FORAGE FISH ABUNDANCE AND DISTRIBUTION AT

FORRESTER ISLAND, ALASKA

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Final contract report   January 2000

Submitted to the North Pacific Universities Marine Mammal Research Consortium
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ABSTRACT

This study examined the abundance and species composition of forage fishes near sea lion and seabird rookeries in Southeast Alaska, East Aleutians, Pribilofs, Central Aleutians, and West Aleutians (Figure 1). Bottom trawls, midwater trawls, surveys of large predatory fish stomach contents, and measurements of physical parameters were conducted at some or all of these five regions during summer 1997.

Sixty-one bottom trawl tows from among all regions collected 4539 fishes of 62 taxa. There were significant differences among regional values of depth, %mud, bottom temperature, bottom salinity, towing speed, cumulative fish abundance, and size of fish. Differences were not detected among regional mean values of %gravel, %sand, and species diversity. Among the tows on sand substrate, there were significant regional differences in species diversity. Regional species abundance and species distribution relative to physical parameters are reported and contrasted; parameters important to distribution are identified.

Fourteen midwater trawl tows from Southeast and the Pribilof Islands collected 23,345 fishes of 10 taxa. Salinity, number of taxa caught, and species diversity were all significantly greater in Southeast Alaska than in the Pribilofs. Regional differences were not detected between depths, temperatures, towing speed, or cumulative fish abundance. Regional values of species abundance are reported.

The stomach contents of 126 Pacific halibut and Pacific cod captured in the Pribilofs and East, Central, and West Aleutians were examined. Frequency of occurrence and numerical composition of prey taxa are reported for each predator species and region.

Fish species diversity, composition, abundance, and size differed between Southeast Alaska and western locations. There were higher species diversity, different species, and fewer individuals in Southeast Alaska than in the Aleutians and Pribilofs. There were also considerable differences between sampling sites in Southeast Alaska and the Aleutian and Pribilof Islands. Trawlable areas within Southeast Alaska were significantly deeper than in the other regions, and were all of sand substrate. Bottom temperatures at bottom trawl tow sites in Southeast Alaska and in the East Aleutian Islands were warmer than in the Pribilofs, Central Aleutians and West Aleutian Islands. Samples were collected from a different vessel in Southeast Alaska than in other regions, in part resulting in a higher tow speed in Southeast Alaska. While these physical differences between regions compound the regional differences detected in fish distribution and abundance, the differences in fish are real, just their magnitude is uncertain.

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EXECUTIVE SUMMARY

Forage fish surveys were conducted during summer 1997 at 11 sea lion and/or seabird rookeries in Southeast Alaska, the Aleutian and Pribilof Islands. These rookeries were separated into five divisions for regional analysis. They are analyzed and reported upon in order of east-to-west latitude, i.e., Southeast, East Aleutians, Pribilofs, Central Aleutians, and West Aleutians (Figure 1). This report emphasizes comparisons between Southeast Alaska and Central Aleutians because those are areas of comparable Steller sea lion feeding studies. Near all rookeries, there were areas where the bottom topography was too steep, uneven or rocky to allow for quantitative bottom trawl catches. Thus, the bottom trawl survey described the groundfish community only at trawlable areas, rather than at all areas near a rookery. Trawl surveys in each region primarily targeted juvenile demersal fishes using a 3.05 m beam trawl with 7 mm mesh and 4 mm codend mesh. Secondarily, trawl surveys targeted midwater fishes using a modified herring trawl with a 30 ft wide headrope and 3.2 mm (Southeast Alaska) or 1.0 mm (Pribilofs) codend mesh.

Physical parameters (depth, temperature, and salinity) generally were different among regions. The depth of bottom trawl sites over all regions ranged from 17 to 140 m, with the average depth range examined within any one bottom trawl tow being 4.2±4.0 m. Bottom trawls were collected in Southeast Alaska at depths of 89−140 m near Forrester Island and 138 m near Lowrie Island, and from the Central Aleutians at depths of 22–96 m at Kasatochi Island and 49 m at Seguam Island. Depth strata contrasted among the five regions were <40 m, 40–70 m, and >70 m. Due to extremely rough and steep topography nearshore of Forrester and Lowrie Islands, no shallow sites in Southeast could be examined by bottom trawl; all sites there were in the deepest stratum. Thus, the shallowest depths examined in Southeast were approximately equal to the deepest depths examined in the other regions. Depths trawled in Southeast were significantly deeper than all other regions ($p<0.001$); depths trawled in Central Aleutians were different only from Southeast Alaska. Three trawlable sediment classes were encountered during the bottom trawl survey, i.e., gravel/larger sediment, mixed sand/gravel, and sand. In Southeast quantitative bottom trawl tows were possible only in relatively deep, flat zones, all of which were sand substrate. In the Central Aleutians, 11 tows were on gravel/larger sediment, two were on mixed sand/gravel, and none were on sand. Bottom temperatures in Southeast (7.1±0.3^{o}C) were significantly warmer than in any other region ($p<0.01$), and bottom temperatures in Central Aleutians (5.2±0.4^{o}C) were significantly cooler than Southeast Alaska and the East Aleutians ($p<0.001$). Bottom salinities in Southeast (32.9±0.40 psu) and Central Aleutians (32.6±1.95 psu) were intermediate within the range of salinities examined (25.8–34.0 psu). Although bottom salinities differed significantly among regions ($F = 2.55$, $p = 0.049$), they were not significantly different between any two regions ($p>0.05$).

Quantitative bottom trawl tows at ten rookeries within five regions collected 4539 fishes, which corresponded to a cumulative CPUE of 4346.0 (# fish/1000 m^2, summed over all species at 61 tows). The average catch over each of 61 sites was 71.2±103.6 fish/1000 m^2. Average cumulative CPUE values for bottom trawl tows were significantly different among regions ($F = 2.72$, $p<0.05$). Although cumulative CPUE values appeared to increase slightly from east to west,

cumulative CPUE was not significantly different between any two regions ($p>0.06$). The lowest average regional catch was in Southeast (11.0±7.1 fish/1000 m^2), and the highest average regional catch was in the West Aleutian (95.7±129.5 fish/1000 m^2). Catches in Southeast Alaska were consistently low ($\leq$22.6 fish/1000 m^2). The three tows with the largest catches were in the West Aleutians (Agattu: 445.5 fish/1000 m^2) and Central Aleutians (Seguam: 442.6 fish/1000 m^2; Kasatochi: 413.9 fish/1000 m^2).

Sixty-two taxa of fish, representative of eight taxonomic families, were caught by quantitative groundfish tows in at least one region. These taxa were grouped for analysis based on taxonomy, visual resemblance to other species, and importance in the diet of Steller sea lions. The eight families represented in groundfish tows were Chimaeridae (ratfish, 1 species), Gadidae (cods, 2 species), Scorpaenidae (rockfishes, not identified further), Cottidae (sculpins, 26 taxa), Agonidae (poachers, 7 taxa), Cyclopteridae (lumpfishes and snailfishes, 2 subfamilies), Bathymasteridae (ronquils, 3 species), and Ammodytidae (Pacific sand lance, 1 species). The 12 most abundant taxa each accounted for $\geq$2% of overall CPUE. They were rock sole (*Pleuronectes bilineatus,* 20.5%), *Sternias xenostethus* (14.8%), *Triglops* spp. (14.7%), northern sculpin (*Icelinus borealis,* 6.0%), slim sculpin (*Radulinus asprellus*, 5.8%), arrowtooth flounder (*Atherestes stomias*, 5.0%), *Myoxocephalus* spp. (4.6%), poachers (Agonidae, 4.0%), lumpfishes and snailfishes (Cyclopteridae, 3.8%), Irish Lords (*Hemilepidotus* spp., 3.7%), Pacific staghorn sculpin (*Leptocottus armatus*, 3.5%) and walleye pollock (*Theragra chalcogramma*, 2.0%). Other species made up the remaining 11.6% of the catch.

Among the five regions, the fewest groundfish taxa were caught in Southeast (17 taxa), followed by the Pribilofs (22 taxa), West Aleutians (27 taxa), East Aleutians (30 taxa) and Central Aleutians (33 taxa). The number of fish taxa caught in each tow did not differ significantly among regions ($F = 1.09$, $p>0.37$), although the lowest average number of taxa per tow was in Southeast (5.0±1.10 taxa/tow) and the highest average number of taxa per tow was in the Central Aleutians (7.8±5.31 taxa/tow). Groundfish species diversity did not differ significantly among regions when depth was a covariate ($F = 0.713$, $p = 0.586$) or when depth was excluded from the analysis ($F = 2.071$, $p = 0.097$). However, when only the tows over sand were considered, species diversity in Southeast was significantly higher than in the West Aleutians ($p<0.05$).

Relative groundfish catch composition differed considerably among regions, and many taxa were caught in only one of the five regions examined. Eight species captured in Southeast were not captured elsewhere, including (in taxonomic order): black skate (*Raja kincaidi*, caught in a non-quantitative tow); ratfish; whitebarred prickleback (*Poroclinus rothrocki*); shortfin eelpout (*Lycodes brevipes*); and four flatfishes, i.e., Pacific sand dab (*Citharichthys sordidus*), slender sole (*Eopsetta exilis*), rex sole (*Errex zachirus*), and English sole (*Pleuronectes vetulus*).

The taxa most commonly caught in Southeast Alaska were “flatfishes, other” (i.e., Pacific sanddab, slender sole, rex sole, flathead sole, Dover sole, and English sole; 82% of tows), ratfish, slim sculpin and arrowtooth flounder (each at 72% of tows), poachers and “roundfishes, other” (each at 45% of tows). The five most abundant taxa in Southeast accounted for 90% of the regional catch, i.e., slim sculpin (35% of CPUE), ratfish (19% of CPUE), “flatfishes, other” (17% of CPUE), arrowtooth flounder (14% of CPUE), and poachers (5% of CPUE).

In the Central Aleutians, the most commonly caught taxa were rock sole (93% of tows), lumpsuckers–snailfishes (71% of tows), *Sternias xenostethus* and *Triglops* spp. (each at 57% of tows), Irish Lords and poachers (each at 50% of tows), and “sculpins, other” (43% of tows). The five most abundant taxa in the Central Aleutians comprised 87% of regional abundance, and included *Sternias xenostethus* (31% of CPUE), *Triglops* spp. (29% of CPUE), *Myoxocephalus* spp. (11% of CPUE), lumpfishes–snailfishes (8% of CPUE), and rock sole (8% of CPUE).

Ten taxa had significantly different CPUE values at one or more pair of regions; abundance for each of these 10 taxa in Southeast Alaska was different from at least one other region ($p<0.05$). Ratfish was only caught in Southeast. Slim sculpin and “flatfishes, other” were more abundant in Southeast than in the East, Central, or West Aleutians. Five taxa were not caught in Southeast though they were caught in another region, i.e., Pacific staghorn sculpin, *Myoxocephalus* spp., tadpole sculpin, *Sternias xenostethus*, and lumpsuckers–snailfishes. *Triglops* spp. was caught at lower abundances in Southeast than in Central Aleutians, and rock sole was caught at lower abundances in Southeast than in East, Central or West Aleutians. Ratfish, slim sculpin, and “flatfishes, other” were not caught in the Central Aleutians.

