Highway. The mitigation includes six wetland creations, eighteen stream channel creations and/or stabilizations, two pond expansions, thirteen culvert replacements, and four areas of river mining reclamation. The flagship restoration project is the creation of a 7,000 foot long extension of 37-mile Creek and associated wetlands and feeder channels. The main channel extension includes a specified sequence of pools, runs, and riffles and the placement of woody debris and spawning and riffle gravels. Juvenile coho salmon and Dolly Varden char rear and overwinter in the main and feeder restoration channels, and coho salmon spawn in the 37-mile Creek extension. In addition, sockeye, Dolly Varden char, and Chinook salmon spawn in the main restoration channel.

Habitat Enhancement for the Juneau Access Project

HCD staff facilitated the development of an innovative mitigation project to offset impacts to coastal habitats from building a new highway 51 miles north from the Juneau road system along Lynn Canal. The mitigation plan includes constructing an artificial reef at a site that will benefit key forage fish species, especially Pacific herring. The University of Alaska will assist with site selection, materials and reef design, baseline studies, and post-construction monitoring. The Alaska Department of Transportation will pay for construction of the artificial reef, and installation is expected in May 2007. Other mitigation for the road includes substantial realignment to minimize wetland impacts, long bridge spans to minimize impacts to anadromous fish and key forage species for Steller sea lions, limiting human access to important estuarine habitats, and acquisition of key wetland parcels for preservation.



Natzuhinni Wetland Mitigation Bank

Alaska's first site-specific riparian mitigation bank is nearing the final public review stage. HCD staff served on the Mitigation Banking Review Team and assisted Sealaska (the regional native corporation sponsoring the bank) with establishing operational procedures to govern the sale of mitigation bank credits for wetland impacts authorized under Corps of Engineers permits. To establish the bank, Sealaska restored riparian habitat on a formerly unbuffered anadromous stream and enhanced and protected a productive estuary. Sealaska anticipates developing more site-specific mitigation banks in the near future.

Galore Creek Mine

HCD coordinated with British Columbia's Environmental Assessment Office to comment on a large new open pit mine for copper, gold, and silver in British Columbia with potential downstream impacts to the Stikine River in Alaska. HCD worked in conjunction with other U.S. agencies to help influence the location of the preferred access route to decrease potential impacts to the Stikine River and to increase the amount of monitoring proposed.

Government Creek Realignment

HCD staff assisted the Alaska Department of Transportation with the development of a major mitigation project associated with the Ketchikan Airport runway safety area upgrade. The mitigation involves constructing a new channel to reroute an anadromous stream at the south end of the runway and constructing an estuary where the new channel meets Tongass Narrows. HCD was part of an interdisciplinary team of state and federal agencies that met over a 2 year period to design the habitat goals and features of the new stream bed and estuary. HCD was instrumental in assuring that a monitoring plan was developed prior to construction to establish performance measures for the new stream and estuary and to develop a method for addressing any deficiencies. The stream and estuary provide habitat for pink, chum, and coho salmon. The new stream channel will enhance coho rearing habitat over the existing channel and should result in a net benefit to salmon.

Habitat Restoration and Protection

Anchorage Salmon Restoration Task Force

HCD served on a Salmon Restoration Task Force to aid the Municipality of Anchorage with salmon restoration plans for three watersheds. The municipality received $5 million from the Pacific Coastal Salmon Recovery Fund to restore salmon habitat. HCD helped prioritize projects to maximize improvements to salmon habitat in urban and industrial areas of the city. HCD also worked to make in-lieu fee mitigation monies from several large local projects available for use by this program. Combining several large sums of money will allow the task force to accomplish significant restoration projects.

Artificial Reef Demonstration Project

HCD staff constructed Alaska's first ever modular artificial reef. HCD staff conceived of the idea as a way to offset unavoidable losses of hard bottom habitats from coastal development.

Last year HCD personnel identified a suitable site and designed the reef in coordination with several partners. This year HCD acquired and deployed the reef units and began a monitoring program to assess how marine life uses the reef in comparison to a reference area. The project received nationwide media coverage and may lead to other artificial reef projects in Alaska for habitat restoration and mitigation. HCD is also working cooperatively with teachers on an education/outreach program on reef ecology for use in pubic schools.

Cooperative Habitat Protection Partnership

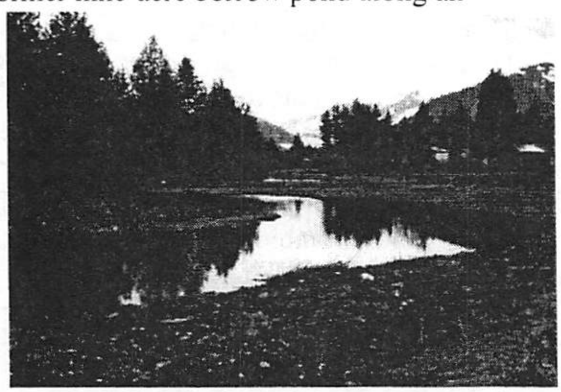
HCD staff were the catalyst for implementing a pilot grant for a Cooperative Habitat Protection Partnership (CHPP) in Anchorage. The idea behind CHPPs is to use non-regulatory approaches to protect fish habitat at the regional and community levels to supplement traditional regulatory activities. HCD secured funding from NOAA Fisheries' Office of Habitat Conservation for a watershed planning effort for Little Campbell Creek. The funding for the Community Outreach Habitat Operation (a.k.a. Project COHO) allows us to partner with the municipal government to add fish habitat information to GIS products, and will yield an improved watershed plan that addresses habitat concerns in a broader context.

Shotgun Cove Habitat Assessments

HCD continued a cooperative study with the University of Alaska to collect baseline information on eelgrass in Shotgun Cove, near Whittier in Prince William Sound. The work examines the genetic structure of the eelgrass beds, assesses the health and stability of the beds by determining changes in carbon isotope ratios, and measures the rate at which plants are lengthening their rhizomes. Data on eelgrass genetics will complement previous studies by HCD documenting the presence and relative abundance of juvenile and adult salmon, herring, forage fish, and other organisms as well as delineating eelgrass beds and shoreline habitats. The cove is a likely site for substantial future harbor development. The site-specific information gathered by HCD will assist local, state, and federal agencies in planning development activities to account for impacts to fishery resources.

Nancy Street Wetland Restoration

Through a multi-year, multi-agency effort a former nine-acre borrow pond along an anadromous creek in Juneau was restored to an emergent wetland and meandering stream with overwintering habitat for juvenile salmon and spawning riffles for cutthroat trout. As part of this project, HCD staff organized volunteers from a local community sustainable agriculture program to collect, store, and plant over 3,000 willow and alder cuttings to stabilize the shoreline. The project yielded private funding for boardwalks and viewing platforms, and over 350 volunteer hours.



Marine Debris Cleanup

Staff from HCD and the NOAA Restoration Center provided technical advice and support to the Ketchikan Borough to organize a cleanup of the Gravina Island coastline using a NOAA marine debris grant. To date 6,660 pounds of trash have been collected and two miles of shoreline have been cleaned.

Other Noteworthy Activities

Coastal America

NOAA Fisheries, represented by HCD, became co-chair of the Coastal America Alaska Regional Implementation Team. Coastal America is a national interagency partnership coordinated by the White House Council on Environmental Quality that promotes efforts to conserve and restore coastal habitats. The Alaska team endorsed seven projects that bring together the resources and expertise of a variety of agencies. Some of the projects also involve contributions from the Alaska Corporate Wetlands Restoration Partnership.

Shorezone Mapping

HCD provided funding for a third field season for the Shorezone mapping project, which inventories coastal habitats using aerial surveys with video, still photos, and classification of habitat features. This year's field work covered major portions of southern southeast Alaska including the areas surrounding Ketchikan and Craig. These areas will be mapped and added to an interactive website (www.fakr.noaa.gov/maps/szintro.htm) that allows users to "fly" the coast and view video or still images. HCD established a flexible contracting mechanism to facilitate future Shorzone work, and worked with a Forest Service intern to evaluate potential benefits of the project for management of the Tongass National Forest. In addition, Coastal America formally endorsed the Shorezone project for multi-agency partnering.

Green Crab Habitat Suitability Model

HCD staff obtained headquarters funding to develop a habitat suitability model for invasive green crabs using the imagery and mapping of the Shorezone project. The Delphi approach will be used to compile green crab habitat characteristics and display them in GIS format. Results will show hotspots that may be correlated with potential resources at risk, such as shellfish concentrations. This effort is part of a larger west coast green crab effort directed at stopping the northward spread of the species.

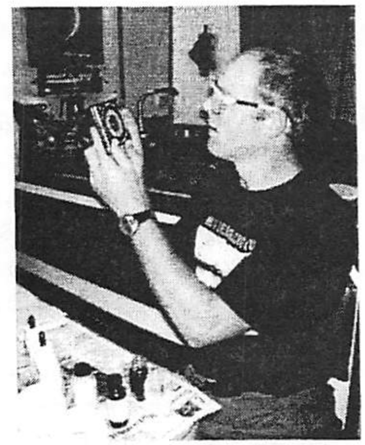
Alaska Invasive Species Working Group

HCD staff participated in a state-wide multi-partner initiative to address invasive species issues in Alaska, and formed and led a marine species subgroup. The group is promoting invasive species awareness, coordination, and responsiveness in Alaska, and developed a Memorandum of Understanding to formalize the partnership. This effort has led to greater coordination of invasive species issues in the state and will continue to grow.

EFH Research Implementation Plan

HCD collaborated with the Alaska Fisheries Science Center to develop the *NOAA Essential Fish Habitat Research Implementation Plan for Alaska for FY 2007-2011*. The plan identifies research themes and priorities to guide scientific investigations related to describing EFH and evaluating effects on EFH from fishing and other human activities. It also clarifies the process to be used to allocate internal funding for EFH research. The plan will help to ensure that EFH research addresses resource managers' top information needs.

Habitat Recovery at Former Log Transfer Facilities



Biologists from HCD, the Auke Bay Lab, and the University of Alaska teamed up to study recovery of EFH at inactive log transfer facilities (LTFs) in southeastern Alaska. LTFs are used to transfer logs from land to the ocean for transport to mills and sort yards. Over time, bark accumulations on the ocean floor have resulted in lost fish habitat and degraded water quality. During a 10-day research cruise the team conducted dive surveys, bottom trawling, and water quality assessments at eight LTFs and adjacent reference sites. Preliminary results indicate that bark deposits near LTFs are relatively small and benthic habitats appear to be recovering biologically. The work will enable HCD to make more informed recommendations to the Forest Service regarding the siting and design of LTFs to minimize impacts to EFH.

National GIS Team

An HCD staffer participated as a member of the Educational & Technical Support Subcommittee and the GIS Education Committee for NOAA Fisheries GIS activities. HCD developed a Frequently Asked Questions list for both web pages, and provided experience related to fishery data sets.

NOAA Small Boat Management

HCD personnel coordinated and provided safety and operational support for small boat operations for Alaska Fisheries Science Center projects as well as HCD field work. The projects included a Pacific right whale investigation in the Bering Sea, nearshore fish habitat studies in Prince William Sound, monitoring for the Whittier artificial reef, and support for the Fish and Wildlife Service Bering Sea ice walrus tagging program.

Outreach and Education

Earth Day

HCD coordinated with NOAA Weather Service and NOAA Fisheries Law Enforcement to hold an Earth Day event for local students. Over 400 1st through 6th grade students and accompanying teachers and parents attended the event.

Alaska Oceans Festival

HCD assisted other Alaska Region staff with a booth at the Alaska Oceans Festival in Anchorage. The booth – one of the most successful at the event – emphasized children's activities and provided materials on regional topics.

Alaska State Fair

HCD staff partnered with NOAA Weather Service in a joint NOAA booth at the 2006 Alaska State Fair. NOAA employees increased public awareness of a variety of topics including federally managed fisheries, habitat conservation, endangered species and marine mammals, tsunami and earthquake hazards, lightning safety, NOAA weather radio, marine and aviation products and services, and flood preparedness.

Student Intern

HCD hosted an intern from the University of Washington DO-IT (Disabilities, Opportunities, Internetworking, and Technology) Program. Alisha Fahey, who is hearing impaired, worked in our Anchorage field office where she helped with field sampling, compiled marine mammal stranding reports into a computer spreadsheet, and inventoried dive video logs for fish presence, habitat type, and structure. This provided an opportunity for a bright young person to work alongside our staff, and opened her eyes to NOAA-related career paths.

Personnel News

HCD wished "fair winds" to our NOAA Corps officer, CDR Mark Boland, who is now Executive Officer aboard the NOAA Ship MILLER FREEMAN. We'll miss his expertise and smile.

LT(jg) Jonathan Taylor joined our HCD staff in Anchorage. JT came to us from the NOAA Ship GORDON GUNTER and previously worked as an Alaska fisheries observer. JT's three year assignment will allow him to get his land legs back and give him exposure to habitat and protected resources management issues.

Katharine Miller was accepted into NOAA's Advanced Studies program, and enrolled in the University of Alaska where she is working toward a doctorate degree in fisheries oceanography. Her research will emphasize community ecology and the linkages between fish and their nearshore habitats.

Cindy Hartmann began a 4 month detail to NOAA's Ecosystem Goal Team staff as part of the NOAA Rotational Assignment Program. She'll be working on budget planning and programming.

Janet Herr left NOAA Fisheries for a new position with the NOAA Weather Service Tsunami Warning Center in Palmer. Janet was an administrative office assistant in Anchorage, and previously worked in the Regional Office in Juneau. We wish her well.

Larry Peltz relocated to Idaho where he accepted a new job with the U.S. Fish and Wildlife Service managing fish hatcheries. We'll miss him too!

Public Testimony Sign-Up Sheet

12/11/06 **Agenda Item** D-3 Bering Sea Habitat Conserv.

	NAME (PLEASE PRINT)	AFFILIATION
1	JOHN GAUVIN	H+G WORKGROUP
2	Mark Kandianis + Richard McClelland	Kodiak Fish Company
3	James Sipary	Nelson Island Villages
4	Dorothy Childers	AMCC
5	IAIN STENHOUSE	NAT.L AUDUBON SOCIETY
6	Bubba Cook	WWF
7	Jon Warrenchuk + Jim Ayers	Oceana
8	GLENN REED/Paul MacGregor	PSPA
9	Donna Parker	HSCC
10	Dave Benton	MCA
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NOTE to persons providing oral or written testimony to the Council: Section 307(1)(I) of the Magnuson-Stevens Fishery Conservation and Management Act prohibits any person " to knowingly and willfully submit to a Council, the Secretary, or the Governor of a State false information (including, but not limited to, false information regarding the capacity and extent to which a United State fish processor, on an annual basis, will process a portion of the optimum yield of a fishery that will be harvested by fishing vessels of the United States) regarding any matter that the Council, Secretary, or Governor is considering in the course of carrying out this Act.

Audubon ALASKA

715 L Street, Suite 200
Anchorage, AK 99501
Tel: 907-276-7034
Fax: 907-276-5069

Statement of Iain J. Stenhouse, PhD, Director of Bird Conservation,
with regard to Bering Sea Habitat conservation

Spectacled Eider critical habitat

The Spectacled Eider (*Somateria fischeri*) is a large-bodied seaduck that spends most of the year in marine waters, where it forages on benthic-dwelling mollusks and crustaceans (Petersen *et al.* 2000). In 1993, it was listed as *Threatened* in the United States, under the Endangered Species Act, largely due to a significant and rapid decline in the number of breeding birds in the core breeding area in Alaska, between the 1970s and 1990s [Federal Register 58(88):27474-27480].

At the time of listing, there were known to be three distinct breeding populations of Spectacled Eiders (the North Slope and Y-K Delta of Alaska, and Arctic Russia), but the wintering range was completely unknown and the subject of much speculation. In 1995, however, large, dense flocks were discovered wintering in small polynyas and leads in the pack ice of the central Bering Sea (Petersen *et al.* 1996, 1999). Since then, most, if not virtually all, of the world population appears to have congregated in this area for months at a time (Petersen *et al.* 2000).

In 2001, the Fish & Wildlife Service designated areas of critical habitat for Spectacled Eiders, including a large block of wintering habitat, between St. Lawrence Island and St. Matthew Island [Federal Register 66(25): 9146-9185]. These areas of critical habitat were designated based on a number of constituent elements, including bathymetry and underlying marine benthic community.

Federal agencies, such as the Fish & Wildlife Service and the National Marine Fisheries Service, are responsible for preventing any actions that would jeopardize the continued existence of a listed species – that is, any activity that would be expected, directly or indirectly, to reduce the likelihood of the survival and/or recovery of a listed species.

Critical habitat & the trawl fisheries footprint

Although direct interaction with fisheries does not appear to have been a problem for Spectacled Eiders in the past, or contributed to their population decline, the potential for indirect impacts of trawl fisheries, through the disruption of benthic communities, is now very real.

Around the world, bottom trawl fishery activities are known to disrupt benthic communities and can permanently damage benthic ecosystems (Jones 1992). Areas subject to bottom trawling are generally found to have reduced benthic habitat complexity (Freese *et al.* 1999), altered benthic community composition (Tillin *et al.* 2006), diminished biodiversity (Probert *et al.* 1998), and decreased biomass and productivity (Prena *et al.* 1999).

(over)

In their final ruling on Spectacled Eider critical habitat in 2001, the Fish & Wildlife Service recognized that commercial trawl fisheries have the potential to destroy or adversely modify critical habitat, through the alteration of the benthic environment by trawling gear. Moreover, they went on to state that *"any activity that would result in an adverse modification of* [Spectacled Eider] *critical habitat would virtually always also jeopardize the continued existence of the species"* [Federal Register 66(25): 9146-9185].

Since the major effect of fisheries on Spectacled Eiders is indirect, through habitat degradation, birds need not even be present during fishing operations for significant harm to occur. Bottom trawl fisheries conducted in this general area **at any time of year** could adversely modify Spectacled Eider foraging habitat and would, therefore, require Section 7 consultation.

Although we now know that Spectacled Eiders are present at high densities on their wintering grounds for many months, their precise distribution is dependent on the particular ice conditions, and, in some years, they may be forced to use areas outside the designated critical habitat. For example, it has been suggested that the polynyas immediately to the south of St. Matthew Island and Nunivak Island may also be important wintering areas in some years (Dau & Kistchinski 1977). Thus, we believe that **any** expansion of trawling northward, beyond the current bottom trawl footprint, has enormous potential to jeopardize the recovery, or indeed the continued existence, of the Spectacled Eider.

Literature cited:

Dau, C.P. & Kistchinski, S.A. (1977) Seasonal movements and distribution of the Spectacled Eider. *Wildfowl* 28: 65-75.

Freese, L., Auster, P.J., Heifetz, J. & Wing, B.L. (1999) Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. *Marine Ecology Progress Series* 182: 119-126.

Jones, J.B. (1992) Environmental impact of trawling on the seabed: a review. *New Zealand Journal of Marine and Freshwater Research* 26: 59-67.

Petersen, M.R., Douglas, D.C. & Mulcahy, D.M. (1995) Use of implanted satellite transmitters to locate Spectacled Eiders at-sea. *Condor* 97: 276-278.

Petersen, M.R., Larned, W.W. & Douglas, D.C. (1999) At-sea distributions of Spectacled Eiders (*Somateria fischeri*): a 120-year old mystery resolved. *Auk* 116: 1009-1020.

Petersen, M.R., Grand, J.B. & Dau, C.P. (2000) Spectacled Eider (*Somateria fischeri*). *In* The Birds of North America, No. 547 (A. Poole & F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Prena, J., Schwinghamer, P., Rowell, T.W., Gordon, D.C., Gilkinson, K.D., Vass, W.P. & McKeown, D.L. (1999) Experimental otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland: analysis of trawl bycatch and effects on epifauna. *Marine Ecology Progress Series* 181: 107-124.

Probert, P.K., McKnight, D.G. & Grove, S.L. (1998) Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. *Aquatic Conservation: Marine & Freshwater Ecosystems* 7: 27-40.

Tillin, H.M., Hiddink, J.G., Jennings, S. & Kaiser, M.J. (2006) Chronic bottom trawling alters the functional composition of benthic invertebrate communities on the sea-basin scale. *Marine Ecology Progress Series* 318: 31-45.

Agenda D-3-1

Chefornak Traditional Council
P.O. Box 110
Chefornak, AK 99561

Resolution No. 06-12-01

WHEREAS, the Chefornak Traditional Council is the recognized sole governing body of the Chefornak Native Village recognized by the United States; and

WHEREAS, the North Pacific Fishery Management Council is in charge of management and conservation of Bering Sea Fisheries under federal jurisdiction; and

WHEREAS, the North Pacific Fishery Management Council is considering whether or not to establish and "open area" in the Bering Sea where bottom trawl fisheries may operate in the future;

WHEREAS, the Council is discussing where the boundaries for the "open area" should be based on past fishing activity; and

WHEREAS, our communities rely on halibut, herring, salmon and other fish for our local commercial fisheries and for traditional subsistence resources; and

WHEREAS, the Nelson Island villages are concerned about the impact of bottom trawl fisheries on waters and habitat nearby our communities; and

WHEREAS, bottom trawl fisheries have occurred in our waters in the past that we believe has had negative impact on our near shore resources.

NOW THEREFORE BE IT RESOLVED THAT, the Village of Chefornak supports the North Pacific Council's effort to limit bottom trawling;

BE IT FURTHER RESOLVED THAT, we recommend protecting areas important for our fishery resources including Etolin Strait and the waters south of Etolin Strait roughly between Nunivak Island and Cape Newenham (the southern end of Kuskokwim Bay);

BE IT FURTHER RESOLVED THAT, the Village of Chefornak offers to work with the North Pacific Fishery Management Council to define the boundaries necessary to protect our commercial and subsistence resources.

CERTIFICATION

Passed and approve on this 9th day of December 2006, at which a quorum of the Council members were in attendance. The Council vote taken was: 4 FOR and 0 AGAINST.

BY: [signature]
Chefornak Traditional Council Vice-President

ATTEST: [signature]
Chefornak Traditional Council Secretary

City of Toksook Bay

P.O. BOX 37008
TOKSOOK BAY, ALASKA 99637
PHONE (907) 427-7613
FAX (907) 427-7811

Resolution No. 06-03

Whereas, the North Pacific Fishery Management Council is in charge of management and conservation of Bering Sea fisheries under federal jurisdiction; and

Whereas, the North Pacific Fishery Management Council is considering whether or not to establish an "open area" in the Bering Sea where bottom trawl fisheries may operate in the future;

Whereas, the Council is discussing where the boundaries for the "open area" should be based on past fishing activity; and

Whereas, our communities rely on halibut, herring, salmon and other fish for our local commercial fisheries and for traditional subsistence resources; and

Whereas, the Nelson Island villages are concerned about the impact of bottom trawl fisheries on waters and habitat nearby our communities; and

Whereas, bottom trawl fisheries have occurred in our waters in the past that we believe has had negative impact on our near shore resources.

Therefore, be it resolved that the City of Toksook Bay supports the North Pacific Council's effort to limit bottom trawling;

Be it further resolved, that we recommend protecting areas important for our fishery resources including Etolin Strait and the waters south of Etolin Strait roughly between Nunivak Island and Cape Newenham (the south end of Kuskokwim Bay);

Be it further resolved, that the City of Toksook Bay offers to work with the North Pacific Fishery Management Council to define the boundaries necessary to protect our commercial and subsistence resources.

Passed and approved this 5th day of Dec, 2006.

Signed: [signature]
Pius Agimuk, Mayor

Attest: [signature]
Harry Tulik,
City Administrator

Native Village of Nightmute
c/o Nightmute Traditional Council
P.O. Box 90021
Nightmute, Alaska 99690

Ph. (907) 647-6215 Fax (907) 647-6112

Resolution No. 06-11-71

WHEREAS, the North Pacific Fishery Management Council is in charge of management and conservation of Bering Sea fisheries under federal jurisdiction; and

WHEREAS, the North Pacific Fishery Management Council is considering whether or not to establish an "open area" in the Bering Sea where bottom trawl fisheries may operate in the future;

WHEREAS, the Council is discussing where the boundaries for the "open area" should be based on past fishing activity; and

WHEREAS, our communities rely on halibut, herring, salmon, and other fish for our local commercial fisheries and for traditional subsistence resources, and

WHEREAS, the Nelson Island villages are concerned about the impact of bottom trawl fisheries on waters and halibut nearby our communities; and

WHEREAS, bottom trawl fisheries have occurred in our waters in the past that we believe has had negative impact on our near shore resources.

THEREFORE, be it resolved that the Native Village of Nightmute supports the North Pacific Council's effort to limit bottom trawling;

BE IT FURTHER RESOLVED that we recommend protecting areas important for our fishery resources including Etolin Strait and the waters south of Etolin Strait roughly between Nunivak Island and Cape Newenham (the southern end of Kuskokwim Bay)

BE IT FURTHER RESOLVED that the Native Village of Nightmute offers to work with the North Pacific Fishery Management Council to define the boundaries necessary to Protect our commercial and subsistence resources.

CERTIFICATION

This resolution was adopted at a meeting in which a quorum of the Nightmute Traditional Council was approved on the 7 th, day of Dec, 2006 with a vote of 7 yes 0 no 0 abstain 0 absent

Joseph Post, President

Christopher George, Sec.

D-3 (did not appear)

My name is George Pletnikoff. Some of you know me – I am an Unungan, an Aleut, born and raised on the Pribilof Islands. I have been a fisherman, a biologist, and a priest, and in all these roles I have tried to protect my people and the sea which we have depended upon for thousands of years. Today I am here on behalf of Greenpeace, an organization representing 3 ½ million people.

I am here because we need to do better. We need to be more consistent in taking a precautionary approach to fisheries management, and stop using insufficient research as an excuse to avoid doing what we know is necessary. We need to do a better job of incorporating the impacts of our fisheries on the ecosystem, and that means doing a better job reducing bycatch, protecting critical habitat, and leaving enough fish in the water to feed the rest of the marine mammals, sea birds, and fish that make up the rest of the food web. And we need to do a better job of remembering the needs of the native villages and other fishing dependent communities that cannot afford full-time lobbyists to counter the perspective of the big money industrial fisheries.

This year, my work with Greenpeace has taken me from Kodiak to the Aleutian Chain, from the Pribilofs up to St. Lawrence. We have heard people in many communities tell us that they must to travel farther and farther to find fish. On St. George Island, many of the foods in our traditional diet are growing scarce, and the community is struggling. We need to do a better job of preventing localized depletion – for the sake of our communities as well as for populations of marine mammals and seabirds that continue to be experiencing declines.

At the last meeting of this Council, several of us urged you to protect Bering Sea canyons. These unique, diverse, and productive areas provide critical habitat for numerous commercially important species, and are likely to be home to as yet undiscovered species not found anywhere else in the world. NMFS has put together a white paper on existing research that confirms that the canyons are "significant geological features" and "rare habitats" that "can support diverse communities," and even that they "are likely to be important at the ecosystem level." The Council has a responsibility to protect these habitats.

Proposals are under consideration to freeze the trawl footprint, closing the northern Bering Sea to future trawl activity. I was just in Savoonga, up on St. Lawrence Island. The contrast between Savoonga and St. George, where I was born, was remarkable. Unlike St. George, where the community is shrinking and industrial fisheries have dramatically impacted our traditional foods, Savoonga is growing. Food is plentiful throughout the year. Preventing trawlers from moving northward will help protect northern Bering Sea communities, and will help ice-dependent species survive the increasing challenges they will face from global warming in the coming years.

These are precautionary steps I am asking you to take, steps that are in the interests of our communities and ecosystems. Because as I mentioned, we must do better here in Alaska. For all the hard work and all the money we spend on managing our fisheries here, we have been unable to prevent the decline of many species and the degradation of a great deal of the seafloor habitat of the Bering Sea and the Gulf of Alaska. A lot of money is still being made here, but fewer people are making it. The good news is that we have not yet fallen off the cliff here – we can turn things around. But it's going to take putting a little more action beyond our rhetoric when it comes to taking a precautionary, ecosystem-based approach in the North Pacific.

Thank you. George 12-4-06

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nchorage Daily News

2006 ALASKA'S NEWSPAPER www.a

COMPASS: *Points of view from the community*

Protecting heritage begins in ocean 'forest'

By GEORGE PLETNIKOFF

What we are talking about is establishing marine protected zones within reasonable areas around our villages where these destructive practices are not allowed to encroach on our ways of living.

Demands for marine resources are at an all-time high, especially depleting the once-abundant resources of the Gulf of Alaska and the Bering Sea. Foreign-owned and operated processing companies have been given ownership to many of our once-public resources, such as the crab of the Bering Sea. Large factory trawlers, many with co-ops fishing for these companies, are dragging our ocean floors, destroying our source of life.

The results of this destructive fishing practice are numerous. Of great importance to our people living on the coastline of Alaska especially is the destruction and depletion of our traditional foods. We would not stand by and watch a person using a bulldozer to hunt for a deer in a forest and not do anything, and yet this is happening to our oceans. We must not be quiet about what is happening to our "forest," the Gulf of Alaska and the Bering Sea. We all understand that without a place to grow and thrive, our food will not return.

Several of our coastal and island communities are facing serious risks of endangerment. Our people are quickly running out of our traditional foods, or are finding that harvesting these foods is becoming more and more difficult as we face climate changes and localized depletions. And yet the large commercial fishing companies are encroaching closer and closer to our villages with their destructive fishing practices.

We need a way to collectively stop that destruction. We are not talking about the need to stop our small-boat commercial fishermen from making a living. Their harvesting practices are done in such a way as to protect our environment and resources. What we are talking about is establishing marine protected zones within reasonable areas around our villages where these destructive practices are not allowed to encroach on our ways of living.

These zones are our heritage zones, there to protect who and what we are. These areas were used, and are used to this day, to allow the survival of our people. These heritage zones are as, or in many cases, more important than our land-based protected hunting areas. They provide the necessary lifeline for many of our other foods to survive and thrive.

■ George Pletnikoff works for the Alaska Oceans Campaign of Greenpeace in Anchorage.

Andrew Malavansky
PO Box 986
St. George Island, Alaska 99591
December 4, 2006

Stephanie Madsen
Chair
North Pacific Fishery Management Council
605 West 4th Avenue, Suite 306
Anchorage, AK 99501-2252

Dear Ms. Madsen:

Thank you for this opportunity to comment regarding the North Pacific Fishery Management Council's developing alternatives to protect the Bering Sea Essential Fish Habitat (EFH).

It is widely accepted by scientists that bottom trawling reduces and in some cases destroys habitat complexity, alters seafloor communities and reduces productivity. A productive and healthy benthic zone is critical for the birds, seals, walrus, whales, fish and crab that we depend upon. As a resident of St. George Island I am seeing many environmental changes come into my Community, and am very concerned.

For centuries the Alaska natives' people lived off the bounties of the land and the sea, now many generations later we sit and watch as our marine resources dwindle before our eyes. Now, in as less than one generation the negative changes can be easily detected. I am very concerned about the health of the Bering Sea. Freezing and reducing the bottom trawl footprint in the Bering Sea is a crucial first step to protecting our people our lifestyles and the very resources we depend upon for food.

The survival of all Bering Sea coastal communities is dependant upon the very health of the Bering Sea and is uniquely tied to this surrounding environment.

Please include and enact an alternative that will freeze and eventually reduce the trawl footprint so that we will be able to continue to live our customary and traditional lifestyles.

Sincerely,

Andrew Malavansky

AGENDA D-3 (a)
DECEMBER 2006

A Review of Scientific Information Related to Bering Sea Canyons and Skate Nursery Areas

Prepared for the North Pacific Fishery Management Council
by the Alaska Fisheries Science Center

18 November 2006

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Background

The North Pacific Fishery Management Council ("Council") is one of eight regional councils overseeing management of the Nation's fishery resources. One of their specific responsibilities is compliance with provisions of the Magnuson-Stevens Fishery Management Act related to essential fish habitat (EFH). EFH is broadly defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity". The mandate includes a requirement to "encourage the conservation and enhancement of such habitat". The Council is currently developing a list of alternatives to be analyzed in an Environmental Assessment for Bering Sea habitat conservation measures.

The Alaska Fisheries Science Center (AFSC) was contacted 25 October and asked to produce a white paper summarizing current scientific information on Pribilof, Middle (actually Pervenets)[1] and Zhemchug Canyons in the eastern Bering Sea (EBS), as well as skate nursery areas in the EBS. This document addresses the specific requests considered most relevant for the Council action:

1. Summarize AFSC research conducted in these areas and the principal findings;
2. Identify specific locations of AFSC sampling or dive surveys in these areas;
3. Document AFSC videos of these habitat features;
4. Summarize other available information regarding the ecology of these areas and their use by commercially important species;
5. Provide a qualitative assessment of the habitat value of these areas for managed species and their susceptibility to disturbance; and
6. Provide a list of pertinent scientific and technical references.

Because of time constraints, the document has been structured as an inventory of available data and information that are applicable to a thorough review and evaluation of the Proposal. Various database queries and GIS projects generated to produce these results have been archived.

[1] Close examination of Figure 6 in the OCEANA public testimony indicates the Middle Canyon closure boundary actually encompasses Pervenets Canyon, which is located due west of St Matthew Island and to the north of Middle Canyon (canyon head located at 58° 37' N, 176° 45' W). For clarity, Pervenets Canyon is used in this document to refer to this area.

AFSC Research on Skate Nursery Areas

The goal of this research is to understand skate nursery dynamics and the physical and biological parameters that support successful skate reproduction. These nurseries are recent discoveries and it is presently unknown how many of these areas exist. To date six skate nursery sites have been identified in the eastern Bering Sea. All sites occur along the shelf-slope interface between 150 and 400 meters in depth and are associated with slope canyon areas and areas of significant upwelling. Three sites for the Alaska skate *Bathyraja parmifera*, two for the Bering skate *B. interrupta* and one for the Aleutian skate *B. aleutica* have been located and investigated in years 2004 and 2006.

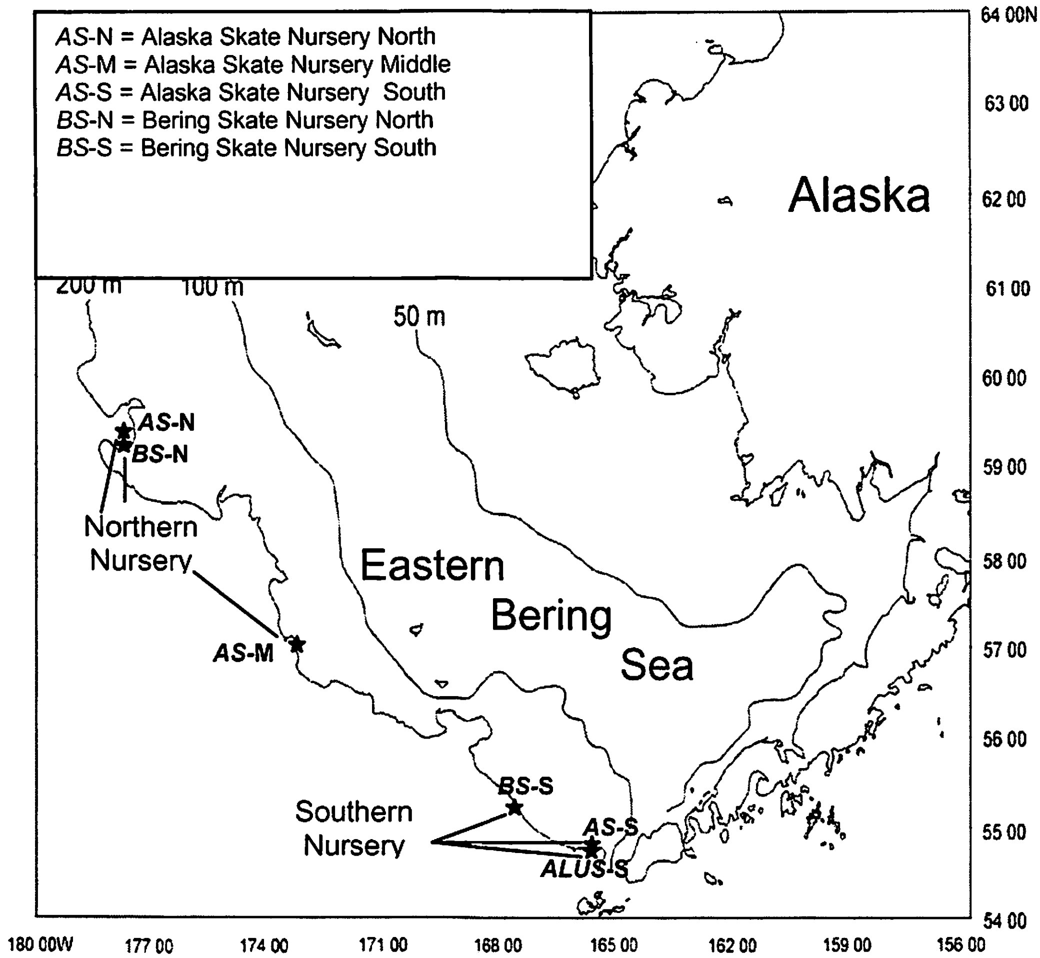
Each site has been explored using bottom trawls to determine the density of egg cases, the extent of the nursery sites, mortality sources to young skates and distinguishing abiotic features of the site that may define essential fish habitat. Two sites, that of the Alaska and Aleutian skates in the south EBS near Unimak Pass have been studied on a seasonal basis to determine timing of egg deposition and hatching as well as seasonal use of the nursery site by predator species.

Details of the Alaska Skate nursery site in the southern EBS have been synthesized in a final report to the North Pacific Research Board (Appendix 1) and are the focus of Gerald Hoff's PhD dissertation, which is currently in draft form. The final dissertation will be available for distribution in late January of 2007. A synthesis of the six nursery sites will be presented in a manuscript that will be available in February of 2007.

All nursery sites show similar characteristics and at this point Hoff feels that many biological and physical processes can be generalized for the six known EBS skate nursery sites:

1. Nursery sites are single species and used over multiple years.
2. Nursery sites are small in area (<2 km^2) with high densities of eggs.
3. Nurseries occur along the shelf-slope environment which may provide many physical and biological features that maximize skate production.
4. Nurseries are used exclusively by mature and developing embryos with other life stages rarely found in nurseries.
5. Embryo development time is long (>3 years) with multiple cohorts developing within the nursery at the same time.