Stepwise multiple regression on individual taxa selected parameters statistically important in the explanation of abundance variation, including depth, %sand, temperature, towing speed and region. Those taxa for which the physical parameters of depth, %sand and/or temperature explained a significant amount of abundance variation include rock sole, arrowtooth flounder, lumpfishes–snailfishes, Irish Lords, Pacific staghorn sculpin, ronquils, Pacific halibut, “flatfishes, other,” ratfish, and rockfishes. Data involving Southeast Alaska, Central Aleutians, and the physical parameters which explained the taxon’s abundance variation are detailed in this section. Rock sole was caught in all five regions, and the parameters of depth and %sand explained 38% of variation in its abundance. Addition of towing speed and region to these parameters increased the explanation to 61% of abundance variation . Rock sole was significantly less abundant in Southeast Alaska than in the West, East and Central Aleutians ($p<0.0001$). A very low abundance of rock sole was caught in Southeast Alaska (18% of tows; mean values: 0.5±0.1 fish/1000 m^2; 92.8±3.9 m depth; %sand not available). In the Central Aleutians, rock sole was caught at 93% of tows (mean values: 10.8±8.8 fish/1000 m^2; 49.8±22.3 m depth; %sand was 44.7±27.6). Abundance of arrowtooth flounder was not significantly different among regions ($p>0.05$); %sand explained 8% of abundance variation of arrowtooth flounder. In Southeast Alaska, arrowtooth flounder was caught at 73% of tows (mean values: 2.1±1.6 fish/1000 m^2; 96.7±1.6 %sand). Arrowtooth flounder was caught at 21% of Central Aleutian tow sites (mean values: 0.8±0.1 fish/1000 m^2; 52.2±11.5 %sand). Lumpfishes and/or snailfishes were caught in all regions; temperature explained 21% of variation in their abundance. Lumpfishes–snailfishes were significantly less abundant at their single capture site in Southeast Alaska (CPUE<0.01 fish/1000 m^2; 7.7 ^{o}C) than in the Central Aleutians ($p<0.001$). Lumpfishes–snailfishes were caught at 71% of tows in the Central Aleutians (mean values: 13.2±21.4 fish/1000 m^2; 5.1±0.1^{o}C). Irish Lords were lacking from Southeast Alaska catches but were captured in each other region. Abundances of Irish Lords were significantly different among ($p<0.05$) but not between regions; temperature explained 17% of abundance variation of Irish Lords. In the Central Aleutians, Irish Lords were caught at 50% of tows (mean values:

10.6±12.5 fish/1000 m^2; 5.2±0.1°C). Pacific staghorn sculpin was caught only in the Pribilofs; temperature explained 19% of its variation in abundance, and the addition of the regional parameter increased this explanation to 31%. Ronquils were lacking from Southeast Alaska catches but were caught in each other region. Abundances of ronquils were not significantly different among regions ($p>0.05$); %sand explained 18% of abundance variation of ronquils. Ronquils were caught at 21% of Central Aleutians tows (mean values: 2.6±1.2 fish/1000 m^2; 52.0±40.9 %sand). Pacific halibut was lacking from Southeast Alaska catches but was caught in each other region. Abundances of halibut were not significantly different among regions ($p>0.05$); the parameters %sand and depth explained 19% of abundance variation of this species. Pacific halibut was caught at 21% of tows in the Central Aleutians region (mean values: 1.6±1.8 fish/1000 m^2; 64.5±38.5 %sand; 49.0±23.9 m depth). The taxon "flatfishes, other," was caught in all regions except the Central Aleutians. Abundance of this taxon was significantly higher in Southeast Alaska than in the East, Central or West Aleutians ($p<0.001$); depth and %sand explained 31% of its abundance variation. This taxon was caught in Southeast Alaska at 82% of tows (mean values: 2.3±2.6 fish/1000 m^2; 116.7±20.6 m depth; 97.2±2.07 %sand). Ratfish was caught only in Southeast Alaska; depth and temperature explained 45% of abundance variation. Ratfish was caught at 73% of tows in Southeast Alaska (mean values: 2.9±2.2 fish/1000 m^2; 128.9±10.8 m depth; 7.0±0.2°C). Rockfishes were caught in the East, Central and West Aleutians, but were not caught in Southeast Alaska or near the Pribilof Islands. Regional abundances of rockfishes were not significantly different ($p>0.05$); in combination with regional abundance, depth explained 18% of abundance variation of this taxon. Rockfishes were caught at 14% of tows in the Central Aleutians (mean values: 0.9±0.1 fish/1000 m^2; 64.5±23.3 m depth).

Midwater tows were taken at five sites in Southeast Alaska and nine sites in the Pribilof Islands. Quantitative midwater trawl tows collected 23,343 fishes, which corresponded to a cumulative CPUE of 8993.1 (#fish/10 min tow, summed over all species at 14 tows). The average 10 min CPUE over 14 sites was 642.4±859.0 fish. Cumulative CPUE values for midwater tows in Southeast Alaska (126.9±173.5 fish/10 min tow) and the Pribilof Islands (928.7±962.1 fish/10 min tow) were not significantly different ($F = 3.29$, $p = 0.09$). However, species diversity in midwater tows was higher in Southeast Alaska (Simpson's complement: 0.336±0.297) than in the Pribilofs (Simpson's complement: 0.002±0.003) ($F = 12.16$, $p<0.01$).

Eight species were captured by midwater tow in Southeast Alaska. In order of decreasing abundance, the species captured were Pacific herring, eulachon, Pacific cod, walleye pollock, rockfish, shortfin eelpout, arrowtooth flounder, and rex sole. A total of 1, 537 fishes were caught, yielding a cumulative 10 min CPUE of 634.7 fish summed over five tows. The largest single catch in Southeast Alaska was taken at the average tow depth of 28 m; the range of towing depths in this area was 14–130 m. Pacific herring and eulachon dominated the midwater catches in Southeast, respectively accounting for 83.7% and 11.0% of total CPUE. Herring was caught in each tow, and eulachon was caught in four of five tows. Herring was the most abundant species in three of five tows, and eulachon was the most abundant in the remaining two tows. The mean size of herring was 218±14 mm, and the mean length of eulachon was 134±30 mm. The mean length of the other six species was 261±110 mm.

Regional midwater tow CPUE of individual species was tested for significant differences. Two species had significantly higher CPUE in Southeast Alaska than in the Pribilofs region, i.e., Pacific herring ($F = 37.10$, $p<0.0001$) and eulachon ($F = 13.16$, $p<0.01$). Walleye pollock was the only species with lower CPUE in Southeast Alaska than in the Pribilofs ($F = 69.43$, $p<0.0001$).

Significantly different sizes of fishes were sampled by the bottom and midwater trawls ($F = 1448.35$, $p<0.0001$). Disregarding capture region, fishes collected by bottom trawl were smallest (70.5±76.7 mm) and midwater fishes were slightly larger (103.2±95.1 mm). The size of fish caught by bottom trawl varied regionally ($F = 35.59$, $p<0.0001$); fishes in Southeast Alaska (113.3±71.5 mm) were larger than all other regions, and fishes caught by bottom trawl in Central Aleutians were smaller (58.6±73.2 mm) than all other regions. Fishes caught by midwater trawl in Southeast (195.8±74.0 mm) were larger than those caught in the Pribilofs (31.7±6.6 mm)($F = 2490.51$, $p<0.0001$).

PURPOSE

Identification of Problem

Steller sea lions have undergone a dramatic and mysterious decline in Alaskan waters during recent decades. Numbers of Steller sea lions (*Eumetopias jubatus*) in Alaska have dropped over 81% since the mid-1960's (Loughlin et al. 1992). Most of this decline has been within the larger and genetically distinct (Bickham et al. 1996) western stock of Steller sea lions (Hill and Demaster 1998), which extends through the Bering Sea and Gulf of Alaska and includes the Aleutian and Pribilof Islands. Concurrently, the number of sea lions in the much smaller eastern stock, which extends from Southeast Alaska through Oregon, has remained fairly stable. At some eastern rookeries, including Forrester Island, the Steller sea lion population has been increasing during the 1980's and 90's (Hill and Demaster 1998). The western stock of Steller sea lions is presently listed as "endangered", and the eastern stock is listed as "threatened" under the U.S. Endangered Species Act. Many possible causes of this decline have been or are now being considered, including intentional harvest, take incidental to commercial fisheries, predation, rookery disturbance, pollution, parasites, disease, and nutritional stress. A prominent hypothesis of concern to the present research is that the food available to Steller sea lions, i.e., species abundance and composition of forage fishes, has changed (Merrick, et al. 1987), and specifically that this change is affecting pups on the rookeries (Merrick et al. 1995).

Steller sea lions eat a variety of fish and invertebrates, including species of primary and secondary importance to Alaskan commercial fisheries. Prey of sea lions are targets of prime commercial fisheries in Alaskan waters, including walleye pollock, Atka mackerel (*Pleurogrammus monopterygius*), Pacific cod (*Gadus macrocephalus*), flatfishes (Pleuronectidae), rockfishes (*Sebastes* spp.), shrimps (Pandalidae), Pacific herring and salmon. Other prey of pinnipeds indirectly affect commercial fisheries in that they are consumed by the target species, including capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes hexapterus*), eulachon (*Thaleichthys pacificus*) and cephalopods. Pinnipeds are opportunistic feeders, feeding on whatever is most abundant and accessible. Their diets are based more on availability of prey than preference for a specific food item (Pitcher 1980, 1981; Kajimura 1985). Utilization of a given prey item may differ among individuals due to age or reproductive status (Frost and Lowry 1986). This and the variability in prey abundance results in seasonal, annual and regional dietary differences among individual Steller sea lions. There is a strong positive correlation between the diversity of sea lion diets from different areas and the amount of decline of sea lion populations in these areas (Merrick et al 1997). As diet diversity decreases, sea lion populations decrease, suggesting that sea lions require a variety of prey for survival.

In recent decades, there have been large changes in population dynamics of marine life in the North Pacific, particularly in the western Gulf of Alaska and the eastern Bering Sea, where the western Steller sea lion population is "endangered". Certain marine mammals have declined, while others have flourished. Concurrently, stocks of crab and Pacific herring (*Clupea pallasi*) have declined, while walleye pollock (*Theragra chalcogramma*) and salmon (*Oncorhynchus* spp.) populations have increased dramatically. These population changes are partly the result of a marked environmental and biological regime shift which occurred in the Gulf of Alaska during the late 1970's (Royer 1989; Ebbesmeyer et al. 1991; Trenberth and Hurrell 1994), that has been demonstrated to affect commercial fish species in the eastern North Pacific Ocean (Hollowed and Wooster 1995). Human impact has undoubtedly caused some of the observed changes in marine population dynamics. Commercial fishing gear, vessels and target species have evolved considerably since 1950 (Alverson 1992). The spatial range of fishing activity has extended from coastal areas into regions over the continental shelf, and there has been an explosive growth in commercial fish harvests.

There is potential for competition between commercial fisheries and marine mammals if increased seasonal or age-specific energetic demands of marine mammals coincide with temporal and spatial scarcity of prey resulting from commercial fisheries. Fishes on which sea lions feed are important natural resources to the Alaskan economy, and the impacts of recent legislation designed to protect sea lions have greatly influenced the spatial and seasonal extent of commercial fisheries. Now that the western stock is listed as "endangered," there is even more interest in comparing the western versus eastern stocks and determining effects of food availability on both stocks.

Correlations between prey fish abundance, harvest and impacts on pinniped populations are ill-defined. Large commercial walleye pollock harvests have been correlated with nutritional stress in Steller sea lions (Calkins and Goodwin 1988; Lowry et al. 1989). However, the recent assessment of the importance of pollock in the diet of Steller sea lions (Sea Grant 1993) may be biased in that it is based on stomach contents of sea lions from the late 1970's and early 1980's (Pitcher 1981) when there was a huge increase of pollock in the Gulf of Alaska. That increased abundance of pollock was not only noted in the diets of sea lions, but precipitated the increase in fishing effort. When there was no fishery for pollock in the 1950's, there were also no pollock in sea lion diets (Mathiesen et al. 1962; Thorsteinson and Lensink 1962; Fiscus and Baines 1966). Furthermore, the diet of sea lions in the eastern Aleutians is dominated by Atka mackerel, the most abundant prey in that area. These temporal and regional differences in sea lion diets reflect the nature of sea lions as opportunistic feeders and may be more indicative of prey availability than an indicator of sea lion feeding preference.