6. Embryos and newly hatched juveniles are susceptible to mortality due to snail and fish predators.
7. Nursery sites may be vulnerable to disturbances from trawling due to the protracted embryo development time, limited habitat area, and low annual productivity of the species.



Map of the six skate nursery sites in the eastern Bering Sea.

AFSC Research in Bering Sea Canyons

Scientific research in the Bering Sea canyon areas by the Alaska Fisheries Science Center is limited to three opportunistic studies in and around the Pribilof Island Area. Two of the studies use data from a pair of cruises aboard NOAA ship *Miller Freeman* which was engaged in a multidisciplinary study of the frontal region near the Pribilof Islands. Summary statements for each of these studies follow.

Rockfish – sea whip associations

Brodeur (2001; Appendix 2) reported on one aspect of a larger multidisciplinary study of fish - zooplankton interactions in and around Pribilof Canyon, a large canyon with depths ranging from 130 – 3200 m. Sampling with a variety of devices was concentrated at the head of the canyon.

Sampler	Deployments	Maximum Depths (m)
CTD[2]	3	246, 256
Light levels[3]	unspecified	unspecified
ROV with color video[4]	7	184-243
Bottom trawl[5]	5	200-248
Acoustic transect[6]	4	230-264
Methot midwater trawl[7]	2	214, 234

Bottom water temperatures in the study area were generally 4-5° C. Illumination levels at 200 m were 4.3 x 10^{-6} μEs^{-1} m^{-2} (day) and 6.2 x 10^{-7} μEs^{-1} m^{-2} (night) and were considered very low however suitable for feeding by planktivorous fish.

The ROV revealed a seabed of compacted mud and silt with little geological relief, except for occasional rocks and small boulders. Five of seven ROV dives encountered dense, evenly spaced

[2] Sea-Bird model SEE-9
[3] In situ light levels recorded at several stations using an International Light IL-1700 Research Radiometer.
[4] Super Phantom II ROV on a 300 m umbilical, with a color CCD video camera recorded on Hi-8 tapes.
[5] Nylon Nor-eastern bottom trawl with roller gear and 1.5 m x 2.1 m steel doors.
[6] Simrad EK-500 calibrated echosounder at 38kHz and 120 kHz (7° beam width)
[7] 5 m^2 opening with 13cm – 8.9 cm mesh sizes, and a 3.2 cm liner in the codend.

1-2 m high stands of sea whips (*Halipteris willemoesi*) along the central and western flank of the canyon. Hundreds of mature adult rockfish were observed in these "forests" at night, or just above them during the day. Other species of groundfish were also observed but with no apparent affinity for the sea whips. Lower densities of rockfish were observed in large sea whip beds with some non-upright specimens. Neither rockfish nor sea whips were observed during the two easternmost and shallowest (181-224 m) ROV dives.

The bottom trawl captured 16 species of groundfish, with Pacific ocean perch, arrowtooth flounder and Pacific cod most abundant. Invertebrate catches were probably small due to the roller gear and, although taxa such as sea whips were collected, invertebrates were not quantitatively assessed due to anticipated losses through the trawl meshes. King crabs (*Paralithodes* spp.), large anemones (*Metridium giganteum*, *Urticinal* spp.), and large basket stars (*Gorgonocephaluseucremis*) were observed during ROV dives.

Acoustic transects along the shelf break and across the axis of the upper canyon detected substantial aggregations of large scatterers within 10 m of the seabed with smaller scatterers above and occasionally overlapping them. Based on theoretical scattering models, the large scatters were thought to be rockfish (or cod), while the smaller scatters could have been either euphausiids or gelatinous zooplankton.

Macrozooplankton and micronekton in the Methot trawls were dominated by euphausiids (primarily *Thyanoessa inermis*), which accounted for 87% (1995) and 98% (1996) of the total catch.

Taken together, the findings are interpreted that rockfish rest in sea whips at night and reside above them during daylight hours possibly feeding on euphausiids. The paper concludes the following:

1. "This study is the first to show the importance of the Pribilof Canyon in general and the sea whip 'forest' in particular as a distinctive habitat for adult Pacific ocean perch in the Bering Sea".
2. The sea whips in this region may provide important structural habitat for Pacific ocean perch in an otherwise featureless environment."

3. Because sea whips may be slow-growing and long-lived, "...fishing operations that disturb the bottom and uproot the sea whips may have a lasting effect on the rockfish population inhabiting this region."

Age and growth of sea whips

Wilson *et al.* (2002; Appendix 3) examined age and growth of the sea whip, *Halipteris willemoesi*, using measurements obtained from the axial rod endoskeleton of 12 colonies. The colonies were selected from two trawl samples in the EBS. The colonies were divided for analysis into three size classes (four colonies each), based on length of the axial rod. The largest colonies came from the northwestern head of Pribilof Canyon (56°16.8' N, 169°25.8' W; 248 m depth; 3.5° bottom temperature), while the "small" and "intermediate" classes were collected on the shelf to the northwest (56°16.8' N, 169°25.8' W; 248 m; 2.0° C.). Age and growth rates were estimated based on an assumption that growth ring couplets visible in thin cross-sections of the axial rod represented annuli. Annuli were counted, and axial rod lengths and diameters were measured to estimate colony ages and annual growth rates.

Group	Size (cm)	Mean ± Standard Error	
		Age (yr)	Growth Rate (cm yr^{-1})
Small	25–29	7.1 ± 0.7	3.9 ± 0.2
Medium	98-130	19.3 ± 0.5	6.1 ± 0.3
Large	153-167	44.3 ± 2.0	3.6 ± 0.1

A predictive age model was developed using the average annual increase in maximum diameter of the axial rod ($R^2 = 0.99$). However, growth rates and corresponding ages could not be validated using two different radiometric methods and alternative methods were suggested for future studies. The authors conclude that:

1. "Growth in total rod length is slow at first, fastest at medium size, and slows toward maximum size, with an estimated longevity approaching 50 years."
2. "...the longevity of these organisms and the biogenic habitat they may provide to other species makes it essential that fishing-related impacts be studied in detail."

Habitat associations of fish and crab

Busby *et al.* (2005; Appendix 4) analyzed 45 ROV dives conducted in the Pribilof Island area of the eastern Bering. Seven of the dives were in Pribilof Canyon and were the basis for the Pacific ocean perch – sea pen analysis by Brodeur (2001).

ROV Dive	Date	Time (GMT)	N. Latitude	W. Longitude	Depth (m)	
					ROV	Bottom
12	9/17/1995	4:06	56.30	-169.44	203	203
13	9/17/1995	11:44	56.29	-169.46	211	211
25	9/24/1995	3:47	56.31	-169.68	209	209
26	9/24/1995	10:41	56.28	-169.60	184	184
27	9/24/1995	22:16	56.29	-169.30	197	197
3	9/10/1997	23:22	56.28	-169.43	243	243
4	9/11/1997	5:41	56.28	-169.43	234	234

These two studies are based on sampling from NOAA ship *Miller Freeman* during 9-26 September 1995 and 8-18 September 1997. The primary objective of the Busby *et al.* analysis was to describe small-scale habitat associations of demersal fish and crabs using underwater video collected with an ROV. Secondarily, the study evaluated video as a survey tool by comparing observed species compositions with those obtained in coordinated bottom trawl samples. Similar to Brodeur (2001), sampling sites were chosen to represent different hydrographic regimes that supported the primary mission focus on frontal regions in the area. Contrary to Brodeur's emphasis on rockfish and canyon locations with sea whips, pleuronectid flatfish (primarily the northern rock sole *Lepidopsetta polyxystra*) were the most frequently observed taxa, and the majority of Busby's observations occurred on silt bottoms with no cover.

Overall, 42 taxa representing 16 families of fish and 8 taxa from 3 families of crabs were observed. Statistical analyses with six habitat classes revealed some species showed clear substrate preferences (e.g. yellowfin sole *Limanda aspera*; snow crab *Chionoecetes opilio*), while other taxa associated with multiple habitat types (e.g. walleye pollock *Theragra chalcogramma*; Korean horsehair crab *Erimacrus isenbeckii*). Most rockfish were associated with rocky outcrops or biogenic structure, and rock sole were frequently observed swimming along troughs in seabed waves. Eight color plates included in the paper show species in their common habitats.

Statistical analyses also indicated significant differences in species composition among habitats and depth intervals. Finally, there was significant correlation between species composition and ranked abundances of taxa from the ROV observations and bottom trawl pairs. Several dives at the head of Pribilof Canyon showed "silt throughout the center with large fields of gravel-cobble and rocks-near the edges of the canyon."

Research summary and significant uncertainties

Relatively few biological studies have been conducted in the three submarine canyons. The three AFSC studies conducted to date were confined to the uppermost head of the Pribilof canyon and adjoining continental shelf. No AFSC research has occurred in Zhemchug or Pervenets Canyons. In all cases, video and trawl sampling was limited to less than 10% of the maximum canyon depth. Sampling for the two habitat studies was further constrained by the primary scientific mission of the research vessel (Brodeur 2001; Busby *et al.* 2005). Although mature POP are reported to associate with sea whips in canyon head areas, the relative importance of this habitat compared to deeper habitats in the canyon is unknown. In fact, Brodeur (p. 219) reports that Krieger[8] "found that adult Pacific ocean perch were more likely to inhabit flat, pebble substrate based on submersible observations off Southeast Alaska." Apparent preference for upright sea pen beds based on high abundance in sea whips, substantially lower numbers in "perturbed" beds, and absence in other shallower areas without whips (Brodeur 2001) could perhaps be related to other environmental factors not being considered. It also is difficult to compare the POP densities observed inside and outside the sea whip beds relative to other areas not being considered for closure. This is due to the inherent difficulty of determining the physical area being observed with video (i.e., the width of the video camera's field of view and the distances traveled by the ROV are frequently unknown and variable; Busby *et al.* 2005). Similarly, significant habitat function in the canyon areas is not demonstrated by Busby *et al.*'s research. The substrates described in this study are rather typical of those found elsewhere in the Bering Sea[9] and inordinately large concentrations of fish or invertebrates were not reported. It would perhaps be

[8] Krieger, K.J. 1992. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fishery Bulletin 91: 87-96.
[9] The authors cite Smith, K.R. and R.A. McConnaughey. 1999. Surficial sediments of the eastern Bering Sea continental shelf: EBSSED database documentation. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-104. 41 p.

useful to compare the relationships between bottom type and fish distribution reported from their study with those for the full EBS shelf [10].

The studies each express concern about possible consequences of destructive fishing practices and losses of important habitat. For example, Brodeur reported that perturbed sea whip beds contained substantially fewer rockfish and "fishing operations that disturb the bottom and uproot the sea whips may have a lasting effect on the rockfish populations inhabiting this region". However, it is unknown whether uprooted sea whips are truly lost as a result, given a propensity in certain whip species to detach, drift and re-attach (Wilson *et al.* 2005). First and foremost in the context of EFH, it is unknown whether there exists an essential functional dependency between rockfish and sea whips that is affected by the disturbance. Concerns about disturbance by fishing are particularly warranted for slow-growing and long-lived species, as reported for the sea whip, *Halipteris willemoesi*. There are however acknowledged uncertainties about the age and growth determinations for this species, including the existence of true annuli and the inability to validate the reported ages (Wilson *et al.* 2005).

AFSC Data Sources

The AFSC is responsible for research on living marine resources in the coastal oceans off Alaska (http://www.afsc.noaa.gov). Its mission is to plan, develop, and manage scientific research programs, which generate the best scientific data available. These data are used to understand, manage and conserve the region's living marine resources, as well as the environmental quality essential for their existence. This section provides information on data holdings from various AFSC monitoring and assessment activities in the conservation areas of interest. These data collectively provide the most comprehensive set of biological and ecological information that is currently available.

Bottom trawl surveys – EBS shelf and EBS slope

The RACE Division of the Alaska Fisheries Science Center conducts annual bottom trawl surveys of the EBS continental shelf. These surveys provide data for stock assessments and management of the fishery resources. Each June–August, the EBS shelf (approximately 463,400

[10] McConnaughey, R.A. and K.R. Smith. 2000. Associations between flatfish abundance and surficial sediments in the eastern Bering Sea. Can. J. Fish. Aquat. Sci. 57: 2410-2419.

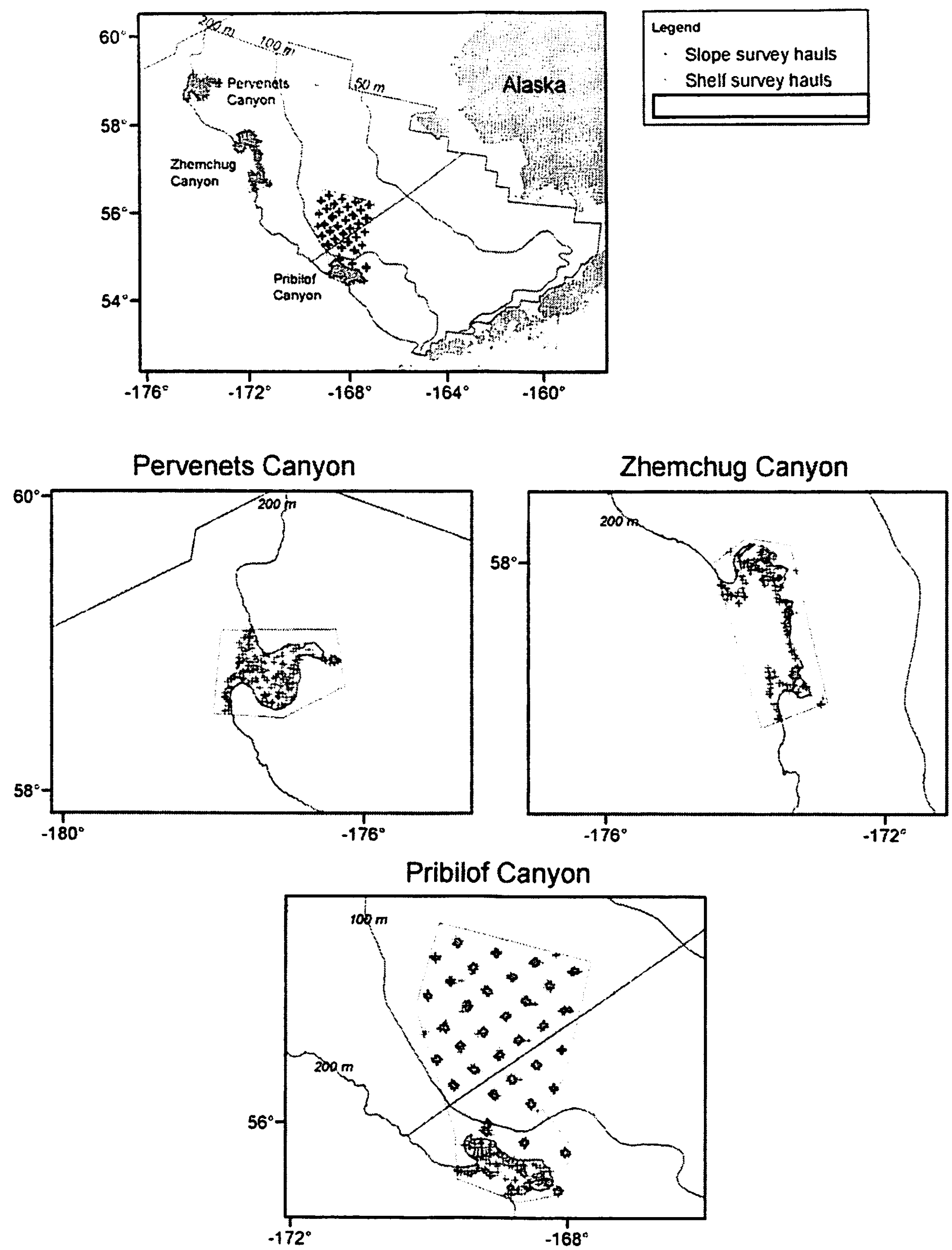
km^2) is systematically surveyed at depths ranging from 20 to 200 m. An 83-112 eastern otter trawl is deployed from chartered vessels at 356 standard stations in a sampling grid with 20 × 20 nautical mile cells. Each sample consists of a 30-min tow at 3 kn. The catch is processed to determine total weight and numbers by species and sex, and a variety of biological measurements and samples are collected from individual specimens. Acoustic net mensuration data and a global positioning system are used to standardize catches (CPUEs) according to area swept.

The RACE Division also conducts bottom trawl surveys along the upper slope of the EBS in order to produce standardized estimates of groundfish and invertebrate abundance. Compared to the shelf survey, the time series is less complete and standard protocols have been implemented only recently. The slope survey was conducted during the period 1975-1991 using a variety of nets, vessels, methods, and sampling locations. A pilot study in year 2000 compared performance of two versions of a Poly Nor'eastern bottom trawl and concluded that the net with mud-sweep roller gear was more efficient and should thereafter be used exclusively. The first standardized biennial survey using this gear occurred in 2002. It should be noted that comparability of data before and after the year 2000 has not been examined and caution is therefore required when examining time series of catches. The standardized survey extends from Unalaska and Akutan Island to the U.S. Russian border near the International Date Line, at depths from 200 to 1,200 m. The survey area encompasses several geologically distinct bathymetric types described as broad low slope areas, canyon areas (including Pribilof and Zhemchug), and steep-slope inter-canyon faces. Trawl sampling occurs at pre-selected locations where depth changes less than 50 m over a distance of 2 nm and the bottom is judged to be free of obstructions that would impede completion of the tow or negatively affect performance of the gear. A standard sample at all depths on the slope consists of a 30-minute tow at 2.5 knots. Available shelf and slope survey data from the three Bering Sea Canyons:

Year	Number of Hauls (Shelf Survey)			
	Pribilof	Zhemchug	Pervenets	Total
1982	32	2	1	35
1983	34	3	1	38
1984	34	3	1	38
1985	34	2	1	37
1986	34	2	1	37

Year	Number of Hauls (Shelf Survey)			
	Pribilof	Zhemchug	Pervenets	Total
1987	34	2	1	37
1988	36	2	1	39
1989	35	2	1	38
1990	34	3	1	38
1991	34	3	1	38
1992	33	2	1	36
1993	33	2	1	36
1994	34	2	1	37
1995	34	2	1	37
1996	34	3	1	38
1997	34	2	1	37
1998	33	3	1	37
1999	34	3	1	38
2000	33	2	1	36
2001	34	2	1	37
2002	34	2	1	37
2003	34	2	1	37
2004	33	2	1	36
2005	33	2	1	36
2006	34	2	1	37
Total	845	57	25	927
Year	**Number of Hauls (Slope Survey)**			
	Pribilof	**Zhemchug**	**Pervenets**	**Total**
1975	0	2	2	4
1976	2	4	0	6
1979	10	19	13	42
1981	27	24	15	66
1982	19	29	32	80
1985	28	32	32	92
1988	10	4	8	22

Year	Number of Hauls (Shelf Survey)			
	Pribilof	Zhemchug	Pervenets	Total
1991	6	5	9	20
2000	14	18	14	46
2002	10	14	12	36
2004	19	19	14	52
Total	145	170	151	466



Distribution of standard eastern Bering Sea bottom trawl survey hauls conducted by the Alaska Fisheries Science Center within the three canyon areas.

Longline survey - EBS slope

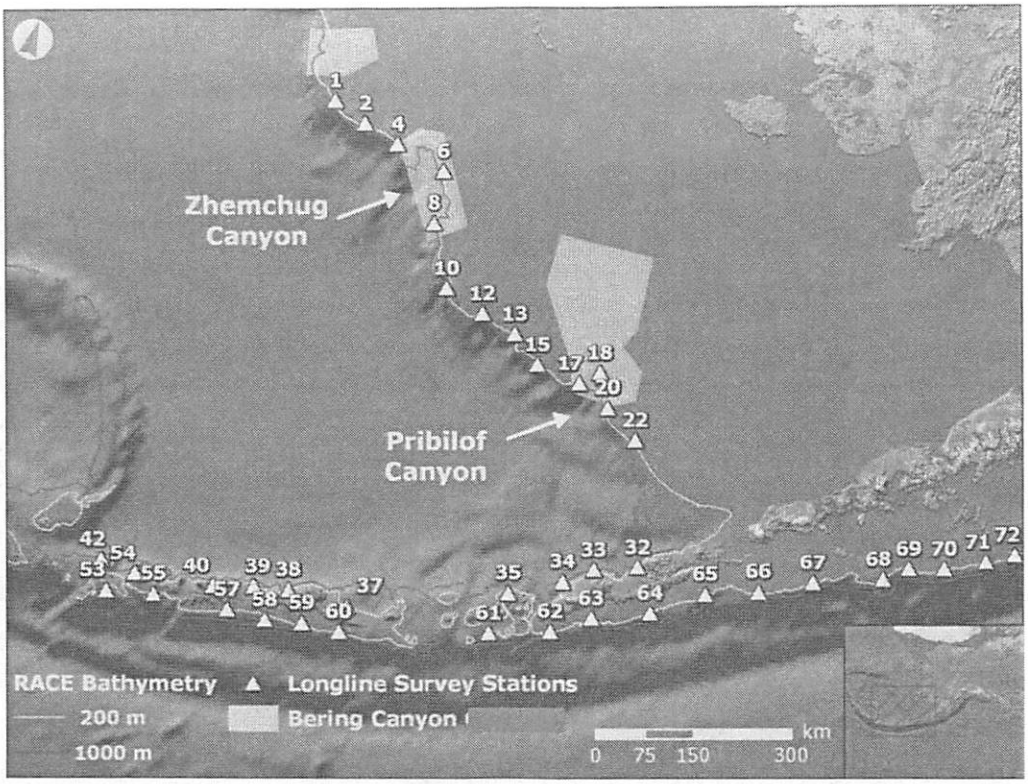
Since 1995, the Auke Bay Laboratory of the Alaska Fisheries Science Center has conducted annual longline surveys of sablefish (*Anoplopoma fimbria*) resources in Alaskan waters. These surveys were designed to continue the time series (1979-94) of the Japan-U.S. cooperative longline survey that was discontinued after 1994. The EBS was sampled annually as part of the cooperative survey between 1982 and 1993 and then biennially since 1997 (Table below).

Sixteen stations along the upper continental slope of the EBS are surveyed (Figure below). Surveyed depths range from approximately 200 to 1000 m, although slightly shallower or deeper depths are fished at some stations. Units of gear (skates) are 100 m long and contain 45 size-13/0 Mustad circle hooks. Hooks are attached to 38 cm gangions that are secured to beckets tied into the groundline at 2 m intervals. Total groundline at each station consists of 180 skates with 8100 hooks.

Catch data are recorded on hand-held electronic data loggers. A scientist records the species of each hooked fish during gear retrieval and the depth strata (100 m intervals) of each gear set. In addition to fish and crab species, coral and sponge catch was generically recorded beginning in 1997. In 2005, coral catch was recorded to higher taxonomic categories (i.e. gorgonians, *Primnoa* sp., *Paragorgia* sp., bamboo corals, scleractinians, black corals, pennatulaceans, and hydrocorals).

Region	Station #	Latitude/Longitude	Survey Years
Pribilof Canyon	17	56.04° N, 169.62° W	82-93,97,99,01,03,05
Pribilof Canyon	18	56.24° N, 169.17° W	82-93,97,99,01,03,05
Pribilof Canyon	20	55.81° N, 168.93° W	82-93,97,99,01,03,05
Zhemchug Canyon	4	58.50° N, 175.68° W	82-93,97,99,01,03,05
Zhemchug Canyon	6	58.33° N, 174.32° W	82-93,97,99,01,03,05
Zhemchug Canyon	8	57.63° N, 174.16° W	82-93,97,99,01,03,05

Stations from AFSC longline survey in submarine canyons of the eastern Bering Sea (see Figures below). Note that the survey does not extend as far north as Pervenets Canyon and consequently no survey data are available for that region.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Pribilof Canyon
RACE Bathymetry
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Longline Survey Stations
Bering Canyon
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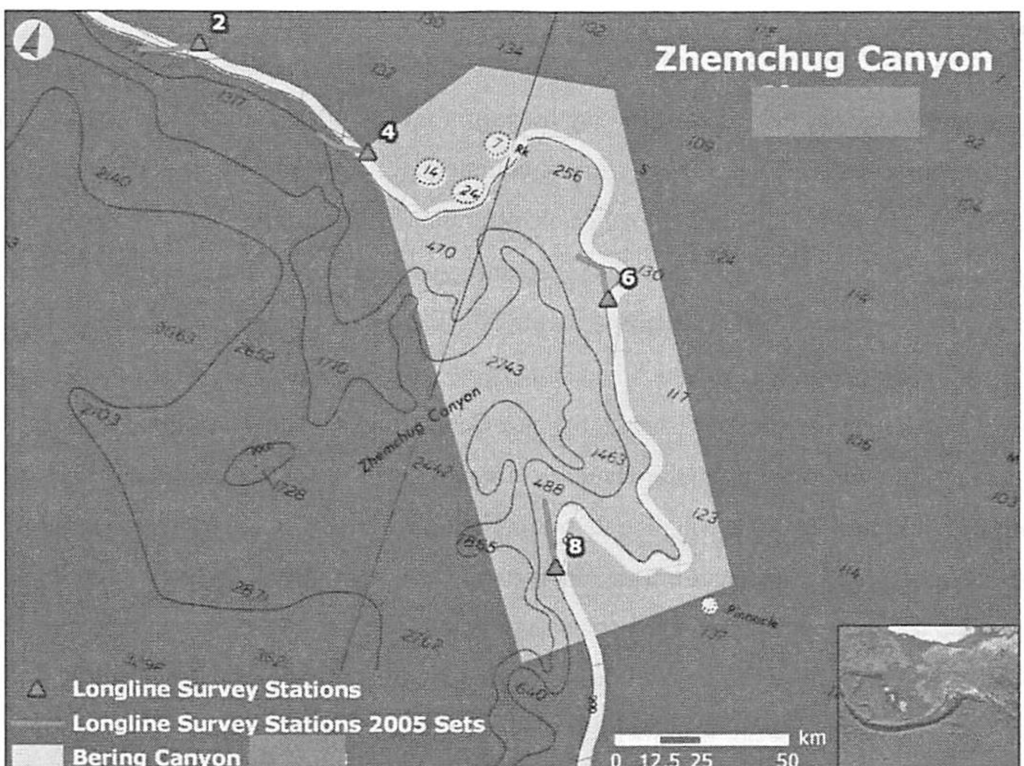
Zhemchug Canyon
2
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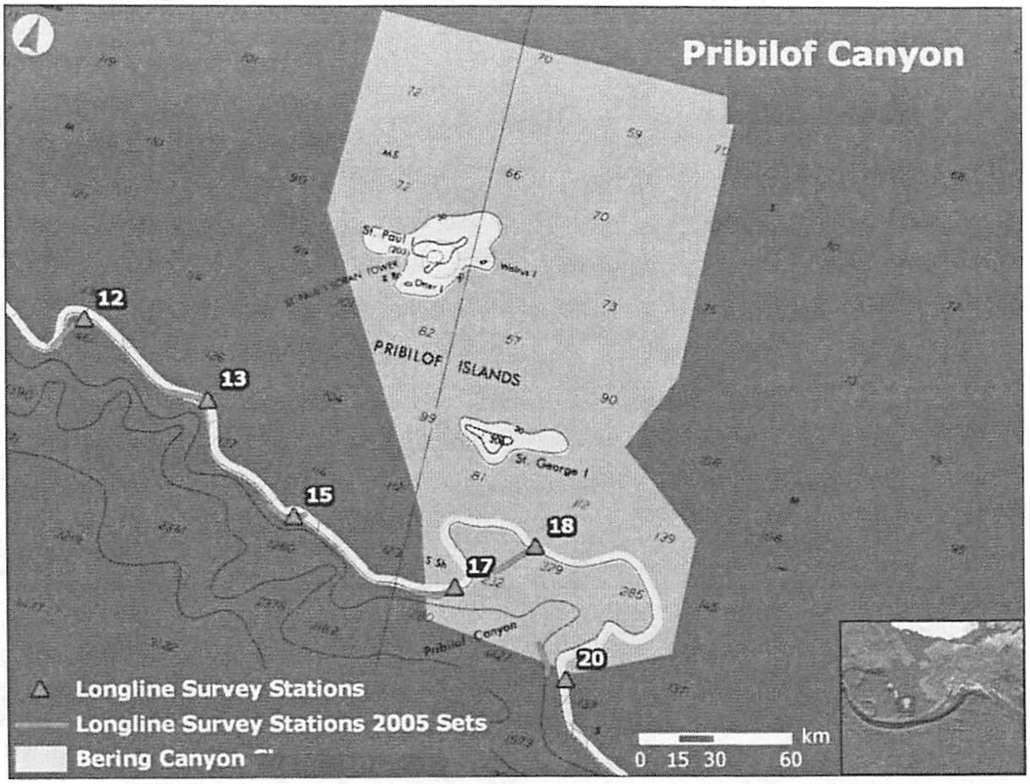


NORPAC fishery observer database

As part of a comprehensive data-gathering program for North Pacific fisheries, certified fishery observers are placed on larger vessels during commercial fishing operations. These observers collect a variety of data, including total catch, effort, catch composition and occurrence of prohibited species. These data are transmitted at regular intervals and are used for in-season fishery management and other scientific purposes. Historical observer data reside in the NORPAC relational database, which is maintained by the Fisheries Monitoring and Analysis (FMA) Division at the Alaska Fisheries Science Center. These data cover three distinct periods in the development of North Pacific fisheries (foreign, joint-venture or j/v, domestic). Commercial bottom trawls during the domestic period are easily identified from gear information recorded in the field. This gear information is not available for hauls during the foreign and j/v period and it was therefore necessary to use a judicious combination of vessel type, processor type and presence of benthic invertebrates in the catch to identify bottom trawl activity. Because observers did not process all catches prior to 1988, roughly half of all hauls during the period are not included by this method (J. Berger, FMA Division, pers. comm.). Furthermore, the estimates of fishing effort do not account for variable and incomplete coverage of vessels over all years so, in general, the counts should be considered conservative. In general, in all three canyon areas commercial trawl hauls were made near or above the 1000m contour.

The following table summarizes the number of commercial bottom trawls observed in the three canyon areas.

Year	Number of Commercial Bottom Trawls		
	Pribilof	Zhemchug	Pervenets
1977	104	13	11
1978	82	159	86
1979	128	251	88
1980	122	96	29
1981	164	119	137
1982	432	407	569
1983	436	966	1,380
1984	616	941	971
1985	564	413	788
1986	627	149	335
1987	446	126	314
1988	445	12	0
1989	591	30	0
1990	2,298	1,388	23
1991	1,989	1,204	449
1992	2,830	467	242
1993	2,205	489	289
1994	1,763	335	455
1995	83	104	169
1996	96	122	9
1997	212	72	102
1998	82	91	95
1999	93	48	30
2000	433	84	135
2001	256	11	222

Year	Number of Commercial Bottom Trawls		
	Pribilof	Zhemchug	Pervenets
2002	367	13	202
2003	316	18	16
2004	229	7	92
2005	107	67	21
2006	257	276	7
Totals	18,373	8,478	7,266

Food habits database

The Resource Ecology Fisheries Management (REFM) Division of the Alaska Fisheries Science Center conducts food habits studies during bottom trawl surveys in the EBS. These data are used to estimate the total biomass and numbers of commercially important crab and groundfish consumed by major groundfish species, as well as describe the diet composition of groundfish species in the region. In most years, stomachs are removed at sea and preserved for laboratory analysis. Beginning in 2005 and 2006, food habits data are based primarily on at-sea scans of stomachs. The capture location, as well as fork length, sex and spawning condition of the source animal are recorded. In the laboratory, prey organisms are identified to the lowest practical taxon, enumerated and wet weights determined. Measurements of standard length (fish prey) and carapace length/width (crab prey) may also be determined. The following tables summarizes the number of predator stomachs collected in the canyon areas, and the corresponding list of predators sampled:

Year	Number of Stomachs Collected			
	Pribilof	Zhemchug	Pervenets	Total
1982	72	58	7	137
1983	200	67	268	535
1984	425	95	177	697
1985	635	99	266	1,000
1986	637	90	201	928
1987	953	347	360	1,660
1988	821	76	59	956
1989	811	86	20	917

Year	Number of Stomachs Collected			
	Pribilof	Zhemchug	Pervenets	Total
1990	689	188	55	932
1991	824	172	142	1,138
1992	991	53	112	1,156
1993	1,213	43	83	1,339
1994	1,183	109	126	1,418
1995	1,740	52	30	1,822
1996	1,396	11	19	1,426
1997	860	59	39	958
1998	832	41	4	877
1999	929	174	23	1,126
2000	769	230	157	1,156
2001	111	0	492	603
2002	733	270	195	1,198
2003	483	1	24	508
2004	393	163	82	638
2005	146	0	10	156
2006	134	0	5	139
Total	17,980	2,484	2,956	23,420

Predator Name	Number of Stomachs Collected			
	Pribilof	Zhemchug	Pervenets	Total
Albatrosia pectoralis (giant grenadier)	43	82	87	212
Anoplopoma fimbria (sablefish)	66	58	78	202
Aptocyclus ventricosus (smooth lumpsucker)	0	0	3	3
Aspidophoroides bartoni (Aleutian alligatorfish)	0	0	10	10
Atheresthes evermanni (Kamchatka flounder)	165	44	156	365
Atheresthes sp.	41	9	188	238
Atheresthes stomias (arrowtooth flounder)	1,168	215	1,374	2,757
Bathyagonus nigripinnis	0	0	12	12
Bathyraja aleutica (Aleutian skate)	36	37	45	118

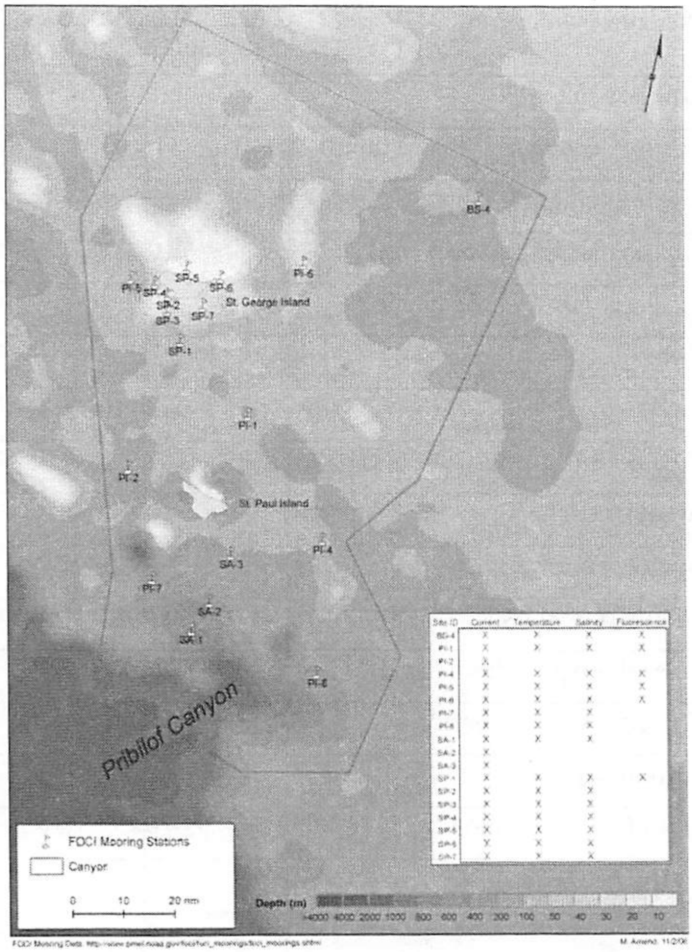
Predator Name	Number of Stomachs Collected			
	Pribilof	Zhemchug	Pervenets	Total
Bathyraja binoculata (big skate)	0	0	2	2
Bathyraja interrupta (Bering skate)	3	0	38	41
Bathyraja lindbergi (commander skate)	21	10	32	63
Bathyraja maculata (white blotched skate)	10	0	23	33
Bathyraja parmifera (Alaska skate)	68	1	408	477
Bathyraja sp. (skate)	2	0	63	65
Bathyraja tarantetzi (mud skate)	12	3	17	32
Bathyraja trachura (black skate)	3	0	3	6
Bothrocara spp. (two-line eelpouts (fat and skinny))	0	0	15	15
Clupea pallasi (Pacific herring)	0	0	27	27
Coryphaenoides acrolepis (Pacific rattail)	0	0	64	64
Coryphaenoides cinereus (popeye grenadier)	92	25	20	137
Embassichthys bathybius (deepsea sole)	0	0	48	48
Errex zachirus (rex sole)	0	11	36	47
Gadus macrocephalus (Pacific cod)	2,785	271	1,574	4,630
Hemilepidotus hemilepidotus (red Irish lord)	0	0	50	50
Hemilepidotus jordani (yellow Irish lord)	15	0	211	226
Hemitripterus bolini (bigmouth sculpin)	10	0	1	11
Hippoglossoides elassodon (flathead sole)	320	86	856	1,262
Hippoglossoides robustus (Bering flounder)	0	0	13	13
Hippoglossus stenolepis (Pacific halibut)	255	20	484	759
Icelus canaliculatus (sculpin)	0	0	1	1
Icelus spiniger (thorny sculpin)	0	0	3	3
Lepidopsetta polyxystra (northern rock sole)	172	4	349	525
Leuroglossus schmidti (northern smoothtongue)	0	0	3	3
Leuroglossus stilbius (California smoothtongue)	0	0	4	4
Limanda aspera (yellowfin sole)	0	0	1,019	1,019
Lycodes brevipes (shortfin eelpout)	0	0	11	11
Lycodes concolor (ebony eelpout)	0	0	5	5
Lycodes diapterus (black eelpout)	0	0	19	19
Lycodes palearis (wattled eelpout)	0	0	12	12

Predator Name	Number of Stomachs Collected			
	Pribilof	Zhemchug	Pervenets	Total
Myoxocephalus jaok (plain sculpin)	0	0	5	5
Myoxocephalus polyacanthocephalus (great sculpin)	0	0	20	20
Oncorhynchus tshawytscha (chinook salmon)	0	0	4	4
Pleurogrammus monopterygius (Atka mackerel)	0	0	8	8
Pleuronectes quadrituberculatus (Alaska plaice)	0	0	168	168
Pleuronectidae (flatfish)	0	0	4	4
Rajidae (skate)	62	0	83	145
Reinhardtius hippoglossoides (Greenland turbot)	117	69	163	349
Sarritor frenatus (sawback poacher)	0	0	44	44
Sebastes alutus (Pacific ocean perch)	95	45	53	193
Sebastes polyspinis (northern rockfish)	0	0	20	20
Sebastolobus alascanus (shortspine thornyhead)	29	0	15	44
Somniosus pacificus (Pacific sleeper shark)	0	0	11	11
Thaleichthys pacificus (eulachon)	0	0	8	8
Theragra chalcogramma (walleye pollock)	5,510	780	2,621	8,911
Zaprora silenus (prowfish)	0	0	6	6
Total	11,100	1,770	10,597	23,467

FOCI ocean moorings

The Alaska Fisheries Science Center's and Pacific Marine Environmental Laboratory's FOCI Program has maintained a number of ocean moorings in the eastern Bering Sea over the period 1994 to the present. 18 of these moorings are located within the Pribilof Island and Pribilof canyon area. The moorings support a number of meteorological and oceanographic instruments, with most data available online at http://www.pmel.noaa.gov/foci/foci_moorings/foci_moorings.shtml. The following figure indicates the location of the moorings relative to the Pribilof Island and Pribilof canyon area, as well as the data types available from the onboard instrument pack.

AFSC FOCI Oceanographic Mooring Locations - Pribilof Islands Region

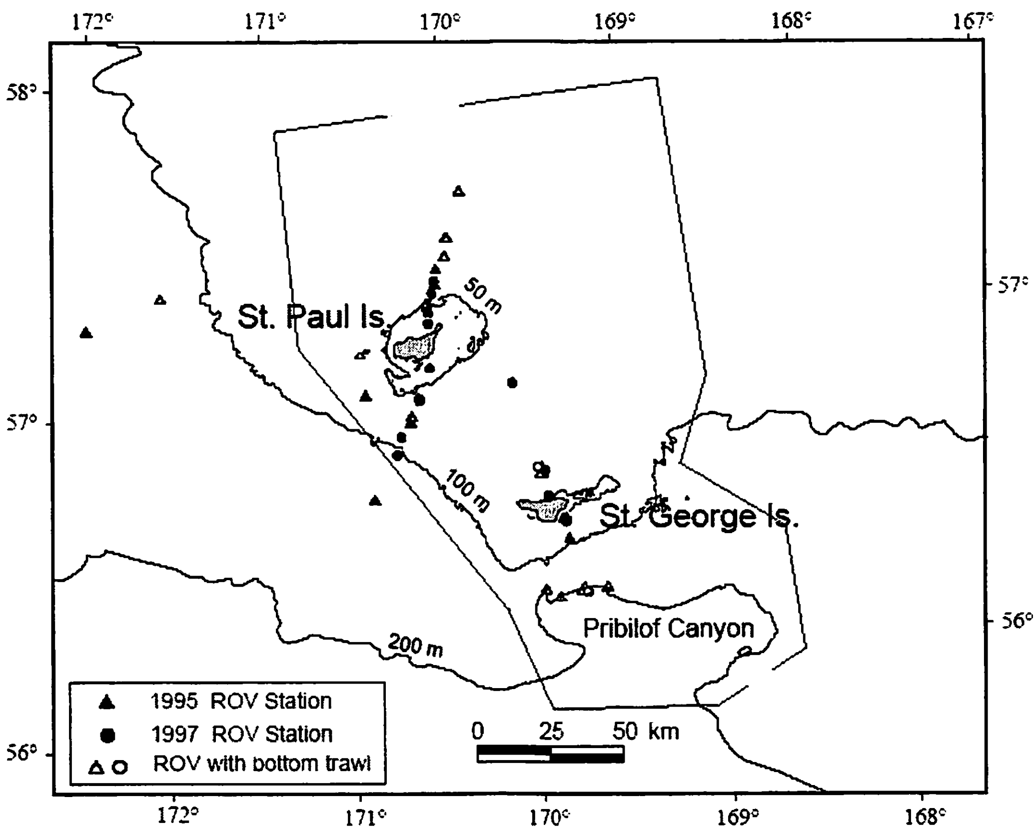


AFSC Underwater Video from Canyon Areas

Pribilof Island / Canyon areas

Seven of the 45 ROV video camera dives conducted in the EBS during the 1995 and 1997 *Miller Freeman* cruises were in Pribilof Canyon (Brodeur 2001; Busby *et al.* 2005). All of this footage and notes of observations are available for additional study if needed. The following table lists the amount and type of video footage recorded at the dive locations indicated in the figure. (Also see additional information included in the Busby *et al.* research summary above.)

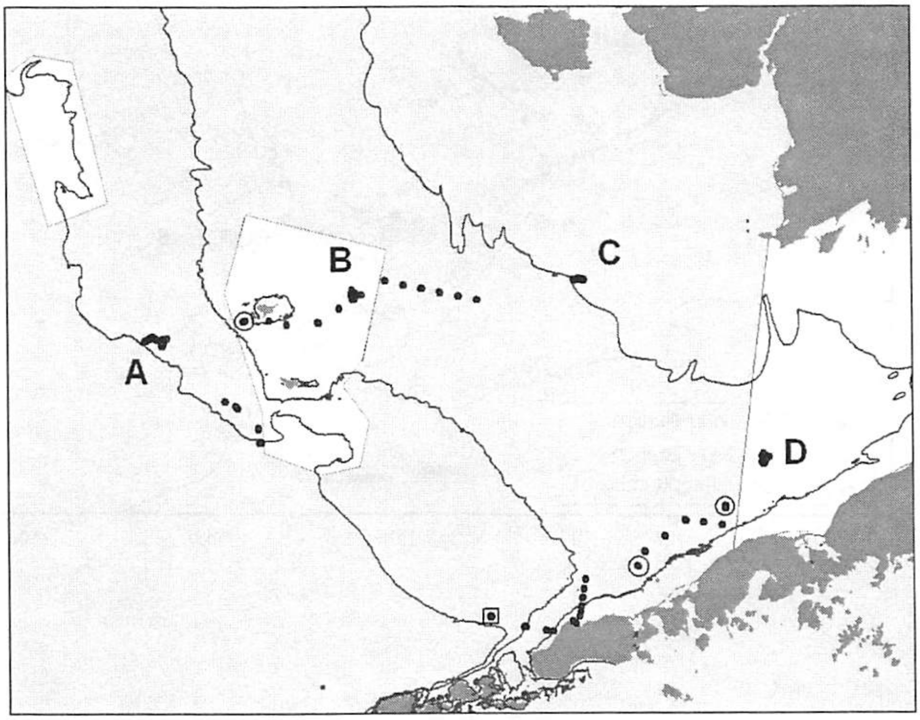
ROV Dive	Elapsed Recording Time (min.)	
	Midwater	On-Bottom
12	30	60
13	35	15
25	60	15
26	20	15
27	25	50
3	30	65
4	25	60



Pribilof Island closure and skate nursery area

From 23 May to 7 June 2006, RACE scientists conducted research to compare the effects of conventional and modified trawl sweeps on sessile invertebrates at four study sites on the EBS shelf. Included were sites 45 nm east of St. Paul Island (area B in the figure), which were primarily characterized by colonial ascidians (*Halocynthia*, *Boltenia* and *Styela*). At each site, experimental trawling created parallel tracks with the four types of gear being investigated. A seafloor sled outfitted with both a Didson imaging sonar and video sensors was then towed across the tracks at several points to compare the condition of seafloor animals in areas affected by these different gears. The imagery from these sensors has not been analyzed, but will be used to estimate the relative effects of the different sweep designs on the structure-forming invertebrates.

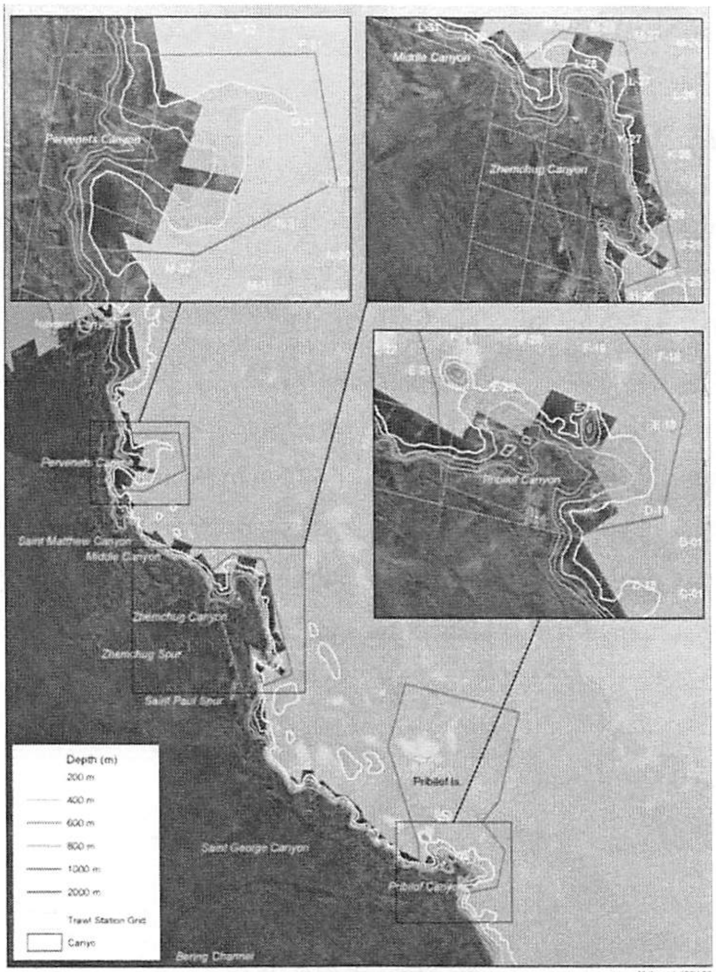
One of the EBS skate nursery areas was also examined with the sled, and very high densities of skate egg cases were observed, confirming prior trawl observations and also providing finer-scale distribution information.



External Data Sources

U.S. Geological Survey – GLORIA mapping

The U.S. Geological Survey conducted a 1986-1987 survey of the Bering Sea, as part of a national program to map the U.S. EEZ. The survey encompassed all of the Aleutian Basin and Bowers Basin deeper than 200 m that is east of the U.S. – U.S.S.R. Convention Line of 1867. This coverage includes many of the canyons located along the shelf margin. The primary mapping tool was GLORIA, a 6.5 kHz long-range sidescan sonar producing digital backscatter data with each pixel representing ~125 m by 45 m of seabed. Additionally, bathymetry data and both acoustic and air-gun seismic reflection data were collected over 40,000 line km of geophysical transects. An atlas summarizing data from this effort is included in the section "Pertinent Scientific and Technical References".



USGS Gloria Sonar Imagery: Bering Sea AFSC Trawl Stations near canyons

OCSEAP Data

NOAA initiated the Outer Continental Shelf Environmental Assessment (OCSEAP) program in 1975, at the request of the Bureau of Land Management. Its purpose was to assess the environmental impact of outer continental shelf oil and gas development in designated large environmental regions or lease areas in Alaska. These areas include the three Bering Sea canyons. Hundreds of biological, chemical, physical and geological/geophysical studies were conducted, many of them in the EBS. A large number of documents including bibliographies[11] and data inventories[12] exist to facilitate identification of studies and data applicable to review of

[11] Anonymous. 1981. Environmental assessment of the Alaskan continental shelf – comprehensive bibliography. Office of Marine Pollution Assessment, National Oceanic and Atmospheric Administration, Washington, D.C. Distributed by the U.S. Government Printing Office, Washington, D.C. 177 pp.

[12] Anonymous. 1979. NODC catalog of OCSEAP data. Part 2. Inventory of digital data by lease area for the Alaska Outer Continental Shelf Environmental Assessment Program. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Information Service.iv + 84 pp.

the Proposal. Hood and Calder (1981)[13], for example, produced a two-volume publication based on a 1979 OCSEAP-sponsored symposium held to review and evaluate the available data for the EBS. Formatted digital data, referenced to the original OCSEAP research study by the Research Unit (RU) number, are archived by NOAA at the National Oceanographic Data Center (NODC) and the National Geophysical Data Center (NGDC).

Summary and Recommendations

The EFH mandate, in very simple terms, is intended to identify, conserve and enhance "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity".

Skate populations are characterized by low fecundity and slow growth rates, suggesting a bottleneck during early life history stages. As such, areas supporting large numbers of egg cases are extremely important and warrant special consideration. This is especially true in this case given evidence of extended embryonic development (> 3 years) and expected vulnerability of egg cases to removal or disturbance by bottom fishing activity. It is admittedly unknown how many of these nursery areas exist in the EBS. Nevertheless, it seems prudent to consider protecting these nursery areas until such time as the extent of their contribution to the skate populations in the EBS (and perhaps elsewhere) is better understood. Such protective action would fall squarely within the scope of the EFH mandate. Furthermore, the aggregate size of the six closures is quite small suggesting impacts on other fisheries would be minor.

Submarine canyons are significant geological features that cut the continental slope and function as conduits for organic and inorganic matter moving between deep basins and the continental shelf.[14,15] The resulting fluxes can support diverse communities with high biomass, as compared to non-canyon regions at similar depths. Canyons are rare habitats, occupying <4% of the world sea floor and commonly contain unique species assemblages.

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[13] Hood, D.W. and J.A. Calder (eds.). 1981. The eastern Bering Sea shelf: oceanography and resources. Volumes I and II. Office of Marine Pollution Assessment, National Oceanic and Atmospheric Administration, Washington, D.C. Distributed by University of Washington Press, Seattle, WA. xviii + 1339 p.

[14] Glover, A.G. and C.R. Smith. 2003. The deep-sea floor ecosystem: current status and prospects of anthropogenic change by the year 2025. Environmental Conservation 30(3): 219-241.

[15] Vetter, E.W. and P.K. Dayton. 1998. Macrofaunal communities within and adjacent to a detritus rich submarine canyon system. Deep-Sea Research II 45: 25-54.

There are at least 15 distinct canyon systems along the EBS continental shelf, including the three largest submarine canyons in the world.[16] Zhemchug is the largest of these; each of its two main branches is larger than typical continental shelf canyons (e.g. Monterey). Pervenets and Pribilof Canyon are substantially smaller. Two of these canyons (Middle, St. Matthew) were discovered as recently as 1982.[17]

Despite rather extensive geological studies of submarine canyons in the EBS, very little biological information is available to assess the value of canyon habitat. Although these canyons, including the three evaluated in this paper, are likely to be important at the ecosystem level, the EFH guideline is much more restrictive and a direct link to commercial fish production has not been established. Unfortunately, fisheries research is limited to two AFSC studies in the upper head of a single canyon. These studies indicate the presence of commercially important groundfish and crabs, characterize different benthic habitats, and describe some common fish-habitat associations (Brodeur 2001; Busby *et al.* 2005). One of these associations is between mature rockfish and sea whips, which provide vertical structure in an otherwise featureless area. A third study suggests that sea whips grow slowly with 50 yr longevity (Wilson *et al.* (2002), and it has been argued that rockfish populations could be negatively affected if sea whips are disturbed by fishing (Brodeur 2001). Although insightful for the areas and times sampled, these studies provide no information about the biology and habitat characteristics found in the majority of this canyon system. Taken together, the information from these three studies do not support any proposals for closures based on the existence of unique and/or essential habitat, nor do they make the case for inordinately sensitive habitat in need of immediate protection. Clearly, additional research is required to evaluate the significance of habitat in the proposed canyon areas. A detailed analysis using other data sources identified in this document would likely address the deficiencies at depth and in other canyons and thereby improve an analysis based on existing data.

Ultimately, a thorough assessment of EBS canyon habitats will require a dedicated study. Although it is relatively straightforward to designate EFH in areas with obvious and significant ecological value, such as the skate nursery sites, it is much more difficult to judge habitat quality and discern true habitat dependencies based solely on patterns of biological abundance. This

[16] Normark, W.R and P.R. Carlson. 2003. Giant submarine canyons: is size any clue to their importance in the rock record? Geological Society of America Special Paper 370. 15 p.
[17] Carlson, P.R. J.M. Fischer, and H.A. Karl. 1983. Two newly discovered submarine canyons on Alaskan continental margin of Bering Sea. U.S. Geological Survey Open-File Report 83-24. 37 pp + 1 plate.

requires a systematic survey of habitats and coordinated biological sampling over *the full range* of a species' abundance. Having done this, the relative importance of different habitat characteristics can be compared and the essential elements identified. Management decisions can then be made based on the expected vulnerability of these habitats to anthropogenic disturbance.

Pertinent Scientific and Technical References

Baldauf, J.G. 1984. Diatom analysis of surface samples recovered from Pervenets Canyon. *In* Carlson, P.R. and H.A. Karl, eds., Surface and near-surface geology, Navarin Basin province; results of the 1980-81 field seasons: U.S. Geological Survey Open-File Report 84-0089, p. 100-112.

Belykh, I.N., S.L. Klemperer, D.W. Scholl, J.R. Childs and H. Gnibidenko. 1995. New deep seismic profiles across the Bering Sea shelf margin, EOS, Transactions, American Geophysical Union, 76(46 suppl.): 590.

Abstract. As part of the NSF-CD Bering Shelf-Chukchi Sea continental transect, in 1994 we recorded two crustal (17 s) marine seismic- reflection profiles across the Beringian margin. One profile runs from the Navarin Basin across the shelf edge at St. Matthew Canyon; the other crosses the shelf edge near Zhemchug Canyon and the epicenter of a 1991 Ms=6.8 earthquake. Although a tilted sedimentary basin sequence is seen in this area, no clear fault-plane reflections are visible. On both profiles the top of oceanic crust can be seen at 8 s travel-time beneath about 4 s of Tertiary sediments of the Aleutian Basin. Oceanic crust and Moho can only reliably be traced beneath the smooth sedimentary pile of the basin to the foot of the rough slope on our (currently) unmigrated profiles. On the Zhemchug Canyon profile, NE-dipping reflections can be traced from the top of oceanic crust near the base of the slope to > 12 s, probably equivalent to reflections identified by Marlow & Cooper (1985) as possibly representing the too of oceanic crust subducted into an early Tertiary trench. Complex layered reflections at 12 s at or beneath the base of oceanic crust are also present in this area. Reflection Moho is intermittently visible beneath the outer Bering Shelf at 10 to 12 s (30 to 38 km?) beneath 1 to 2 s carapace sedimentary deposits, but shallows to <10 s, thinning significantly to c. 10 km basement thickness beneath the >6 s (c. 10 km) Navarin Basin.

Bering Sea EEZ-SCAN Scientific Staff. 1991. Atlas of the U.S. Exclusive Economic Zone, Bering Sea. U.S. Geological Survey, Miscellaneous Investigations Series I-2053. 145 pp.

Summary. This atlas compiles results from a 1986-1987 survey of the Bering Sea by the U.S. Geological Survey as part of a national program to map the U.S. EEZ. The survey encompassed all of the Aleutian Basin and Bowers Basin deeper than 200 m that is east of the U.S. – U.S.S.R. Convention Line of 1867. This coverage includes canyons located along the shelf margin. The primary mapping tool was GLORIA, a 6.5 kHz long-range sidescan sonar producing digital backscatter data with each pixel representing ~125 m by 45 m of seabed. Additionally, bathymetry data and both acoustic and air-gun seismic reflection data were collected over 40,000 line km of geophysical transects. Data summaries in the atlas consist of (1) sonar imagery mosaics with geologic interpretations and bathymetry, and (2) seismic reflection, magnetic, and gravity profiles.

Blueford, J. R. 1983. Distribution of Quaternary Radiolaria in the Navarin Basin geologic province, Bering Sea. Deep-Sea Research. 30(7A): 763-781.

Abstract. Radiolarians from the surface sediments of the Navarin Basin geologic province in the western part of the Bering Sea are more diverse and abundant than previous reports indicate. The shelf is dominated by two spongy radiolarian species groups (Stylochlamydium venustum and Spongotrochus glacialis groups), while the slope has more diversity. The distributions can in part, be explained by present oceanographic conditions. Studies of five cores along the slope show that there is a faunal change within the top 5 m of sediment. The spongy radiolarians are more abundant in recent sediments but gradually decrease downcore as Cycladophora davisiana becomes the dominant species, which probably reflects an environmental change. The disappearance of Lychnocanoma grande in the area occurred around 17,000 to 34,000 y BP, but more research is needed to confirm whether the extinction is a useful biostratigraphic marker.

Blunt, D.J., and K.A. Kvenvolden. 1984. Aspartic acid geochronology of mollusks. *In* Carlson, P.R. and H.A. Karl, eds., Surface and near-surface geology, Navarin Basin province; results of the 1980-81 field seasons: U.S. Geological Survey Open-File Report 84-0089, p. 113-118.

Brodeur, R.D. 2001. Habitat-specific distribution of Pacific ocean perch (*Sebastes alutus*) in Pribilof Canyon, Bering Sea. Continental Shelf Research 21(3): 207-224.

Abstract. Shelf edge canyons are well-known sites of enhanced biomass due to on-shore transport and concentration of zooplankton along their axes, both of which contribute to the high densities of nekton frequently found in these canyons. Using a combination of acoustics, trawling, and in situ observations with a remotely operated vehicle (ROV), the distribution of pelagic and demersal biota within Pribilof Canyon in the Bering Sea was examined in September of 1995 and 1997. Near-bottom acoustic scattering patterns in the 38 kHz data showed high concentrations of biomass beginning around the 180m bottom depth contour and continuing to about 220m, which were presumed to be adult fish based on their target strength distributions. The 120 kHz data also showed very strong scattering in the water column between 150 and 175 m, which was absent from the 38 kHz data, and therefore attributed mainly to zooplankton. The dominant taxa collected in bottom trawls and mid-water plankton tows were adult rockfishes (Pacific ocean perch, *Sebastes alutus*) and euphausiids (*Thysanoessa* spp.), respectively. In situ videos revealed dense aggregations of these rockfishes inhabiting a ``forest" of attached sea whips, *Halipteris willemoesi*, during night deployments of the ROV, while areas with damaged sea whips had far fewer rockfish, and areas without this biotic habitat structure had no rockfish. During the day, the rockfishes were seen above the ``forest", where they were apparently feeding on dense swarms of euphausiids. It appears that these rockfish utilize this predictable and abundant food resource in the canyon during the day and are associated with the sea whip habitat at night during periods of inactivity. More research is needed on these slow-growing biotic habitats and how fishing activities in the Bering Sea and elsewhere may impact these habitats.

Busby, M.S., K.L. Mier and R.D. Brodeur. 2005. Habitat associations of demersal fishes and crabs in the
Pribilof Islands region of the Bering Sea. Fisheries Research 75: 15–28.

Abstract. Habitat associations of demersal fishes and crabs were determined from observations of videotapes recorded by a camera equipped remotely operated vehicle (ROV) in the Bering Sea near the Pribilof Islands in September 1995 and 1997.We identified 42 taxa

representing 16 families of fishes and 8 taxa from 3 families of crabs. Families Pleuronectidae (righteye flounders) and Cottidae (sculpins) were represented by the greatest number of taxa. *Lepidopsetta polyxystra* and *Chionoecetes opilio* were the most frequently observed fish and crab species. Other fish species in the families Pleuronectidae, Gadidae, Scorpaenidae, Agonidae, and Bathymasteridae were also encountered frequently. Six classifications based on substrate and cover were used to describe the habitat where each fish and crab was observed. Agonids and pleuronectids were typically observed on silt, mud, or sand substrate with no cover while other taxa, particularly cottids and bathymasterids, were encountered in more varieties of habitat including areas covered with rocks and boulders. Significant differences in species composition were found among habitats and stratified depth ranges. Similarity analyses showed that different taxa were responsible for these differences, but within each habitat type and depth range, two to five species contributed to 90% of the average similarity. Some ROV dives were paired with bottom trawls in the same general locations. Species compositions of the ROV observations were significantly correlated with that of the corresponding bottom trawl catch compositions. Overall, we believe that in situ observations provide useful information on fish habitats and behaviors not readily available from conventional trawling surveys.

Carlson, P.R., H.A. Karl and K.A. Johnson. 1981. Morphology, sedimentology, and genesis of three large submarine canyons adjacent to Navarin Basin, Bering Sea. American Association of Petroleum Geologists Bulletin, 65(5): 909-909.

Carlson, P.R., H.A. Karl and B.D. Edwards. 1982. Puzzling mass movement features in the Navarinsky Canyon head, Bering Sea. Geo-Marine Letters 2(3-4): 123-127.

Abstract. Two types of morphologic features in the head of Navarinsky Canyon are attributed to mass movement of near-surface sediment. A series of pull-aparts is located downslope of large sand waves. These pull-aparts, possibly induced by liquefaction, affect the upper 5 to 10 m of sandy sediment (water depths 350 to 600 m) on a 1° slope. A hummocky elongate mound of muddy sand (water depths 550 to 800 m) contains chaotic internal reflectors to a subbottom depth of 30 to 40 m and possibly is the product of a shallow slide. We speculate that Holocene seismicity is the likely triggering mechanism.

Carlson, P.R., H.A. Karl and P.J. Quinterno. 1982. Sedimentologic processes in world's largest submarine canyons, Bering Sea, Alaska. *In* Braunstein, Jules, and A.F. Thomson, chairperson, 95th annual meeting, The Geological Society of America: Geological Society of America Abstracts with Programs, 14(7): 459-460.

Carlson, P.R., J.M. Fischer and H.A. Karl. 1983. Two newly discovered submarine canyons on the Alaskan continental margin of Bering Sea. U.S. Geological Survey Open-File Report 83-0024, 38 pp.

Carlson, P.R. and H.A. Karl. 1984. Discovery of two new large submarine canyons in the Bering Sea. Marine Geology 56(1-4): 59-179.

Abstract: The Beringian continental margin is incised by some of the world's largest submarine canyons. Two newly discovered canyons, St. Matthew and Middle, are hereby added to the roster of Bering Sea canyons. Although these canyons are smaller and not cut back into the Bering shelf like the five very large canyons, they are nonetheless comparable in size to most of the canyons that have been cut into the U.S. eastern continental margin and much larger than the well-known southern California canyons. Both igneous and sedimentary

rocks of Eocene to Pliocene age have been dredged from the walls of St. Matthew and Middle Canyons as well as from the walls of several of the other Beringian margin canyons, thus suggesting a late Tertiary to Quaternary genesis of the canyons. We speculate that the ancestral Yukon and possibly Anadyr Rivers were instrumental in initiating the canyon-cutting processes, but that, due to restrictions imposed by island and subsea bedrock barriers, cutting of the two newly discovered canyons may have begun later and been slower than for the other five canyons.

Carlson, P.R., and H.A. Karl. 1984. Rates of sediment accumulation. *In* Carlson, P.R., and H.A. Karl, eds., Surface and near-surface geology, Navarin Basin province; results of the 1980-81 field seasons: U.S. Geological Survey Open-File Report 84-0089, p. 21-27.

Carlson, P.R., M. Golan-Bac, H.A. Karl and K.A. Kvenvolden. 1985. Seismic and geochemical evidence for shallow gas in sediment on Navarin continental margin, Bering Sea: American Association of Petroleum Geologists Bulletin 69(3): 422-436.

Abstract. Marine seismic studies coupled with geochemical investigations demonstrate that hydrocarbon gases are ubiquitous in the near-surface (less than or approximate to 250 m or 820 ft depth) sediment of the Navarin continental margin in the northern Bering Sea. Three types of acoustic anomalies appear to be related to the presence of gas in the sediment. These anomalies are most prevalent in the northern half of the Navarin Basin. Acoustic anomalies attributed to gas hydrates and to diagenetic boundaries are present on seismic records of the lower slope between Navarinsky and Zhemchug canyons.

Carlson, Paul R., and H.A. Karl. 1988. Development of large submarine canyons in the Bering Sea, indicated by morphologic, seismic, and sedimentologic characteristics. Geological Society of America Bulletin, 100(10): 1594-1615.

Abstract. Seven large submarine canyons cut the Beringian continental margin. Three of these are among the world's largest submarine canyons. Bering is 400 km long, Navarinsky and Zhemchug are each 100 km wide at the shelf break, and volumes of sediment removed from these three canyons range from 4,300 to 5,800 km super(3), an order of magnitude larger than any submarine canyons incised in the margin of the lower 48 states. Two major events set the stage for the development of the Beringian margin and the dissection of these canyons: (1) the jump of the subduction zone to the Aleutian trench in Late Cretaceous-early Tertiary time that changed the margin from active to passive and (2) the low stands of sea level during the Cenozoic glacial stages.

Carlson, Paul R., H.A. Karl and B.D. Edwards. 1991. Mass sediment failure and transport features revealed by acoustic techniques, Beringian margin, Bering Sea, Alaska. Marine Geotechnology, 10(1-2): 33-51.

Abstract: GLORIA sidescan sonar imagery and seismic-reflection profiles show pervasive evidence for a wide variety of slides and slumps associated with the large canyons of the 1400-km-long Beringian margin. Styles of failure include mud and debris flows, slumps, and massive block slides. A 100-km-long shelf-edge segment on the northern margin is characterized by a series of scalloped slide scars and incipient scars associated with sedimentary blocks, 1-2 km across, that seem to be the initiators of a series of small canyons. Some of the largest single slide masses, including huge blocks tens of kilometers wide, occur on the rise of the central margin. Sliding of these blocks may have initiated the incision of some of the world's largest submarine canyons, a prime example of which is the massive

Zhemchug Canyon. Mass movement along the southern margin is widespread at the edges of Umnak Plateau. One mass failure, particularly well defined by GLORIA, is 55 km long. This slide and others along the plateau are associated with diapiric-like structures indicative of relatively recent tectonism.

Carlson, P.R., H.A. Karl, B.D. Edwards, J.V. Gardner and R. Hall. 1993. Mass movement related to large submarine canyons along the Beringian margin, Alaska. *In* Schwab, W.C., H.J. Lee and D.C.Twichell, eds., Submarine landslides; selected studies in the U.S. Exclusive Economic Zone: U.S. Geological Survey Bulletin 2002, p. 104-116.

Edwards, B.D., and H.J. Lee. 1984. Summary of Navarin Basin geotechnical characteristics. *In* Carlson, P.R. and H.A. Karl, eds., Surface and near-surface geology, Navarin Basin province; results of the 1980-81 field seasons: U.S. Geological Survey Open-File Report 84-0089, p. 39-54.

Evsyukov, Y.D., and L.P. Volokitina. 1985. Main results of geomorphological studies in the Navarin Canyon area (the northwestern Bering Sea). Okeanologiya 25(2): 254-257. Moscow.

Abstract. On the basis of a 2000 mile echo-survey performed in the polygon of about 44,300 km super(2), during the 29th cruise of the R/V "Dmitrij Mendeleev" in 1982, bathymetric and geomorphological charts were constructed. The Navarin Canyon was found to be the main morphological element of the area. The shelf zone was characterized by a smooth relief. The continental slope was of a complicated structure due to erosive and tectonic processes.

Feder, H.M., R.H Day, S.C. Jewett, S.G. McGee and S.V. Schonberg. 1981. Analysis of van Veen grab samples collected during 1979 and 1980 in the northern Bering Sea and southeastern Chukchi Sea. NOAA/OMPA, BOULDER, CO (USA). NOAA/OMPA, BOULDER, CO (USA).

Abstract. The van Veen grab survey for the investigation of infaunal invertebrates was effective, and excellent spatial coverage of most of the study areas was obtained. To date 24 stations from the Navarin Basin lease area, 5 from the vicinity of the Hope Basin lease area, and 1 from the St. Matthew Basin lease area have been sorted and the organisms identified and quantified. Stations from the central Navarin Basin, were dominated by polychaetous annelids, especially maldanids, capitellids, cirratulids, and lumbrinerids. Mollusks were present but not abundant. The stations from the Chukchi Sea (Hope Basin area) appear to be considerably different from those further south in the Bering Sea (Navarin Basin area). In general, mollusks and amphipods were more prevalent in this area.

Field, M.E., P.R. Carlson, and R.K. Hall. 1983. Seismic facies of shelf edge deposits, U.S. Pacific continental margin. *In* Stanley, Daniel Jean and George T. Moore, eds., The shelf break; critical interface on continental margins: Society of Economic Paleontologists and Mineralogists Special Publication 33: 299-313.

Abstract: Pacific-style continental margins, such as that of western N America, are marked by large contrasts in the type of shelf edge sedimentary deposits and the processes that form them. Many of the sediment sources of the NW US and S Alaska feed directly onto swell- and storm-dominated shelves. On such narrow unprotected shelves, sediment has a short residence time in submarine deltaic deposits before being remobilized and dispersed to outer-shelf and upper-slope environments. Through study of high-resolution seismic-reflection profiles, we have identified four principal types of shelfedge deposits: 1) starved, 2) draped, 3) prograded, and 4) upbuilt and outbuilt. Each type of shelfedge deposit results from a characteristic balance between sedimentation rate and distributive energy (waves and currents) and is, therefore, characterized by distinctive seismic facies and bedding patterns.

Fischer, J.M., P.R. Carlson and H.A. Karl. 1982. Bathymetric map of Navarin Basin Province, northern Bering Sea. U.S. Geological Survey Open-File Report 82-1038. 11 pp.

Galloway, B. K., S.L. Klemperer and J.R. Childs. 1994. New seismic coverage of the continental crust and moho, Bering and Chukchi Seas Transect, Alaska. EOS, Transactions, American Geophysical Union 75 (44 suppl.): 642.

Abstract. Stanford University, in conjunction with the USGS, conducted deep seismic investigations of the continental crust beneath the Bering and Chuckchi Seas, Alaska, during the month of August, 1994. The data was recorded to two-way travel-times of 15 to 23 seconds, with 50 to 75 meter shot spacing. Two north-south transects were profiled. The eastern transect extended from 58d 50m N, 169d 32m W, well within the continental shelf of the Bering Sea, north of the Pribilof Islands, to just south of the shelf edge north of Barrow, Alaska, at 71d 49m N, 154d 33m W. Ice prevented continuation of the line beyond the shelf edge. The western transect extended from the central Chukchi Sea, within the shelf at 71d 30m N, 163d 00m W, into the Aleutian basin at 58d 00m N, 178d 30m W, near the Navarinsky Canyon. An additional short line crossing over the Beringian margin a second time was recorded near Zemchug Canyon east of the western transect. Constant-offset sections were plotted on board the ship during acquisition. These plots exhibit large differences in lower crustal reflectivity across the breadth of the continental crust. The profiles cross important strike-slip faults, possible terrane boundaries, two continental margins, and several Cretaceous/Tertiary sedimentary basins (Norton, Hope, Chuckchi, Navarin Basins). Together with the preceding cruise EW94-09, led by Sue McGeary, the profiles provide a continuous transect across the North American continent, from the Pacific to the Arctic Ocean. Most of the multi-channel seismic data is generally of high quality. Gravity, magnetic, and sonobuoy data were also recorded along the profiles. Wide-angle recording was done in conjunction with the seismic profiling, at recording sites located along the central west coast of Alaska and the Chukchi Peninsula, as well as on islands in the Bering Strait and Bering Sea.

Gardner J.V. and T.L Vallier. 1977. Areas of faulting and potentially unstable sediments in the St. George Basin Region, Southern Bering Sea. *In* Environmental assessment of the Alaskan continental shelf: Principal investigators' reports 17(hazards): 230-241.

Abstract. Preliminary analyses of seismic and sediment data collected during the 1976 field year in the St. George Basin region of the southern Bering Sea continental margin, indicate that the large submarine canyons in the region, the Pribilof and Bering Canyons, exert a profound influence on the sediment distribution and dynamics of the adjacent outer continental shelf region including St. George and Amak Basins. In addition data show that the upper continental slope and shelf break are areas of mass movement of sediment (creeping, slumping, and catastrophic movement as shown by steep scarps). The effects of the canyons on the distribution of sediment and the near-bottom dynamics must be known before man-made structures, whether they be offshore rigs, underwater completion systems, storage facilities, or pipelines, are placed in this area. An investigation of slumping along the continental margin should allow an estimate of the present rate of sediment flux over the outer continental shelf region and what it has been in the past. This study focuses on faulting and potential sediment instability by describing the types and distribution of faults and by outlining areas where potentially unstable sediment masses occur.

Gardner, J.V., H.A. Karl and Q. Huggett. 1986. Origin and development of Zhemchung Canyon (Bering Sea), adjacent continental margin, and abyssal plain as revealed by GLORIA (long-range side-scan sonar) and seismic data. EOS, Transactions, American Geophysical Union 67(44): 1229.

Kaplan I.R., W.E. Reed, M.W. Sandstrom and M.I. Venkatesan. 1977. Characterization of organic matter in sediments from Gulf of Alaska, Bering and Beaufort Seas. *In* Environmental assessment of the Alaskan continental shelf: Principal investigators' reports 13; contaminant baselines: p. 751-838.

Abstract. The paraffin fraction of the high molcular weight hydrocarbons have been identified from sediment samples from the Eastern Gulf of Alaska and the Eastern Bering Sea. In general it has been shown that: The concentrations of total hydrocarbons in surface sediments from both areas, with the exception of one sample near Pribilof Canyon, is low compared to recent marine sediments from other environments; the hydrocarbons in the sediments appear to be derived from a mixture of terrigenous and marine sources. In the Bering Sea, a terrigenous source predominates, while in the Gulf of Alaska, contribution from marine and terrigenous sources is approximately equal; a series of n-alkanes and unresolved hydrocarbons in the n-C21 to n-C23 molecular weight range occurs in some samples from the Bering Sea and many of the sediments of the Gulf of Alaska. The source of these hydrocarbons may be either from petroleum or from unidentified marine organisms; and sediments near the head of Pribilof Canyon appear to contain petroleum derived hydrocarbons. This is in contrast to most other samples of the Bering Sea which have no indications of petroleum addition. Several of the Gulf of Alaska sediments analyzed seem to indicate some petroleum contribution.