The listing of Steller sea lions as "endangered" is now affecting commercial fisheries although the extent to which commercial fishery harvests influence pinniped populations is unknown (Lavigne 1982; Swartzman and Haar 1983; Harwood and Croxall 1988; Loughlin and Merrick 1989; Alverson 1992; NMFS 1992). Uncertainty about interactions between fisheries and marine mammals has forced resource managers to make conservative decisions, erring on the side of the declining mammal populations, until adequate fisheries data are available. Based on the limited diet studies available, National Marine Fisheries Service (NMFS) has implemented conservation measures to encourage Steller sea lion recovery, including time and area restrictions for potentially competitive fisheries. Because pollock and Atka mackerel were found in sea lion stomachs in the Gulf of Alaska and Bering Sea, NMFS established 10–20 nm buffer zones around rookeries. Additionally, in recent years the North Pacific Fisheries Management Council (NPFMC) has substantially reduced the Gulf of Alaska walleye pollock total allowable catch (TAC) from the recommended allowable biological catch (ABC).

The emphasis on pollock and Atka mackerel and concomitant measures to establish buffer zones around rookeries obscure the significance of other known pinniped prey such as flatfishes, Pacific herring, cod, salmon, capelin, Pacific sand lance and cephalopods. Stomach contents of sea lions reflect interdecadal changes in pinniped consumption of all these species. Between 1973 and 1978, Steller sea lions around Kodiak Island consumed mainly capelin with cephalopods as a second food source (Pitcher 1981). In 1985–86, sea lion diets were dominated by walleye pollock, octopi and flatfishes, but no capelin were consumed (Calkins and Goodwin 1988; Merrick and Calkins 1996). Pollock was the main prey species from 1990 to 1993, followed by large percentages of salmon, small schooling fishes and flatfishes (Merrick et al. 1997). Although gadids are likely to be of lower nutritional value than fatty forage fish (Alverson 1992; Rosen and Trites 1997), their high frequency of occurrence in Steller sea lion scats may imply that sea lions have little else to eat during the current 'regime shift', thus enhancing the relative importance of pollock to Steller sea lions.

Although demersal fishes were significant components of sea lion diets in the Gulf of Alaska in 1985–86 (Calkins and Goodwin 1988; Merrick and Calkins 1996), their availability to juvenile sea lions was unknown prior to research by this principal investigator (e.g., Mueter and Norcross 1998). The observed switch from capelin to walleye pollock as the major dietary component may reflect changes in the composition of the juvenile groundfish community. A marked shift from a shrimp-dominated crustacean community to a community dominated by gadids and flatfishes occurred in the nearshore zones around Kodiak Island in the late 1970's and early 1980's (Anderson et al. 1997; Mueter and Norcross in press). This decline in shrimps occurred concurrent with a decline in capelin and other forage fishes. The role of changes in prey availability on sea lion populations and the extent and causes of these changes are uncertain. A current working hypothesis is that mortality of juvenile pinnipeds due to decreased availability of suitable food is causing the population decline (Sea Grant 1993). Therefore, this study concentrated on evaluating availability of small fishes, which are the principal prey of juvenile sea lions and seals, at Forrester and Lowrie Islands, the major rookeries within the "threatened" eastern Steller sea lion population, and at various Aleutian and Pribilof Island rookeries within the "endangered" western population. We surveyed fishes in conjunction with onshore surveys of sea lions at Forrester and Lowrie Islands by UBC, and onshore and nearshore surveys of pinnipeds and seabirds at major pinniped rookeries in the Aleutian Islands by NMFS/NMML (National Marine Mammal Lab) and in the Pribilof Islands by USFWS/ANMWR (Alaska National Maritime Wildlife Refuge). The emphasis of the study was on small fishes near rookeries because current thinking is that poor survival of sea lion pups is causing the decline in the mammal population, and that juvenile survival may be less successful because of reduced availability of forage.

Program Goals and Objectives

The original objective of this study was to assess the distribution and abundance of juvenile and subadult stages of fishes within a 15 nm radius of the Forrester Island Steller sea lion rookery. To give perspective on how forage fishes in Southeast Alaska compare with forage fishes in other Alaskan regions, in this document we also report results of analogous collections made during summer 1997 in conjunction with NMFS/NMML. Those comparative data were collected within foraging range of sea lion and seabird rookeries in the Aleutian Islands and the Pribilof Islands.

METHODS

Sample collections

We conducted a total of three cruises to survey the forage fishes near sea lion and seabird rookeries during June–July 1997. Regions examined were Forrester and Lowrie Islands in Southeast Alaska (Appendix A), the Aleutian Islands (Appendix B), and the Pribilof Islands in the Bering Sea (Appendix C).

Collections in Southeast Alaska were made near Forrester and Lowrie Islands during 11–16 June 1997 from the *F/V Tracey Ann*, a 96 ft trawler charted through UBC. The vessel operated 12 hrs per 24-hour period and was devoted solely to fish collections and ancillary bird observations. Generally, groundfishes were collected and birds were observed during daylight and midwater fishes were collected at night. Onshore investigations of marine mammals were conducted concurrently by Andrew Trites, University of British Columbia and, as with the bird observations, are reported separately. Fish collections in the Aleutians (near pinniped rookeries on Agattu, Attu, Buldir, Kasatochi, Seguam and Ugamak Islands) were made 19 June–13 July 1997 from the *M/V Tiĝlax̂*, the same 120 ft USFWS vessel used in similar collections during 1995–1996 (Müter and Norcross 1998). Fish collections in the Aleutians were in conjunction with Steller sea lion pup and prey distribution surveys conducted by Richard Merrick, NMFS National Marine Mammal Lab in Seattle, WA. Collections in the Pribilofs (St. George, St. Paul, and Walrus Islands) were made 19–28 July 1997 also from the *M/V Tiĝlax̂*, in conjunction with seabird abundance surveys conducted by Vernon Byrd, Arctic Marine National Wildlife Refuge, Homer, AK. The collections of fishes aboard the *M/V Tiĝlax̂* were done whenever the boat was released from its primary task of supporting the sea lion and seabird surveys; thus fish collections were generally at night or when weather was too rough for onboard pinniped and seabird observations

Bottom trawl sites were selected within 15 km of shore from among suitable depths on trawlable bottom topography and substrates. The vessel's echo sounder was used at potential bottom trawl sites to assess bottom topography and hardness for trawlability. We did not trawl where the bottom was steeply sloped and only rarely trawled where grain-size was larger than gravel (>64 mm). As during previous examinations of groundfishes in the Aleutian Islands (Müter and Norcross 1998), we followed a stratified random sampling design with three depth strata. Depth strata were based on previous results (Norcross et al. 1995a) and were <40 m, 40–70 m and >70 m. We attempted to sample at least three tows within each depth stratum along a transect radiating out from each rookery, but sampling was often limited by the constraints of depth, available trawlable substrate, time, and weather conditions.

Substrate, temperature and salinity were evaluated at most sites. A Van Veen sediment grab and/or underwater video camera was used prior to bottom trawl tows to assess bottom type. Sediment collected via the grab was retained and frozen for laboratory grain-size analysis. Additionally, we visually assessed bottom type at most sites by deploying a tethered sled-mounted video camera for 3–10 min prior to deploying the bottom trawl. In conjunction with the bottom trawl survey and at some midwater trawl sites, a portable CTD (Seabird Seacat Profiler) was deployed at each site to obtain salinity and temperature profiles for the entire water column.

The principal gear for sampling juvenile and subadult stages of demersal fishes was a 3.05 m plumb staff beam trawl modified from Gunderson and Ellis (1986). The net mesh was 7 mm in the body and 4 mm in the codend. Weak links were made between 1) one side of the bridle and the beam, 2) one side of the bridle and the headrope, 3) one side of the footrope and the tip weight, and 4) one side of the footrope and the double tickler chain. Generally, when the net hung up during fishing, these weak links would break and the net would close without ripping. Aboard both vessels, the bottom trawl was set aft, using an A-frame and a winch, and was towed by a single warp for approximately 10 minutes in the direction of the water current at approximately 1.0–2 kts over ground. This slow vessel speed was achieved by alternating the vessel in and out of gear during the tow. Positions of the start (wire out and net fishing on bottom) and end (begin to retrieve wire) of the tow were obtained via standard GPS. Tow time was reduced if trawlable substrate was limited or if the net hung on hard bottom or boulders. The bottom trawl was fished at approximately 3:1 line:depth ratio. The tow line was observed during the tow to ensure the net was fishing the bottom; when the net was moving over the bottom properly, the tow line would jerk slightly up and down. Non-quantitative tows included tows less than 3 min., where the net ripped, the weak links on the net broke without closing the net, the net did not reach bottom due to strong currents, or the net wrapped around the beam.

Midwater trawling was conducted during straight-line hydroacoustic transects near a rookery where a strong acoustic signal indicated aggregations of fishes or zooplankton in the water column. Transects in Southeast Alaska were limited to within 15 nm of Forrester Island. The area north of Forrester Island was selected for transects due to its proximity to the Lowrie

Island sea lion rookery and previously recorded foraging patterns of radio-tracked seals. Scientific hydroacoustic equipment was not available onboard the *F/V Tracey Anne* due to the lateness of securing an acceptable boat for the cruise. Therefore midwater fish aggregations in Southeast Alaska were observed via the vessel's depth sounder. In Southeast Alaska, a modified herring trawl with a 30 ft wide mouth, 1/8 in. (3.2 mm) codend mesh, and netsounder on the headrope was towed by a double warp for 6.5–31 min., at a speed of approximately 50–80 m/min, at a depth dependent on the depth of maximum acoustic signal strength. Midwater trawling in the Pribilof Islands was conducted in support of hydroacoustics surveys, which were parallel transects approximately 20 km apart within 50 nm of the Pribilof Islands (Dragoo and Byrd 1998). The midwater net and fishing technique used in the Pribilofs were similar to those used in Southeast Alaska, but the codend was reduced to a 11.5 cm diameter bucket of 1 mm mesh, and the net was towed for 15–37 min at a speed of approximately 50–150 m/min. Midwater tows in the Aleutians were collected by NMML but are not reported here because the data have not been made available to this investigator. Midwater tows were considered quantitative where the duration of the tow was recorded and the net did not foul.

The capture of large predatory groundfishes for an analysis of stomach contents was accomplished by deploying longline gear at Buldir, Kasatochi and Ugamak in the Aleutian Islands, and at St. George and Walrus in the Pribilof Islands, and by deploying hook and line at Attu and Ugamak in the Aleutian Islands. These captures provided for a method of discerning taxa eaten by large groundfishes and presumably available as prey to Steller sea lions. No longline samples were collected in Southeast Alaska because longline gear was not available aboard the *F/V Tracey Anne* although it was requested in boat bid specifications. At each longline site, one skate of approximately 500 m length was set with approximately 100 circle hooks spaced at 5 m intervals (snap gear, 3.0 and 5.0 size hooks). Salted herring was used as bait, and soaking time was limited to two hours to limit digestion of stomach contents (Müter and Norcross 1998). Hook and line gear was deployed with salted herring as bait and fish were retrieved immediately after capture. Stomach contents of opportunistic predators are assumed to reflect the abundance of common prey species in the same location (e.g., Pacific cod consuming capelin, Fahrig et al. 1993). Because Pacific cod and Pacific halibut were the most common opportunistic predator species caught by longline in previous Aleutian samples (Müter and Norcross 1998), these species were retained for stomach content analysis after being measured to the nearest cm and sexed (Aleutians and Pribilofs) and weighed to the nearest 0.5 kg (Aleutians only). Other fishes were identified and measured to the nearest cm. After capture, stomachs were removed from the cod and halibut that showed no evidence of regurgitation and were preserved in 10% buffered formaldehyde solution. Preserved stomachs were shipped to our Fairbanks laboratory (Aleutians) or Patricia Livingston's NMFS laboratory in Seattle, WA (Pribilofs) for analysis of stomach contents.

Fishes were identified in the field to the lowest possible taxonomic level, and total length (groundfishes) or fork length (Pacific herring and eulachon) was measured to the nearest mm using an electronic fish measuring board (Limnoterra FMBIV). Specimens that could not be positively identified in the field were frozen and returned to the Fairbanks laboratory for closer analysis. When many fish of a species were captured during a single tow, a subsample of approximately 50 fish was measured.