Karl, H.A., P.R. Carlson and D.A. Cacchione. 1981. Factors influencing sediment transport at shelf break. American Association of Petroleum Geologists Bulletin, 65(5): 943-943.

Karl, H.A., and P.R. Carlson. 1982. Location and description of sediment samples: Navarin Basin Province, Bering Sea, 1980-81. U.S. Geological Survey Open-File Report 82-0958. 6 pp.

Karl, H.A., and P.R. Carlson. 1982. Large sand waves in Navarinsky Canyon head, Bering Sea. Seafloor stability of continental margins research conference: Geo-Marine Letters 2(3-4): 157-162.

Karl, H.A., P.R. Carlson and David A. Cacchione. 1983. Factors that influence sediment transport at the shelfbreak. *In* Stanley, Daniel Jean and George T. Moore, eds., The shelfbreak; critical interface on continental margins: Society of Economic Paleontologists and Mineralogists Special Publication 33: 219-231.

Abstract: Because the shelf edge bridges shallow and deep ocean environments, sedimentary processes characteristic of each of these provinces interact at the shelfbreak to influence sediment transport in the benthic boundary layer. Sophisticated instruments deployed for long periods of time are necessary to acquire data adequate for an assessment of the forcing mechanisms that control sediment transport. The few existing measurements of this type support the concept that shelfedge processes differ with place and time among continental margins and on any given continental margin.

Karl, H.A., and P.R. Carlson. 1984. Geologic hazards. *In* Carlson, P.R. and H.A. Karl, eds., Surface and near-surface geology, Navarin Basin province; results of the 1980-81 field seasons. U.S. Geological Survey Open-File Report 84-0089, p. 11-14.

Karl, H.A. and P.R. Carlson. 1984. Textural variations of surficial bottom sediment. *In* Carlson, P.R., and H.A. Karl, eds., Surface and near-surface geology, Navarin Basin province; results of the 1980-81 field seasons: U.S. Geological Survey Open-File Report 84-0089, p. 15-20.

Karl, H.A., P.R. Carlson and K.H. Johnson. 1984. Sediment distribution on the outer continental margin of an epicontinental sea; Bering Sea, Alaska. *In* Society of Economic Paleontologists and Mineralogists first annual midyear meeting: Society For Sedimentary Geology Midyear Meeting Abstracts 1: 41-41.

Karl, H.A., D.A. Cacchione and P.R. Carlson. 1986. Internal-wave currents as a mechanism to account for large sand waves in Navarinsky Canyon head, Bering Sea. Journal of Sedimentary Petrology 56(5): 706-714.

Abstract. Sand waves average 5m in height and about 650m in wavelength, with crests oriented subparallel to isobaths and almost perpendicular to the axes of the 2 main branches of the canyon. Speculates that inter-wave currents are responsible for the sand waves. However, the sand waves could have originated in the Pleistocene when Navarinsky Canyon headed in a shallow embayment that was receiving large quantities of sediment discharged by glacial meltwater streams.

Karl, H.A., and P.R. Carlson. 1987. Surface current patterns suggested by suspended sediment distribution over the outer continental margin, Bering Sea. Marine Geology 74(3-4): 301-308.

Abstract. Samples of total suspended matter (TSM) were collected at the surface over the northern outer continental margin of the Bering Sea during the summers of 1980 and 1981. Volume concentrations of surface TSM averaged 0.6 and 1.1 mgl super(-1) for 1980 and 1981, respectively. Organic matter, largely plankton, made up about 65% of the near-surface TSM for both years. Distributions of TSM suggested that shelf circulation patterns were characterized either by meso- and large- scale eddies or by cross-shelf components of flow superimposed on a general northwesterly net drift. These patterns may be caused by large submarine canyons which dominate the physiography of this part of the Bering Sea continental margin.

Karl, H.A., P.R. Carlson, K.H. Johnson and D.M. Rearic. 1987. Grain-size parameters and constituent grain composition of surface sediment in Navarin Basin Province, Bering Sea. U.S. Geological Survey Open-File Report 87-0064, 26 pp.

Kotenev, B. N. 1964. Sea valleys in the continental slope of the Bering Sea. Pages 23-32 *in* P. A. Moiseev (ed.). Soviet fisheries investigations in the Northeast Pacific. Part IV. Sovetskie rybokhozyaistvennye issledovaniya v severo-vostochnoi chasti Tikhogo okeana. Translated from Russian by Israel Program for Scientific Translations, Jerusalem.

Summary. Geomorphology of the continental slope "seavalleys" of the Bering Sea is described, including the northwest continental slope, northeast continental slope (Navarin, Pervenets, Zhemchug, and Pribilof canyons), and Commander-Aleution slope regions. The large seavalleys of the northeast continental slope are 5-25 miles wide, 50-200 miles long, and begin at 100-150 m depth. The vertical transitions that mark the edges of the upper slope

become most dramatic at depths of 500-700 m. The author states that this zone represents a major demarcation that has a profound influence on water mass circulation and likely causes fronts. This characteristic of the upper slope also influences the success of trawling in these areas, as shallow as 300 m. Zhemchug and Pribilof seavalleys are described as being more complex than Navarin or Pervenets, with continental slope sections having "northwestern and sublatitudinal trends". All seavalleys of the northeast slope are troughlike in shape at their heads and resemble canyons in the middle part of the slope.

Kowalik, Z., and P. Stabeno. 1999. Trapped motion around the Pribilof Islands in the Bering Sea. Journal of Geophysical Research 104(C11): 25667-25684.

Abstract. Observations in the region of the Pribilof Islands and Canyon (PIC) reveal a clockwise circulation around the group of islands and around each of the two largest islands, St. Paul and St. George. Six current meters deployed around St. Paul Island revealed a steady clockwise flow around the island, which was strongest south of the island and weakest to the east. We use a high-resolution tidal model in the PIC region to show that this flow pattern results from tidal rectification over the shallow topography tides. Tidal residual currents of 10-15 cm s[-1] were predicted by the model, compared to mean currents of 5-20 cm s[-1] observed at the mooring sites. Both diurnal and semidiurnal tidal oscillations contribute to the clockwise circulation around the islands. In the diurnal band the enhanced currents occur also at the shelf slope where a tidal wave generates a shelf wave due to resonance with topography. In the PIC region the main shelf wave occurs in the Pribilof Canyon where both observations and measurements show enhancement of the diurnal tidal currents.

Lus, V. Y. 1970. Quantitative distribution of benthos on the continental slope of the eastern part of the Bering Sea. Pages 116-124 *in* P. A. Moiseev (ed.). Soviet fisheries investigations in the Northeast Pacific. Part V. Sovetskie rybokhozyaistvennye issledovaniya v severo-vostochnoi chasti Tikhogo okeana. Translated from Russian by Israel Program for Scientific Translations, Jerusalem.

Summary. As part of the USSR Bering Sea Expedition from 1958-60, benthic grab samples were collected across the continental slope. Samples were collected at 102 stations using 0.25 m2 grabs covering depths of 150 - 3045 m. Cruise transects were perpendicular to isobaths, placed at even along the eastern continental slope, with one additional transect extending north from Island of Four Mountains. Dominant taxa from all eastern slope stations combined (average biomass 27 g / m2) were from four groups: polychaetes (26 %), echinoderms (primarily ophiuroids), sponges (23 %), and mollusks (16 % mostly bivalves). The southern slope transect differed markedly from those on the eastern slope (average biomass 626 g / m2) and was primarily composed of sponges (84 %, 527 g / m2) and soft corals (12 %, 76 g / m2). Vertical zonation of overall biomass was observed, decreasing with increasing depth, on all transects. The northern transects contained a zone of high biomass at shallow depths, with the zone expanding and descending to deeper depths at southern transects. In certain transects, biomass was "markedly depleted" over extents as much as 1000 m.

McLean, H. 1979. Pribilof segment of the Bering Sea continental margin: A reinterpretation of Upper Cretaceous dredge samples. Geology 7(6): 307–310.

Abstract. Samples of an Upper Cretaceous sandstone dredged from Pribilof Canyon, Bering Shelf margin, do not compare well with rocks of the Shumagin Formation of presumed Late Cretaceous age on Sanak Island. Contrary to repeated published inferences, the rocks from Pribilof Canyon do not appear to be strongly deformed. They show no evidence of slaty

cleavage or penetrative deformation and were probably deposited in a shelf environment at neritic or possibly upper bathyal depth rather than in a trench or deep continental slope basin. The presence of shelf-facies rocks in Pribilof Canyon at the edge of the Bering Shelf leaves little room for a subduction-related accretionary terrane such as exists along the Shumagin shelf near Sanak Island. The concept of strongly folded deep-water trench-facies rocks in Pribilof Canyon has led to the development of Late Cretaceous subduction-related scenarios that include magmatic arcs parallel to the hypothetical subduction zone. Alternative hypotheses include a strike-slip plate boundary along the Pribilof segment of the Bering margin, which is consistent with the petrographic character of the Pribilof Canyon rocks, or a transitional trench-transform boundary–for example, the modern central to western Aleutian Trench.

Normark, W.R., and P.R. Carlson. 2003. Giant submarine canyons: Is size any clue to their importance in the rock record? Geological Society of America Special Paper 370. 16 pp.

Abstract. Submarine canyons are the most important conduits for funneling sediment from continents to oceans. Submarine canyons, however, are zones of sediment bypassing, and little sediment accumulates in the canyon until it ceases to be an active conduit. To understand the potential importance in the rock record of any given submarine canyon, it is necessary to understand sediment-transport processes in, as well as knowledge of, deep-sea turbidite and related deposits that moved through the canyons. There is no straightforward correlation between the final volume of the sedimentary deposits and size of the associated submarine canyons. Comparison of selected modern submarine canyons together with their deposits emphasizes the wide range of scale differences between canyons and their impact on the rock record. Three of the largest submarine canyons in the world are incised into the Beringian (North American) margin of the Bering Sea. Zhemchug Canyon has the largest cross-section at the shelf break and greatest volume of incision of slope and shelf. The Bering Canyon, which is farther south in the Bering Sea, is first in length and total area. In contrast, the largest submarine fans—e.g., Bengal, Indus, and Amazon—have substantially smaller, delta-front submarine canyons that feed them; their submarine drainage areas are one-third to less than one-tenth the area of Bering Canyon. Some very large deep-sea channels and turbidite deposits are not even associated with a significant submarine canyon; examples include Horizon Channel in the northeast Pacific and Laurentian Fan Valley in the North Atlantic. Available data suggest that the size of turbidity currents (as determined by volume of sediment transported to the basins) is also not a reliable indicator of submarine canyon size.

Palacios, R. 1987. Community structure of the macro epifauna of the Pribilof Islands. Ph.D. Dissertation, University of Washington, School of Fisheries, Seattle, WA. 112 p.

Abstract. The macrobenthos of the Pribilof Islands was surveyed on three cruises of the R/V MILLER FREEMAN in May and August 1983 and April 1984. Information on the dominant species as numbers per hectare was used to perform cluster analyses to investigate the community structure. Using the Bray-Curtis coefficient and flexible sorting strategy (B = -0.5) 3 groups of stations were defined throughout the cruises. Cluster Group 1composed stations located nearshore, around St. Paul Island and east of St. George Island. Characteristics of these stations were rocky bottoms with large deposits of shellhash. Dominant species included sea urchins (*Strongylocentrotus droebachiensis*), several bivalves (*Chlamysl* sp., *Pododesmus macrochisma*, and Mytillid mussels), the gastropod *Fusitriton oregonensis*, starfish *Henricia* sp., sea cucumber *Cucumaria* sp., barnacles, hermit crab *Elassochirus cavimanus*, *Cancer oregonensis* crab and juvenile blue king crab (*Paralithodes platypus*). Stations in Cluster Group 3 were found in the basin between the two main islands over sand-mud bottoms. Dominant species were Tanner crab (*Chionoecetes* sp.)hermit crabs (*Labidochirus splendescens* and *Pagurus ochotensis*), adult blue king crab (*P. platypus*), gastropods of the genus *Neptunea* sp. and the flatfishes *Lepidopseta bilineata* and *Hippoglossoides elassodon*. Stations in Cluster Group 2 were intermediate between the other two groups both in their geographic location, substrate characteristics, and dominant species.

Reed, R.K. 1991. Circulation and Water Properties in the Central Bering Sea During OCSEAP Studies, Fall 1989-Fall 1990. NOAA Technical Report ERL 446.

Abstract. Data from three CTD surveys conducted during Outer Continental Shelf Environmental Assessment Program (OCSEAP) cruises in the central Bering Sea during fall 1989, spring 1990, and fall 1990 are used to examine circulation and property distributions. Geostrophic flow was quite variable, except in Pribilof and Zemchug Canyons where it was consistently westward. The variability of flow and small transports are difficult to reconcile with any permanent current system. The relatively cold temperatures near the temperature maximum suggest the absence of inflow through Amukta Pass near 172 degree W. The distributions of nutrients in fall 1989 and spring 1990 are also presented and discussed.

Schumacher, J. D. and R. K. Reed. 1992. Characteristics of currents over the continental slope of the eastern Bering Sea. Journal of Geophysical Research- C Oceans 97(6): 9423-9433.

Abstract. Between September 1989 and 1990, twenty-six current records were collected by instruments on eight moorings located in Pribilof and Zhemchug canyons, and at a site midway between these features. These records provide the first long-term Eulerian measurements from the slope and mid-slope of the eastern Bering Sea. Results from the current records, together with water property observations, permit a characterization of the Bering Slope Current. Moderate flow (similar to 2 to 18 cm/s) followed the bathymetry toward the northwest and existed primarily in the upper 300 m. Wind and current energy increased in winter, but vector mean current did not increase at all sites. Wind forcing accounted for only a small fraction of the current fluctuations. At one mid-slope location in Pribilof Canyon, bathymetry resulted in rectification of the strong daily tidal current. Estimates of heat and salt fluxes indicate some significant shoreward transport; however, this flux did not occur preferentially in the canyons.

Starratt, S. W. 1993. Late Quaternary paleoceanography of the Pervenets Canyon area of the Bering Sea: evidence from the diatom flora. Diatom Research 8(1): 159-170.

Abstract. Sediments from three gravity cores from an east-west shelf-to-slope transect along the axis of Pervenets Canyon in the northern Navarin basin, Bering Sea were analyzed for diatoms. The diatom floras present in the cores were divided into four assemblages following Sancetta (1981). The Bering Basin (deep water open ocean) and Sea Ice (ice cover at least six months per year) Assemblages were dominant in each core. The taxa that comprise the Bering Shelf Assemblage (continental shelf) indicate that downslope transport plays only a minor part in the development of the thanatocenoses. The presence (up to 10% of the total valve count) of the Productivity Assemblage, which consists mainly of poorly silicified, easily dissolved taxa, indicates that nutrient flux is relatively high in the region

Starratt, S. W. 1995. Latest Quaternary foraminifers and sediment transport in Pervenets Canyon, Bering Sea. Marine Micropaleontology 26(1-4): 233-243.

Abstract. A combination of microfossil and sediment analysis has been used in an attempt to

understand oceanographic processes and the late Quaternary history of the Pervenets Canyon region. The primary sedimentation process in Pervenets Canyon is downslope transport. Near the shelfbreak, there is evidence of turbidite and debris-flow activity, but at the distal end of the upper canyon and on the continental slope there is nomacroscopic evidence for these processes. Analysis of the foraminiferal assemblages shows that the fauna is 97.6% from the Suborder Rotaliina and about 2.0% from the Suborder Textulariina. The Suborder Miliolina accounts for approximately 0.4% of the fauna. The Pervenets Canyon fauna is most similar to other faunas from the Bering Sea, indicating a North Pacific Ocean influence on the fauna. Foraminiferal abundance and species diversity vary widely in the samples studied. The major factors controlling these values are downslope transport of sediment, disintegration of arenaceous taxa, dissolution of calcareous taxa, and diversity limited by low-oxygen bottom waters. Downslope transport of shelf species is indicated by the presence of Elphidium clavatum and E. Excavatum. Shallow-shelf and low-oxygen foraminiferal faunas are often intermixed in the samples. The distribution of these low-oxygen faunas in Core 81-65 suggests that the oxygen-minimum zone fluctuated with sea level.

Shin, K.-H., and N. Tanaka. 2004. Distribution of dissolved organic matter in the eastern Bering Sea, Chukchi Sea (Barrow Canyon) and Beaufort Sea. Geophysical Research Letters 31(24).

Abstract. The distribution of dissolved organic carbon (DOC) in the western Arctic Ocean is greatly influenced by conservative riverine DOC flux into the northern Bering Sea, Bering Strait and Beaufort Sea, as indicated by an inverse correlation with salinity. Based on the relations between DOC, salinity and seawater temperature, several water masses could be identified. These included riverine water, ice-melt water, surface mixed water, cold and saline shelf water, and Atlantic Ocean water. High concentrations of chlorophyll *a* and DOC were found in some parcels of dense shelf water in Barrow Canyon. In addition, labile DOC compounds, such as polyunsaturated fatty acids (PUFA), were found in the dense shelf water, suggesting the dense shelf water contains a product (marine organic matter) of the biological CO_2 pump.

Swartzman, G., J. Napp, R. Brodeur, A. Winter, and L. Ciannelli. 2002. Spatial patterns of pollock and zooplankton distribution in the Pribilof Islands, Alaska nursery area and their relationship to pollock recruitment. ICES Journal of Marine Science 59(6): 1167-1186.

Abstract. Data from six years, September 1994-1999, of bio-acoustic surveys near the Pribilof Islands, Alaska, (AK), from which age-0 walleye pollock (Theragra chalcogramma) school and zooplankton patch locations have been extracted, were analysed using image-processing methods. Multiple passes along four transects in this major pollock nursery area were examined. The data showed high year-to-year variability in overall abundance of both fish and plankton, but consistent abundance differences between the transects. Juvenile pollock abundance was generally highest in the shallow shelf region to the north of the Pribilof Islands and lowest in the mouth of the Pribilof Canyon to the south. Plankton biomass patterns tended to be the reverse. Fronts and regions within the transects were identified based on changes in hydrography (e.g. vertical stratification) and bathymetry. Diel migration patterns of pollock and zooplankton within these regions appear to depend on the degree of stratification, the depth, the size of the pollock and the relative abundance of the pollock and zooplankton. Several hypotheses are also discussed concerning the relationship of pollock recruitment year-class strength to large year classes including differences in the environmental conditions, the pervasiveness of the pollock, the size of juvenile pollock and the density of predators.

Wilson, M.T., A.H. Andrews, A.L. Brown and E.E. Cordes. 2002. Axial rod growth and age estimation of the sea pen, *Halipteris willemoesi* Kölliker. Hydrobiologia 471: 133–142.

Abstract. *Halipteris willemoesi* is a large octocoral commonly found in the Bering Sea. It is a member of a ubiquitous group of benthic cnidarians called sea pens (Octocorallia: Pennatulacea). Sea pens have a skeletal structure, the axial rod, that in cross section exhibits growth rings. Pairs of adjacent rings, or ring couplets, were assumed to be annuli and were used to estimate the age and growth of *H. willemoesi*. Twelve axial rods, extracted from *H. willemoesi* collected in the Bering Sea, were selected to represent small (25–29 cm total length), medium (97–130 cm TL) and large (152–167 cm TL) colonies. Each rod resembled a tapered dowel; the thickest part (0.90–6.75 mm in diameter) was at about 5–10% of total length from the base tip, the distal part was more gradually tapered than was the base. The number of ring couplets increased with rod size indicating their utility in estimating age and growth. Estimated age among rods was based on couplet counts at the thickest part of each rod; the average estimated age (±SE) was 7.1 ±0.7, 19.3 ±0.5, and 44.3 ±2.0 yr for small, medium and large-size rods, respectively. Based on these estimated ages, average growth rate in total length was 3.9 ± 0.2, 6.1 ± 0.3, and 3.6 ± 0.1 cm yr−1 for small, medium, and large-size colonies. The average annual increase in maximum rod diameter among all colonies was 0.145 ± 0.003 SE mm yr−1; therefore, age prediction from maximum rod diameter was calculated (estimated age (yr) = 7.0 * (maximum rod diameter, mm) −0.2; *R*2 = 0.99). At maximum diameter, the average couplet width was relatively constant among the three colony sizes (0.072 ± 0.05 mm). X-ray diffraction and electron microprobe analyses revealed that the inorganic portion of the rod is composed of a high-magnesium calcite. Radiometric validation of these age and growth rate estimates was attempted, but high amounts of exogenous 210Pb precluded using the disequilibria of 210Pb:226Ra. Instead, 210Pb activities were measured in a series of cores extracted along the axial rod. These activities ranged from 0.691 ± 0.036 (SE) to 2.76 ± 0.13 dpm g−1, but there was no pattern of decay along the length of the rod; therefore, the growth rates and corresponding ages could not be validated. Based on estimated age from ring couplet counts, growth in total rod length is slow at first, fastest at medium size, and slows toward maximum size, with an estimated longevity approaching 50 yr.

Contributors

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Appendices attached as follows:

Appendix 1 – Skate Nurseries
Appendix 2 – Brodeur (2001)
Appendix 3 – Wilson *et al.* (2002)
Appendix 4 – Busby *et al.* (2005)

NORTH PACIFIC RESEARCH BOARD PROJECT FINAL REPORT

Investigations of a Skate Nursery Area in the Eastern Bering Sea

NPRB Project 415 Final Report

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ABSTRACT

The dynamics of a nursery area for the Alaska skate was investigated in the southeastern Bering Sea. The nursery is located in 149 meters of water near the shelf-slope interface in a highly productive area of the eastern Bering Sea. The nursery is small in area (>2 nm), persistent, and highly productive. Density estimates from trawling showed the most active part of the nursery contained >100,000 eggs/km^2 Seasonal sampling suggested that reproduction occurs throughout the year but peaks occurred during spring and summer months. Hatching events likewise were throughout the year but peaked in fall and winter months. Embryo development was slow taking >3.5 years from deposition to hatching. The developing embryos and newly hatched juveniles suffered natural mortality due to gastropod snails and piscivory by the Pacific cod and the Pacific halibut. The Oregon trition *Fusitrion oregonensis* was the most likely predator on newly deposited egg cases and mortality was estimated at 3.64%. The nursery is located in a highly fished area and vulnerable to disturbances due to continuous use of the nursery grounds by skates throughout the year.

Predation → indicates species present?
Interference?

Remember – is in <u>this</u> area only

KEY WORDS

Skate, *Bathyraja parmifera*, nursery, skate reproduction, eastern Bering Sea, skate egg case

INTRODUCTION

Skate species (Family Rajidae) are of growing concern worldwide as they are threatened by increased fishing or habitat disturbances (Musick et al. 2000a, 2000b, Stevens et al. 2000, Jennings et al. 1998). In general they are characterized as slow-growing, late maturing, long-lived, and have small brood size (Jennings et al. 1998, Musick et al. 2000a, 2000b, Dulvy 2000, Stevens et al. 2000, Frisk et al. 2002). Elasmobranch life history strategies are unlike many teleost fishes and complete understanding of habitat requirements and reproduction dynamics are lacking for most species, yet they may be the most critical aspects of population survival and success.

Most elasmobranchs are known to utilize dedicated nursery grounds as a critical part of their reproductive strategy. For many viviparous sharks and rays nursery grounds become pupping areas where live young are birthed in mass. skate nurseries are used as areas for egg deposition and embryo development.

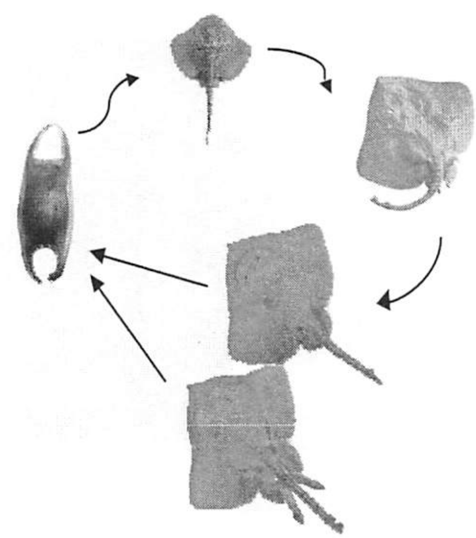

Figure 1. Life history stages of the Alaska Skate *Bathyraja parmifera*. Gray area represents amount of time spent in the nursery. Clockwise: egg case, newly hatched juvenile, sub-adult, adult female and male.

Skates are oviparous species that produce relatively large chitinous egg cases that are deposited directly onto the sea floor. In general the case contains a single embryo that develops independent of maternal input and hatches fully developed appearing similar to adults. The embryo developmental period is poorly known for most species of skate s but evidence suggests periods >1 year are not uncommon in temperate and deepwater species (Berestovskii 1994). Reproductive cycles and annual fecundity are likewise poorly known for many species. Those that have been studied show low production (<100) of estimated annual offspring and protracted reproductive cycles that vary in length and timing. Species show reproductive cycles of semi-annual, annual, or continuous reproduction throughout the year (Sulikowski et al 2004, Templeman 1982). Combining the reproductive cycles with long developmental periods for the embryos suggests that nurseries are in continuous use throughout the year and an important habitat for successful reproduction. Reproductive adults and offspring are two of the most critical life stages dictating successful skate populations (Simpfendorfer 2004, Stevens et. al. 2000). Understanding the dynamics of skate reproduction and nursery habitat is essential for successful management and conservation for skates.

For eastern Bering Sea shelf waters (20-200 m) the Alaska skate *Bathyraja parmifera* comprises >95% of the abundance of skate species (Acuna and Kotwicki 2004). All life stages are encountered in the shelf environment and the species depth range is limited to approximately 20-400 m. The species reaches a large size (122 cm) and locally can be very abundant (Hoff & Britt 2003, 2005). Life history characteristics and their accessibility in relatively shallow waters make the Alaska skate vulnerable to as a targeted fishery or as bycatch.

OBJECTIVES

This proposal addressed the hypothesis that there exists a distinct nursery habitat in a heavily fished area of the southeastern Bering Sea that could be characterized and defined using trawl and video camera. The main objectives of this project were: to determine the species utilizing the habitat; determine the timing of egg deposition; track the development and hatching time of cohorts; and determine mortality sources to young skate s in the nursery.

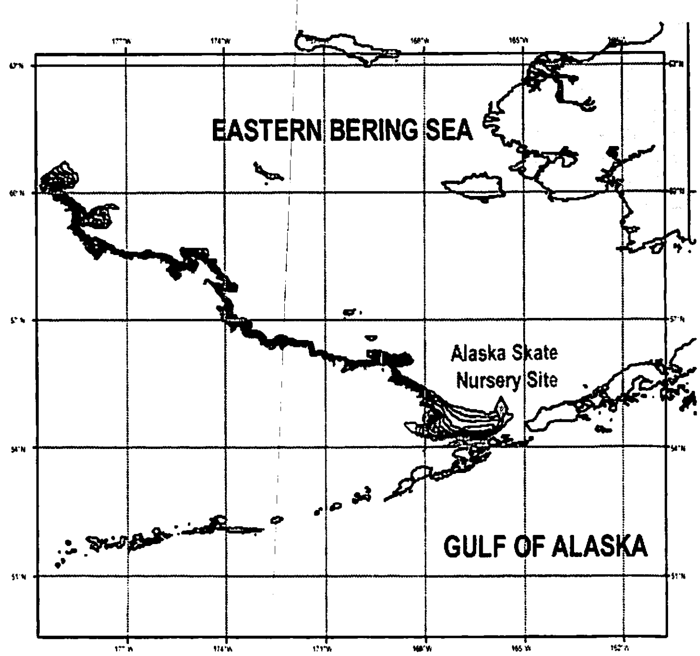

Figure 1. Location of the study area and nursery site for the Alaska skate in the eastern Bering Sea.

Achievements of Objectives

The initial hypothesis was supported in that a nursery site for the Alaska skate exists and persists in the southeastern Bering Sea (Figure 1) and was successfully studied using bottom trawl and seasonal sampling to determine timing and seasonality processes of reproduction. The preliminary results and conclusions of this study are reported here. Much more data was collected during the course of this study and will be reported in manuscripts to be submitted for publication. These will be made available as they are prepared.

Nursery sites for the Alaska skate *Bathyraja parmifera*, the Aleutian skate, *B. aleutica*, and the Bering skate, *B. interrupta* were found during this study. Although three nursery sites were investigated only the results for the Alaska skate are reported here due to a more complete understanding of the reproduction processes and timing resulting from an increased effort at this study site. One aspect of the original objective that was not met during this study was using video cameras to assess the nursery habitat. This was attempted during the summer of 2004 but due to video camera failure, increased cost of vessel charter time which limited survey time, video recording was not successful. Recent developments may allow me to successfully obtain video footage of this nursery in the near future and if successful, will be incorporated into subsequent reports from this study.

METHODS

Initial Investigation

The Alaska skate nursery site was sampled using bottom trawl gear similar to that used by the AFSC standard eastern Bering Sea bottom trawl survey (see Acuna and Kotwicki 2004). The initial trawl survey for this study was conducted in July-August of 2004 employing the *F/V Ocean Explorer*. During this investigation the extent and spatial density of egg cases was determined utilizing an adaptive sampling trawling approach. An index site was chosen during the initial investigation which was sampled subsequently during each seasonal sampling period. The criteria used to select the index site included an area of high density live skate eggs in early stage of development and constituted a circle of approximately 1 km^2 over the highest density area. The nursery index site was then sampled over the next 14 months at a rate of approximately once every 60 days (Figure 2). The sampling dates and associated designated Julian calendar dates are presented in Table 1.

Table 1. Sampling dates and associated Julian Date assignments for each sample at the index site at the Alaska skate nursery.

Sampling Period	Julian Date
June 3 2004	155
July 27 2004	209
September 11 2004	255
November 17 2004	322
January 16 2005	382
April 18 2005	474
June 1 2005	519
July 7 2005	554

Haul Data

Haul data was collected from each tow using Scanmar net mensuration gear from the bridge and attached to the trawl net. During each tow starting and ending latitude, longitude, bottom depth, time, vessel speed, net height and width, and bottom temperatures were recorded. Area swept was estimated from average net width and distance fished during each tow. Egg case and fish and invertebrate densities were calculated from area swept estimate and the estimated numbers from each trawl.

Species Composition

Species composition of the sample catches was collected from each trawl. All species were weighed and enumerated or a weighed numerical subsample was used to estimate total numbers from weighed samples. All species of fish and invertebrate were identified to the lowest taxonomic level possible by the onboard fish and invertebrate taxonomist during the July 2004 sampling. At all subsequent sampling all fish and only selected invertebrates were identified to species due to time limitations. Species diversity estimates were calculated from the July 2004

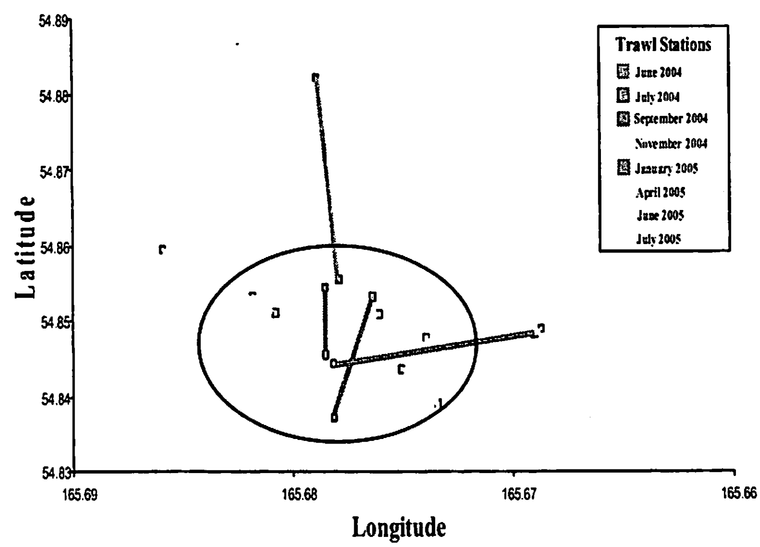

Figure 2. Index site trawl locations conducted in the Alaska Skate nursery during the eight seasonal sampling periods. Circle indicates the area targeted as the index site for seasonal sampling.

sampling only. Biological specimens of interest or importance were either frozen in the onboard ships freezer or preserved in 10% formalin for later study. All egg cases were identified to species and categorized as empty (post hatching), full (pre hatching, including eggs which may have been damaged by the trawl), or predated egg cases (empty and contain a bore hole). Each category of egg case was enumerated and weighed separately and recorded.

Stomach Scans of Predatory Fish Species

Stomachs of selected predatory fish species were scanned for evidence of predation on newly hatched skate s. Only fish species that could consume newly hatched skate s were included in this analysis. Species that were targeted included; Pacific halibut *Hippoglossus stenolepis*, Pacific cod *Gadus macrocephalus*, Arrowtooth flounder *Atheresthes stomias*, great sculpin *Myoxocephalus polyacanthocephalus*, Greenland turbot *Reinhardtius hippoglossoides*, Alaska skate *Bathyraja parmifera*, and the Bering skate *Bathyraja interrupta*. In most cases all individuals of each species were scanned during each sampling period, however when large numbers of any of these species were encountered subsamples were taken. A random length frequency sample was collected for each scanned species in cases where not all individuals were scanned. During stomach scanning, the species, sex, fork length or total length, total weight, stomach content weight, general diet composition, and presence of skate s consumed were recorded. In the cases where skate embryos were detected in the stomach the entire stomach contents were preserved in 10% formalin for later species identification. In the course of stomach scanning of the skate species both gonads were also removed and weighed to the nearest 0.1g and recorded for subsequent Gonadal Somatic Index (GSI) estimates.

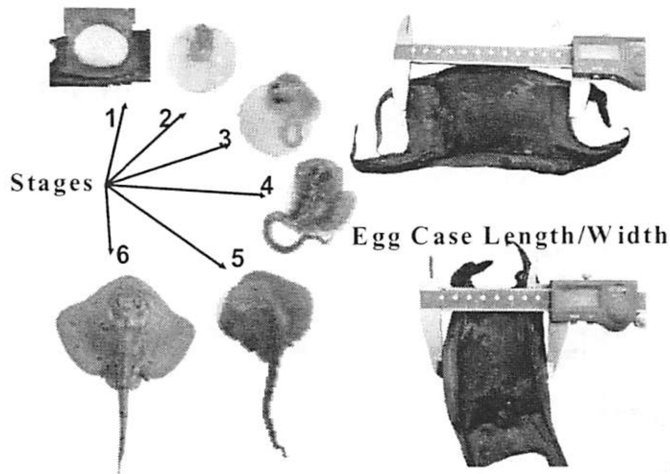

Figure 3. Development of the Alaska Skate embryo and the numbers assigned to each developmental stage (Left). Egg case measurements of Length and width were taken for each egg case staged during this study (Right).

Embryo Staging and Length Frequency Measurements

During each sampling period approximately 100 Alaska skate embryos were staged at sea and an additional 100 were preserved in 10% formalin for detailed study in the laboratory. Stage determination roughly followed that of Hitz (1964) determined for *Raja binoculata* with an additional stages of 1 for undeveloped newly deposited egg cases and stage 6 for embryos with the yolk sac completely absorbed (last stage before hatching Figure 3). Egg case length (excluding horns) and width (including keels at mid case) (Figure 3) were recorded to the nearest millimeter as well as embryo stage. In the laboratory identical data was recorded from preserved eggs as well as embryo total length (TL). All embryo stage data were pooled from each sampling period.

Seasonal Monitoring

The index site at the Alaska skate nursery was visited a total of eight times over the 14 month period during June, July, September and November 2004, and January, April, June and July of 2005 (Table 1). During each two-day sampling period a single 5-10 minute bottom trawl was completed at the index site targeting the designated index sampling area (Figure 2). The biological and catch workup was similar to that previously described for the initial 2004 trawl survey. However, species composition was limited to fish and gastropod snail species and net mensuration and trawl data was limited to bottom depth, temperature, and distance fished and start and end latitude and longitude during seasonal sampling.

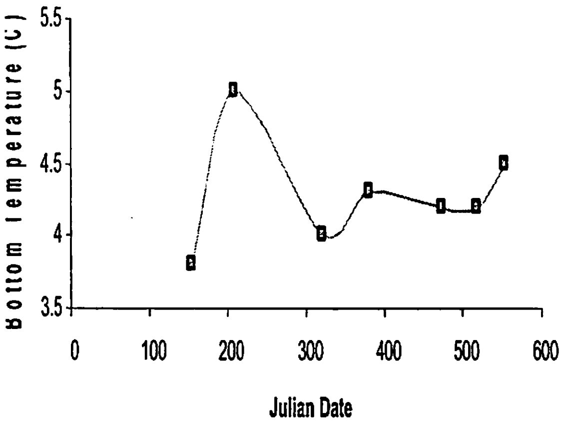

Figure 5. Bottom temperatures recorded at the index site in the Alaska skate nursery at each sampling period from June 2004 through July 2005.

RESULTS

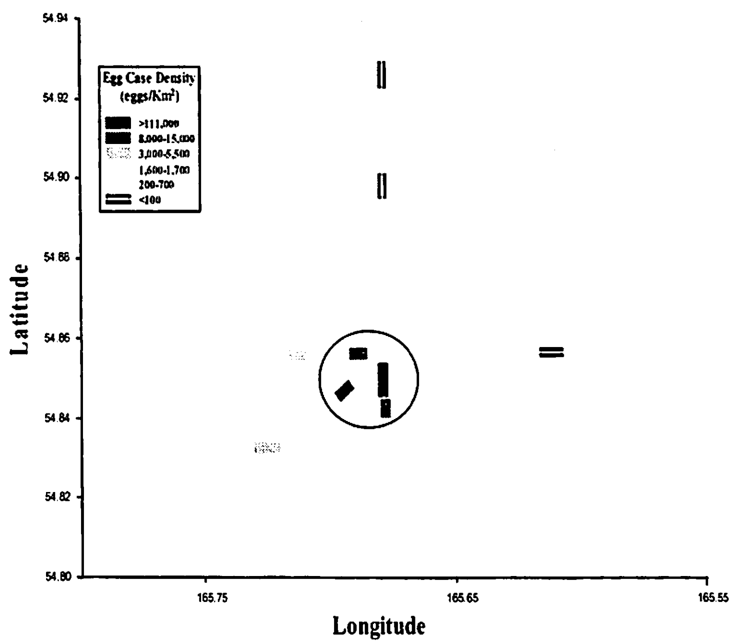

Figure 4. Trawl locations and egg case density estimates in the Alaska skate nursery site during the July 2004 investigation. Circle indicates the index site location used for seasonal sampling

Nursery Site Location and Habitat

The nursery site for the Alaska skate was relatively small in area. Results from trawl samples taken in July 2004 suggest that the most active nursery area was only from 1-2 kilometers across (Figure 4). Analysis of the trawl catch data showed the nursery site had little benthic structure or habitat diversity from trawl analysis. The bottom was relatively flat sandy muddy bottom with no detectable abiotic or biotic structure. Bottom depths varied by only several meters throughout the nursery site for the highest density areas (145-150 meters) with the average bottom depth, weighted by egg case density, being 149 meters. Bottom temperatures varied between 3.8-5.0°C throughout the year with a low in June of 2004 at 3.8 C and a high temperature of 5.0 C in July of 2004 (Figure 5). Both these temperatures appear extreme for this area of the eastern Bering Sea as temperatures recorded for the subsequent sampling period (after July 2004) showed between 4.0-4.5 C from November 2004 through July of 2005.

Species Composition

Results from species composition sampling showed that within the nursery site areas of higher egg densities there was higher species diversity. Figure 6 shows that although species diversity varied in low egg case density areas (17-29 species), diversity was consistently high where egg case densities were high with 30-31 species. The two highest diversity stations consisted of 13 fish species and the remainder were invertebrate species. The most abundant fish species encountered in the nursery site throughout the sampling period included walleye pollock *Theragra chalcogramma*, arrowtooth flounder, flathead sole *Hippoglossoides elassodon,* rex sole *Glyptocephalus zachirus*, Alaska skate and Pacific cod . The most abundant invertebrate species (from initial summer 2004 investigations) were the Tanner crab *Chionoecetes bairdi*, tentacle-shedding anemone *Liponema brevicornis*, and Oregon triton *Fusitriton oregonensis*.

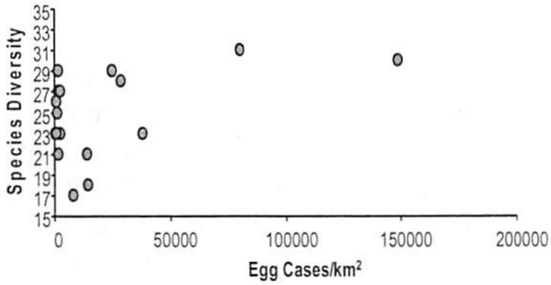

Figure 6. The relationship between species diversity and egg case density at the Alaska Skate nursery site.

The Alaska skate and the Bering skate were both found at the index site during most sampling periods. The Alaska skate predominated in number of skate s (96%) and in egg case composition (99.6%). Although the Bering skate accounted for about 4% of the skate s found at the site, their egg cases only contributed about 0.4% of the egg cases found at the site and this site proved to be predominately at single species nursery site for the Alaska skate.

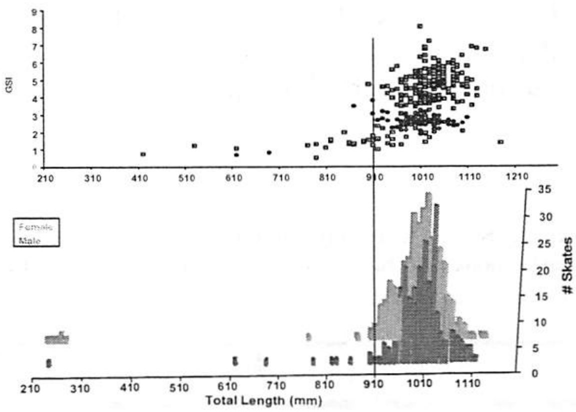

Figure 7. Gonadal somatic index (GSI) for males (blue) and females (red) Alaska skates collected from the nursery site (top). Length frequency of male and female skates found in the nursery throughout the study (bottom). Vertical line indicates size at first maturity.

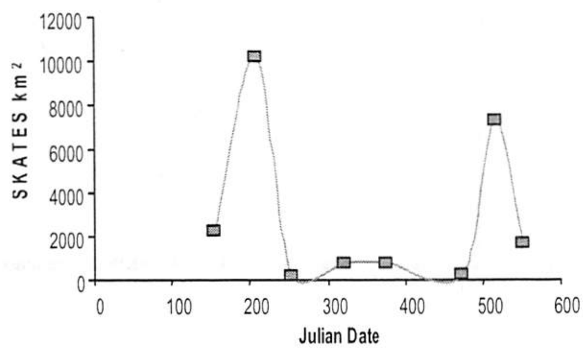

Figure 8. Density estimates for the Alaska skate from each sampling period at the nursery index site.

The length frequency of the Alaska skate from all sampling periods combined suggested that the nursery site was used primarily by mature reproductively active adult male and female skates (Figure 7). Data from gonadal somatic index showed that nearly all Alaska skates found in the nursery were adults and gonadal examination showed that developed ovaries and the presence of egg cases in the uterus were found during all sampling periods. Although present during all sampling periods, the Alaska skate showed seasonal trends of increased abundance in the nursery during summer months. suggesting increased reproductive activity during these months (Figure 8). Increased abundance of newly deposited egg cases during summer sampling periods coincided with the increase in skate abundance confirming that the summer was a period of high reproductive activity.

Predatory Fish Species

Seven species of predatory fish were examined for stomach contents during this study (Table 2). The most common prey items of all species combined included the walleye pollock, *Chionoecetes* sp. Crabs, and euphasid shrimps. Pacific cod and The Pacific halibut consumed newly hatched Alaska skate juveniles as part of their diet. The Pacific cod consumed skate s at a rate of 0.06 skates/cod and the Pacific halibut at 0.13 skate s/Halibut. Although predation rates were low for both species, they showed a seasonal preference for consuming skate s during the winter (January 2005) and early summer (June 2005) months based on the index site samples (Figure 9). Pacific cod and Pacific halibut were found in higher abundance at the index site during winter months and possibly in summer months suggesting they move into the nursery area during these periods (Figure 9).

Table 2. Sample sizes and length range by sex of all predatory species scanned for evidence of predation on newly hatched Alaska skates. Of the seven species scanned only the Pacific cod and the Pacific halibut showed evidence of predation on skates.

	Males		Females				
Species	Stomachs scanned	length range (cm SL)	Stomachs scanned	length range (cm SL)	Total scanned	Total Skates consumed	Predominant prey item
Arrowtooth Flounder	31	25-54	109	20-81	140	0	euphausid shrimp / pollock
Pacific Cod	79	42-99	83	35-102	162	10	crab / pollock
Pacific Halibut	35	33-84	17	46-92	52	7	crab / pollock
Great Sculpin	2	47-49	1	63	3	0	pollock / tanner crab
Greenland Turbot	0	NA	1	83	1	0	empty
Bering Skate	25	56-79	11	55-82	36	0	euphasid shrimp
Alaska Skate	72	62-111	106	79-115	178	0	pollock

The Alaska skate and the Bering skate stomachs were also scanned for cannibalism of newly hatched skates. A total of 178 Alaska and 36 Bering skates were scanned over the 14 month study with no instances of predation on juvenile skate s observed. The Alaska skate consumed almost exclusively walleye pollock and the Bering skate consumed euphausid shrimp in the size range scanned (Table 2).

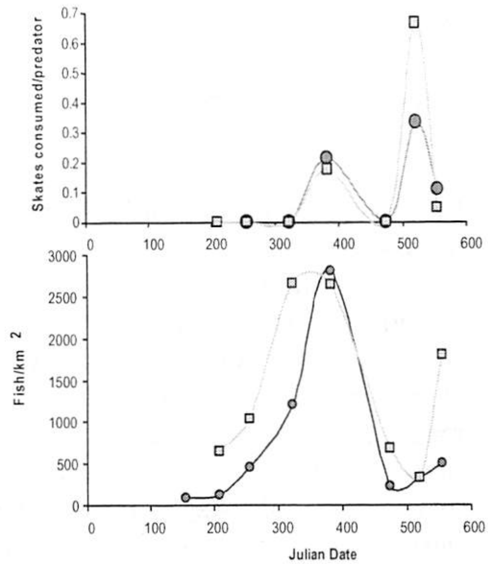

Figure 9. Predation rates of Pacific cod (Blue) and Pacific halibut (Yellow) on newly hatched Alaska skates found during the nursery study (Top) Density estimates of Pacific cod (Blue) and Pacific halibut (Yellow) found at the Alaska skate nursery site throughout the sampling period (Bottom). Peak predation occurred during winter and summer months coinciding with peak predator estimates.

Predation on Egg Cases By Snails

Gastropods have been reported in multiple cases of consuming skate egg cases by drilling a hole in the newly deposited egg, inserting its proboscis and sucking out the large yolky egg mass (Lucifora and Garcia 2004, Cox et al. 1999). skate egg cases preyed upon by gastropod snails were evident from the presence of gastropod holes penetrating into the inside chamber in the main case area, and the cases was empty of all contents. Predation rates by snails were estimated in each trawl from egg cases containing bore holes. A predation rate of 3.64% was estimated from the 8 sample periods at the Alaska skate nursery index site. Approximately 24,885 Alaska skate egg cases were examined throughout this study and a total of 906 egg cases were encountered which contained bore holes. The most likely candidate preying upon egg cases is believed to be the Oregon triton (Figure 10). The Oregon triton was the most common snail species found throughout the study period and showed a positive relationship between snail density and predated egg case densities (Figure 11).

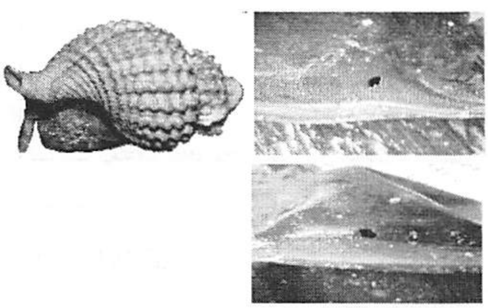

Figure 10. Left-The snail *Fusitriton oregonensis* is the most likely predator on newly deposited egg cases of the Alaska Skate. Right-holes left in Alaska skate egg cases by snail predators.

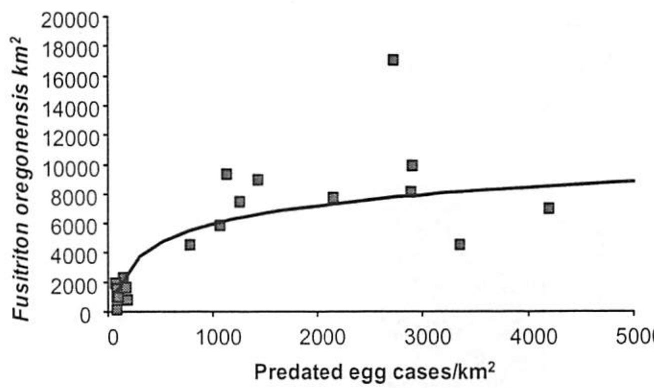

Figure 11. Relationship between *Fusitriton* density and predated egg case density in the Alaska skate nursery site.

In a simple experiment conducted at sea during this study, the Oregon triton was held in small buckets with egg cases of the Alaska skate for up to three weeks. The buckets were constantly flushed with fresh seawater and submitted to very low natural light levels. After three weeks time the egg cases were examined and only in a single instance was an egg case containing a single hole found. This suggests that the Oregon triton is at least one of the gastropod species that may prey on the Alaska skate egg cases.

Embryo Staging and Length Frequency Measurements

A sample of Alaska skate embryos were staged at each sampling period while at sea. Approximately 100 random egg cases were staged at the time of collection and the remainder of the random sample were staged up to 1.5 years after preservation in 10% formalin. Figure 12 shows the distribution of stage frequencies encountered during the initial July 2004 trawling study. The largest modes found in the nursery during the summertime were in stage 1, 2 and 5. This distribution differed from the index site during the same period in that there were a larger portion of stage 5 embryos at the index site (Figure 13, top Box).

Figure 13 shows the distribution of stage frequencies for all sampling periods collected at the index site combining both the preserved and live staged samples. In all sampling periods the highest proportion of egg cases were in early

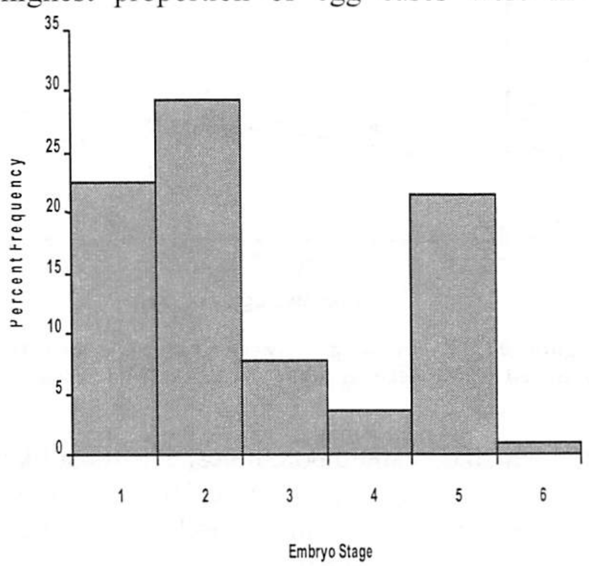

Figure 12. Developmental stages of embryos from the Alaska skate nursery site during the July 2004 study. Frequency is all egg cases staged for each trawl combined extrapolated to nursery wide density estimates.

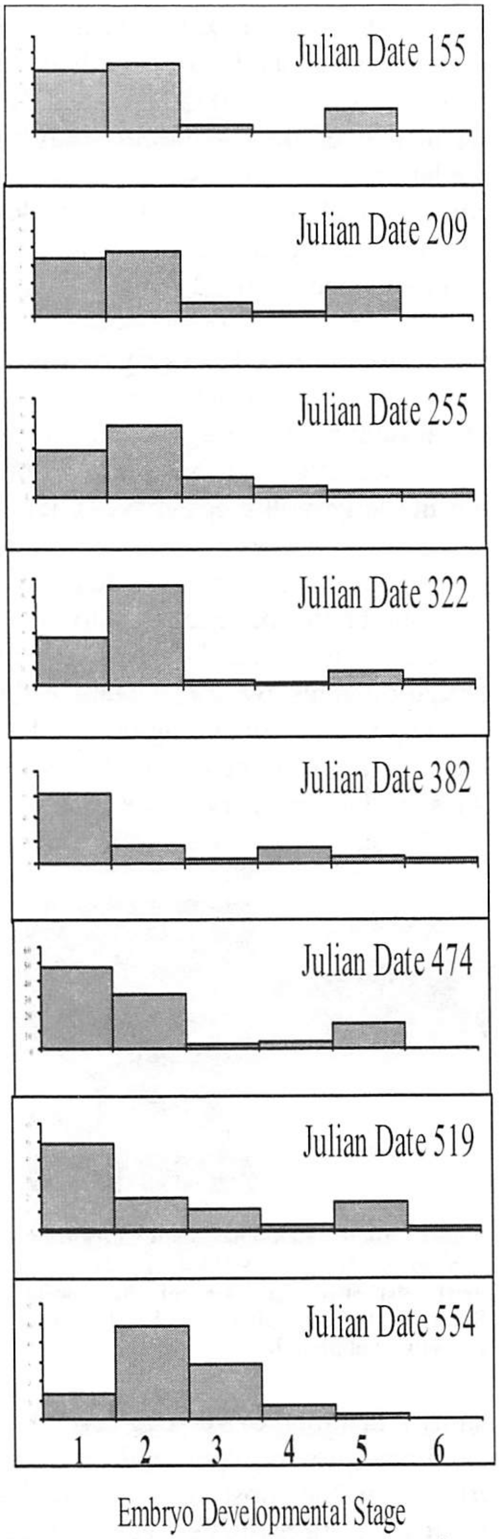

Figure 13. Stage frequency of embryo development from the Alaska skate nursery site over the 14 month study period. Stage 1 is newly deposited egg cases and 6 is fully developed.

stages (1 and 2) of development and all other stages were less frequent with embryos in stage 6 being rare. The distribution of embryo stages at the index site did not mimic the overall nursery stage frequency indicating that there was high heterogeneity of nursery use by egg laying skate s. Tracking stage frequency changes throughout the 14 months of sampling period was difficult from this data and stage frequency alone proved to be of limited use to track embryo development and timing.

Preserved egg cases containing embryos were examined in the laboratory. In addition to embryo development stage frequencies, embryo length measurements were obtained from preserved samples taken during each sampling period. Each egg case was measured to length and width, the egg case opened and the embryo stage recorded, the total length including accessory tail filament recorded and additional embryonic developmental parameters such as disc width, the state of the egg gel, yolk diameter, accessory tail filament length and sex of the embryo were documented.

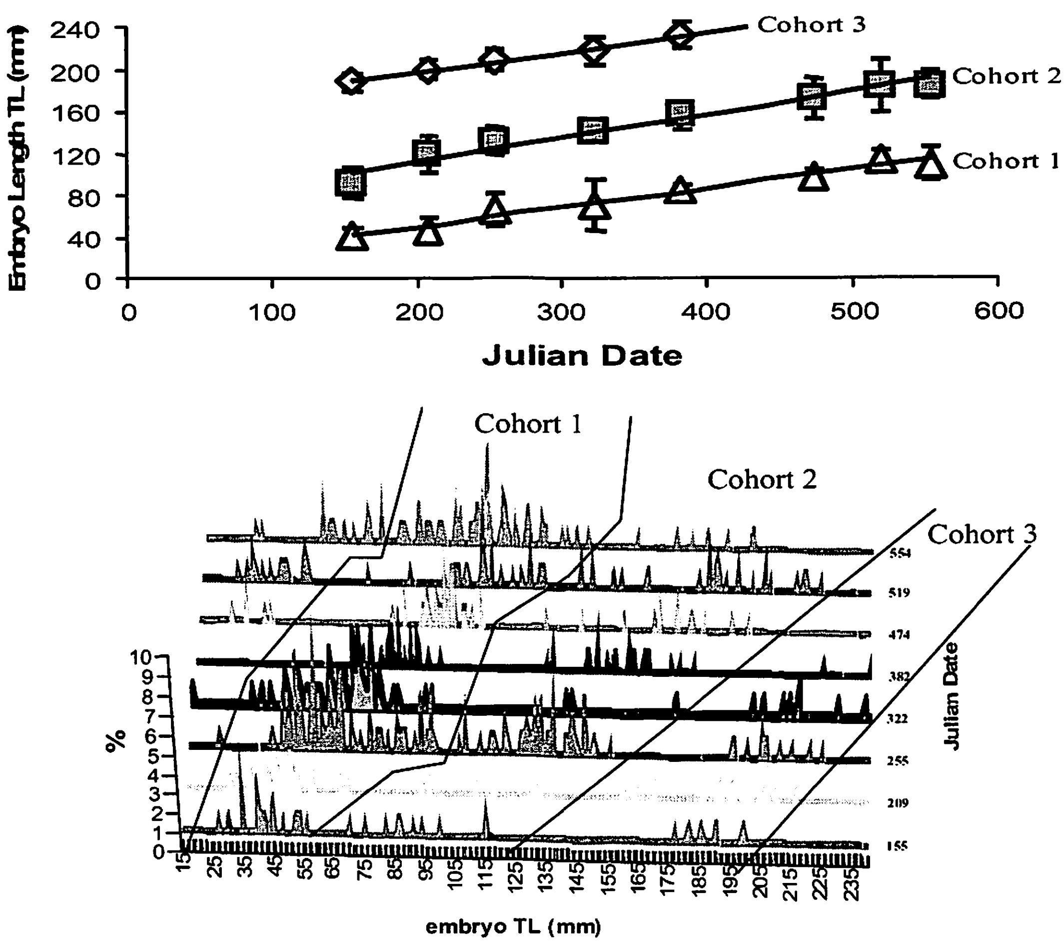

Figure 14. Mean and standard deviation of three cohorts based on embryo length frequencies from the seasonal sampling at the Alaska skate nursery site.

Figure 14 (bottom) is the result of the length frequency measurements taken from preserved samples. Each sampling period suggested a minimal of three cohorts developing simultaneously based on the length frequency modes. Each cohorts length mode shifted at each subsequent sampling and showed there was a natural progression of development from sampling period to sampling period.

Cohort Analysis

Growth rates were estimated for each cohort by calculating the mean total length for the cohort at each sampling period. Subjective criteria were used to determine inclusion for each cohort from natural mode breaks of embryo lengths (Figure 14 bottom). Figure 14 shows the entire data set of length frequencies and the frequencies included in each cohort. The mean lengths for each cohort at each time period was plotted and a linear equation obtained for each cohorts growth throughout the study period (Figure 14 top). Each cohort showed similar linear growth rates throughout their size ranges. An average growth rate of 0.1977 mm/day was calculated from the three cohorts and this estimate was used for embryo developmental timing, hatching and egg case depositional events (Table 3).

Birthdates and egg case deposition dates were estimated for each individual embryo that was sampled. Approximate hatching date was estimated by using a mean hatching size of 224 mm TL (mean of all stage 6 embryos (n=39) from fresh and preserved samples) and estimating the time required to reach hatching size at a constant growth rate of 0.1977 mm/day. The deposition dates were obtained in a similar manner by determining the time required to reach the measured size and subtracting the number of days from the collection date. For deposition dates, an additional 180 days were added based on the stage data (Figure 13) which suggested that it took approximately 6 months from the time of deposition until visible embryo development (> 10 mm TL) could be detected.

Figure 15 shows the distribution of expected birthdates and deposition dates from the embryo length frequencies. The frequency distributions shows that although there is continuous hatching and egg case deposition throughout the year, the peak hatching event happens during fall and winter months (September-February) and egg case depositional events peak during spring and summer months (May-August).

Average growth rates of 0.1977 mm/day provide an estimate of embryo gestation duration to be approximately 3.5 years to reach 224 mm TL. Cohorts also averaged a difference of approximately one year growth between groups (lag time mean of 379 days, Table 3) at any single period suggesting a single depositional event each year.

DISCUSSION

Skate Nursery habitat mapped for the Alaska skate appears to be the first recorded for detailed information of a skate nursery in the Northeastern Pacific. The location of nursery sites along the shelf-slope interface appears common in the eastern Bering Sea as 4 additional skate nursery sites have been located at depths between 150 and 360 meters (Authors unpublished data). All sites are located in highly productive upwelling areas near canyons or otherwise show high species diversity. Site selection criteria for skate nurseries are as of yet unknown. Areas of high production may be critical as nursery sites due to the protracted reproductive activity and high energy expenditure of egg production. Having a ready supply of food would allow for skate s to remain within the nursery site and minimize foraging excursions during reproductive cycles. In addition adequate current flows such as those encountered in the slope area of the eastern Bering Sea may be critical for the successful hatching and embryo development. Development within the egg cases is dependent on a current of seawater to supply oxygen to the embryo and remove metabolic wastes from the egg case which the slope region may supply. A steady current would also ensure the egg cases would not become buried in areas of soft bottom types, undoubtedly fatal to the fragile embryos. The shelf-slope interface may provide the delicate balance of all these elements to ensure the highest production and survival of adult and developing offspring.

Table 3. Sampling periods and embryo length means and standard deviations of each cohort from the Alaska Skate nursery site. Included are the linear equations of growth for each cohort and the estimated growth rate for the embryo period of development. The time lag between cohorts was estimated as the difference in mean lengths divided by average growth rates. Estimated time between each cohort was around 1 year suggesting an annual depositional event at this nursery site.

Sampling Period	Julian Date	Cohort 1	Cohort 2	Cohort 3
June 3 2004	155	41.6 +- 8.09	91.5 +- 15.12	187.89 +- 7.88
July 27 2004	209	46.96 +- 10.43	118.13 +-16.76	199.53 +- 8.86
September 11 2004	255	57.44 +- 8.13	131.89 +- 12.97	207.82 +- 9.57
November 17 2004	322	65.24 +- 10.33	141 +- 1.41	217 +- 12.28
January 16 2005	382	84.17 +- 6.19	156.38 +-13.31	233 +- 11.31
April 18 2005	474	97.11 +- 7.25	171.85 +-18.75	
June 1 2005	519	113.83 +- 10.25	193.27 +- 7.92	
July 7 2005	554	116.07 +- 11.45	200.5 +- 0.71	
linear equation		y=0.1819x + 13.401	y=0.2214x + 68.17	y=0.1899x + 158.8
R^2 of equation		0.9771	0.9688	0.9890
Growth Rate of Cohort		0.1819 mm/day	0.2214 mm/day	0.1899 mm/day
Average growth rate		0.1977 +- 0.0208 mm/day		
time lag between cohort 1 & 2		348.79 +- 41.27 days		
time lag between cohort 2 & 3		411.07 +- 44.28 days		

This study suggests that specific requirements for newly hatched juveniles may not be a criteria for nursery habitat selection as very few hatchlings were ever found at the nursery site. The most likely explanation is that quickly after emerging from the eggcase the skate moves out of the nursery area. Trawl studies done adjacent to the Alaska skate nursery study found newly hatched juvenile Alaska skate s in great abundance using similar trawl methods (Kotwicki and

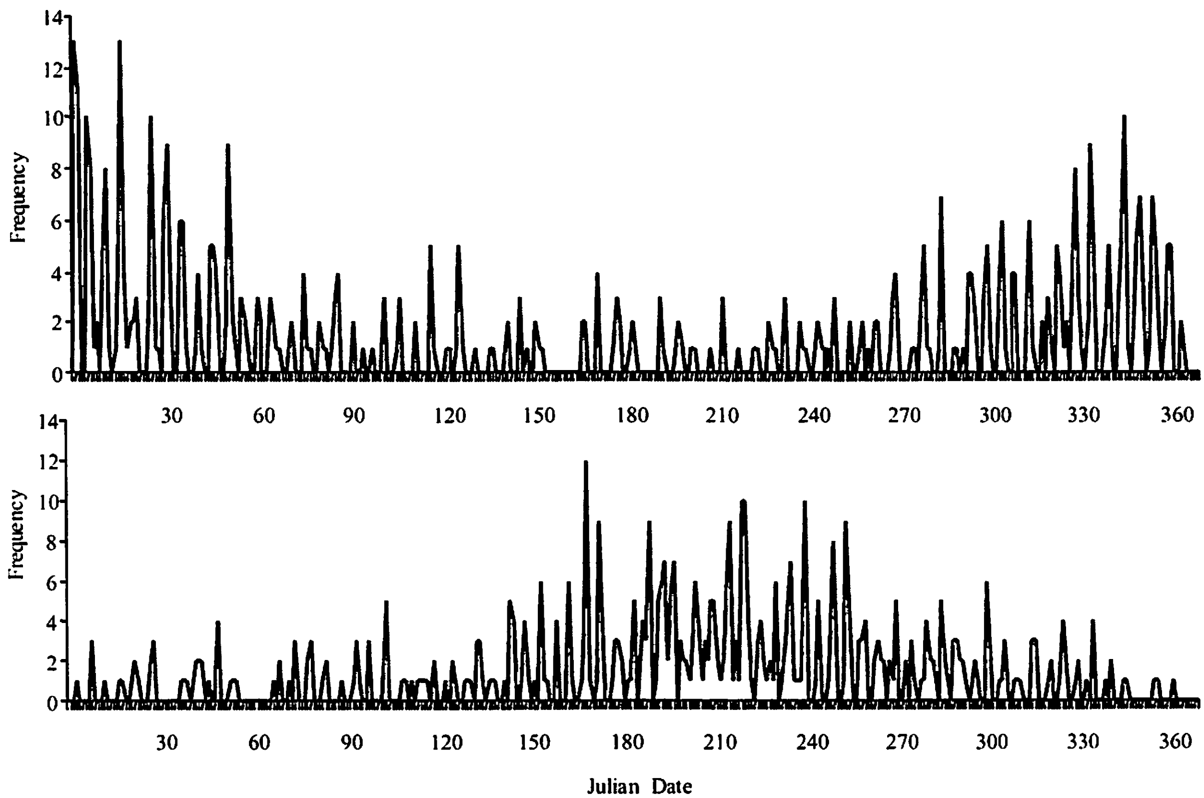

Figure 15. Estimated frequency of hatching dates (top) and deposition dates (bottom) from all embryos measured from the Alaska skate nursery site.

Weinberg 2006). This study suggested an exodus from the nursery area soon after emerging from the egg case.

The Alaska skate nursery site was utilized by the Bering skate and the Alaska skate for egg case deposition. The Bering skate was found in low abundance throughout the sampling period and egg cases were always found at this site. The egg case density of the Alaska skate and seasonal abundance indicate this site is primarily a single species nursery area with the Bering skate sharing the habitat to some extent. The Alaska skate s use of the nursery site is limited for reproduction as only reproductive adult males and females were found at the site throughout the year. Reproductive cycles in temperate to arctic and deepwater skate species is poorly known. Due to their inherent low fecundity and slow growth rates it is speculated that skate s may reproduce over long protracted periods or in some cases continuously throughout the year (Sulikowski et al 2004, Templeman 1982). For the Alaska skate it appears that in general there is reproduction throughout the year with peak egg laying events in the summer months. However this timing is at the population level and the reproductive cycle at the individual level is still unknown.

Embryo development progressed slowly based on length frequency cohort analysis and estimated growth rates. A single cohort was estimated to take >3.5 years from deposition until hatching with multiple cohorts developing simultaneously within the nursery due to continued annual reproduction. Embryo developmental rates are most likely coupled with environmental temperatures. The bottom temperature recorded during this study shows that there was little change over the study period and therefore probably little growth rate change. Cohort analysis confirmed that during the study period growth rates were linear and similar between cohorts.

Predation sources to newly hatched skate s included gastropod snails and piscivorous fishes. Gastropod snails have been shown to predate on skate egg cases worldwide with predation rates between 14-42% (Lucifora and Garcia 2004, Cox et al. 1999). Predation rates for the Alaska skate were on the lower than this range at 3.64% from the nursery site. For the Alaska skate this may be a very reasonable predation rate that is averaged over multiple cohorts since egg cases take many years to hatch. These estimates based on a nursery site are novel since most estimates come from marginally valid samples. Samples collected from beach collections, random trawl hauls and museum collections are included in literature cited estimates. All samples have obvious biases due to low sample sizes and collection methods and the nonrandom distribution of predated egg cases. Predation rates from widely distributed egg cases outside the nursery area show higher predation rates for the Alaska skate . Random collections from trawl hauls during 3 years of bottom trawl surveys in the eastern Bering Sea resulted in a collection of 149 Alaska skate egg cases. This entire collection was not associated with a nursery site and were widely collected across the shelf and slope area of the eastern Bering Sea. Predation rates from this collection showed that 38% had evidence of snail predation by containing bore holes in the case. This rate is an order of magnitude greater than that within the nursery site and demonstrates how widely distributed collections show much higher predation rates. Whether egg cases widely distributed have increased vulnerabilities to predation due to the limited resource to snail predators or are the result of increased vulnerability to the trawl is unknown. Clearly predation rates from large samples collected from nurseries are more meaningful to embryo mortality and should be considered as more reasonable values of pre-hatching predation on pre-recruitment mortality. Lucifora (Lucifora and Garcia 2004) estimated the effect of high snail predation on skate fecundity and mortality for four skate species from the Atlantic. The conclusion suggested that even given the high estimates of around 15-42% predation on eggs, oviparous skate s can be more productive than their counterpart viviparous shark cousins due to the increased advantage of oviparity. The results of this study suggest an even much lower predation rate for the Alaska skate allowing for even greater production success.

Predation by Pacific cod and Pacific Halibut were at low levels and appeared to have a seasonal component to piscivory. Pacific cod are known to migrate along the shelf adjacent to the Aluetian Islands in the area of Unimak Pass seasonally for spawning. The increased abundance of Pacific cod during the winter months may be indirectly related to skate predation due to these reproductive migrations, however the increased abundance during peak hatching periods increases the likelihood of juvenile predation by Pacific cod . Pacific Halibut followed a similar pattern of increasing in the nursery area during winter months during peak hatching events and like Pacific cod may utilize the nursery area as a food resource during other behavioral activity.

CONCLUSIONS

It is clear that a nursery habitat exists in the southeastern Bering Sea for the Alaska skate . The nursery is persistent, small in area, and highly productive. Reproduction occurs throughout the year at low levels with a peak in egg deposition in summer months and peak hatching in winter months. Embryo development is extremely slow with an estimated 3.5 years from deposition to hatching. Natural mortality sources include gastropod snail predation and piscivory from large predator species. Both showed moderate to low levels of mortality suggesting high survivability of newly hatched skate s. The nursery for the Alaska skate is highly vulnerable to perturbation due to its location in a highly fished area in the eastern Bering Sea. The low reproductive potential and long life cycles of the Alaska skate should warrant measures to conserve this critical habitat.

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OUTREACH

WebPage developed: none
Exhibits/Demonstration Project Developed: none
Conference Presentations: American Fisheries Society Meeting September 2005; Alaska Marine Science Symposium, January 2006

Community Meetings: none
Presentations at Festivals/Events: none
WorkShop Participation: none
Presentations in Schools: none
Other Presentations: Alaska Fisheries Science Center January 2005, September 2005, University of Washington May 2005, March 2006
Press Articles: NOAA Press Release in September 2005
Factsheets Produced: none
Video Produced: none
Radio Television Interviews: none
Other: Information gathered from this study is included in a new forthcoming publication "A Field Guide to the Chondrichthyans of Alaska".

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PERGAMON

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Habitat-specific distribution of Pacific ocean perch (*Sebastes alutus*) in Pribilof Canyon, Bering Sea

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Abstract

Shelf edge canyons are well-known sites of enhanced biomass due to on-shore transport and concentration of zooplankton along their axes, both of which contribute to the high densities of nekton frequently found in these canyons. Using a combination of acoustics, trawling, and in situ observations with a remotely operated vehicle (ROV), the distribution of pelagic and demersal biota within Pribilof Canyon in the Bering Sea was examined in September of 1995 and 1997. Near-bottom acoustic scattering patterns in the 38 kHz data showed high concentrations of biomass beginning around the 180 m bottom depth contour and continuing to about 220 m, which were presumed to be adult fish based on their target strength distributions. The 120 kHz data also showed very strong scattering in the water column between 150 and 175 m, which was absent from the 38 kHz data, and therefore attributed mainly to zooplankton. The dominant taxa collected in bottom trawls and mid-water plankton tows were adult rockfishes (Pacific ocean perch, *Sebastes alutus*) and euphausiids (*Thysanoessa* spp.), respectively. In situ videos revealed dense aggregations of these rockfishes inhabiting a "forest" of attached sea whips, *Halipteris willemoesi*, during night deployments of the ROV, while areas with damaged sea whips had far fewer rockfish, and areas without this biotic habitat structure had no rockfish. During the day, the rockfishes were seen above the "forest", where they were apparently feeding on dense swarms of euphausiids. It appears that these rockfish utilize this predictable and abundant food resource in the canyon during the day and are associated with the sea whip habitat at night during periods of inactivity. More research is needed on these slow-growing biotic habitats and how fishing activities in the Bering Sea and elsewhere may impact these habitats. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Habitat; Acoustics; Demersal fishes; Zooplankton; Bering Sea; Pribilof Canyon

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1. Introduction

Submarine canyons are a common feature of many of the world's continental shelf breaks. Owing to their abrupt and steep topography, these canyons often modify the downstream circulation and increase shelf-slope exchange of water masses and nutrients (Klinck, 1996; Hickey, 1997). They are known to be areas of enhanced productivity due to topographically induced upwelling along their axes (Freeland and Denman, 1982). Canyons also transport large quantities of organic matter offshore through sediment flushing (Okey, 1997; Granata et al., 1999), thus enriching the deep ocean (Rowe, 1971). These physical processes enrich canyon regions (Denman and Powell, 1984), which may show enhanced concentrations of macrobenthos (Haedrich et al., 1980; Sardà et al., 1994; Vetter and Dayton, 1998), micronekton (Cartes et al., 1994; Macquart-Moulin and Patriti, 1996), demersal fishes (Stefanescu et al., 1994), and cetaceans (Kenney and Winn, 1987; Schoenherr, 1991) relative to the slope as a whole.

Another mechanism by which accumulations of planktonic organisms occur in canyons involves the interaction of diel vertical migration and onshore transport. In the case of large offshore euphausiids normally found over deeper water, onshore advection of individuals near the surface at night deposits them over bottom depths shallower than their normal daytime depths (Isaacs and Schwartzlose, 1965; Koslow and Ota, 1981; Genin et al., 1988). This process may deposit large aggregations of euphausiids near bottom at the upstream end of canyons (Koslow and Ota, 1981; Greene et al., 1988), where they become easy prey for planktivorous fishes (Mackas et al., 1997). In the North Pacific Ocean, rockfishes in the genus *Sebastes* often inhabit the offshore edges of banks or canyons and are known to capitalize on these advected prey resources (Isaacs and Schwartzlose, 1965; Pereyra et al., 1969; Brodeur and Pearcy, 1984; Chess et al., 1988; Genin et al., 1988).

In 1994, a dense acoustic scattering of near-bottom fish was detected at the upstream end of the Pribilof Canyon in the Bering Sea. Trawling through this acoustic sign revealed that it was comprised almost entirely ($>92\%$ of total catch) of Pacific Ocean perch (*Sebastes alutus*). In this paper, acoustic and trawl data collected from 1995 and 1997 are presented along with in situ observations using remotely operated vehicle (ROV) videos that revealed a biogenic habitat association between Pacific Ocean perch and pennatulaceans in Pribilof Canyon.

2. Methods

2.1. Study site

Surveys were conducted at the head of Pribilof Canyon, a large canyon situated at the outer edge of the Bering Sea continental shelf some 370 km from the Aleutian Island Chain and approximately 40 km south of St. George Island, the southernmost of the Pribilof Islands (Fig. 1). The Pribilof sea valley begins at a depth of 130 m and drops off to a maximum depth of 3200 m (Carlson and Karl, 1988), with the main incision of the canyon cutting from 100 to 1000 m into the slope (Kotenov, 1965). The upper part of the canyon is bifurcated (Fig. 1), forming a trough 90 km long and 30 km wide parallel to the continental margin (Scholl et al., 1970). The total canyon volume is 1300 km^3, which classifies it among the largest canyons in the world (Carlson and Karl, 1988).