Data processing and analysis

Environmental data

Grouping of rookeries for analysis

Because of small sample sizes, data from multiple rookeries were combined into five regional groups to increase the number needed for statistical analysis. Collections in Southeast Alaska at Forrester and Lowrie Islands were grouped. Collections from the Aleutian Islands were divided into three groups based on longitude. Ugamak Island (East Aleutians) was not combined with another rookery. Kasatochi and Seguam were grouped together (Central Aleutians), as were Buldir, Agattu and Attu Islands (West Aleutians). Collections in the Pribilof Islands at St. George, St. Paul, and Walrus Islands were grouped. Regions are organized and reviewed from east-to-west latitude, i.e., Southeast Alaska, East Aleutians, Pribilofs, Central Aleutians, and West Aleutians. During 1995–1996 collections (Müter and Norcross 1998), rookeries were considered on an individual rather than grouped basis.

Depth survey

Depths reported and analyzed are the average or predominant depths of individual tows. Regional differences between sample depths of bottom trawl tows and midwater tows were tested separately by ANOVA followed by Tukey HSD test for unequal samples (StatSoft 1995). Differences were considered significant where $p<0.001$.

Sediment survey

Sediment samples were analyzed using a simplified sieve/pipette procedure by which the percents of gravel, sand and mud (silt + clay) were obtained. Grain size analysis was performed as follows. Sediment wet weight was determined for approximately 200–300 g gravelly sediment, 25 g of sand or 10 g of mud. Samples were dried for 24 hr at 100°C to determine dry weight. A subsample of approximately 25 g dry sand or 10 g mud was then weighed and added to a beaker with 200–300 ml distilled water and disaggregated. This suspension was wet sieved through a 63 μm mesh sieve, and washed with distilled water to separate the silt and clay from sand. The fraction larger than 63 μm was sieved through 2 mm mesh to separate the sand (<2 mm) and gravel (2–64 mm) components. Additional sieve analysis was performed on any sample containing more than 2% gravel. This analysis yielded relative percent at each Phi level of gravel and of sand (Sheppard 1973). The Wentworth grade scale (Sheppard 1973) defined grain sizes of boulder, cobble, gravel (pebble + granule), sand and mud (silt + clay). Results of grain size analyses were categorized after Folk (1980), where the main sediment type (boulder, cobble, gravel, sand, mud) is represented by a capital letter (B, C, G, S, or M) and the modifiers bouldery, cobbly, gravelly, sandy, and muddy (represented by lowercase b, c, g, s, and m) were used to distinguish among mixtures of sediments present at individual sites (Appendix D). For example, S = sand, gS = gravelly sand, and mS = muddy sand. We employed Folk's classifications with the following exceptions. Folk's classifications of (g)sM and (g)mS (meaning less than 5% gravel) were incorporated within the categories of sM and mS for our analysis. Additionally, substrates larger than Folk had analyzed (i.e., containing cobble or boulder). were classified visually according to the Wentworth scale (Sheppard 1973). Where significant regional differences between percentages of cobble, gravel, sand and mud at bottom tow sites were detected by ANOVA ($p<0.05$), a Tukey HSD test for unequal samples was performed to determine significant differences between pairs (StatSoft 1995). Sediment type was estimated for sites where no sediment grab was available based on observations of the towed video camera footage.

CTD survey

Vertical profiles of temperature, salinity and depth were recorded in the field with a portable CTD (SeaBird SBE 19 profiler) and downloaded to computer disk. Raw data were processed with SeaBird CTD software. Data from the downcast were averaged over 0.5 m intervals at each site. The bottom values of temperature and salinity were used for analysis of bottom trawls. Differences were considered significant where $p<0.001$. The values of temperature and salinity at the greatest depth sampled by the midwater trawl were used for analysis of midwater trawls. Regional differences among bottom temperatures and salinities at bottom trawl sites and at midwater trawl sites were tested separately, using ANOVA followed by Tukey HSD test for unequal samples (StatSoft 1995). Regional differences among bottom temperatures were additionally tested by ANCOVA using depth as a covariate (StatSoft 1995).

Prey surveys

Species diversity

We calculated Simpson’s complement (1-D) as index of species diversity for each sample, based on the raw catch data (counts of fishes caught). Simpson’s D is defined as:

$$D = \sum_{i=1}^{S} \frac{n_i (n_i - 1)}{N(N-1)}$$

where n_i = the number of individuals of species i in a sample from the population and N = the total number of individuals in the sample. Simpson’s D is an unbiased estimator of the probability that two randomly chosen individuals belong to the same species, and its complement (1-D) has been used as an index of diversity and is the probability that two randomly chosen individuals belong to different species (Krebs 1989). Krebs (1989) recommends the use of Simpson’s complement as a measure of heterogeneity if more weight should be put on the common species. We compared Simpson’s complement graphically and statistically among years and regions.

Standardization of fish abundances

Abundance of each species at each bottom trawl site was standardized to catch-per-unit-effort (CPUE) based on the tow distance and effective net swath (2.717 m, after Gunderson and Ellis

1986). Tow distance was calculated from standard GPS coordinates obtained at the beginning and end of each tow. Bottom trawl species abundances are expressed as number of fish per 1000 m^2 because that rounded amount best approximated the area sampled by the bottom trawl. For statistical comparisons, we used log-transformed CPUE values (log [CPUE +1]). Values of species CPUE for bottom trawls were compared graphically and statistically among five regions, using ANOVA followed by Tukey HSD for unequal N. Differences were considered significant where $p<0.05$.

We standardized fish species abundance at midwater trawl sites to CPUE based on time fished. We did not standardize to distance towed because distance data were not available for two catches in Southeast Alaska. Midwater trawl species abundances are expressed as number of fish per 10 min. tow., and for statistical comparisons we used log-transformed CPUE values (log [CPUE+1]). Values of species CPUE for midwater trawls were compared statistically between the two regions sampled, i.e., Southeast Alaska and Pribilof Islands, using ANOVA. Differences were considered significant where $p<0.05$.

Grouping of fishes for analysis

Fish species were grouped for analysis where species closely resembled one another and could be confused during identification, or where the cumulative catch (summed CPUE of that species over all sites) was <5 and the species provided less than 10% of the summed CPUE of all species at any one site. Although Pacific cod, rockfishes, and Pacific sandlance each amounted to a small percentage of the summed CPUE, these species were evaluated separately from other species because of their importance in the diet of Steller sea lions.

Data processing

We prepared tables, graphics and statistics which summarized CPUE in each region. Microsoft Excel (Microsoft Corp. 1997) and R:BASE (Microrim, Inc. 1990) were used as database managers. Graphics were prepared using ArcView (ESRI 1998) and Microsoft Excel (Microsoft Corp. 1997). Statistics were calculated using Statistica (StatSoft 1995) and Microsoft Excel.

Stomach content analysis

Stomach fullness of a fish was estimated to the nearest 10% before removing all stomach contents for identification. All prey were enumerated, weighed and identified to the lowest possible taxonomic level. Prey were in different stages of digestion and were identified based on remaining hard parts including shells, bones, scales, and otoliths. Taxa identified in the stomachs were grouped into the following nine categories for analysis (after Merrick et al. 1997).

(1) Cephalopods: octopus and squid.

(2) Crustacea: isopods; gammarid amphipods including *Anonyx* spp.; crabs, including fuzzy crab (*Acantholithodes hispidus*), Korean horsehair crab (*Erimacrus isenbeckii*), helmet crab (*Telmessus cheiragonus*), tanner crab (*Chionecetes opilio*), arctic lyre crab (*Hyas coarcticus*) and lyre crab (*Hyas lyratus*), Pygmy cancer crab (*Cancer oregonensis*), decorator crab (*Oregonia gracilis*), king crab (*Paralithoides camtschatica*); shrimps

(Pandalidae including *Pandalus* sp., Crangonidae, Hippolytidae including *Eualus* spp. and *Spirontocaris* spp.), and unidentified decapods.

(3) Other benthic invertebrates: unidentified tunicates; unidentified bivalves and gastropods; bryozoans; ribbon worms; polychaetes: brittle stars; sea urchins including the green urchin (*Strongylocentrus droebackiensis*); and unidentified invertebrate fragments.

(4) Gadidae: walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), and unidentified cods.

(5) Small schooling fishes: Pacific herring (*Clupea harengus*) and Pacific sand lance (*Ammodytes hexapterus*).

(6) Pleuronectid flatfishes: flathead sole (*Hippoglossoides elassodon*), rock sole (*Pleuronectes bilineata*), and unidentified flatfishes.

(7) Other demersal fishes: rockfishes (Scorpaenidae), pricklebacks (*Lumpenus* spp.), unidentified poachers (Agonidae) and sculpins (Cottidae) including *Triglops* spp., northern sculpin (*Icelinus borealis*), yellow Irish Lord (*Hemilepidotus jordani*), and unidentified sculpins.

(8) Unidentified fishes: This category could possibly include members of the other fish categories.

(9) Seabird: crested auklet (*Aethia cristatella*).

Diet composition was estimated for seven groups of stomach samples caught by longline or by hook and line. Pacific halibut were examined at one rookery in each of three regions: Attu (West Aleutians), Kasatochi (Central Aleutians), and Ugamak (East Aleutians). Similarly, Pacific cod were examined at one rookery in each of three regions: Buldir (West Aleutians), Kasatochi (Central Aleutians), and Ugamak (East Aleutians). Halibut and cod stomachs were examined from St. George and Walrus Islands in the Pribilofs, but the stomach samples from the Pribilofs were not differentiated as to predator species or rookery. We assumed that stomach contents at the time of capture were representative of the diet composition of the predator species in the sampling area.

The relative importance of prey in the diet of a predator species caught in a region was measured using frequency of occurrence of each prey category in the region:

$$FO_{jk} = \sum_{i=1}^{n_j} \left(I_{ijk} \Big/ \sum_{k=1}^{7} I_{ijk} \right) \Big/ n_j$$

where i = individual stomach, j = a region, k = prey categories 1–9, and I_{ijk} = a binary variable for the presence of prey category k in the ith stomach from region j. The frequency of occurrence approach considers only presence–absence of a prey taxon, and therefore we also analyzed the proportional number of prey items consumed.

The regional numerical composition of the diet of each predator species was calculated by the dividing the counts of individuals within each prey category by the count of individuals within all prey categories at a region:

$$N = \sum_{i=1}^{n_j} n_{ijk} \Big/ \sum_{i=1}^{n_j} \sum_{k=1}^{7} n_{ijk}$$

This index of numerical importance is a less than satisfactory index of diet composition because it assumes that each prey item is of equal importance, which is clearly not the case given the variety of invertebrate and fish species consumed. However, a more satisfactory index could not be obtained because an analysis of prey weights was precluded due to the differential degree of digestion of prey items in the stomachs. A lack of suitable prey structures did not allow us to backcalculate weights of prey at the time of consumption.

The above indices were used as simple descriptors of diet composition and were assumed to reflect prey availability of commonly consumed prey groups in each region. A rigorous statistical comparison of diet composition / prey availability among regions was not possible because the variance of the estimators is unknown.

RESULTS AND DISCUSSION

Environmental data

Sample locations

Forage fish surveys were conducted during summer 1997 at 11 sea lion and/or seabird rookeries in Southeast Alaska, the Aleutian and Pribilof Islands (Figure 1). These rookeries were separated into five divisions for regional analysis. They are analyzed and reported upon in order of east-to-west latitude, i.e., Southeast, East Aleutians, Pribilofs, Central Aleutians, and West Aleutians. Near all rookeries, there were areas where the bottom topography was too steep, uneven or rocky to allow for quantitative bottom trawl catches. Thus, the bottom trawl survey provided a description of the groundfish community only at trawlable areas, rather than at all areas near a rookery.

Collections in Southeast Alaska (Figure 1) were at Forrester and Lowrie Islands (Figure 2a). These islands provide a rookery for Steller sea lions and seabirds in Southeast Alaska, southwest of the town of Ketchikan. Forrester and Lowrie Islands are subject to the Alaska Coastal Current and tidal range in the Southeast region is approximately 3 m. The nearshore topography of Forrester and Lowrie Islands is extremely rough and is characterized by steep slopes and rocky pinnacles. The only areas where the topography was sufficiently flat and sediment was sufficiently fine-grained to trawl successfully were extremely deep compared with bottom trawl depths at rookeries in the Aleutian and Pribilof Islands. Three bottom trawl tows were collected within one km of the west shore of Forrester Island, six were taken less than 10 km from northwest Forrester Island, and two were taken about 10 km north of Lowrie Island. Five midwater tows were taken northeast of Lowrie Island within 25 km of shore. No longline was deployed in Southeast Alaska.

The Aleutian Islands (Figure 1) are further downstream of the Alaska Coastal Current and are subject to oceanographic influences from both Gulf of Alaska and Bering Sea water masses. The Aleutian rookeries are located in areas of moderate to strong tidal currents (1.3–4 kts average maximum flow) with small tidal ranges (approximately 0.5 m).

Ugamak Island, within the Fox Islands section of the Aleutian Islands, was the only rookery examined in the East Aleutians (Figures 1 and 2b). Ugamak Island is near the western edge of Unimak Pass, a relatively broad and shallow (approximately 18 km across and <100 m depth) pass between the Gulf of Alaska and the Bering Sea which is largely governed by tidal flow. There are few seabirds at Ugamak Island due to introduced arctic fox (*Alopex lagopus)*, but Ugamak serves as one of the largest Steller sea lion rookeries in the world (Loughlin et al. 1984; Merrick et al. 1988). A sea lion rookery is located in Ugamak Bay, at the southeast end of Ugamak Island. Water is relatively shallow near the rookery and drops off to around 50 m with some deeper pockets (e.g., 150 m) within 8 km of the rookery. Bottom trawl tows were collected in a transect radiating 5 km out from the rookery to the south–southeast. A single longline set was made about 2 km south of the rookery and hook and line were deployed near the rookery. One midwater trawl tow was collected at Ugamak, but data are the property of NMML and are not reported here.

Collections in the Pribilofs were at St. George, St. Paul, and Walrus Islands (Figures 1, 2c, and 2d). In the central Bering Sea, these islands are home to large populations of northern fur seals (*Callorhinus ursinus*) and seabirds, particularly northern fulmar (*Fulmarus glacialis*), shearwaters (*Puffinus* spp.), red phalarope (*Phalaropus fulicaria*), common murre (*Uria aalge*), thick-billed murre (*Uria lomvia*), and least auklet (*Aethia pusilla*) (Dragoo and Byrd 1998). St. George is southernmost, with St. Paul and Walrus Islands approximately 60 km to the northwest. The Pribilof Islands have a tidal range of approximately 0.5 m, and currents near the Pribilof Islands are approximately 1 knot average maximum flow.

The area nearshore of St. George Island is generally rocky according to navigational charts (Figure 2c). Five bottom trawl tows were collected within 5 km of St. George, including one tow east and one tow of Tolstoi Pt., one tow at the North Anchorage, and two tows south of Dalnoi Pt. Seven midwater trawl tows were collected near St. George. Three nearshore midwater tows were collected, including one south of Tolstoi Pt., one at the North Anchorage, and one north of Dalnoi Pt. One midwater tow was 40 km to the southwest of St. George, and three tows were approximately 90 km to the southwest of St. George. Four longline sets made near St. George, including sets to the south, northeast and north of Tolstoi Pt. and a set south of Dalnoi Pt.

Walrus Island is a small island approximately 10 km east of St. Paul Island (Figures 1 and 2d). One bottom trawl tow and one longline set were collected just west of Walrus Island, and two midwater trawl tows were taken between Walrus and St. Paul Islands.

Collections from Seguam and Kasatochi were grouped together as 'Central Aleutians' (Figure 1). These islands lie 175 km apart within the Andreanof Islands section of the Aleutian Islands. One site approximately 2 km north of Seguam Island was sampled by bottom trawl (Figure 2e), but no midwater tows or longline sets were made at Seguam. Kasatochi Island was sampled by 13 bottom trawl tows, radiating out from the island approximately 4 km to the south (Figure 2f). A single longline set was taken within 1 km of the west coast of Kasatochi, but no midwater trawl tows were taken there.

Buldir, Agattu and Attu Islands were grouped together based on longitude within our defined ‘West Aleutians’ region (Figure 1). Buldir is within the Rat Islands section, and Agattu and Attu are located in the Near Islands section of the West Aleutian Islands.

Buldir Island is an extremely important area for breeding seabirds. It has large breeding populations of storm petrels, Canada geese, glaucous-winged gulls, ancient murrelets, horned puffins and tufted puffins, among others. Twenty-one species of seabirds and 11 species of land-based birds have breeding populations and 95 migrant or vagrant bird species have been recorded at Buldir Island (Byrd and Day 1986). Buldir Island is one of only two large Aleutian Islands where the Arctic fox was not introduced, thereby causing an extreme effect on bird populations. Southeast of Buldir Island, Buldir Reef runs northwest–southeast. One bottom trawl tow was taken about 2 km east of East Cape, and four bottom trawl tows were taken within 3 km of the west coast of Buldir Island (Figure 2g). No midwater tows were collected, but two longline sets were taken within 2 km of the south coast of Buldir Island.

Fish were sampled by bottom trawl at three sites in Armeria Bay, northwest Agattu Island (Figure 2h). All sites were within three km of shore. No midwater tows or longline sets were made at Agattu. Agattu is 40 km southeast of Attu Island, and is separated from Attu by Agattu Strait.

Attu Island (Figure 2i) is the farthest west rookery we examined; it is northwest of Agattu Island. Five bottom trawl tows were collected within or just outside the mouth of Steller Cove, north Attu Island. All sites were within three km of shore. No midwater tows or longline sets were taken at Attu.

Depth distribution of sites

The depth of bottom trawl sites ranged from 17 to 140 meters (Table 1). The range of depths trawled within any one region was ≤81 m (Figure 3). The average depth range examined within any one bottom trawl tow was 4.2±4.0 m. Sites at which the depth ranged greatly, i.e., which had a steep slope, were not trawled due to difficulties in keeping the trawl dragging the bottom consistently without either digging into the substrate or “flying” over it. In Southeast Alaska, bottom trawls were collected from depths of 89–140 m near Forrester Island, and from a depth of 138 m north of Lowrie Island. In the East Aleutians, depths trawled at Ugamak Island ranged from 26 to 91 m. In the Pribilofs, bottom trawl tows were collected at depths from 50 to 82 m at St. George Island, and at 46 m at Walrus Island; no bottom trawl tows were collected near St. Paul Island. In the Central Aleutians, one site at 49 m depth was examined by bottom trawl at Seguam, and depths from 22 to 96 m were examined at Kasatochi Island. In the West Aleutians, depths from 70 to 98 m were sampled at Buldir Island, depths from 57 to 83 m were sampled at Agattu, and depths from 17 to 63 m were sampled at Attu.

We attempted to sample at least three tows within each depth stratum along a transect radiating out from the rookery, due to sampling constraints at all other rookeries this was possible for only two of ten rookeries, i.e., Ugamak and Kasatochi Islands (Table 2). The shallowest depth stratum (<40 m) was examined only at three rookeries, one each in East, Central and West Aleutians, and none in Southeast Alaska or the Pribilofs. Collections in the 40–70 m depth stratum were taken from each rookery in each region except for the Forrester and Lowrie rookeries in Southeast Alaska. Due to extremely rough topography nearshore of Forrester and Lowrie Islands, no shallow sites could be examined by bottom trawl; all sites there were 89 m or deeper. Thus, the shallowest depths examined in Southeast were approximately equal to the deepest depths examined in the other regions. The deepest stratum (>70 m) was sampled in all regions, and at each rookery except Walrus, Seguam, and Attu Islands.

Table 2. Depth distribution of quantitative bottom trawl tows at rookeries within five regions.

Rookery	Region	40 m	40–70 m	>70 m	Total
Forrester	Southeast	0	0	9	9
Lowrie	Southeast	0	0	2	2
Ugamak	East Aleutians	5	8	4	17
St. George	Pribilofs	0	3	2	5
Walrus	Pribilofs	0	1	0	1
Seguam	Central Aleutians	0	1	0	1
Kasatochi	Central Aleutians	5	4	4	13
Buldir	West Aleutians	0	2	3	5
Agattu	West Aleutians	0	2	1	3
Attu	West Aleutians	3	2	0	5
Total		13	23	25	61

The depth distribution of tows differed significantly among regions ($F = 16.97$, $p<0.0001$). Depths sampled in Southeast were significantly deeper than all other regions (Table 3, $p<0.001$); there were no other significant differences between bottom trawl tow depths in any two regions.

Table 3. Differences in depth among regions. Results of Tukey HSD test for unequal N. * = significance level of $\geq$0.05.

	Mean depth (m)	East Aleutians	Pribilofs	Central Aleutians	West Aleutians
Southeast	118.7	0.0001*	0.0006*	0.0001*	0.0001*
East Aleutians	58.5		0.9984	0.9678	0.9988
Pribilofs	62.3			0.9523	1.0000
Central Aleutians	53.1				0.8992
West Aleutians	60.9				

Sediment distribution of sites

The composition of sediment samples reflects the substrate type only at trawlable locations. The composition of sediments at all quantitative bottom trawl sites is summarized by region (Table 4, Figures 4–6). Sediment was collected at 54 bottom trawl sites for grain size analysis, and was viewed by video at 53 of these and seven additional tow sites (Table 4). Only three trawlable sediment classes were encountered during our bottom trawl survey, e.g., gravel/larger sediment, mixed sand/gravel, and sand (Table 4, Appendix D). No mud substrates were encountered. Because of the extremely rough bottom topography near Forrester and Lowrie Islands, we were able to collect quantitative bottom trawl tows only in the relatively flat, deep zones in Southeast Alaska, all of which had sand substrate. Each of the three sediment classes was sampled in the East Aleutians, Pribilofs, and West Aleutians, and the two larger-grained sediment classes were sampled in the Central Aleutians.

There were significant regional differences in percents gravel, sand and mud at bottom trawl tow sites, but not in percent cobble (Table 1). There were no significant differences between the %gravel (Figure 4, Table 5: p>0.05) or %sand (Figure 5, Table 6: p>0.06) in any two regions. Although the %mud was low in all regions, sites sampled by bottom trawl in the Pribilofs had a significantly higher %mud than the East, Central or West Aleutians (Figure 6, Table 7: p<0.05).

Table 4. Sediment categories of quantitative bottom trawl sites sampled in 1997 by region: SE = Southeast Alaska, WA = West Aleutians, CA = Central Aleutians, , EA = East Aleutians, and PR = Pribilofs. The category "gravel or larger" includes substrates of cobbly boulder, cobbly gravel, gravel, sandy gravel and muddy sandy gravel. The category mixed sand and gravel includes gravelly sand and gravelly muddy sand. Substrates are described in further detail within Appendix D.

Rookery	Region	Gravel or larger	Mixed sand and gravel	Sand	# Sediments (observed via video)	# Sediments (grain size analyzed)	# Quantitative tows
Forrester	SE	0	0	9	9	4	9
Lowrie	SE	0	0	2	2	1	2
Ugamak	EA	5	6	6	17	17	17
St. George	PR	3	1	1	5	5	5
Walrus	PR	1	0	0	1	1	1
Seguam	CA	1	0	0	1	1	1
Kasatochi	CA	11	2	0	13	13	13
Buldir	WA	5	0	0	5	4	5
Agattu	WA	0	1	2	3	3	3
Attu	WA	2	0	3	5	5	5
Total		28	10	22	60	54	61

Table 5. Differences in percentage of gravel among regions. Results of Tukey HSD test for unequal N. * = significance level of $\geq$0.05.