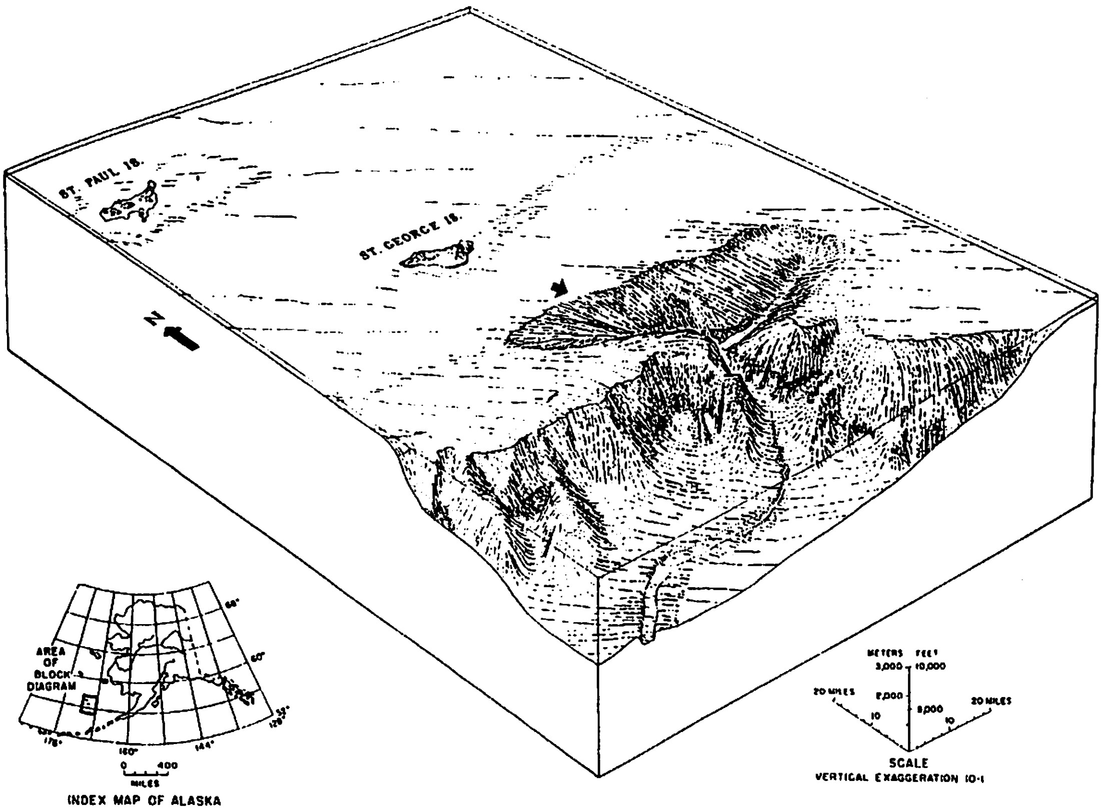

Fig. 1. Physiographic plot of Pribilof Canyon looking onto the shelf showing the study area (arrow) relative to the Pribilof Islands (modified from Scholl et al., 1970).

Results from hydrographic surveys, satellite track buoys and moored current meters in the vicinity of Pribilof Canyon suggest the presence of two circulation features: the Bering Slope Current (Schumacher and Reed, 1992) and a flow over the outer continental shelf (Schumacher and Stabeno, 1998). The Bering Slope Current is most marked in the upper 300 m of the water column, flowing along isobaths generally toward the northwest at speeds of 0.1–0.2 m s^{-1}. The increased speed of the outer shelf current apparently results from the marked decrease in width of the outer shelf (from ~160 km to less than 30 km) in the canyon area. Satellite-tracked buoy trajectories support the existence of this stronger flow. Exchange of slope water onto the shelf occurs in the vicinity of Pribilof Canyon. Interaction of tidal currents with canyon topography results in rectified onshore flow, and the acceleration of the outer slope current appears to draw deeper nutrient-rich water up onto the outer shelf (Stabeno et al., 1999).

2.2. Field sampling

The observations reported here were part of a multi-disciplinary study of biophysical interactions between fish and zooplankton in the area of the Pribilof Islands (Brodeur et al., 1997).

Cruises were conducted during 9–26 September, 1995, and 8–18 September, 1997 and a broad suite of physical and biological measurements were made in the Pribilof Canyon area (Table 1; Fig. 2) from the NOAA vessels *Miller Freeman* and *Surveyor* working in tandem.

In situ water temperatures and light levels were recorded at several stations within the canyon (Table 1). Conductivity-temperature-depth (CTD) casts were taken using a Sea-Bird SEE-9 system and light and light measurements were made with an IL1700 Research Radiometer (International Light, Newburyport, MA).

2.3. ROV deployments

Underwater observations in the Pribilof Canyon were made using video cameras mounted on a Deep Ocean Engineering Super Phantom II ROV deployed from the *Miller Freeman*. Most surveys were done with a color CCD video camera (Hitachi Model HV-C20) with the viewing area illuminated by two confocal 250 W tungsten–halogen lights mounted externally on the vehicle. These lights were dimmed to about 75% of full power to minimize the backscatter from biogenic

Table 1
Operations carried out in Pribilof Canyon region in 1995 and 1997. The first station conducted in 1995 (S80) was done by the ship Surveyor. All other stations were done by the Miller Freeman. Bottom depth is the maximum depth encountered during the operation

Station No.	Haul No.	Date	Time (ADT)	Latitude °N	Longitude °W	Bottom depth (m)	Operation
1995							
S80	1	16-September	19:17	56.28	169.44	246	CTD
29	1	16-September	20:06	56.30	169.44	203	ROV
29	2	16-September	22:41	56.29	169.47	215	Bottom trawl
29	4	17-September	0:58	56.29	169.45	214	Methot trawl
29	6	17-September	3:44	56.29	169.46	211	ROV
30	1	17-September	5:06	56.28	169.44	240	Acoustic transect
56	1	23-September	8:02	56.28	169.43	236	Bottom trawl
57	1	23-September	9:14	56.28	169.44	230	Acoustic transect
59	1	23-September	19:47	56.31	169.68	209	ROV
59	2	23-September	21:59	56.31	169.68	200	Bottom trawl
60	1	24-September	2:41	56.28	169.60	184	ROV
60	3	24-September	5:40	56.28	169.60	205	Bottom trawl
61	2	24-September	14:16	56.29	169.30	197	ROV
1997							
1	1	9-September	13:31	56.28	169.44	256	CTD
1	2	9-September	14:23	56.28	169.44	246	CTD
10	2	10-September	3:59	56.28	169.44	264	Acoustic transect
14	1	10-September	13:46	56.28	169.44	257	Acoustic transect
15	1	10-September	15:22	56.28	169.43	243	ROV
15	2	10-September	17:47	56.28	169.43	248	Bottom trawl
15	3	10-September	21:41	56.28	169.43	234	ROV
16	1	11-September	0:41	56.28	169.47	234	Methot trawl

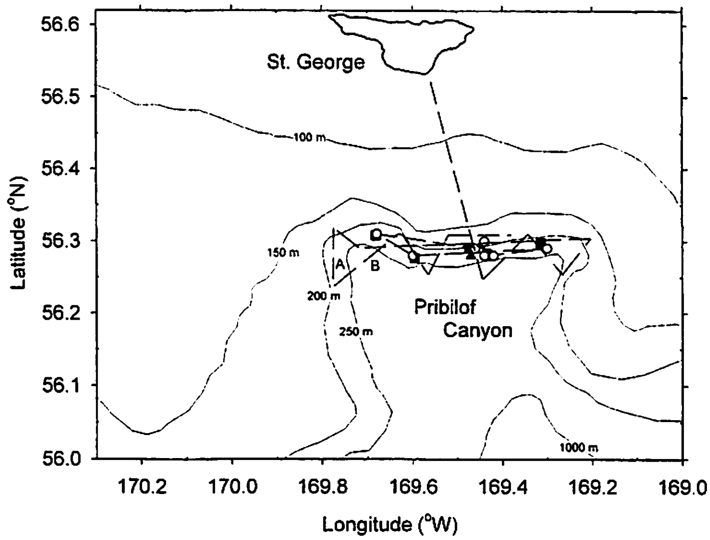

Fig. 2. Locations of ROV deployments (circles), bottom trawls (squares), Methot trawls (triangles) and acoustic transects (dashed lines) in Priblilof Canyon during September 1995 and 1997. Also shown are acoustic transect lines A and B shown in Figs. 4a and b, respectively.

particulate matter in the water column. A silicon intensifier target low-light level black and white camera (Osprey OE1323), which provided a 110° field of view, was used to initially survey each site. In addition, still photos were taken in 1997 using a submersible camera (Benthos Model 3782) and strobe on the ROV.

The ROV was lowered from the vessel using a 300 m umbilical cord while the vessel maintained a constant heading using its bow thrusters. A 108 kg down weight was attached 25 m from the end of the umbilical cord to provide stability and reduce the angle of drift of the ROV away from the vessel. The ROV was generally propelled at slow speed to keep it in front of the down weight and the speed over ground was less than 1 knot ($<1.6\,\mathrm{km\,h^{-1}}$) for all deployments in the canyon. Video images were viewed in real time at an on-deck console that allowed the operator to maneuver the vehicle and control the cameras and lights. The depth of ROV was annotated onto the tape by observers throughout the deployment. Recordings were made on two Hi-8 VHS tape decks and identification of organisms and characterization of habitats were made during playback.

2.4. Acoustic transects

Acoustic backscatter data were collected along transects radiating from the Pribilof Islands, including one transect south of St. George Island which bisected the canyon, to quantify midwater and bottom acoustic sign (see Swartzman et al., 1999a, b, for detailed collection and analytical methodology). A Simrad EK-500 echosounder, equipped with calibrated split-beam 38 and 120 kHz transducers (7° beam width), provided estimates of echo integration and target strength, which is indicative of the approximate size of the scatterers. The transducers were mounted in the centerboard of the ship at a depth of 10 m. The system was calibrated before the survey using a copper ball of known acoustic properties suspended below the ship. Shorter acoustic transects were also conducted across the axis of the canyon to determine the east-west extent of the echosign (Fig. 2). The position at the start and end of each transect was recorded using GPS.

Mean backscattering area per square nautical mile (nm) of sea surface (S_A) was calculated for each 5 m depth interval [units in $m^2\,nm^{-2}$] as follows:

$$S_A = 4\pi r_0^2 1852^2 \int_{z=r_1}^{z=r_2} S_v \, dz,$$

where z is the depth, r_0 is the reference range for backscattering strength (1 m), r_1 and r_2 are the top and bottom of the 5 m depth intervals which ranged from 10 to 250 m, and S_v is the volume backscattering strength.

2.5. Net tows

Short (< 1 h) bottom tows were made in areas of substantial near-bottom acoustic backscatter and along several of the ROV transects using a nylon Nor'eastern bottom trawl with 1.5 m × 2.1 m steel doors fished with roller gear. The mesh size varied from 13 cm in the forward part of the net to 8.9 cm in the codend, which was also equipped with a 3.2 cm liner. The mean effective path width of this trawl was estimated to be 13.4 m with a mean vertical opening of 9.2 m. The entire catch was processed aboard deck and numbers and weights of all taxa were recorded. Length measurements were made to the nearest centimeter on all fish species. Subsamples of rockfish were frozen and transported to shore for later laboratory processing. Number and biomass per km^2 were then estimated for all taxa using the area-swept method.

Macrozooplankton and micronekton were collected in 1995 and 1997 using a 5 m^2 Methot mid-water trawl with 3 mm × 2 mm oval mesh in the body and 1 mm mesh in the codend. The net was fished obliquely to within 10 m of the bottom to obtain depth-integrated abundance estimates of zooplankton and fish (Brodeur et al., 1997). The depth of tow was monitored using a SCANMAR acoustic sensor on the frame of the trawl and volume filtered was estimated by mounting flowmeters in the center of the frame. Since euphausiids and other micronekton are known to exhibit significantly lower daytime densities with this gear (e.g., Sugisaki et al., 1998), I examined only the night samples collected in the Pribilof Canyon area in this analysis.

2.6. Laboratory analysis

Methot collections were sorted into major taxonomic categories in the laboratory and fish, euphausiids and chaetognaths were identified to species. Raw counts were converted to numbers per 1000 m^3. Stomach contents of Pacific Ocean perch were analyzed in the laboratory. Because of the closed nature of rockfish swimbladder and the great depth from which they were collected, many of the stomachs that were brought back to the lab were empty and believed to be regurgitated. The stomachs containing food were examined under a dissecting microscope and the contents were identified to the lowest possible taxon. Otoliths of a representative subsample of Pacific Ocean perch were removed at sea for age determination in the laboratory by two experienced readers at the Alaska Fisheries Science Center using the break and burn technique.

3. Results

3.1. ROV deployments

ROV deployments were made in the vicinity of the canyon in both years and at different times of the day (Table 1). Transects were made both perpendicular and parallel to isobaths. On several descents to the bottom, the ROV passed through layers of squid (*Berryteuthis* sp.) and dense aggregations of euphausiids. The bottom generally was composed of compacted mud and silt. Occasionally rocks and small boulders were present but the bottom generally contained little geologic relief. However, in five out of seven of the deployments in the canyon, the ROV passed through areas containing dense aggregations of 1–2 m high sea whips (*Halipteris willemoesi*) evenly spaced about 2 m apart. During nighttime observations, hundreds of rockfishes (mainly Pacific Ocean perch) were seen inside the sea whip "forest" (Fig. 3). These rockfish were all oriented in the same direction (generally facing into the current) and were also evenly dispersed with approximately 3–4 m between adjacent fish. The rockfish appeared to be in a resting state and did not move until the ROV approached within a few meters. The sea whips and associated rockfish were observed over the depth interval of 185–240 m, but the highest densities (>30 fish min^{-1}) were recorded around 198 m. Other fishes were occasionally seen within the sea whip habitat, including arrowtooth flounders (*Atheresthes stomias*), sawback poachers (*Leptagonus frenatus*), and big skates (*Raja binoculata*), but none seemed to be consistently associated with this habitat as the rockfish. Several large areas contained numerous sea whips that were no longer upright and had much lower rockfish densities (<2 fish min^{-1}).

During the day, the Pacific Ocean perch were more active and in some cases were seen milling above the forest, presumably feeding on the euphausiids. In the two canyon deployments in which

Fig. 3. Photograph of several adult Pacific Ocean perch inside sea whip "forest". The slanting vertical lines are the center portions of sea whips which are around 2 m high.

no sea whips were observed (depth range 181–224 m), there were also no Pacific Ocean perch observed, although many other bottom fishes such as Pacific cod (*Gadus macrocephalus*), arrowtooth flounders, and sawback poachers were observed. These were the easternmost and shallowest of the deployments, and apparently missed the main sea whip habitat, which appeared to be mainly in the central and western flank of the canyon. In addition to the sea whips, the most obvious invertebrate macrofauna observed in the canyon were king crabs (*Paralithodes* spp.), large anenomes (*Metridium giganteum* and *Urticina* spp.) and large basket stars (*Gorgonocephalus eucremis*). Most of the basket stars had their arms extended indicating that they were actively feeding.

3.2. Acoustic transects

Transects along the shelf break (ca. 210 m) and those that crossed the axis of the canyon both showed substantial near-bottom aggregations of large scatterers at the upper edge of the canyon (Fig. 4). These large scatterers extended generally less than 10 m off bottom and were present in both the 38 and 120 kHz images. In addition, the 120 kHz echograms contained a dense layer of smaller scatterers above the larger ones that at times extended down to and overlapped the vertical distribution of the large scatterers (Fig. 4a), but was restricted to mid-water when it crossed the canyon axis (Fig. 4b).

Based on the mean acoustic backscatter from 4 inshore-offshore transects (2 each year) in the central and western part of the canyon for the 10 m above the bottom (38 kHz) and the layer between 150 and 175 m (120 kHz), these aggregations mainly occurred over a very narrow bottom

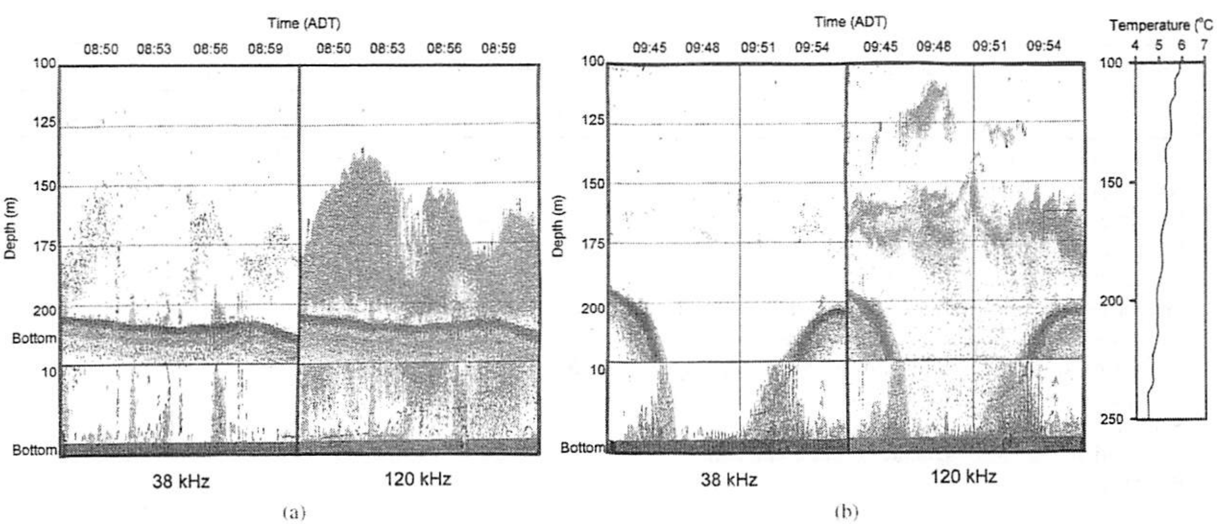

Fig. 4. Acoustic transect showing backscatter signals (a) along the 210–220 m isobath and (b) across the northwest end (Fig. 2) of Pribilof Canyon on 23 September 1995 for 38 kHz (left panel) and 120 kHz (right panel). The top part of each panel shows the water column from 100 m to the bottom or 250 m. The bottom part of each panel is an expanded view of the 10 m of the water column right above bottom. The time of day is shown at the top of the panel. To the right is the distribution of temperature with depth measured from a nearby CTD cast.

depth range. High acoustic backscatter first became apparent around 180 m depth, peaked around 200 m, and declined after 220 m at both frequencies (Fig. 5). The mean areal backscatter at the 200 m isobath was 2233 and 59,443 $m^2 nm^{-2}$ for these depth strata using 38 and 120 kHz data,

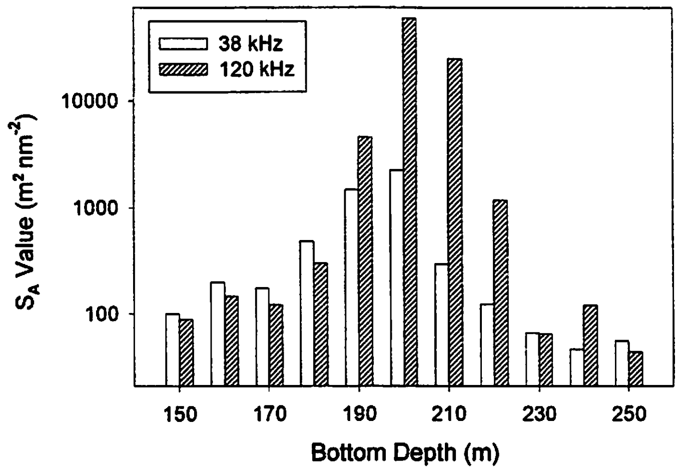

Fig. 5. Acoustical backscatter (S_A) from the EK-500 for the 10 m directly above bottom (38 kHz) and the layer between 150 and 175 m in the water column (120 kHz) by 10 m bottom depth intervals. Data are averaged by depth bin for four transects (two each in 1995 and 1997) in the northwest part of the canyon. Note that the ordinate scale is logarithmic.

Table 2
Fish catches (density and biomass) from bottom trawls ranked in order of decreasing mean density for 1995 and 1997. Shown only are the species which made up greater than 0.1 of the numerical catch. The 1995 data represent the mean of four tows

Common name	Scientific name	1995 ($n=4$)				1997 ($n=1$)			
		No./km²	(%)	Kg/km²	(%)	No./km²	(%)	Kg/km²	(%)
Pacific Ocean perch	*Sebastes alutus*	1106.2	87.7	793.5	71.8	366.7	34.6	288.1	43.0
Arrowtooth flounder	*Atheresthes stomias*	100.0	7.9	152.1	13.8	126.4	11.9	178.7	26.7
Pacific cod	*Gadus macrocephalus*	17.4	1.4	67.0	6.1	46.8	4.4	141.2	21.1
Darkfin sculpin	*Malacocottus zonurus*	10.3	0.8	4.5	0.4	—	—	—	—
Sturgeon poacher	*Podothecus acipenserinus*	8.7	0.7	0.2	<0.1	—	—	—	—
Spectacled sculpin	*Triglops scepticus*	3.3	0.3	0.3	<0.1	—	—	—	—
Sawback poacher	*Leptagonus frenatus*	2.3	0.2	0.1	<0.1	449.2	42.3	18.9	2.8
Alaska ronquil	*Bathymaster caeruleofasciatus*	2.3	0.2	0.5	<0.1	—	—	—	—
Big skate	*Raja binoculata*	1.8	0.1	19.5	1.8	—	—	—	—
Sablefish	*Anoplopoma fimbria*	1.3	0.1	2.5	0.2	—	—	—	—
Flathead sole	*Hippoglossoides elassodon*	1.0	0.1	0.5	<0.1	51.4	4.8	23.4	3.5
Prowfish	*Zaprora silenus*	1.0	0.1	5.7	0.5	—	—	—	—
Rex sole	*Errex zachirus*	1.0	0.1	0.4	<0.1	19.2	1.8	17.2	2.6
Pacific sleeper shark	*Somniosus pacificus*	0.8	0.1	42.7	3.9	—	—	—	—
Dusky rockfish	*Sebastes ciliatus*	0.8	0.1	1.2	0.1	—	—	—	—
Sharpchin rockfish	*Sebastes zacentrus*	—	—	—	—	1.1	0.1	2.2	0.3
	Total catch	1229.5	100.0	1104.6	100.0	1060.8	100.0	669.7	100.0

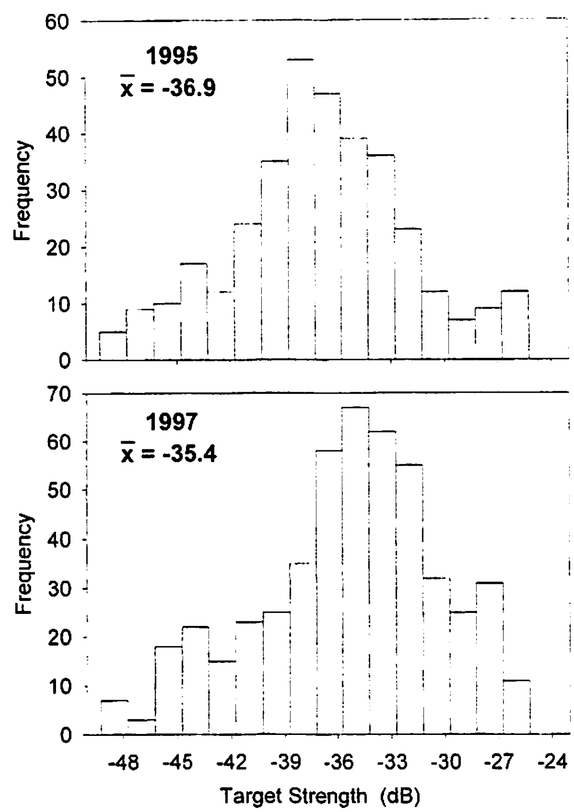

Fig. 6. Distribution of 38 kHz target strengths in the 10 m directly above bottom for 1995 (top) and 1997 (bottom). Shown also is the mean overall target strength by year.

respectively. Mean backscatter for two transects over similar bottom depth ranges in the easternmost head of Pribilof Canyon (Fig. 2) was 63.6 ($\pm$11.3 SE) and 79.3 ($\pm$10.4) $m^2\,nm^{-2}$ for these two frequencies, respectively.

The target strength (TS) distributions for 38 kHz were similar for both years, although the values were about 1.5 dB higher in 1997, indicating larger scatterers were present that year (Fig. 6). The target strengths obtained with the 120 kHz were similar in both years (mean TS = −75.1 and −76.0 dB for 1995 and 1997, respectively), but were substantially lower than those seen with the 38 kHz, suggesting that these scatterers were predominantly zooplankton.

3.3. *Net tows*

A diverse group of shelf and deepwater teleost and elasmobranch species were collected in the five bottom trawls (Table 2). In 1995, Pacific Ocean perch was the dominant species both in terms of number and biomass caught. The only other species comprising at least 5% of either the number or biomass were arrowtooth flounder and Pacific cod. In the one tow taken in 1997, Pacific Ocean perch was again the dominant species by weight but the smaller sawback poachers

Table 3
Densities (number per 1000 m^3) of macrozooplankton and micronekton collected in Methot tows in the Pribilof Canyon region by year

Taxa	1995 Density	1995 % of total	1997 Density	1997 % of total
Cnidaria	13.0	3.7	25.9	1.5
Chaetognatha				
Sagitta elegans	2.0	0.6	0.3	0.0
Eukrohnia hamata	1.3	0.4	—	—
Hyperiidea	0.2	0.1	—	—
Gammaridea	2.5	0.7	—	—
Euphausiacea				
Thysanoessa inermis	194.6	56.0	1124.1	63.5
Thysanoessa longipes	85.4	24.6	490.5	27.7
Thysanoessa raschii	—	—	51.1	2.9
Thysanoessa spinifera	22.1	6.4	61.3	3.5
Decapoda Natantia	1.0	0.3	—	—
Osteichthyes				
Theragra chalcogramma	22.7	6.5	16.3	0.9
Anoplopoma fimbria	0.9	0.3	—	—
Hexagrammos decagrammus	0.8	0.2	0.2	0.0
Lumpenus maculatus	—	—	0.2	0.0
Atheresthes stomias	0.9	0.3	—	—
Lepidopsetta bilineata	—	—	0.2	0.0
Total	347.3	100.0	1770.0	100.0

were more important numerically (Table 2). Other rockfish species (*Sebastes* spp.) were caught in both years, but these made up a minor component of the total biomass. Many sea whips were also collected in the trawls during both years, but these could not be quantitatively assessed due to loss through the trawl meshes.

The catch of the Methot tows was dominated by euphausiids, which comprised 87.0 and 97.6% of the total densities in 1995 and 1997, respectively (Table 3). *Thysanoessa inermis* was more than twice as abundant as the next most important species, *T. longipes*. Small cnidarian jellyfish were the only other invertebrate taxa collected in moderate densities. Several juvenile fishes were collected but, other than walleye pollock (*Theragra chalcogramma*), they were of negligible importance.

The size distributions of Pacific Ocean perch caught in the bottom trawls were similar in both years, although in 1997 slightly larger fish were caught (Fig. 7). These fish ranged in age from 8 to 15 yr (median = 11 yr) and were all classified as mature adults. Out of the 306 fish examined for stomach contents in both years, only 26 were found to contain food. Of these, 25 contained mainly euphausiids, most of which were *Thysanoessa inermis*. The remaining stomach contained a juvenile squid, *Berryteuthis magister*. A few other stomachs contained well-digested squid and fish remains and could not be formally analyzed.

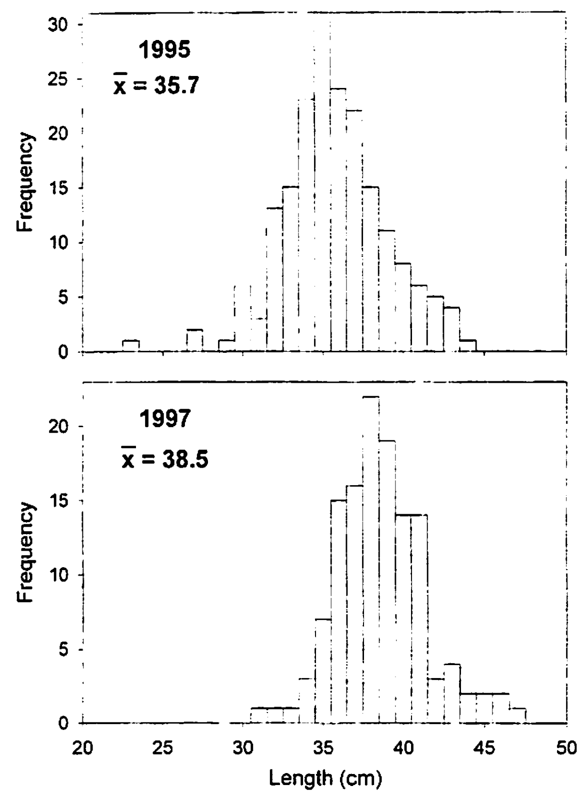

Fig. 7. Size distribution of Pacific Ocean perch collected in four bottom trawls in 1995 (top) and one bottom trawl in 1997 (bottom). Shown also is the mean size by year.

3.4. Environmental conditions

Temperatures at the bottom generally varied between 4 and 5°C on all CTD deployments (Fig. 4), which is typical of the offshelf waters at these depths (Stabeno et al., 1999). Ambient light levels measured around 200 m in the canyon were very low both day and night (4.3×10^{-6} and $6.2 \times 10^{-7}\,\mu E\,s^{-1}\,m^{-2}$, respectively), but were at or above threshold feeding levels of typical planktivorous fishes (Ryer and Olla, 1999).

4. Discussion

Many in situ studies examining the habitat preferences of demersal fishes show that these fishes are not randomly distributed but are often generally aggregated near some structure on the bottom (Auster et al., 1995). In some instances, these structures can be of biogenic origin, such as depressions or holes dug into the substrate (Able et al., 1982). In rockfishes of the genus *Sebastes*, however, the majority of studies have revealed a dependence on hard bottom substrates, often with substantial vertical relief (Richards, 1986, 1987; Pearcy et al., 1989; O'Connell and Carlile, 1993; Krieger and Ito, 1999). Krieger (1992), however, found that adult Pacific Ocean perch were more likely to inhabit flat, pebble substrate based on submersible observations off Southeast Alaska. In ROV observations in other shelf and slope areas of the Bering Sea, Pacific Ocean perch were occasionally found in other deepwater deployments outside the canyon, but these were for the most part solitary individuals associated with large boulders (Busby and Brodeur, in prep.).

In this study, the highest densities of Pacific Ocean perch were found at the northwest edge of the canyon based on both ROV observations and trawl collections, and were clearly associated with the sea whip 'forest'. Krieger (1992), in a photograph taken by submersible, also shows an aggregation of adult Pacific Ocean perch near several sea whips in the Gulf of Alaska. Similar to the present study, he found these fish to be evenly spaced and oriented into the current. This utilization of the sea whip 'forest' by Pacific Ocean perch apparently satisfies some need by this species to associate with a high-profile substrate in the absence of high relief rock substrates.

The high densities of vertebrate and invertebrate macrofauna in the canyon attest to the high productivity in this area. In addition to the sea whips, the high densities of other filter-feeding organisms such as anenomes and basket starfish suggest the presence of a substantial near-bottom flow containing high concentrations of zooplankton. This flow is apparently quite consistent over time to develop such a complex assemblage of sessile or slow-moving organisms. A cross section of a calcareous axial rod in several sea whip specimens revealed up to 130 circulli (M. Wilson, AFSC, personal communication). Presently, it is unknown whether these growth rings represent annual growth rings, but other related deep-sea sessile invertebrates are known to have extended life spans (Druffel et al., 1995).

It seems likely that the high densities of euphausiids found in the water column at the western head of the canyon originate from deeper areas of the Bering Sea Basin and are advected up the canyon by the prevailing currents. Most of the specimens found in the Methot mid-water tows and stomach contents of Pacific Ocean perch were *Thysanoessa inermis*, a characteristic euphausiid species of the outer shelf and basin of the Bering Sea (Smith, 1991; Sugisaki et al., 1998; Stockwell et al., in press). These euphausiids then impinge on the bottom at the head of the canyon as they attempt to migrate down to their normal daytime depths, similar to that observed in other canyons (Mackas et al., 1997). Although no depth-discrete plankton tows were conducted in this study area, other studies in the outer shelf region of the Pribilof Islands show higher concentrations of euphausiids in the epibenthic layer than in the water column, especially during the day (Coyle and Cooney, 1993; J. Napp, AFSC, unpublished data). An intense acoustic player layer of the type shown here has been consistently observed at the head of the Pribilof Canyon, but nowehere else, every year (1994–1999) that fall acoustic surveys have been conducted in this area (G. Swartzman, University of Washington, personal communication).

The foraging behavior of most shelf rockfish appears to be highly opportunistic and they are known to take advantage of oceanic mesopelagic prey that are advected onto the shelf near canyons or offshore banks (Pereyra et al., 1969; Brodeur and Pearcy, 1984; Chess et al., 1988; Genin et al., 1988). Information on the diet of Pacific Ocean perch in the Bering Sea is fragmentary, perhaps due in part to the difficulty in obtaining non-inverted stomachs from deep-water tows. Brodeur and Livingston (1988) found that of the 50 stomachs of this species examined, only 19 contained food, with euphausiids and caridean shrimp dominating the diet. Poltev (1999) found *S. alutus* on a seamount off the Kuril Islands were feeding mainly on euphausiids (86.3% by volume) with smaller contributions by fish (4.6%) and squid (3.2%) during

September 1997. These fish were not observed to undergo pronounced diel vertical migrations but did feed exclusively during the daytime. Although the number of stomach samples available in the present study was insufficient to elucidate the diel feeding cycle of Pacific Ocean perch in Pribilof Canyon, it seems likely that they are feeding mainly during the day when their activity level is higher and they are swimming above the 'forest'. This was also the time when high densities of euphausiids were seen in the ROV videos swarming in a layer just above the bottom.

It is not presently known what the predation impact of these large aggregations of rockfishes is on the euphausiid biomass advected over them on a daily basis. Demersal rockfishes have been shown to deplete populations of euphausiids advected over shallow banks off Southern California during the day such that 'gaps' appear in the acoustic echograms (Genin et al., 1988, 1994). Estimation of this predation impact by Pribilof Canyon rockfish on euphausiids will require more precise abundance estimates of both predator and prey as well as daily ration estimates of Pacific Ocean perch.

Although trawling and ROV deployments took place in a relatively small subarea of the canyon, it appeared to be one of the main aggregation areas based on the densities of near-bottom acoustic scatterers. It is highly probable that most of the acoustic sign observed near-bottom around 200 m was due to rockfish. The only other species with a swimbladder that was collected in any abundance in the trawls was Pacific cod, although their abundances were relatively low compared to Pacific Ocean perch. Although no in situ target strength measurements exist for Pacific Ocean perch, I applied Foote's (1987) generic target strength (TS) to length (L) relationship for physoclist fishes ($\mathrm{TS} = 20 \log L - 67.5\,\mathrm{dB}$), which appears to be appropriate for rockfishes in general (R. Kieser, Pacific Biological Station, DFO, Nanaimo, B.C. Canada, personal communication), to the mean size of Pacific Ocean perch caught in the trawls. The predicted TS from this relationship would be −36.88 and −35.42 dB for 1995 and 1997, respectively, reasonably close to the observed mean TS of −36.44 and −35.77 dB for these two years. More systematic acoustic surveys of the entire canyon region could yield more precise estimates of the total rockfish population inhabiting this area.

Similarly, no target strength measurements exist for the dominant euphausiid species (*Thysanoessa inermis*) collected in the Methot trawls, but the values taken with the 120 kHz echosounder are within the range expected for similar-sized euphausiids, based on theoretical scattering models (Stanton, 1989; Miyashita et al., 1997; Simard and Lavoie, 1999). However, other organisms that were caught in the Methot trawls, such as gelatinous zooplankton, could also fall within this range of target strengths.

This study is the first to show the importance of the Pribilof Canyon in general and the sea whip 'forest' in particular as a distinctive habitat for adult Pacific Ocean perch in the Bering Sea. Past attempts to define marine habitats of this species have relied on physical variables such as temperature and depth (Scott, 1995). Although this may narrow the range of possible habitats that could be occupied, the utilization of species such as Pacific Ocean perch of highly predictable but dynamic food sources and relatively static physical features renders such simple classifications inadequate.

The sea whips in this region may provide important structural habitat for Pacific Ocean perch in an otherwise featureless environment. An important consideration in this habitat is the slow growth rates and potential longevity of the sea whips providing this habitat. If they do indeed live for extended periods of time, fishing operations that disturb the bottom and uproot the sea whips may have a lasting effect on the rockfish populations inhabiting this region that could be potentially more detrimental than the direct effects of removing fish. The similar orientation of the sea whips observed in the ROV videos that had been apparently knocked down and were lying on the seabed suggests that fishing operations, including possibly some of my own trawl sampling, could have uprooted them. The substantially lower densities of Pacific Ocean perch observed in this perturbed habitat suggests that it is less preferred by this species compared to the undisturbed "forest". Destructive fishing methods have been widely observed to have major and long-lasting effects on sessile benthic megafauna (Jennings and Kaiser, 1998; Freese et al., 1999). More research needs to be done to determine the importance of areas such as Pribilof Canyon to Pacific Ocean perch production in the Bering Sea, so that we may protect and allow restoration of these utilized habitats for commercially and ecologically important species such as rockfishes.