	Mean	East	Pribilofs	Central	West

	%Gravel	Aleutians		Aleutians	Aleutians
Southeast	0.3	0.6487	0.0984	0.0598	0.3837
East Aleutians	27.2		0.7042	0.1557	0.9622
Pribilofs	50.1			0.9993	0.9271
Central Aleutians	54.4				0.5800
West Aleutians	35.6				

Table 6. Differences in percentage of sand among regions. Results of Tukey HSD test for unequal N. * = significance level of ≥0.05.

	Mean %Sand	East Aleutians	Pribilofs	Central Aleutians	West Aleutians
Southeast	97.2	0.7142	0.0644	0.0782	0.4207
East Aleutians	72.4		0.5033	0.1602	0.9473
Pribilofs	43.8			1.0000	0.8147
Central Aleutians	45.4				0.6302
West Aleutians	63.1				

Table 7. Differences in percentage of mud among regions. Results of Tukey HSD test for unequal N. * = significance level of ≥0.05.

	Mean %Mud	East Aleutians	Pribilofs	Central Aleutians	West Aleutians
Southeast	2.5	0.8135	0.4324	0.7997	0.8193
East Aleutians	0.3		0.0275*	1.0000	1.0000
Pribilofs	6.1			0.0255*	0.0284*
Central Aleutians	0.2				1.0000
West Aleutians	0.3				

Many nearshore areas were characterized on nautical charts as having rocky or reef-like substrate; these areas were rarely sampled quantitatively by the bottom trawl. We found very little mud at any site, due to the exposed nature of most rookeries, strong tidal currents extending to the bottom, and our constraint of sampling within 10 km of shore. Much of the gravel fraction of many sediment samples consisted of shells and shell hash. Substrates consisting of coarser sediment than gravel were rarely sampled effectively by trawl (without gear damage). In Southeast Alaska, successful bottom trawl tows were collected from the available flat areas near Forrester and Lowrie Islands, each of which had sand substrate. Non-sampled areas in Southeast had extremely steep slopes and rocky pinnacles. Trawled sites near the rookery on Ugamak Island in the East Aleutians had substrates of sandy gravel, gravelly sand and sand. Large untrawled areas close to the Ugamak Island in the East Aleutians consisted of hard bottom and reef-like structures. Bottom trawl tows were collected over a variety of substrates at St. George Island in the Pribilofs, including gravel, gravelly muddy sand, and sand. The single bottom trawl site at Walrus Island in the Pribilofs was gravel. In the Central Aleutians, bottom trawl sites at Kasatochi were on substrates of sandy gravel, gravel or gravelly sand, and the bottom trawl site at Seguam was on gravel. A wide range of substrates was sampled by bottom trawl in the West Aleutians. Substrates at bottom trawl sites near Buldir were large grained, e.g., sandy gravel, gravel, cobbly boulder. Bottom trawl sites near Agattu Island were of sand or gravelly sand, and bottom trawl sites near Attu Island were sand or sandy gravel.

Regional CTD survey

Samples were collected during summer, with the earliest sampling in Southeast Alaska during June, followed by samples from the West, Central and East Aleutian Islands during June–July, and ending with samples in the Pribilof Islands in late July. Bottom temperatures differed significantly among regions (1-way ANOVA: $F = 25.38$, $p<0.0001$, Table 1). It is likely that differences among regions are confounded with differences in the depth distribution of sampling sites as bottom temperatures tend to be inversely correlated with depth (Norcross et al. 1995b). Therefore we compared bottom temperatures among regions using depth as a covariate, again detecting significant temperature differences across regions (1-way ANCOVA: $F = 36.196$, $p<0.0001$). However, it must be noted that the Southeast region had the warmest bottom temperatures and also the deepest sites sampled, which is counter to the previous statement. Southeast Alaska, the southernmost and easternmost region sampled, had the warmest bottom temperatures observed (7.1±0.3^{o}C, Table 1, Figure 7). Bottom temperatures of bottom trawl sites in Southeast Alaska were significantly warmer than in any other region (Table 8: $p<0.01$). Bottom temperatures at East Aleutians bottom trawl sites (6.3±0.7^{o}) were significantly colder than Southeast ($p<0.01$) and significantly warmer than the three westernmost regions ($p<0.001$). Bottom temperatures were coolest at bottom trawl sites in the Pribilofs, the northernmost region sampled (4.6±1.4^{o}C). Temperatures near the Pribilofs, Central Aleutians (5.2±0.4^{o}C) and West Aleutians (5.3±0.4^{o}C) were not significantly different from each other. Bottom temperature was regressed on longitude, yielding the equation $y = -0.039x + 12.322$, $R^2 = 0.4474$.

Table 8. Differences in bottom temperature among regions. Results of Tukey HSD test for unequal N. * = significance level of $\geq$0.05.

	Mean temperature (^{o}C)	East Aleutians	Pribilofs	Central Aleutians	West Aleutians
Southeast	7.1	0.0075*	0.0001*	0.0001*	0.0001*
East Aleutians	6.3		0.0002*	0.0002*	0.0003*
Pribilofs	4.6			0.2649	0.1951
Central Aleutians	5.2				0.9992
West Aleutians	5.3				

Bottom temperatures at bottom trawl sites in Southeast Alaska ranged from 6.9 to 7.7^{o}C at Forrester Island, and 6.8^{o}C at Lowrie Island. Bottom trawl sites at Ugamak in the East Aleutians ranged from 4.7 to 7.3^{o}C. In the Pribilof Islands, bottom trawl samples were taken where bottom temperature was 3.3–6.4^{o}C at St. George Island, and 5.9^{o} at Walrus Island. In the Central Aleutians, bottom trawl sites were 5.0–6.6^{o}C at Kasatochi Island and 4.6^{o}C at Seguam Island. In the East Aleutians, bottom trawl sites were 4.8–4.9^{o}C at Buldir Island, 5.6–5.7^{o}C at Agattu Island, and 5.2–5.7^{o}C at Attu Island. Within each region, bottom temperature was generally colder at greater depths.

Bottom salinity values were similar among bottom trawl sites within a single region (Table 1, Figure 8), and with two exceptions, all bottom trawl sites within a single rookery were within a salinity range of 0.2 psu. These exceptions include a bottom trawl site one km west of Forrester Island in Southeast Alaska (34.0 psu) which was more saline than other sites at Forrester or Lowrie Islands (32.5–33.0 psu) and a site one km south of Kasatochi Island which was very fresh (25.8 psu) compared with other sites at that rookery (all were 33.1 psu). Bottom salinity values in Southeast Alaska (32.9±0.4 psu, Table 1) were intermediate within the range of salinities examined in other regions. Bottom salinities in the East Aleutians and Pribilof Islands were relatively low (32.1±0.1 psu and 32.0±0.1 psu, respectively). Salinity values in the Central (32.6±2.0 psu) and West Aleutians (33.1±0.1 psu) were slightly higher than in regions to the east, except the Southeast region. Bottom salinities differed significantly among regions ($F = 2.55$, $p = 0.049$, Table 1), but were not significantly different between any two regions (Table 9: $p>0.12$).

Table 9. Differences in bottom salinity among regions. Results of Tukey HSD test for unequal N. * = significance level of $\geq$0.05.

	Mean Salinity (psu)	East Aleutians	Pribilofs	Central Aleutians	West Aleutians
Southeast	32.9	0.3254	0.4866	0.9625	0.9978
East Aleutians	32.1		0.9995	0.6312	0.1256
Pribilofs	32.0			0.7878	0.3499
Central Aleutians	32.6				0.8208
West Aleutians	33.0				

Prey surveys

Catch composition of groundfishes

Quantitative bottom trawl tows at ten rookeries within five regions, collected 4539 fishes, which corresponded to a cumulative CPUE of 4346.0 (# fish/1000 m^2, summed over all species at 61 tows)(Table 10). The average catch over each of 61 sites was 71.2±103.6 fish/1000 m^2. Mean cumulative CPUE values were significantly different among regions (Table 1: $F = 2.72$, $p<0.05$; # fish/1000 m^2, summed over all tows at the region and divided by the number of tows at that region). Although cumulative CPUE values increased from east to west (Table 1, Figure 9), as found by similar research from the Barren and Aleutian Islands 1994–1996 (Müter and Norcross 1998), cumulative CPUE was not significantly different between any two regions (Table 11: $p>0.06$). The lowest average regional catch was in Southeast (11.0±7.1 fish/1000 m^2), and the highest average regional catch was in the West Aleutians (95.7±129.5 fish/1000 m^2) (Table 1, Figure 6). Catches in Southeast Alaska were consistently low ($\leq$22.6 fish/1000 m^2). The three tows with the largest catches were in the West Aleutians (Agattu: 445.5 fish/1000 m^2) and Central Aleutians (Seguam: 442.6 fish/1000 m^2; Kasatochi: 413.9 fish/1000 m^2); all other tows caught $\leq$252 fish/1000 m^2. The large catches in the Central Aleutians were each due to a single sculpin taxon: *Sternias xenostethus* at Seguam and *Triglops* spp. at Kasatochi. The large tow at Agattu was primarily due to large abundances of age-1 arrowtooth flounder and age-0 rock sole. In collections similar to this research which took place 1994–1996, high CPUE values in the West Aleutians were attributed to high numbers of small halibut and recently settled age-0 rock sole (Müter and Norcross 1998). Low abundances of fish in Southeast during the present research may be partly attributable to timing, particularly if the Southeast cruise occurred before settling of age-0 rock sole and halibut, an event which takes place early to mid July in the Unimak Pass area (Müter and Norcross 1998), or if rock sole do not settle at depths as deep as those sampled in Southeast Alaska.

Table 11. Differences in cumulative CPUE among regions. Results of Tukey HSD test for unequal N. * = significance level of $\geq$0.05.

	Mean cumulative CPUE (# fish/1000 m^2)	East Aleutians	Pribilofs	Central Aleutians	West Aleutians
Southeast	11.0	0.9508	0.6421	0.0650	0.2688
East Aleutians	41.2		0.9141	0.1788	0.6209
Pribilofs	89.3			0.9712	1.0000
Central Aleutians	124.5				0.9441
West Aleutians	95.7				

Sixty-two taxa of fishes, representative of eight taxonomic families, were caught by quantitative groundfish tows (Table 10). These taxa were grouped for analysis based on taxonomy, visual resemblance to other species, cumulative catch, and importance in the diet of Steller sea lions. The eight families represented in groundfish tows were Chimaeridae (ratfish: 1

species, Figure 10a), Gadidae (cods: 2 species, Figure 10b), Scorpaenidae (rockfishes: not identified further, Figure 10c), Cottidae (sculpins: 26 taxa, Figure 10d), Agonidae (poachers: 7 taxa, Figure 10e), Cyclopteridae (lumpfishes and snailfishes: 2 subfamilies, Figure 10f), Bathymasteridae (ronquils: 3 species, Figure 10g), Ammodytidae (Pacific sand lance: 1 species, Figure 10h), "other roundfishes" (9 taxa, Figure 10i), and Pleuronectiformes (flatfishes: 9 taxa, Figure 10j). The 12 most abundant taxa each accounted for $\geq$2% of overall CPUE. These taxa included rock sole (*Pleuronectes bilineatus,* 20.5%), *Sternias xenostethus* (14.8%), *Triglops* spp. (14.7%), northern sculpin (*Icelinus borealis,* 6.0%), slim sculpin (*Radulinus asprellus*, 5.8%), arrowtooth flounder (*Atherestes stomias*, 5.0%), *Myoxocephalus* spp. (4.6%), poachers (Agonidae, 4.0%), lumpfishes and snailfishes (Cyclopteridae, 3.8%), Irish Lords (*Hemilepidotus* spp., 3.7%), Pacific staghorn sculpin (*Leptocottus armatus*, 3.5%) and walleye pollock (*Theragra chalcogramma,* 2.0%). Other species made up the remaining 11.6% of the catch.

Among the five regions, the fewest fish taxa were caught in Southeast (N = 17 taxa), followed by the Pribilofs (22 taxa), West Aleutians (27 taxa), East Aleutians (30 taxa) and Central Aleutians (33 taxa) (Table 1). The mean number of fish taxa caught in a tow did not differ significantly among regions (Table 1: F = 1.09, p = 0.371), although the lowest average number of taxa per tow was in Southeast Alaska (5.0±1.10 taxa/tow) and the highest average number of taxa per tow was in the Central Aleutians (7.8±5.31 taxa/tow).

Species diversity as measured by Simpson's complement did not differ significantly among regions when depth was a covariate (F = 0.713, p = 0.586). Similarly, diversity indices computed for overall species composition were not significantly different among regions when depth was excluded from the analysis (F = 2.071, p = 0.097). Species diversity was significantly different among regions at sites within the <40 m depth stratum (F = 5.305, p<0.05), where species diversity was significantly higher in the East Aleutians (0.53$\pm$0.14) than in the Central Aleutians (0.47$\pm$0.34, p<0.01) or West Aleutians (0.0054$\pm$0.0094, p<0.05). Species diversity was not significantly different among regions where sites were within the 40–70 m depth stratum (F = 1.143, p = 0.357) or over 70 m depth stratum (F=2.607, p = 0.067). When only the tows over sand were considered, species diversity in Southeast was significantly higher than in the West Aleutians (p<0.05). Regional values of species diversity were not significantly different among sites on gravel (F = 0.951, p = 0.473) or mixed sand/gravel (F = 1.358, p = 0.279). As with the present data, research based on NMFS groundfish surveys has found that species diversity in Southeast Alaska is higher than in the rest of the Gulf of Alaska (Mueter and Norcross in review).

Relative catch composition differed considerably among regions, and many fish taxa were caught in only one of the five regions examined (Table 12). Eight species captured in Southeast were not captured elsewhere, including (in taxonomic order): black skate (*Raja kincaidi*, caught in a non-quantitative tow); ratfish; whitebarred prickleback (*Poroclinus rothrocki*); shortfin eelpout (*Lycodes brevipes*); and four flatfishes, i.e., Pacific sand dab (*Citharichthys sordidus*), slender sole (*Eopsetta exilis*), rex sole (*Errex zachirus*), and English sole (*Pleuronectes vetulus*). The six species caught only in the East Aleutians included: Pacific cod; three sculpins, i.e., short masked sculpin (*Nautichthys robustus*), grunt sculpin (*Rhamophocottus richardsoni*), and spectacled sculpin (*Triglops scepticus*); rock greenling (*Hexagrammos lagocephalus*); and decorated warbonnet (*Chirolophis decoratus*). Species unique to the Pribilofs included: masked greenling (*Hexagrammos octogrammus*); Pacific staghorn sculpin; ribbed sculpin (*Triglops pingeli*); and nutcracker prickleback (*Bryozoichthys lysimus*). Species caught only in the Central Aleutians included silverspotted sculpin (*Blepsias cirrhosus*), fourhorn sculpin (*Myoxocephalus quadricornis*), *Artedelius* spp., and spotfin sculpin (*Icelinus tenuis*). No species were caught only in the West Aleutians. This may reflect true differences in fish taxa distributions, or it may result from either the relatively small number of collections we made over broad geographic areas, or uneven stratification of collections among depth and sediment strata.

There were regional differences in both the taxa caught most often and the most abundant taxa. The taxa most commonly caught in Southeast Alaska (Table 12) were “flatfishes, other” (i.e., Pacific sanddab, slender sole, rex sole, flathead sole, Dover sole, and English sole; 82% of tows), ratfish, slim sculpin and arrowtooth flounder (each at 72% of tows), poachers and “roundfishes, other” (each at 45% of tows). The five most abundant taxa in Southeast Alaska accounted for 90% of the regional catch, i.e., slim sculpin (35% of CPUE), ratfish (19% of CPUE), “flatfishes, other” (17% of CPUE), arrowtooth flounder (14% of CPUE), and poachers (5% of CPUE).

The most commonly caught fishes in the East Aleutians were not the same as those in Southeast Alaska. In the East Aleutians (Table 12), the species most commonly caught were rock sole (76% of tows), *Triglops* spp. (71% of tows), and northern sculpin (41% of tows). The five most abundant taxa in the East Aleutians accounted for 79% of regional abundance, and included rock sole (30% of CPUE), *Triglops* spp. (13% of CPUE), walleye pollock (12% of CPUE), poachers (12% of CPUE), and northern sculpin (11% of CPUE). Only poachers were among the most abundant taxa in both the East Aleutians and Southeast Alaska.

In both Southeast Alaska and the Pribilofs, poachers were among the most commonly caught fishes. Rock sole, northern sculpin and *Triglops* spp. were commonly caught in the Pribilof Islands as they were in the East Aleutian Islands. In the Pribilofs, Irish Lords and Pacific staghorn sculpin were the most commonly caught fishes (each at 67% of tows), followed by six taxa which were caught at 50% of sites (northern sculpin, *Triglops* spp., poachers, Cyclopteridae, ronquils, and rock sole). The five most abundant taxa in the Pribilofs accounted for 82% of regional abundance, and included slim sculpin (38% of CPUE), Pacific staghorn sculpin (28% of CPUE), Irish Lords (7% of CPUE), Pacific halibut (5% of CPUE) and rock sole (4% of CPUE). Similar percentage abundances of slim sculpins were captured in both the Pribilofs and Southeast Alaska. While rock sole was among the most abundant fishes in both the Pribilofs and East Aleutians, the percentage differed greatly between regions.

As in the East Aleutians and the Pribilofs, rock sole and *Triglops* spp. were commonly captured in the Central Aleutians. Frequency of capture of Cyclopteridae, Irish Lords, and poachers was shared by both the Central and East Aleutians Islands. In the Central Aleutians, the most commonly caught fishes were rock sole (93% of tows), Cyclopteridae (71% of tows), *Sternias xenostethus* and *Triglops* spp. (each at 57% of tows), Irish Lords and poachers (each at 50% of tows), and “sculpins, other” (43% of tows). The five most abundant taxa in the Central Aleutians comprised 87% of regional abundance, and included *Sternias xenostethus* (31% of CPUE), *Triglops* spp. (29% of CPUE), *Myoxocephalus* spp. (11% of CPUE), lumpfishes–snailfishes (8% of CPUE), and rock sole (8% of CPUE). Again, as in the East Aleutians and Pribilofs, rock sole was one of the most abundant species captured. *Triglops* was abundant in the East and Central Aleutians, but not in the Pribilofs Islands or in Southeast Alaska.

Of the regions sampled, the West Aleutians were less unique in species of most commonly caught and most abundant fishes. Rock sole was captured in the West Aleutians commonly as it was in the East and Central Aleutians and the Pribilofs, though the percentage of catch was much greater in the West Aleutians. Northern sculpin were commonly caught in the West Aleutians as in the East Aleutians and Pribilof Islands, whereas poachers were commonly caught in the Central and West Aleutians (but not East), Pribilofs and Southeast Alaska. In the West Aleutians, the most common species were rock sole (85% of tows), northern sculpin and poachers (each at 46% of tows). The five most abundant taxa in the West Aleutians accounted for 83% of regional abundance, and included rock sole (42% of CPUE), Pacific halibut (15% of CPUE), northern sculpin (12% of CPUE), *Sternias xenostethus* (8% of CPUE), and tadpole sculpin (6% of CPUE). Rock sole again was among the most abundant species, as it was in every other region except Southeast Alaska. The region also shared one other abundant species with those three regions: Pacific halibut with the Pribilofs, northern sculpin with the East Aleutians, and *Sternias xenostethus* with the Central Aleutians. There were no abundant species common to both the West Aleutians and Southeast Alaska.

There were distinct regional differences among CPUE values of a fish taxon over all regions and between CPUE values at pairs of regions (Table 13). To identify significant differences in catches of a taxon among regions we analyzed standardized catches (log CPUE+1). The identified differences may indicate true regional differences, the spatial distribution of sites, associated environmental variables, and differences in fishing effort among regions. Eleven fish taxa were significantly different overall among regions (Table 13). Ten of these 11 taxa had significantly different CPUE values at $\geq$1 pair of regions. Although there was a significant difference in abundance of “sculpins, all” overall across regions ($F = 3.21$, $p<0.05$), there were no differences in abundance of this taxon between pairs of regions.

Of the ten taxa which had significantly different abundances between pairs of regions, abundance for each taxon in Southeast Alaska was different from at least one other region (Table 13: $p<0.05$). Ratfish was only caught in Southeast, and its abundance in Southeast was different from each other region. Slim sculpin and “flatfishes, other” were more abundant in Southeast than in the East, Central or West Aleutians. Five taxa not caught in Southeast had significantly lower abundances in Southeast than another region, i.e., Pacific staghorn sculpin, *Myoxocephalus* spp., tadpole sculpin, *Sternias xenostethus,* and lumpsuckers–snailfishes. *Triglops* spp. was caught at lower abundances in Southeast than in Central Aleutians, and rock sole was caught at lower abundances in Southeast than in East, Central or West Aleutians.

Abundances of eight taxa were significantly different in East Aleutians from at least one other region (Table 13: $p<0.05$). Rock sole were more abundant in East Aleutians than in Southeast Alaska, and ratfish, slim sculpin and "flatfishes, other" were less abundant in East Aleutians than in Southeast Alaska. Pacific staghorn sculpin was less abundant than in the Pribilofs, and *Myoxocephalus* spp., *Sternias xenostethus* and lumpfishes–snailfishes were less abundant than in Central Aleutians.

Abundances of two taxa were significantly different in the Pribilofs than at least one other region (Table 13: $p<0.05$). Pacific staghorn sculpin was more abundant in the Pribilofs than any other region, and ratfish was less abundant in the Pribilofs than in Southeast Alaska.

Abundances of ten taxa were significantly different between the Central Aleutians and at least one other region (Table 13: $p<0.05$). *Myoxocephalus* spp. was more abundant in the Central Aleutians than in Southeast Alaska, East or West Aleutians. *Sternias xenostethus* and lumpsuckers–snailfishes were more abundant in the Central Aleutians than in Southeast Alaska or the East Aleutians. *Triglops* spp. was more abundant in the Central Aleutians than in Southeast Alaska or West Aleutians. Rock sole was more abundant in the Central Aleutians than in Southeast Alaska. Ratfish, slim sculpin, and "flatfishes, other" were not caught in the Central Aleutians, and abundances of these taxa were significantly lower than in Southeast Alaska. Pacific staghorn sculpin was not caught in Central Aleutians; abundance of this species was lower than in the Pribilofs. Tadpole sculpin was caught in lower abundance in the Central Aleutians than in the West Aleutians.

Abundances of eight taxa were significantly different between the West Aleutians and at least one other region (Table 13: $p<0.05$). Tadpole sculpin had a significantly higher abundance in the West Aleutians than in Southeast Alaska or the Central Aleutians. Rock sole was caught in higher abundance than in Southeast. Ratfish, slim sculpin, and "flatfishes, other" were caught in lower abundances in the West Aleutians versus Southeast Alaska. Pacific staghorn sculpin was caught in lower abundance in West Aleutians versus the Pribilof Islands. *Myoxocephalus* spp. and *Triglops* spp. were caught in lower abundance in the West Aleutians than in the Central Aleutians.

Physical parameters important to abundance across all regions were selected for each fish taxon by step-wise multiple regression (Table 14). The parameters selected included depth (N = 6 taxa), %sand (5 taxa), bottom temperature (5 taxa), region (5 taxa), and towing speed (1 taxon). The maximum variability accounted for by parameter regression was 61% for rock sole, using the parameters of depth, %sand, towing speed and region. The next highest amount of variability accounted for was 45% for ratfish, using the parameters of depth and bottom temperature. One to two parameters were selected for rockfishes, Irish Lords, Pacific staghorn sculpin, tadpole sculpin, slim sculpin, Sternias xenostethus, lumpfishes–snailfishes, ronquils, arrowtooth flounder, Pacific halibut, and "flatfishes, other;" the maximum variance accounted for was 31% for any of these taxa. No significant physical parameters were detected for ten taxa, i.e., cods, *Gymnocanthus* spp., northern sculpin, *Myoxocephalus* spp., arched sculpin, *Triglops* spp., “sculpins, other,” poachers, Pacific sand lance, and “roundfishes, other.”