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Axial rod growth and age estimation of the sea pen, *Halipteris willemoesi* Kölliker

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Abstract

Halipteris willemoesi is a large octocoral commonly found in the Bering Sea. It is a member of a ubiquitous group of benthic cnidarians called sea pens (Octocorallia: Pennatulacea). Sea pens have a skeletal structure, the axial rod, that in cross section exhibits growth rings. Pairs of adjacent rings, or ring couplets, were assumed to be annuli and were used to estimate the age and growth of *H. willemoesi*. Twelve axial rods, extracted from *H. willemoesi* collected in the Bering Sea, were selected to represent small (25–29 cm total length), medium (97–130 cm TL) and large (152–167 cm TL) colonies. Each rod resembled a tapered dowel: the thickest part (0.90–6.75 mm in diameter) was at about 5–10% of total length from the base tip, the distal part was more gradually tapered than was the base. The number of ring couplets increased with rod size indicating their utility in estimating age and growth. Estimated age among rods was based on couplet counts at the thickest part of each rod; the average estimated age (±SE) was 7.1 ±0.7, 19.3 ±0.5, and 44.3 ±2.0 yr for small, medium and large-size rods, respectively. Based on these estimated ages, average growth rate in total length was 3.9 ± 0.2, 6.1 ± 0.3, and 3.6 ± 0.1 cm yr^{-1} for small, medium, and large-size colonies. The average annual increase in maximum rod diameter among all colonies was 0.145 ± 0.003 SE mm yr^{-1}; therefore, age prediction from maximum rod diameter was calculated (estimated age (yr) = 7.0 ∗ (maximum rod diameter, mm) −0.2; $R^2 = 0.99$). At maximum diameter, the average couplet width was relatively constant among the three colony sizes (0.072 ± 0.05 mm). X-ray diffraction and electron microprobe analyses revealed that the inorganic portion of the rod is composed of a high-magnesium calcite. Radiometric validation of these age and growth rate estimates was attempted, but high amounts of exogenous ^{210}Pb precluded using the disequilibria of ^{210}Pb:^{226}Ra. Instead, ^{210}Pb activities were measured in a series of cores extracted along the axial rod. These activities ranged from 0.691 ± 0.036 (SE) to 2.76 ± 0.13 dpm g^{-1}, but there was no pattern of decay along the length of the rod; therefore, the growth rates and corresponding ages could not be validated. Based on estimated age from ring couplet counts, growth in total rod length is slow at first, fastest at medium size, and slows toward maximum size, with an estimated longevity approaching 50 yr.

Introduction

Sea pens and whips (Octocorallia: Pennatulacea) are colonial organisms that inhabit soft-bottom areas over a broad range of depths (intertidal – 6200 m) in all oceans (Williams, 1995, 1999). They can form vast forest-like patches of biogenic habitat that may play an important role as fish habitat (Krieger, 1993). Each colony stands erect and is secured to the sea floor by peristaltic burrowing of the peduncle, a slightly swollen basal (proximal) part of the fleshy tissue. The upper or distal part, the rachis, is populated with feeding polyps (autozooids). Sea pens are considered to be sessile (Williams, 1999), but movement by detaching, drifting, and re-attaching has been noted in the shallow-water species *Ptilosarcus gurneyi* (Birkeland, 1974) and *Renilla kollikeri* (Kastendiek, 1976), and the deep-water sea pen *Umbellula lindahli* (Flores, 1999). Despite this potential for movement, sea pens may contain useful records of environmental conditions stored in the skeletal tissues.

The endoskeleton of sea pens is a simple unbranched structure called an axial rod. The axial rod of the sea pen *Veretillum cynomorium* consists of a matrix of longitudinally oriented collagen fibrils embedded in columns of calcite that radiate out from a nodular core (Franc & Chassagne, 1974; Ledger & Franc, 1978). At the base (inferior) end, a calcification gradient exists between the non-calcified tip and the rest of the rod. The autoradiography (^{3}H-proline labeling) results of Franc et al. (1985) indicate that deposits are made onto the rod exterior: the interior is closed to deposition. Chia & Crawford (1977) found evidence of initial axial rod formation in *P. gurneyi* primary polyps soon after settlement of the planula. Birkeland (1974) found that growth rings in the axial rods of young sea pens (*P. gurneyi*) were formed annually, based on observed growth, and averaged 0.1 mm in width. Some colonies were estimated to be 15 years old based on rod diameter but, because of core degeneration, these estimates remain unvalidated. Linear extension rates and radiometric age determination provide evidence that skeletal growth rings in other octocorals are formed annually (Grigg, 1974; Szmant-Froelich, 1974; Andrews et al., 2002).

In September 1997, numerous large sea pens (*Halipteris willemoesi*) were collected as bycatch during bottom-trawl sampling in the Bering Sea prompting an investigation of the structure of the axial rod as a tool for determining age. Transverse sections revealed many growth rings in the axial rods indicating that *H. willemoesi* colonies may be slow growing and long lived: therefore, anthropogenic disturbance or removal of sea pen 'forests' could have a lasting effect on the structure of soft-bottom communities. In addition, chronologically ordered sequences of ring widths may be useful for constructing a history of variation in the surrounding environment. This concept is supported by studies on other organisms that indicate skeletal microstructure can be used as a record of age and environmental variability; for example trees (Stokes & Smiley, 1996), fish (Woodbury, 1999), bivalves (Cerrato, 2000), and other colonial anthozoans (Druffel et al., 1995; Cole et al., 2000; Andrews et al., 2002; Risk et al., 2002). Despite the cosmopolitan distribution and large size of *H. willemoesi* (Williams, 1995), we found no literature describing colony age or the growth of its axial rod. Therefore, the focus of this study was to: (1) describe the structure of different-size axial rods; (2) estimate colony age from axial rod ring counts; (3) create growth models from estimated ages; and 4) attempt to validate colony age and growth estimates using radiometric age validation.

Material and methods

Twelve *H. willemoesi* colonies were selected from two trawl samples collected in the eastern Bering Sea (Fig. 1). Species identification was based on the recent revision of the order Pennatulacea (Williams, 1995). Colonies were selected by total rod length to form three size groups (small, 25–29 cm; medium, 98–130 cm; large, 153–167 cm) consisting of four colonies each (Table 1). The largest colonies were from Pribilof Canyon (11 September 1997, 56°16.8′ N, 169°25.8′ W, 248 m depth, 3.5°C bottom temp.), the others were collected farther northwest (28 July 1998, 60°0.6 N, 177°56.4′ W, 142 m, 2.0°C). Soft tissue surrounding the axial rod was easily removed because it was securely attached only to the rod base.

Each rod was allowed to dry for 1 month at room temperature before measuring and sectioning. Rod diameter along the full length of each rod was measured with a micrometer to the nearest 0.05 mm. Cross sections were cut at set distances from the base tip with a diamond blade saw and mounted onto slides with LR White resin. Each mounted section was ground down to a thickness of approximately 0.3 mm using 320 and 600 grit wet/dry sand paper and coated with immersion oil for viewing. Sections were viewed through a dissecting microscope with transmitted light to make all counts and measurements at a magnification of 16 times. Although higher magnification revealed rings nested within rings, these finer rings were often hard to distinguish. Growth rings were evident as couplets, each consisting of one translucent and one adjacent opaque band.

For each cross section, the number of couplets was counted three non-consecutive times. In addition, radial measurements of cross sections of the rod base were made to quantify and construct a longitudinal view of the thickness of a core of smooth rings and the overlaying layer of rough material. These measure-

Table 1. Axial rod measurements and age estimates at maximum rod diameter for twelve *Halipteris willemoesi* colonies collected in the eastern Bering Sea, with calculated total length and diameter growth rates

Size-group and colony	Total length (cm)	Maximum diameter (mm)	Average increment width (mm)[a]	Estimated age (yr ± SD)[b]	Length growth rate (cm yr^{-1})[c]	Diameter growth rate (mm yr^{-1})[d]
Small						
BS-G	25.3	0.90	0.075	6.0 ± 1.0	4.21	0.150
BS-E	26.2	0.95	0.079	6.0 ± 1.7	4.36	0.158
BS-F	29.0	1.15	0.075	7.7 ± 1.2	3.78	0.150
BS-H	29.3	1.05	0.060	8.7 ± 0.6	3.38	0.121
Medium						
BS-D	97.8	2.55	0.070	18.3 ± 0.6	5.33	0.139
BS-B	118.4	2.80	0.074	19.0 ± 1.0	6.23	0.147
BS-A	124.4	2.85	0.075	19.0 ± 2.6	6.54	0.150
BS-C	130.3	3.05	0.074	20.7 ± 2.1	6.30	0.148
Large						
PC-C	152.6	5.85	0.073	40.0 ± 5.3	3.81	0.146
PC-D	156.9	6.35	0.076	41.7 ± 2.1	3.76	0.152
PC-B	162.6	6.75	0.072	47.0 ± 1.7	3.45	0.144
PC-A	166.7	6.40	0.066	48.3 ± 1.5	3.44	0.132

[a]Calculated as half the diameter divided by increment count.
[b]Triplicate count of the growth increments resulting in an average age at the maximum rod diameter.
[c]Total length divided by the estimated age.
[d]Maximum diameter divided by the estimated age.

ments were also repeated three non-consecutive times. Triplicate counts and measurements were averaged before calculating the average and standard error (SE) for each rod size group and cross-section position. Cross-section positions were constant within each size group and were determined by distance from the base tip. Average couplet width was calculated as one-half rod diameter divided by couplet count.

Rod length and diameter measurements and growth increment counts (estimated age) were used to estimate growth rates. In addition, growth rates were calculated for the change in colony size, from small to medium and from medium to large, by dividing the difference of the average rod lengths by the difference of the average estimated age.

To gain a better understanding of the composition and structure of the carbonate matrix, X-ray diffraction was performed at the Department of Geology and Geophysics at the University of Alaska, Fairbanks.

To attempt a validation of age and growth estimates, a radiometric age-validation technique was applied to the calcified axial rod among and within colonies. Skeletal material from three sea pen colonies was used in these analyses. Whole and core skeletal material from one colony was used in a preliminary analysis to determine the levels of ^{210}Pb and ^{226}Ra. Core material at the center of the rod was exposed when the rod exterior was removed using a milling machine. The result was a 1-mm diameter, 3-cm long core estimated to be the first few years of growth. Extracted samples were cleaned and processed for ^{210}Pb and ^{226}Ra using well established protocol as described by Andrews et al. (1999 a, b). Two approaches were utilized to attempt to validate age and growth. First, to determine radiometric age using the disequilibria of ^{210}Pb and ^{226}Ra, core material from the thickest, and presumably oldest, part of the axial rod in two colonies was analyzed. The aim of this approach was to age individual cores using the disequilibria of ^{210}Pb and ^{226}Ra. Second, core material at locations along the axial rod (base to tip) was analyzed for ^{210}Pb only. The aim of this approach was to measure the decay of ^{210}Pb activity along the rod from the apical tip to near the base tip that presumably corresponds with a young-to-old gradient.

Results

The axial rods of *H. willemoesi* resembled a thin tapered dowel, and extended the length of the colony (Fig. 1). The upper part of the rod was white, well

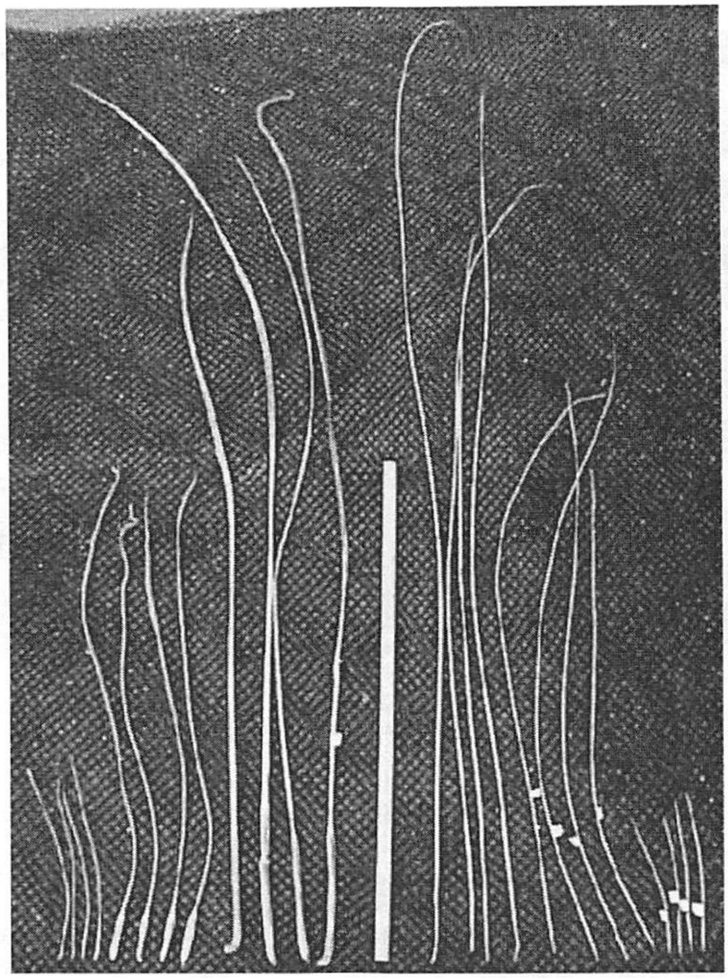

Figure 1. Twelve intact *Halipteris willemoesi* colonies from the Bering Sea (left of meter stick) next to the twelve axial rods from similar-size colonies. The cleaned rods on the right were used to describe rod structure, and to estimate colony age and growth rate.

calcified, and smooth and circular in cross section (Fig. 2A). Soft tissue easily sloughed off this part. The lower part, hereafter referred to as the base, comprised about 10% of the total rod length and differed from the upper part by having a rough exterior and by being irregular in cross section (Fig. 2B). Except at its very tip, which was brown and pliable when wet, the base was also white and well calcified. Soft tissue was securely attached to the base, particularly the tip.

Transverse sections of the rod base revealed that the rough material overlays a core of smooth, concentric growth rings that are similar in cross-section appearance to the rings in the upper part of the rod (Fig. 2). Series of radial measurements of this core were used to construct longitudinal views to show how core thickness decreases toward the base tip (Fig. 3). Comparing core thickness among different size rods helps to illustrate how the rod base may grow. Assuming no structural variation after deposition, the core of small rods corresponds in thickness to the lower part of the core in large rods indicating that the youngest part of large rods is probably close to the base tip.

Rod shape was similar among the different size groups (Fig. 4A). From the point of maximum diameter, rod thickness decreased sharply before assuming a more gradual taper to the apical tip. The distance from the base tip to the point of maximum rod diameter increased with rod size. As a percent of total length, however, this distance was about 5–10% regardless of size group. Maximum rod diameter was similar among the four rods in each size group (Table 1). The average maximum thickness for small,

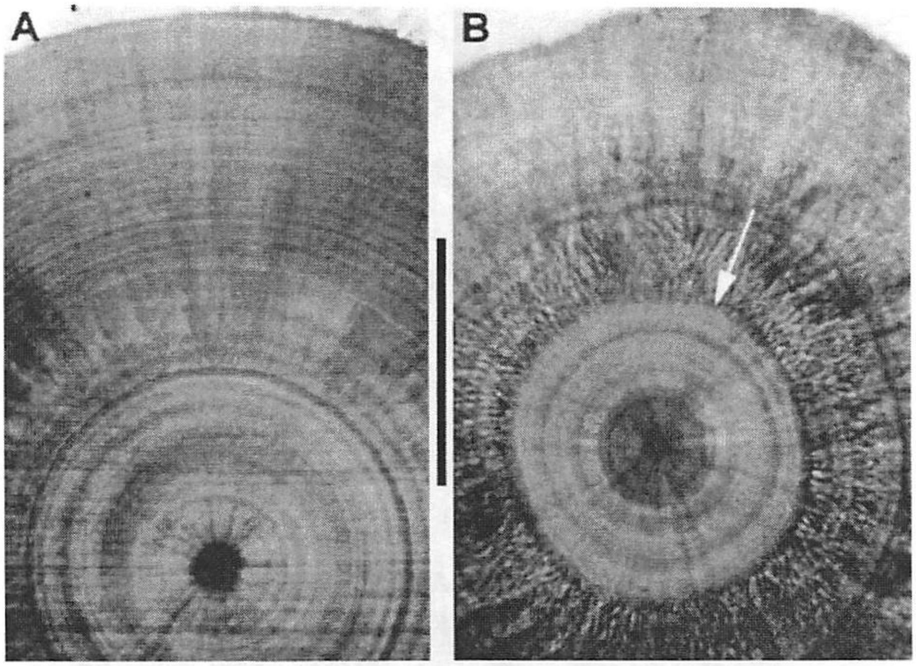

Figure 2. Photographs (32×) of transverse sections of an axial rod taken in the distal part at 25 cm from the basal tip (A), and in the basal part at 5 cm (B) from the basal tip. The axial rod, 167 cm total length, was from a *Halipteris willemoesi* colony collected in the Bering Sea. The arrow points to the interface within the rod base between the inner core of smooth, concentric increments, and the outer rough material (scale bar = 1 mm).

medium, and large rods was 1.01 mm ±0.06 (SE), 2.81 mm ±0.10, and 6.34 mm ±0.19, respectively.

The number of couplets per cross section changed with rod diameter (Fig. 4A, B). For each rod, maximum couplet count occurred at the maximum rod diameter. Among the rods examined, the average count at maximum diameter increased with rod size (Table 1): small, 7.1 ±0.7 (SE); medium, 19.3 ±0.5; and large, 44.3 ±2.0. These counts are assumed to indicate colony age in years; thus, the maximum estimated age for the largest colony, 167 cm total length, was 48.3 ± 1.5 SD yr.

Assuming an annual rate of couplet formation, the estimated annual growth rate in colony length varied with rod size, whereas change in diameter was near constant (Table 1). Total colony length divided by the average estimated age resulted in average annual growth rates of 3.9 ± 0.2 (SE), 6.1 ± 0.3, and 3.6 ± 0.1 cm yr^{-1} for small, medium, and large-size colonies, respectively. Estimated growth rates calculated for change in size, from small to medium and medium to large, also varied as the rod increased in length. Growth estimates from small to medium colony size was 7.42 cm yr^{-1} and 1.68 cm yr^{-1} from medium to large. Estimated annual increase in rod maximum diameter varied little among colonies (small, 0.145 ±0.008 (SE); medium, 0.146 ±0.002; and large, 0.144 ±0.004 mm yr^{-1}) reflecting low among-group variability in mean couplet width. The average annual increase in rod maximum diameter among all colonies was estimated to be 0.145 ± 0.003 SE mm yr^{-1}. This relationship was used to estimate an age prediction model using maximum rod diameter (estimated age (yr) = 7.0∗(maximum rod diameter, mm) - 0.2; R^2 = 0.99). The average width of each couplet was somewhat variable along the rod for all sizes (0.128 ± 0.013 mm; Fig. 4C), particularly at the base and apex which reflects our observation that the innermost couplets tend to be relatively wide. At maximum diameter, the average increment width was near constant among the three colony sizes (0.072 ± 0.050 mm; Table 1).

The X-ray diffraction analysis of the axial rod indicated the carbonate structure is a high-magnesium calcite. Magnesium comprised 3–4 weight percent of the carbonate. Sodium was present at 1–1.5 weight percent.

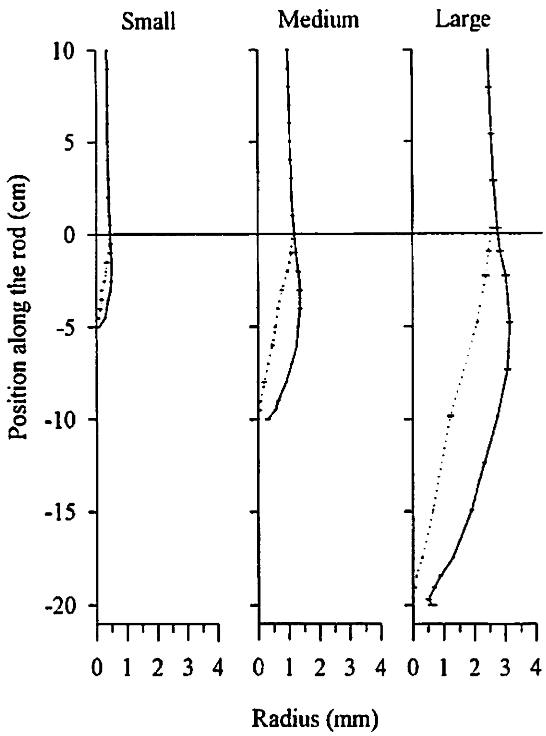

Figure 3. Measurements from cross sections taken throughout the base of twelve axial rods of *Halipteris willemoesi* were used to calculate the average (±SE) radius of the inner core (dotted line. Fig 2B) and the average (±SE) total rod radius (solid line) for each size group (four rods per group. Table 1). For each size group, superimposed plots of these two measurements *versus* cross section position along the rod (distance from the base tip) illustrate how core radius and thickness of the rough outer material varies longitudinally, and that the core extends to the basal tip regardless of rod size. Position along the rod is scaled so that zero (solid horizontal bar) corresponds with the probable relative position of the seafloor surface.

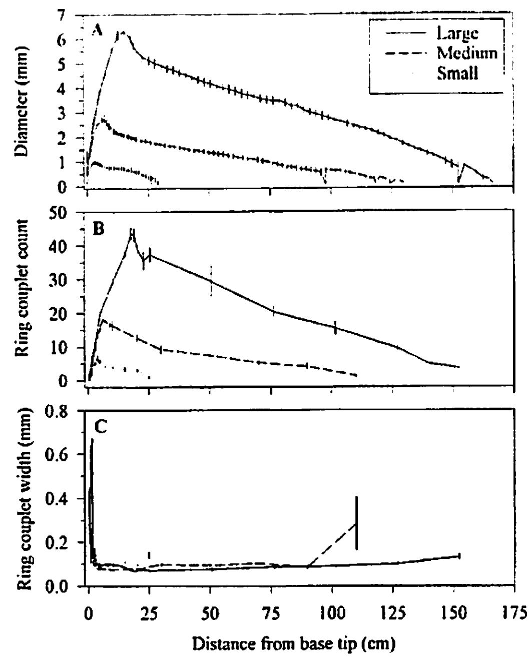

Figure 4. Average diameter (A) and growth increment count (B) from along the axial rods of small (n=4), medium (n=4), and large (n=4) *Halipteris willemoesi* colonies collected in the Bering Sea. Average increment width (C) was calculated as one-half diameter divided by increment count. Vertical bars indicate the standard error of the mean.

Radiometric results indicated that ^{210}Pb activities were relatively high and that exogenous ^{210}Pb was present in all samples except one (Table 2). Whole and cored samples had ^{210}Pb activities that exceeded the activity of ^{226}Ra in 7 out of 8 samples. The one sample that had a ^{210}Pb activity (0.0229 ± 0.0022 dpm/g) that was lower than ^{226}Ra activity (0.121 ± 0.0013 dpm/g) allowed for the calculation of an age from the disequilibrium of ^{210}Pb:^{226}Ra. The result was 5.7 yr (1.7–10.2 yr range) for that colony. The next set of 5 samples from colonies 2 and 3, all of which were cores, had ^{210}Pb:^{226}Ra ratios that exceeded 1.0. Therefore, the ageable sample was thought to be anomalous and the method of disequilibria dating was dropped.

The alternate approach to determining a growth rate was to pursue the decay of ^{210}Pb over the length of the colony (Andrews et al., 2002). In general, ^{210}Pb activity in cores taken from near the basal and apical tips was high relative to activity in the middle of the rod. The range of activities for the 8 core samples taken from colony 3 ranged from 0.692 ± 0.036 to 2.76 ± 0.13 dpm/g. No growth rate or age was determined because the ^{210}Pb activities did not follow a consistent pattern over the length of the colony.

Discussion

Knowledge of structural and temporal growth are important factors in understanding the life history of organisms like coral whose structure provides habitat for other species (i.e., biogenic habitat), and in understanding how skeletal structures may record environmental variability. *In situ* observations indicate that *H. willemoesi*, or similar species, stand erect on the sea floor with the peduncle, which corresponds to the base of the axial rod (Fig. 1), embedded in sed-

Table 2. Results from the radiometric analysis of axial rod sections (whole or core) taken from three *H. willemoesi* colonies collected in the eastern Bering Sea.

Colony	Distance (cm)[a]	Sample type (whole/core)	Sample weight (g)	Activity of ^{210}Pb (dpm/g)	Sigma (1 SE)	Activity of ^{226}Ra (dpm/g)	Sigma (1 SE)	^{210}Pb:^{226}Ra activity ratio
1	11.6	Whole	0.699[b]	1.79	0.12	0.125	0.001	14.3
	11.6	Whole	0.699[b]	1.92	0.10	0.125	0.001	15.4
	16.7	Whole[c]	0.7244	0.0229	0.0022	0.121	0.001	0.19
2 (PC-C)	13.1[d]	Core	0.1543	0.875	0.033	0.147	0.002	5.95
	18.2[d]	Core	0.1711	0.728	0.028	0.132	0.002	5.52
3 (PC-B)	11.6	Core	0.0691	0.917	0.050	0.157	0.001	5.84
	16.7	Core	0.0700	0.773	0.045	0.149	0.006	5.19
	24.4	Core	0.0313	0.715	0.055	0.178	0.044	4.02
	52.3	Core	0.0633	0.727	0.041	N.P.	-	-
	77.7	Core	0.0415	0.774	0.046	N.P.	-	-
	103.1	Core	0.0702	0.692	0.036	N.P.	-	-
	128.5	Core	0.0600	1.03	0.050	N.P.	-	-
	156.4	Core	0.0200	2.76	0.13	N.P.	-	-

N.P. Not processed
[a]Distance from basal end to the center of each section.
[b]Same sample for ^{226}Ra analysis, split for ^{210}Pb analysis.
[c]Small amount of exterior removed by grinding.
[d]Sample length was 6 cm.

iments (Krieger, 1993). The rough part of the base corresponds to secure attachments between the rod and the surrounding soft tissue. In contrast, the upper part of the rod may be smooth so that the soft tissue better slides along it as the colony flexes in near-bottom currents. Based on cross sections through the base, the rough material overlays a core of well defined rings resembling the distal, above-sediment, part of the colony (Fig. 2).

As with *P. guerneyi* (Chia & Crawford, 1973), *H. willemoesi* probably begin to burrow into the sediment as newly settled planula larvae. The axial rod probably forms early after settlement (Chia & Crawford, 1977), but exactly when is unclear. With development, each colony probably burrows deeper to better anchor and support itself. We believe that depositions onto the rod above the seafloor surface result in smooth concentric rings and that lower depositions result in the rough material. Thus, the two layers of the base (Fig. 3) can be explained by rough material being deposited onto the rod as burrowing by the colony draws the rod farther into the sediment. The core of smooth rings at the base tip is difficult to explain unless the tip is the first-formed part of the rod. The relatively thin covering of rough material over this core at the tip probably results from relatively little material being deposited onto the tip during subsequent growth. Deposits onto the remaining parts of the rod must therefore cause it to thicken and elongate. This is relevant to ring-count age estimates because our couplet counts at the maximum diameter of axial rods from large colonies (ca. 160 cm total length) probably did not include the youngest part of the rod, perhaps the first couple of growth rings were missed.

Average width of growth-ring couplets was nearly constant in cross sections of the axial rod. This was especially true for determinations made at the maximum diameter of the rod (Table 1). The calculated average width of the couplets (0.072 ± 0.005 mm) was similar to the result from a study on the axial rod of the sea pen *Ptilosarcus gurneyi* (0.1 mm), a shallow-water species (Birkland, 1974).

Age, estimated from counts of ring couplets, was similar within size groups and was used to determine growth rates (Table 1). The average growth rate for each colony indicated that growth was fastest for the medium sized colonies (97.8–130.3 cm), slower in the small size class (25.3–29.3 cm), and slowest for largest sizes (152.6–166.7 cm). Calculated interval growth, small to medium size and medium to large size, clearly indicated that growth was rapid (7.42 cm yr^{-1}) from an average length of 27.5 cm to 117.7 cm. Interval growth from 117.7 cm to 159.7 cm was slower at 1.68 cm yr^{-1}.

The growth pattern in length indicates slow initial growth followed by rapid growth at intermediate rod size progressing towards an asymptotic length. This is similar to growth models used in other studies of octocoral growth. Velimirov (1975) used a sigmoidal function to describe the growth of the Mediterranean gorgonian *Eunicella cavolinii*, which approached asymptotic size at approximately 15 years. Cordes et al. (2001) used a Gompertz function to model the growth of the deep-sea alcyonacean *Anthomastus ritteri*, which reached an asymptotic size between 30 and 35 years. Although neither study formed conclusions about the maximum age for these colonies, the ages estimated for asymptotic size for *A. ritteri* were similar to the maximum ages reported in this study. No growth model was applied to the data for *H. willemoesi* because few length intervals were sampled.

In contrast to the rate of growth in length, the rate of growth in diameter was nearly constant despite differences in rod size. An age prediction equation was developed based on maximum rod diameter (estimated age (yr) = 7.0∗(maximum rod diameter, mm) − 0.2, R^2 = 0.99). This relationship needs to be further reinforced, however, because of the low number of samples (n = 12). Assuming the age estimates are valid, this relationship could be used in age composition monitoring of trawl bycatch.

Radiometric age determination using the disequilibria of ^{210}Pb:^{226}Ra and the decay of ^{210}Pb was unsuccessful in establishing a validation of age or growth rate estimates for *H. willemoesi*. In one sample, an age estimate of 5.7 yr (1.7–10.2 yr range) was determined for a colony (Table 2). This estimate, however, is suspect because subsequent samples had ^{210}Pb and ^{210}Pb:^{226}Ra activity ratios that exceeded 1.0 (Table 2). These high activity ratios indicate an accumulation of ^{210}Pb from an exogenous source. Because all ^{210}Pb must result from the decay of ^{226}Ra for the technique to work (Burton et al. 1999), the presence of exogenous ^{210}Pb in these samples precluded the use of measured ^{210}Pb:^{226}Ra activity ratios as an indicator of age.

An alternate approach using the decay of ^{210}Pb over the length of a coral colony was successfully applied to red tree coral (*Primnoa resedaeformis*; Andrews et al., 2002). The approach was successful for *P. resedaeformis* because the activities of ^{210}Pb in a series of core samples (material from the inner part of the skeleton when viewed in cross section) from near the apical tip to near the base followed the expected decay pattern and allowed for growth rate estimation and validation of annual growth rings. This approach was applied to one sea pen colony (PC-B), but was unsuccessful because the activity of ^{210}Pb from near the apical tip to near the basal tip did not follow a consistent reduction in activity (Table 2). This may indicate that ^{210}Pb was taken up by the colony unequally throughout life, which may be a reflection of either environmental variability or a violation of the closed system assumption (Burton et al., 1999).

It is increasingly common to find that deep-sea organisms can attain ages that are on the order of decades to hundreds of years (Andrews et al., 1999a; Kastelle et al., 2000; Andrews et al., 2001; Cailliet et al., 2001). The patterns of growth in their skeletal tissues may therefore reflect long histories of environmental variability such as the seasonal flux of particulate matter. This flux has been linked to reproductive cycles in some deep-sea organisms (Valiela, 1984), but not deep-sea pennatulids (Rice et al., 1992; Tyler et al., 1995; Eckelbarger, 1998). Furthermore, the longevity of these organisms and the biogenic habitat they may provide to other species makes it essential that fishing-related impacts be studied in detail (Krieger, 1993; Auster & Langton, 1999; Freese et al., 1999), particularly as fishing activities reach greater depths and fish stocks decline. This perspective on fishing-related impacts has been mandated in management practices in 1996 with the Sustainable Fisheries Act, where understanding and protection of essential fish habitat has become paramount (Rosenburg et al., 2000).

Future efforts using other methods, such as fluorochemical marking and linear extension rates may provide validated estimates of age and growth rates for *H. willemoesi*. It remains to be seen if the growth rates and age estimates determined in this study are accurate; however, in light of their importance as biogenic habitat, it is prudent to take heed of the high estimated longevity of *H. willemoesi*, which may approach or exceed 50 years.

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Habitat associations of demersal fishes and crabs in the Pribilof Islands region of the Bering Sea

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Abstract

Habitat associations of demersal fishes and crabs were determined from observations of videotapes recorded by a camera-equipped remotely operated vehicle (ROV) in the Bering Sea near the Pribilof Islands in September 1995 and 1997. We identified 42 taxa representing 16 families of fishes and 8 taxa from 3 families of crabs. Families Pleuronectidae (righteye flounders) and Cottidae (sculpins) were represented by the greatest number of taxa. *Lepidopsetta polyxystra* and *Chionoecetes opilio* were the most frequently observed fish and crab species. Other fish species in the families Pleuronectidae, Gadidae, Scorpaenidae, Agonidae, and Bathymasteridae were also encountered frequently. Six classifications based on substrate and cover were used to describe the habitat where each fish and crab was observed. Agonids and pleuronectids were typically observed on silt, mud, or sand substrate with no cover while other taxa, particularly cottids and bathymasterids, were encountered in more varieties of habitat including areas covered with rocks and boulders. Significant differences in species composition were found among habitats and stratified depth ranges. Similarity analyses showed that different taxa were responsible for these differences, but within each habitat type and depth range, two to five species contributed to 90% of the average similarity. Some ROV dives were paired with bottom trawls in the same general locations. Species compositions of the ROV observations were significantly correlated with that of the corresponding bottom trawl catch compositions. Overall, we believe that in situ observations provide useful information on fish habitats and behaviors not readily available from conventional trawling surveys.
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Keywords: Fishes; Crabs; Habitat; ROV; Bering Sea; Pribilof Islands

1. Introduction

There has been a recent surge of interest in ecosystem-based management of marine resources. Regulatory agencies are now mandated to identify,

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describe and protect essential fish habitats in order to sustain the long-term viability of these resources. Managers are often faced with the dilemma of defining and preserving critical fish-habitat associations without supporting scientific data, which renders any decisions made toward this objective tenuous at best. Anthropogenic effects on demersal habitats attributable to various sources but particularly mobile bottom fishing gear have been shown to have adverse and long-lived effects on biogenic structure and sediment quality (Auster et al., 1996; Collie et al., 1997, 2000; Jennings and Kaiser, 1998; Schwinghamer et al., 1998; Auster and Langton, 1999; Freese et al., 1999). The extent of habitat disturbance can be related to the size and type of gear used and the frequency and severity of impact, but the type and structure of the habitat itself is also an important consideration. There is increasing concern that fishing effort in many shelf systems has reached a level that it is negatively affecting the productivity and diversity of these ecosystems (Boehlert, 1996). Despite these concerns, we have little baseline data on the habitat requirements and utilization of most continental shelf regions of the world. This is particularly true in much of the North Pacific Ocean and Bering Sea.

Manned submersibles, underwater cameras carried by remotely operated vehicles (ROVs), and towed platforms have become widely used tools for conducting fishery research. These devices have provided the ability to observe fishes and invertebrates in their natural environment and have added a new dimension to fishery surveys beyond traditional net and hydroacoustic sampling (Gunderson, 1993). A majority of the studies utilizing these technologies has focused on characterizing the habitat utilized by a particular species or community (Carlson and Straty, 1981; Richards, 1986; Pearcy et al., 1989; Stein et al., 1992; Krieger, 1992, 1993; Felley and Veccionne, 1995; Auster et al., 1995; Norcross and Mueter, 1999; Johnson et al., 2003). In most of these studies, the behavior of individuals or groups of a particular species was observed and noted, and the characteristics of their habitat evaluated in terms of depth and substrate composition, size, or texture.

The National Marine Fisheries Service (NMFS) has been conducting fishery-independent bottom trawl surveys in the Eastern Bering Sea since the 1960s (Conners et al., 2002). These surveys have yielded important information on the distribution and ecology of Bering Sea fishes and invertebrates. However, little effort has been expended on examining smaller-scale association of the biota with the substrates they inhabit. With the exception of McConnaughey and Smith (2000) and Brodeur (2001), no studies have examined the relationship between bottom type and fish distribution in the Bering Sea. In this study, we describe small-scale habitat associations of demersal fishes and crabs in the southeastern Bering Sea using underwater video cameras mounted on a ROV. Seafloor habitat characteristics are described and substrate associations of several fish and commercially important crustacean species determined. In addition, we compare species composition observed using ROV-mounted video cameras to that determined from bottom trawl collections at the same general locations.

2. Materials and methods

2.1. Field operations

Cruises were conducted in the vicinity of the Pribilof Islands, a group of islands situated at the outer edge of the Bering Sea continental shelf some 370 km north of the Aleutian Islands Archipelago during 9–26 September 1995 and 8–18 September 1997 (Fig. 1). This research was conducted as part of an intensive multidisciplinary study of the frontal regions around the Pribilof Islands and a substantial amount of ancillary physical and biological data were collected at each deployment site (Brodeur et al., 2002). Most of the sites were chosen to represent the different hydrographic habitats (inner shelf, fronts, outer shelf) around the Pribilof Islands that were being studied. Other sites were added based on acoustic signals detecting high biomass near the bottom (e.g. Pribilof Canyon sites).

Underwater observations were made with video cameras mounted on a Deep Ocean Engineering Super Phantom II ROV deployed from the NOAA R/V *Miller Freeman*. ROV surveys were performed with a color CCD video camera (Hitachi Model HV-C20). The viewing area was illuminated by two 250 W tungsten–halogen lights mounted externally on the vehicle. We generally dimmed these lights to about 75% of full power to minimize the backscatter from biogenic particulate matter (organisms and marine snow) in the water column. In 1997, the ROV was also

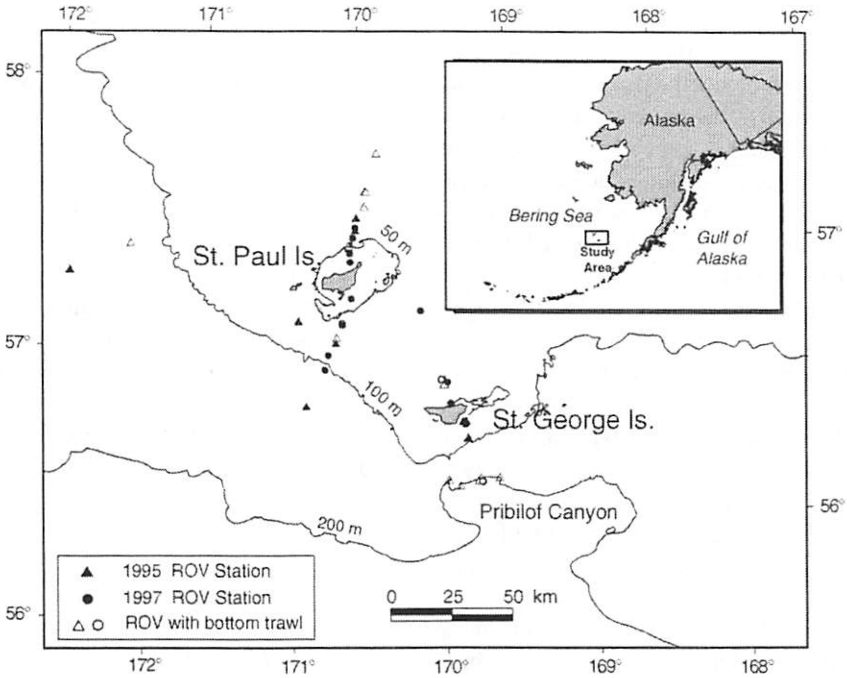

Fig. 1. Pribilof Island study area in the Southeast Bering Sea and station locations of 1995 and 1997 ROV deployments and bottom trawls. Multiple deployments were conducted at some stations.

fitted with a 35 mm still minicamera (Benthos Model 3782) and strobe. The ROV was deployed 25 times in 1995 and 16 times in 1997 (Fig. 1). Mean deployment time was 35.8 min (range 10–78 min).

During each deployment, the vessel drifted with the currents while maintaining a constant heading using its bow thruster. A 108-kg weight was attached 25 m from the end of the ROV umbilical cord to provide stability and reduce the angle of drift of the ROV away from the vessel. The ROV had the capability of moving in all directions within a 25 m radius sphere, but was generally propelled in a linear trajectory at a slow speed to keep it away from the weight. The bottom depth range over which observations were made was from 33 to 248 m. Video images were viewed in real-time using an on deck console that allowed the ROV operator to maneuver the vehicle and control the cameras and lights and provide the depth of the ROV which was annotated throughout the deployment. The video camera had zoom capability but was used only when necessary to identify organisms on transects. Continuous video recordings were made on two Hi-8 mm tape decks.

Following 13 ROV deployments in 1995 and 3 in 1997, a short tow was made along the ROV transect using a nylon northeastern bottom trawl with 1.5 m × 2.1 m steel doors fished without roller gear (Feldman and Rose, 1981). These sites were selected for having bottom types suitable for fishing with a bottom trawl (Fig. 1). The mesh size decreased from 13 cm in the forward part of the net to 8.9 cm in the codend which was also equipped with a 3.2-cm liner. The mean effective path width of the trawl was estimated to be 13.4 m with a mean vertical opening of 9.2 m. The entire catch was processed on deck and the number and weights of all taxa were recorded.

2.2. Laboratory procedures

Videotape footage for each ROV transect was reviewed by two observers in the laboratory. Methods for data collection from videotape footage were similar to those used by Felley and Veccionne (1995) with some modifications. Observations of videotape footage were divided into 1-min intervals. Within each interval, all fishes and crabs were identified to the lowest possible taxa. Depth was recorded and substrate was characterized into categories of silt, mud or sand. Silt was categorized as very fine and could be disturbed into visible plumes by the ROV thrust propellers and moving organisms. Mud was notably more compact, had a slick appearance with a visible sheen on the surface, and could not be disturbed by ROV movements. Sand was notably coarser with no visible sheen and usually appeared as wavy bedforms. Substrate cover was categorized as absent or comprised of broken shell hash, gravel-cobble, or rocks-boulders.

2.3. *Analytical methods*

Habitat types are modified after Norcross and Mueter (1999). Six habitat classifications were identified from the video footage based on observations of substrate and cover (Table 2A). These habitats were: silt (1); mud (2); sand with no cover (3); silt, mud, or sand with broken shell hash (4); silt, mud, or sand with gravel and/or cobble (5); silt, mud, or sand with rocks and/or boulders (6). Habitats were distributed over similar depth intervals with minimum depths from 33 to 55 m and maximum depths from 207 to 248 m. Observations were stratified into depth intervals of ≤100, 101–150, 151–200, and >200 m. Because of the large number of gelatinous zooplankton encountered in midwater during most of the deployments (Brodeur, 1998), we were not able to use any external calibration scale on the ROV to measure the field of view. We estimated this to be about 1 m (wide) × 1 m (tall) for the Hitachi video camera based upon measurements made aboard the research vessel with a typical drifting altitude of about 1 m off bottom.

To examine fish assemblages and relate these to habitat classification, we used presence/absence data within 1-min time intervals as our sampling unit (Felley and Veccionne, 1995). This was found to be necessary as observations were often affected by water clarity. Species with less than 1% occurrence in all intervals were eliminated. To test if differences in species composition occurred among habitat classifications and depth intervals, we performed two analysis of similarity (ANOSIMs), using a Bray–Curtis similarity matrix of samples (1-min intervals). ANOSIM is a nonparametric, multivariate permutation test, analogous to the parametric, univariate ANOVA that is particularly applicable when analyzing multiple species data that do not meet the assumptions required for multivariate ANOVA (MANOVA) (Clarke and Green, 1988). Beginning with a matrix of Bray–Curtis similarity indices, which measures how similar the species composition is for each pair of samples, the matrix is ranked, and then reordered so that all samples within each habitat group are grouped together. An R-statistic is then calculated, which is defined as a measure of how the between-group variance compares to the within-group variance, as does an ANOVA. The formula is,

$$R = \frac{\bar{r}_B - \bar{r}_W}{\frac{1}{2}M}$$

where $\bar{r}_B$ and $\bar{r}_W$ are the average rank similarities for each pair of intervals for between- and within-groups, respectively, $M = n(n-1)/2$, and n is the sample size. Sample sizes for the different habitats do not need to be equal for an ANOSIM, as only the average rank similarities between- and within-groups are compared. We first tested for significant differences between habitats, and then between depth intervals. Whenever a significant difference was found, we followed this with pairwise ANOSIM tests between-groups using a Bonferroni correction. When significant differences were found by the ANOSIM, we then wanted to determine the discriminating species behind the differences. This was done with a SIMPER (similarity percentages) analysis that determines: (1) how much each species contributes to the dissimilarity between two groups and (2) how much each species contributes to the average similarity within a particular group (Clarke, 1993).

In order to compare the ROV data with the trawl data, a separate analysis was used. Instead of presence/absence data, densities per square kilometer were estimated for taxa collected with the bottom trawl using the area swept method as follows:

$$D = \frac{N \times 10^6 \mathrm{m}^2\,\mathrm{km}^{-2}}{L \times W}$$

where D is the density of fish per square kilimeter, N the number of fish observed, L the length of transect (m), and W is the width of transect (m). Sixteen stations where both ROV (standardized to numbers seen per 1 min) and bottom trawl data (standardized to catch per square kilimeter) occurred were selected and a separate Bray–Curtis similarity matrix of the fourth root transformed data was created for both the ROV and trawl data. A fourth root transformation was necessary so that rare taxa were not overwhelmed by the most common taxa. Although the ROV data could not be standardized by area sampled, we assumed that the speed of the ROV was constant, and therefore standardizing by the total number of intervals within each dive should yield comparable rank correlations between the two matrices. A nonparametric Mantel-type test using Spearman correlation coefficients between the two similarity matrices (RELATE procedure in PRIMER software) was used to determine if there was a relationship between the species compositions in the ROV and trawl data (Clarke and Gorley, 2001).

3. Results

3.1. Observations of fishes and crabs

Overall, 42 taxa representing 16 families of fishes were observed with the ROV with a total of 35 taxa identified in 1995 and 31 in 1997 (Table 1). The family Pleuronectidae was represented by the greatest number of taxa ($n = 8$) followed by Cottidae ($n = 7$). Identifications of fishes only to the family level (Cottidae or Pleuronectidae) were usually the consequence of rapid escape movement, the subject being visually obscured by suspended sediments or other particulate matter, or were based on smaller individuals (juveniles) for which we could not discern specific characteristics. Seven taxa of crabs representing three families were observed in 1995 and six in 1997. Table 1 also lists the number of observations in each habitat for each taxon of fishes and crabs identified and how each ranks if within the top 10 in the number of observations.

3.2. Habitat

Overall, a total of 1013 1-min intervals of videotape was examined for the presence of fishes and crabs and for determination of habitat type (Table 2). In 1995, the greatest number ($n = 260$) of ROV observation time intervals was conducted on silt substrate with no cover (habitat 1) followed by mud with no cover (habitat 2) ($n = 138$)(Table 2B). Habitats 3–6 were occupied for substantially lesser amounts of time (Table 2B). Fish or crabs were observed in 67% of the intervals overall. Habitats 2 and 6 had the highest percentage of intervals with fish or crabs observed (77%), followed closely by habitat 3 (76%), while habitat 4 had the lowest (42%).

In 1997, habitat 1 was again the most frequently encountered habitat type ($n = 157$) but was instead followed by habitat 4 ($n = 121$). Habitats 2 ($n = 54$), 5 ($n = 48$), and 6 ($n = 41$) were occupied for similar but substantially lesser amounts of time, and habitat 3 was only encountered once. Fishes or crabs were observed in 61% of the intervals overall and excluding habitat 3, habitat 6 had the highest percentage of intervals with fish or crabs observed (73%) and habitat 2 had the lowest (50%).

3.3. Habitat—species associations

Lepidopsetta polyxystra (Fig. 2A) was the most frequently observed fish ranking first overall in 1995 and second in 1997 (Table 1) and was most commonly encountered on habitat 2 at depths <100 m. *Leptagonus frenatus* (Fig. 2B) ranked second in number of observations overall and was found most often (76.9%) on habitat 1. *Bathymaster signatus* (Fig. 2C and D) ranked third and were usually observed in habitat 6 (68.6%) and sometimes in areas covered with gravel and cobble (habitat 5). *B. signatus* were typically encountered at depths <100 m but some observations were made at depths >200 m. *Sebastes alutus* (Fig. 2E) were most frequently observed (73.8%) on habitat 1 which was often covered with "forests" of the sea whip *Halipterus willemoesi* at depths near 200 m. More detailed descriptions of the habitat of *S. alutus* based on these and other observations can be found in Brodeur (2001). *Theragra chalcogramma* (juveniles and adults) ranked seventh in overall number of observations and were most frequently encountered over habitat 2 (34%) or habitat 4 (34%). *Limanda aspera* (Fig. 2F) were seen mostly on habitat 1 (71.5%) at depths <100 m. *Chionoecetes opilio* (Fig. 2G), the only crab species ranking in the top 10 for number of overall observations, was also encountered most frequently on habitat 1 (81.1%) at depths <100 m and sometimes at depths 101–150 m. Another crab species, *Paralithodes camtschaticus*, ranked fifth in 1997 but did not rank within the top 10 for both years combined. *Gadus macrocephalus* (Fig. 2H) ranked 10th in number of observations overall and was usually observed on habitat 1 (61.1%) at depths both <100 and >200 m. Observations of less frequently encountered taxa in specified habitats are summarized in Table 1.

Some individual taxa displayed associations with or were dominant in single or multiple habitats (Fig. 3).

Table 1
List of fish and crab taxa observed from video tapes recorded during 1995 and 1997 ROV deployments with number of observations in each habitat type and total number of observations

Family	Scientific name	Common name	Presence/absence		Numbers of observations Habitat type						Total no. of observations
			1995	1997	1	2	3	4	5	6	
Fishes											
Rajidae	Rajidae	Unidentified skates	×	×	3	1					4
	Bathyraja aleutica	Aleutian skate	×		1						1
	Bathyraja interrupta	Bering skate		×	1						1
	Bathyraja taranetzi	Mud skate		×	3						3
	Raja binoculata	Big skate	×		1				1		2
Gadidae		Unidentified cods	×	×	5	1			5	1	12
	Gadus macrocephalus	Pacific cod	×	×	22	4			7	3	36
	Theragra chalcogramma	Walleye pollock (juveniles and adults)	×	×	13	20		20		6	59
Scorpaenidae	*Sebastes* spp.	Unidentified rockfishes	×	×		1			2	3	6
	S. alutus	Pacific ocean perch	×	×	48		1		2	14	65
	S. ciliatus	Dusky rockfish		×						1	1
Hexagrammidae	*Hexagrammos* spp.	Unidentified greenlings		×				3			3
Cottidae		Unidentified sculpins	×	×	15	17	11	11	5	3	62
	Hemilepidotus jordani	Yellow Irish Lord	×	×	3	6		1	4	8	22
	Malacocottus spp.	Unidentified *Malacocottus*	×						1		1
	Malacocottus zonurus	Darkfin sculpin		×	1					2	3
	Myoxocephalus spp.	Unidentified *Myoxocephalus*	×			1					1
	Triglops spp.	Unidentified *Triglops*	×	×	4			3	4	2	13
	Triglops scepticus	Spectacled sculpin	×	×	3						3
Psychrolutidae	*Dasycottus setiger*	Spinyhead sculpin		×	1					1	2
	Psychrolutes paradoxus	Tadpole sculpin	×			4					4
	Psychrolutes sigalutes	Soft sculpin	×			2					2
Hemitripteridae	*Hemitripterus bolini*	Bigmouth sculpin	×	×	3	1					4
Agonidae		Unidentified poachers	×	×	19	6		2	2	2	31
	Leptagonus frenatus	Sawback poacher	×	×	70	5		10	3	3	91
	Podothecus acipenserinus	Sturgeon poacher	×	×	4			2			6

Cyclopteridae	*Aptocyclus ventricosus*	Smooth lumpsucker	×		1						1
Liparidae	*Careproctus* spp.	Unidentified snailfishes	×		1						1
Bathymasteridae	*Bathymaster signatus*	Searcher	×	×		1			21	48	70
Zoarcidae		Unidentified eelpouts	×	×	13	3		2			18
Stichaeidae		Unidentified pricklebacks	×	×	11						11
	Lumpenus spp.	Unidentified *Lumpenus*	×	×	13	1					14
Trichodontidae	*Trichodon trichodon*	Pacific sandfish	×		1						1
Zaproridae	*Zaprora Silenus*	Prowfish	×			1			1		2
Pleuronectidae		Unidentified flatfish	×	×	21	24		12	1	2	60
	Atheresthes spp.	Arrowtooth or Kamchatka flounder	×	×	8	5		2	12		27
	Glyptocephalus zachirus	Rex sole		×	3						3
	Hippoglossus stenolepis	Pacific halibut	×	×	8	3				2	13
	Hippoglossoides elassodon	Flathead sole	×		1						1
	Lepidopsetta polyxystra	Northern rock sole	1	×	32	106	28	67	7	6	246
	Limanda aspera	Yellowfin sole	×	×	35	6		8			49
	Pleuronectes quadrituberculatus	Alaska plaice	×	×	1			1			2
Total number of taxa		42	35	31							
Crabs											
Majidae	*Brachyura*	Unidentified crab	×	×	10	4		1			15
	Chionoecetes sp.	Unidentified Tanner crab	×		4						4
	C. bairdi	Tanner crab	×	×	7	5		4			16
	C. opilio	Snow crab	8	×	30	3		4			37
Lithodidae	*Paralithodes* spp.	Unidentified king crab		×		2					2
	Paralithodes camtschaticus	Red king crab	×	5	1	3		18	2	1	25
	P. platypus	Blue king crab	×			1					1
Atelecyclidae	*Erimacrus isenbeckii*	Korean horsehair crab	×	×	1	9		5	2	3	20
Total number of taxa		8	7	6							

Table 2
(A) List of habitat types, characteristics, depth ranges, and percentage of observations in selected depth intervals and (B) number of 1 min video observation intervals in each habitat with number and percentage of intervals where fish and/or crabs were observed for 1995, 1997, and combined ROV deployments

Habitat	Characteristics	Depth range (m)	Depth interval (m) (% of observations)			
			<100 m	101–150 m	151–200 m	>200 m
(A)						
1	Silt, no cover	55–248	32	16	8	44
2	Mud, no cover	50–207	96			4
3	Sand, no cover	50–247	97			3
4	Silt, mud, or sand covered with broken shell hash	33–208	95			5
5	Silt, mud, or sand covered with gravel-cobble	36–208	58		35	7
6	Silt, mud, or sand covered with rocks-boulders	36–222	74		6	20

Habitat	1995			1997			1995, 1997 combined		
	Total 1 min intervals	# w fish/crabs	% w fish/crabs	Total 1 min intervals	# w fish/crabs	% w fish/crabs	Total 1 min intervals	# w fish/crabs	% w fish/crabs
(B)									
1	260	169	65	157	99	63	417	268	64
2	138	106	77	54	27	50	192	133	69
3	37	28	76	1	1	100	38	29	76
4	50	33	66	121	71	59	171	104	61
5	67	28	42	48	29	60	115	57	50
6	39	30	77	41	30	73	80	60	75
Total	591	394	67	422	257	61	1013	651	64

For example, although dominant in habitats 2–4, *L. polyxystra* was present in all habitats, and had a wide range of substrate utilization. Cottidae (unidentified sculpins) was the only other taxon identified in all habitats. *L. frenatus* was dominant in habitat 1 but was also present in all other habitats except 3. *B. signatus* was the dominant taxon in habitats covered with cobble-gravel (5) and rocks-boulders (6). One noteworthy observation was the relatively high number of encounters of the pleuronectid flatfishes *Atheresthes* spp. and *L. polyxystra* on cobble-gravel (habitat 5). *L. aspera* were most frequently encountered on silt substrate (habitat 1) and at depths always less than 100 m. Crabs were most frequently observed on habitats 1 and 4 and were completely absent on habitat 3.

There were significant differences in species composition among habitats ($P < 0.01$, ANOSIM). Pairwise tests showed that (a) species assemblages on habitats 1–4 were all different from habitats 5 and 6 and (b) species composition of habitat 1 was different from habitats 2 and 4. The subsequent SIMPER analysis, corresponding to result (a) above, showed that in order of highest to lowest importance, *L. polyxystra*, *B. signatus*, *L. frenatus*, Cottidae, *Hemilepidotus jordani*, *Atheresthes* spp., *S. alutus*, Pleuronectidae, *T. chalcogramma*, *G. macrocephalus*, and Agonidae contributed to 75% of the average dissimilarity between combined habitats 1–4 and combined habitats 5 and 6, therefore making these the primary discriminating species for this difference. The second SIMPER analysis, corresponding to result (b) above, showed that, in order of highest to lowest importance, *L. polyxystra*, *L. frenatus*, Pleuronectidae, *T. chalcogramma*, Cottidae, *C. opilio*, *L. aspera*, *S. alutus*, Agonidae, and *G. macrocephalus* contributed to 75% of the average dissimilarity between habitat 1 and combined habitats 2 and 4, therefore making these species the primary taxa responsible for the observed difference.

Species composition was also significantly different among all four depth intervals ($P < 0.01$, ANOSIM). Subsequent SIMPER analysis showed that different sets of taxa were responsible for these differences, but within each depth interval, there were 2–5 taxa unique to that interval contributing to 90% of the aver-

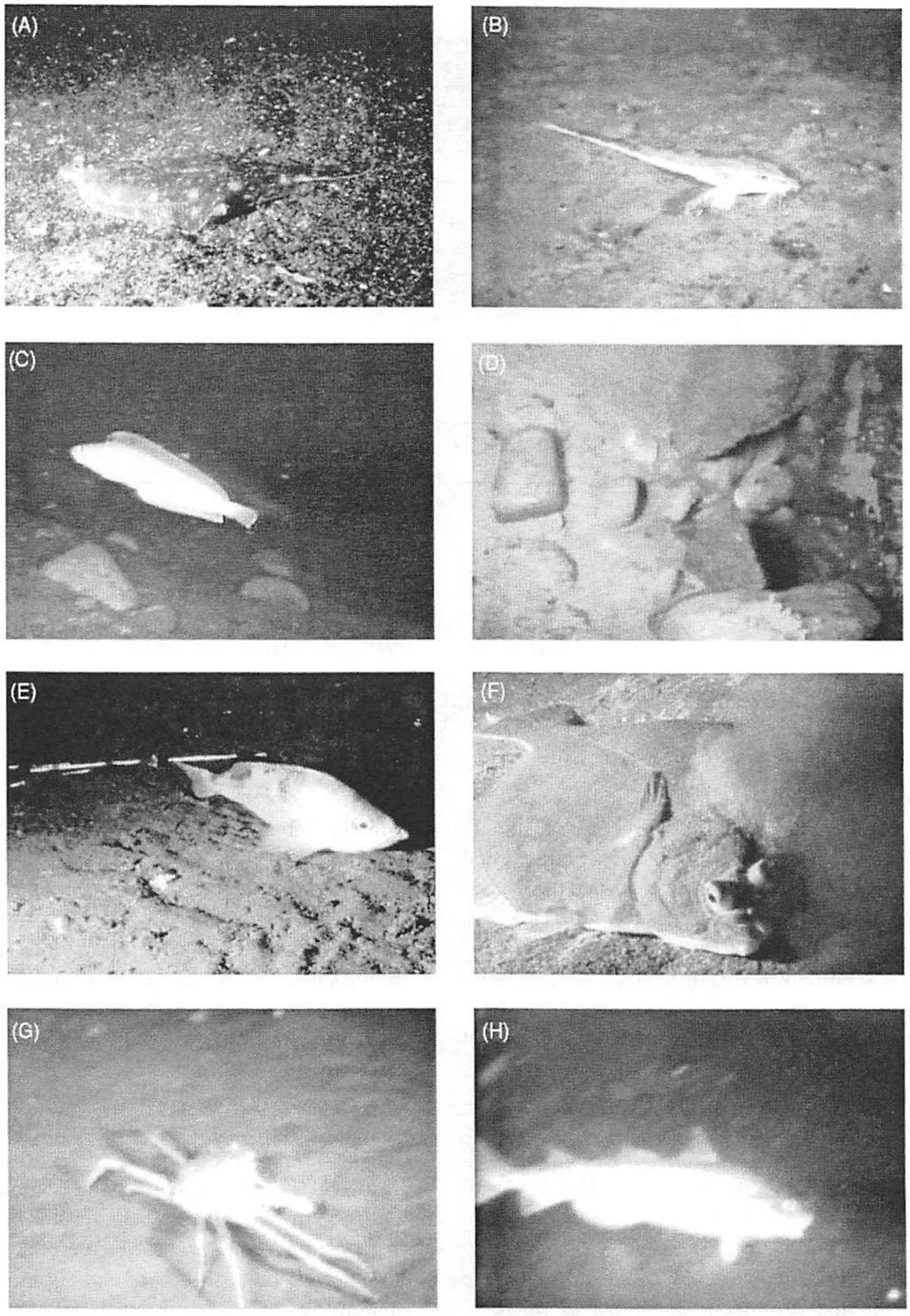

Fig. 2. Photographs and digitized video taped images of some of the most frequently observed fish and crab species. (A) *Lepidopsetta polyxystra* on sand with broken shell hash (habitat 4) depth 57 m. (B) *Leptagonus frenatus* on silt with no cover (habitat 1) depth 208 m. (C) *Bathymaster signatus* over silt with rocks and boulders (habitat 6) depth 175 m. (D) *Bathymaster signatus* hiding in hole in silt with rocks and boulders (habitat 6) depth 207 m. (E) *Sebastes alutus* on silt with no cover (habitat 1) depth 248 m; note downed sea whip *Halipterus willemoesi* in background. (F) *Limanda aspera* on silt with no cover (habitat 1) depth 62 m. (G) *Chionoecetes opilio* on silt with no cover (habitat 1) depth 114 m. (H) *Gadus macrocephalus* feeding in silt with no cover (habitat 1) depth 204 m.

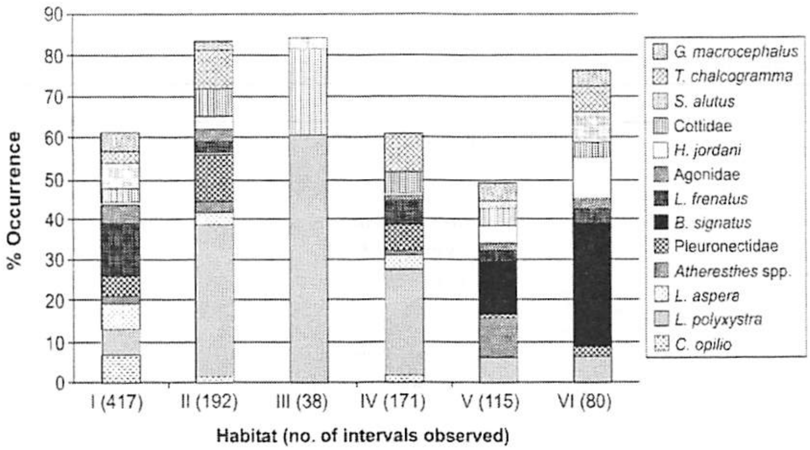

Fig. 3. Percent occurrence in each habitat type for some of the most frequently observed taxa.

age similarity. Listed by depth interval, the unique species were (<100 m) *L. polyxystra*, Pleuronectidae, *T. chalcogramma*, Cottidae, and *B. signatus*; (101–150 m) *C. opilio*, *Lumpenus* spp., Stichaeidae; (151–200 m) *S. alutus* and *Atheresthes* spp.; (>200 m) *L. frenatus*, *G. macrocephalus*, and Agonidae.

3.4. Comparisons of ROV observations with bottom trawl catches

Overall, 46 taxa of fishes and 8 taxa of crabs were collected in bottom trawls paired with ROV deployments in 1995 and 1997. Although we observed nine fish taxa on the tapes recorded from the ROV deployments that were not collected in bottom trawls, there were 21 taxa of fish and crabs identified in bottom trawls that were not seen in the video footage (Table 3). Among these was *Somniosus pacificus*, the only shark encountered in the study. Species composition and ranked abundances of taxa of the ROV observation data from dives paired with bottom trawls was significantly correlated with those of the bottom trawl data ($P < 0.01$, Mantel).

4. Discussion

4.1. Habitat observation

Video observations provided us with a wealth of information on microhabitat usage and behavior of fishes and crabs in the Eastern Bering Sea that would not be discernable from trawling. For example, *B. signatus* individuals were seen darting into crevices or burrows often in close proximity to rockpiles upon the approach of the ROV, and thus would likely not be caught by bottom trawls in these habitats. It is unknown whether they excavate these burrows themselves, similar to tilefishes (*Lopholatilus chamaeleonticeps*) in the Atlantic (Able et al., 1982, Grimes et al., 1986), or whether they occupy previously excavated holes. Most rockfishes (*Sebastes* spp.) were associated with rocky outcrops or with some sort of biogenic structure such as the sea whip 'forest' in Pribilof Canyon (Brodeur, 2001), anenomes or sponges. Although most of the habitats we surveyed lacked substantial vertical relief, many other fish and invertebrate taxa showed apparently thigmotactic responses to natural or biogenic features such as excavated pits, anemones and sponges, basket stars, and sand waves, as has been observed in other continental shelf habitats (Auster et al., 1991). We also observed large depressions in sand and mud that were occupied and apparently excavated by skates. *Lepidopsetta polyxtstra* were frequently seen swimming along troughs between sand waves. This behavior likely reduces their vulnerability to capture in bottom trawls. Several flatfish species including *Atheresthes* spp. and *L. polyxystra* were seen in small pockets of silt, sand, or mud surrounded by cobble-gravel (habitat 5) or rocks and boulders (habitat 6) (Fig. 3). In these untrawlable habitats, the ROV could be used as a means to enhance or "fine tune" trawl surveys.

Table 3
List of fish and crab taxa observed from video tapes recorded during 1995 and 1997 ROV deployments that were not collected in bottom trawls and fish and crab taxa collected in bottom trawls that were not observed on video tapes in paired ROV and bottom trawl deployments

ROV	Bottom trawl	
Bathyraja aleutica	*Somniosus pacificus*	Pacific sleeper shark
Bathyraja taranetzi	*Bathyraja parmifera*	Alaska skate
Hexagrammos spp.	*Clupea pallasi*	Pacific herring
Psychrolutes sigalutes	*Mallotus villosus*	Capelin
P. paradoxus	*Oncorhynchus keta*	Chum salmon
Aptocyclus ventricosus	*Sebastes aleutianus*	Rougheye rockfish
Stichaeidae	*S. zacentrus*	Sharpchin rockfish
Lumpenus spp.	*Anoplopoma fimbria*	Sablefish
Trichodon trichodon	*Artediellus pacificus*	Hookhorn sculpin
	Gymnocanthus galeatus	Armorhead sculpin
	Icelus spiniger	Thorny sculpin
	Myoxocephalus jaok	Plain sculpin
	M. polyacanthocephalus	Great sculpin
	Triglops forficata	Scissortail sculpin
	Triglops macellus	Roughspine sculpin
	Triglops pingelli	Ribbed sculpin
	Lycodes palearis	Wattled eelpout
	Atheresthes evermanni	Kamchatka flounder
	Reinhardtius hippoglossoides	Greenland halibut
	Hyas spp.	Lyre crabs
	Telmessus cheiragonus	Helmet crab

Common names of ROV taxa are given in Table 1.

This study provides the first descriptive community-wide account of demersal fishes and crabs and their habitat associations in the Bering Sea based on in situ observations. Video observation is a useful tool in many habitats, particularly where trawling is difficult, and it readily provides valuable information on habitat associations and behavior. However, this sampling gear does have its own drawbacks and difficulties in both collecting and analyzing data that are discussed here.

4.2. Species identifications

Identification of fish species images recorded on videotape is somewhat problematic because of viewing angles, flight responses, and cryptic behavior. In particular for this region of the Bering Sea near the Pribilof Islands, several congeners are similar in appearance and often require detailed examination to differentiate. Consequently, a large number of identifications were made to family and genus in the families Cottidae and Pleuronectidae in all habitats and depths. Among the Cottidae, *Myoxocephalus jaok* and *M. polyacanthocephalus* were identified in bottom trawls, but such distinctions could not be made from the video recordings, though it is highly likely both species were encountered. The same can be said for *Triglops forficata*, *T. macellus*, and *T. pingeli*.

In the family Pleuronectidae, we could not distinguish *Atheresthes evermanni* from *A. stomias* in video footage although both species were caught in bottom trawls. Although *L. polyxystra* is the only species of rock sole known from the Pribilof Island region, it would be extremely difficult to distinguish this species from *L. bilineata* in the Gulf of Alaska where the two species occur sympatrically (Orr and Matarese, 2000). The best characters for distinguishing *L. bilineata* from *L. polyxystra* require close examination of the lateral line, blind side of the fish, and gill rakers which would be impossible with a video camera. Similar detailed examinations are necessary to distinguish species within other pleuronectid genera such as *Hippoglossoides* and *Limanda*, and may limit the utility of the ROV as a survey tool for flatfishes in the Bering Sea. Perhaps with higher resolution cameras and increased zoom capabilities, these identifications can be accomplished.

4.3. Habitat distribution and human impacts

Although we did not collect and analyze sediment samples as part of this study, large areas of the eastern Bering Sea continental shelf, particularly around the Pribilof Islands, have been surveyed for surficial sediment particle sizes, degree of sorting, and composition (Smith and McConnaughey, 1999) and associated flatfish abundances (McConnaughey and Smith, 2000). Some generalized comparisons of our habitat observations and their sediment maps can be made. Our apparently finest unconsolidated substrate that we called silt (habitat 1) would be most similar to their mud while mud (habitat 2) and sand (habitat 3) approximate their sandy mud and muddy sand. Our remaining habitat types use these three categories for underlying substrate with cover of varying composition (broken shell hash—habitat 4) and size classes (gravel-cobble—habitat 5; rocks-boulders—habitat 6). We conducted several dives in Pribilof Canyon, south of St. George Island (Fig. 1), and observed silt (habitat 1) throughout the center with large fields of gravel-cobble (habitat 5) and rocks-boulders (habitat 6) near the edges of the canyon. Moving north from Pribilof Canyon to the south end of St. George Island, we encountered habitats 2 and 3 that were covered with gravel-cobble (habitat 5) and rocks-boulders (habitat 6) in dives closest to the island. All dives in the area between St. George and St. Paul Islands were either on habitats 1 or 2 suggesting that this large area has rather uniform and consistent substrate composition. This observation is consistent with those of Smith and McConnaughey (1999) who reported numerous collections of sandy mud and muddy sand in this area. Immediately north of St. Paul Island we encountered predominantly mud (habitat 2) and mud covered with broken shell hash (habitat 4). The northern and western most dives were on silt substrate (habitat 1).

On several occasions, we encountered evidence of human influence on the sea floor. This was usually in the form of "ghost" crab pots. Some of these had obviously been present for long periods of time and had been colonized by large anemones, sea stars, and barnacles. *Sebastes* spp. were usually seen in the vicinity of these objects. On one occasion, a clothes washer/dryer combination was collected in a bottom trawl and the drums found to be full of juvenile crabs (*C. opilio*). However, we observed few examples of bottom trawl tracks in our study region despite substantial trawling that has occurred here. This may be due in part, to the substantial near bottom tidal currents (>2 kts) that likely "erase" trawl tracks or naturally compacted sediments which resist scouring.

4.4. ROV-bottom trawl comparisons

We compared two methods of assessing fish distribution and habitats in our study. Trawling has some obvious advantages in that the specimens are captured so that positive identification, size, sex, age, and other biological variables can be determined. In addition, the effort tends to be more standardized and does not suffer from variability with respect to visibility and viewing angle as an ROV does. For purposes of habitat definition, trawling provides few details about the small-scale distribution patterns since it integrates the sample over the entire length of the trawl and provides almost no information on bottom type or topographic relief. Trawling also does not work well in rocky or high-relief environments. Even in flatter terrain, some flatfish are known to escape under the trawl footrope or through the meshes (Adams et al., 1995; Munro and Somerton, 2002). Finally, trawling provides little information about small-scale animal/substrate interactions that were readily apparent in our ROV observations (e.g. fishes that occupy burrows in the sediments).

Although the bottom trawl collected four more fish taxa than were identified on the videotapes, there are a few problems with this comparison that should be addressed. Firstly, three of these taxa collected in the bottom trawl (*Clupea pallasi*, *Mallotus villosus*, *Oncorhynchus keta*) are considered pelagic species and were most likely caught during deployment or retrieval of the bottom trawl and were unlikely to have been observed with an epibenthic video camera. With these three taxa removed from the trawl species list, the number of fish taxa nearly equals that observed on videotape (43 taxa versus 42 taxa). With these taxa excluded, a significant correlation in species composition and ranked abundance of taxa occurred between ROV observations and bottom trawls.

Although we were able to calculate densities of fish and crab taxa from bottom trawls, estimating densities from the video observations was more difficult. This is due to variations in altitude, pitch and roll of the ROV that affect the area of each view. Had we been able to measure the width of the video camera's field of view and distance traveled by the ROV accurately, a more meaningful comparison of the ROV and bottom trawl as sampling devices could have been made (e.g. Adams et al., 1995). Also, we have little information on how the presence of the ROV (e.g. lights, vibrations, and thruster noise) may have impacted the behavior of the fish in the path of the deployment. Previous studies have shown attraction, repulsion, and no apparent response to ROVs and submersibles (Carlson and Straty, 1981; Pearcy et al., 1989; Krieger, 1993; Adams et al., 1995; Norcross and Mueter, 1999). We were not able to directly address the effects of lights on the behavior of fishes although on several occasions, we turned off the lights for short periods of time and then turned them on and found no apparent 'startle' behavior for fish, although this reaction could still be occurring outside our visual range.

Another complicating factor encountered during the video survey was reduced and variable visibility levels. Reduced visibility was most frequently caused by large amounts of suspended sediment and other particulate matter mostly on unconsolidated substrate (e.g. silt). On several occasions, visibility was dramatically reduced by large swarms of euphausiids and other zooplankton in close proximity to the bottom during daylight hours. Moreover, in 1997, there was a pervasive bloom of the coccolithophore, *Emiliania huxleyi*, in the Eastern Bering Sea (Napp and Hunt, 2001) and at several locations, this bloom of highly-reflective particles extended to the bottom severely restricting visibility (Stockwell et al., 2001).

Our use of ROV video analysis of demersal fishes and crabs provided new and important information on the types of habitats utilized by these important taxa in the Bering Sea. Although the cost and logistic difficulties in using ROVs may prohibit their use for large-scale surveys, we feel that their potential advantages may someday make their widespread use more desirable in fishery surveys. Towed vehicles supporting underwater video cameras show promise as a lower cost alternative for habitat surveys (Barker et al., 1999). Future ROV video and manned submersible studies in the Bering Sea should be equipped with the necessary instrumentation to collect quantitative data (e.g. width of camera field of view and distance traveled) for estimating fish and crab abundance and to quantify the environment in which they occur.

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December 4, 2006

LATE COMMENT

Stephanie Madsen
Chair
North Pacific Fishery Management Council
605 West 4th Avenue, Suite 306
Anchorage, AK 99501-2252

Dear Ms. Madsen:

Thank you for this opportunity to comment regarding the North Pacific Fishery Management Council's developing alternatives to protect the Bering Sea Essential Fish Habitat (EFH).

It is widely accepted by scientists that bottom trawling reduces and in some cases destroys habitat complexity, alters seafloor communities and reduces productivity. A productive and healthy benthic zone is critical for the birds, seals, walrus, whales, fish and crab that we depend upon. As a resident of St. George Island I am seeing many environmental changes come into my Community, and am very concerned.

For centuries the Alaska natives' people lived off the bounties of the land and the sea, now many generations later we sit and watch as our marine resources dwindle before our eyes. Now, in as less than one generation the negative changes can be easily detected. I am very concerned about the health of the Bering Sea. Freezing and reducing the bottom trawl footprint in the Bering Sea is a crucial first step to protecting our people our lifestyles and the very resources we depend upon for food.

The survival of all Bering Sea coastal communities is dependant upon the very health of the Bering Sea and is uniquely tied to this surrounding environment.

Please include and enact an alternative that will freeze and eventually reduce the trawl footprint so that we will be able to continue to live our customary and traditional lifestyles.

Sincerely,

Andrew Malavansky