We expect that due to species behavior, the bottom trawl did not accurately assess species abundance and distribution of some fish taxa. Data for Pacific sand lance, Pacific cod, walleye pollock, and rockfishes taxa are presented with the following reservations. Pacific sand lance have a varied distribution; school in surface water, and bury in beach and possibly deep water sediments (Hart 1980). The bottom trawl generally drags over the surface of the sediments, digging into the bottom infrequently, and thus possibly may be collecting sand lance only during those incidents where it digs into the sediments and collects buried individuals. The schools of age-0 Pacific cod and walleye pollock caught by the bottom trawl have extremely patchy local distributions (Norcross et al. in review.); thus rare catches of schools of cods may bias the data. Juvenile rockfishes are generally associated with rocky areas (Kreiger 1993; O’Connell and Carlile 1994), region which were avoided in our sampling design.

Statistically important physical parameters for each groundfish taxon

The mean values of physical parameters that were statistically important in explaining abundance variation (Table 14) were calculated over the tows in each region where each fish taxon was caught (Table 15). Where depth, %sand, or temperature was important in explaining abundance variation for a taxon, the mean regional values of the important environmental parameter are summarized below. The taxa for which depth, %sand or temperature was selected as important include rock sole, arrowtooth flounder, lumpfishes–snailfishes, Irish Lords, Pacific staghorn sculpin, ronquils, Pacific halibut, “flatfishes, other,” ratfish, and rockfishes.

Rock sole was caught in all five regions; it was significantly less abundant in Southeast Alaska than in the East, Central, or West Aleutians (Table 13: $p<0.0001$). Sixty-one percent of the variance in rock sole abundance was accounted for by the parameters of depth, %sand, towing speed and region (Table 14). Rock sole was most abundant (47.1±63.5 fish/1000 m^2) in the West Aleutians, where it was caught at 85% of tows. In the West Aleutians, rock sole presence was at the average physical measurements of 54.5±20.8 m depth and 71.0±35.5 %sand (Table 15). Rock sole was caught at 76% of tows in the East Aleutians, where its abundance was considerably less (16.3±17.1 fish/1000 m^2) than in the West Aleutians. The mean values of physical parameters at sites where rock sole was captured in the East Aleutians were 50.8±17.1 m and 86.2±20.4 %sand. In the Central Aleutians, rock sole was caught at 93% of tows and its mean abundance was 10.8±8.8 fish/1000 m^2; mean depth of capture was 49.8±22.3 m, and mean %sand was 44.7±27.6%. Rock sole was caught at 50% of tows in the Pribilofs, with an average of 6.9±5.0 fish/1000 m^2 at these tows, which had mean parameter measurements of 58.8±19.7 m and 55.1±6.1 %sand. Very low abundances of rock sole were caught in Southeast Alaska (0.5±0.1 fish/1000 m^2, at 18% of tows); mean depth of rock sole capture in Southeast Alaska was 92.8±3.9 m; no %sand data were available from these tows.

Arrowtooth flounder was caught in all five regions, and its abundance was not significantly different among regions (Table 13, p>0.05). Eight percent of abundance variation of this species was accounted for by %sand (Table 14). Arrowtooth flounder was most abundant in the West Aleutians, where it was caught at 15% of tows (94.6±129.5 fish/1000 m^2) over an average of 89 %sand (Table 15). At the Pribilof Islands, arrowtooth flounder was caught at 17% of tows (N = 1 tow, 4.1 fish/1000 m^2, 94.8 %sand. In Southeast Alaska, arrowtooth flounder was caught at 73% of tows; mean values at these tows were 2.1±1.6 fish/1000 m^2 and 96.7±1.6 %sand. Arrowtooth flounder was caught at 18% of tows in the East Aleutians, where mean values were 1.2±0.5 fish/1000 m^2 and 92.6±12.1 %sand. Arrowtooth flounder was caught at 21% of Central Aleutian tow sites; mean values at these sites were 0.8±0.1 fish/1000 m^2 and 52.2±11.5 %sand.

Lumpfishes and snailfishes were caught in all regions (Table 12); they were significantly more abundant in the Central Aleutians than in Southeast Alaska or the East Aleutians (Table 13: p<0.001). Twenty-one percent of abundance variation was accounted for by temperature (Table 14). Lumpfishes–snailfishes were caught at 71% of tows in the Central Aleutians, where mean values were 13.2±21.4 fish/1000 m^2 and 5.1±0.1˚C (Table 15). These taxa were caught at 50% of tows in the Pribilof Islands, where mean values were 5.1±5.7 fish/1000 m^2 and 4.2±1.9˚C. Lumpfishes–snailfishes were caught at 38% of tows in the West Aleutians, where mean values were 3.0±2.3 fish/1000 m^2 and 5.2±0.4˚C. They were caught at 12% of tows in the East Aleutians, where mean values were 1.5±1.2 fish/1000 m^2 and 5.6±1.4˚C. In Southeast Alaska, lumpfishes–snailfishes were caught at 9% of tows (N = 1 tow, 0.4 fish/1000 m^2, 7.7˚C).

Irish Lords were caught in the three Aleutian regions and in the Pribilofs, but were lacking from Southeast Alaska catches (Table 12). The abundance of this taxon was significantly different overall among regions, but there were no significant differences between pairs of regions (Table 13: p>0.05). Seventeen percent of variation in abundance was explained by differences in bottom temperature (Table 14). Irish Lords were caught at 50% of tows in the Central Aleutians, at mean values of 10.6±12.5 fish/1000 m^2 and 5.2±0.1˚C. Irish Lords were caught at 67% of tows in the Pribilofs region, at mean values of 9.7±14.0 fish/1000 m^2 and 4.5±1.2˚C. In the West Aleutians, Irish Lords were caught at 38% of tows, at mean values of 8.5±5.4 fish/1000 m^2 and 5.1±0.4˚C. Twenty-four percent of tows in the East Aleutians captured Irish Lords; the mean values at these tows were 1.6±0.8 fish/1000 m^2 and 6.1±0.6˚C.

Pacific staghorn sculpin was caught only in the Pribilof Islands (Table 12); it was significantly more abundant in the Pribilofs than in any other region (Table 13: p<0.0001). Temperature and region accounted for 31% of variability in abundance of this species (Table 14). Pacific staghorn sculpin was caught at 67% of tows near the Pribilof Islands; the mean values at these tows were 37.5±59.1 fish/1000 m^2 and 4.3±1.5˚C (Table 15).

Ronquils were caught in the Pribilofs and in the three Aleutian regions, but were lacking from Southeast Alaska catches (Table 12). Abundances of this taxon were not significantly different among regions (Table 13: p>0.05). Eighteen percent of variation in abundance was accounted for by %sand (Table 14). Ronquils were caught at 35% of tows in the East Aleutians region, where mean values were 6.4±6.9 fish/1000 m^2 and 37.3±26.9 %sand. Near the Pribilof Islands this taxon was caught at 50% of tows; mean values at these tows were 5.1±3.4 fish/1000 m^2 and 32.5±29.5 %sand (Table 15). Ronquils were caught at 23% of tows in the West Aleutian region, where mean values were 2.7±1.8 fish/1000 m^2 and 46.2±36.9 %sand. Ronquils were caught at 21% of Central Aleutians tows, where mean values were 2.6±1.2 fish/1000 m^2 and 52.0±40.9 %sand.

Pacific halibut was caught in the Pribilofs and in the three Aleutian regions, but was lacking from Southeast Alaska catches (Table 12). Abundances of this taxon were not significantly different among regions (Table 13: $p>0.05$). Nineteen percent of abundance variation was explained by the parameters of %sand and depth (Table 14). Near the Pribilof Islands, halibut was caught at 17% of tows (N = 1 tow, 28.1 fish/1000 m^2, 66.0 %sand and 49.5 m depth) (Table 15). In the East Aleutians region, halibut was caught at 35% of tows, where mean values were 3.7±3.7 fish/1000 m^2, 91.3±9.9 %sand, and 51.3±17.4 m depth). Pacific halibut was caught at 21% of tows in the Central Aleutians region, where mean values were 1.6±1.8 fish/1000 m^2, 64.5±38.5 %sand, and 49.0±23.9 m depth). Halibut was caught at 31% of tows in the West Aleutians, where mean values were 1.1±0.3 fish/1000 m^2, 94.0±11.2 %sand, and 56.5±22.5 m depth.

The taxon "flatfishes, other," was caught in Southeast Alaska, the Pribilofs, and in the East and West Aleutian regions (Table 12). Abundance of this taxon was significantly higher in Southeast Alaska than in the East, Central or West Aleutians (Table 13: $p<0.001$). Thirty-one percent of abundance variation in "flatfishes, other" was accounted for by depth and %sand (Table 14). This taxon was most abundant in Southeast Alaska, where it was caught at 82% of tows, which had the mean values of 2.3±2.6 fish/1000 m^2, 116.7±20.6 m depth, and 97.2±2.07 %sand (Table 15). "Flatfishes, other" was caught at 8% of tows in the West Aleutians (N = 1 tow, 3.5 fish/1000 m^2, 83.0 m depth, 99.4 %sand). The taxon was caught at 12% of tows in the East Aleutians, at sites with the mean values of 2.2±1.9 fish/1000 m^2, 37.0±5.6 m depth, and 99.5±0.1 %sand. It was caught at 17% of tows in the Pribilofs (N = 1 tow, 0.8 fish/1000 m^2, 81.5 m depth, and 94.8 %sand).

Ratfish was caught only in Southeast Alaska (Table 12); its abundance in Southeast Alaska was significantly higher than abundance in any other region (Table 13: $p<0.0001$). Forty-five percent of abundance variation was explained by depth and bottom temperature (Table 14). Ratfish was caught at 73% of tows in Southeast Alaska, at sites with the mean values of 2.9±2.2 fish/1000 m^2, 128.9±10.8 m depth, and 7.0±0.2˚C.

Rockfishes were caught in the East, Central and West Aleutians, but were not caught in Southeast Alaska or near the Pribilof Islands (Table 12). Rockfish abundance was not significantly different among regions (Table 13: $p>0.05$). Region and depth accounted for 18% of the abundance variation in this taxon (Table 14). Rockfishes were caught at 23% of tows in the West Aleutians, at sites with the mean values of 5.7±6.7 fish/1000 m^2 and 85.3±19.4 m depth

(Table 15). In the East Aleutians, rockfishes were caught at 6% of tows (N = 1 tow, 1.2 fish/1000 m^2, 69.0 m depth). Rockfishes were caught at 14% of tows in the Central Aleutians, at sites with the mean values of 0.9±0.1 fish/1000 m^2 and 64.5±23.3 m depth.

Catch composition of pelagic fishes

Midwater tows were taken at five sites in Southeast Alaska and nine sites in the Pribilof Islands (Table 16, Figures 2a, 2c, and 2d). Quantitative midwater trawl tows collected 23,343 fishes, which corresponded to a cumulative CPUE of 8993.1 (#fish/10 min tow, summed over all species at 14 tows). The average 10 min CPUE over 14 sites was 642.4±859.0 fish. Cumulative CPUE values were not significantly different ($F = 3.29$, $p = 0.09$) for midwater tows in Southeast Alaska (126.9±173.5 fish/10 min tow) and the Pribilof Islands (928.7±962.1 fish/10 min tow). However, diversity of overall species composition, as measured by Simpson's complement, was significantly higher in Southeast Alaska (0.336±0.297) than in the Pribilofs (0.002±0.003)($F = 12.16$, $p<0.01$).

Eight species were captured by midwater tow in Southeast Alaska (Table 16). In order of decreasing abundance, the species captured were Pacific herring, eulachon, Pacific cod, walleye pollock, rockfish, shortfin eelpout, arrowtooth flounder, and rex sole. A total of 1, 537 fishes were caught, yielding a cumulative 10 min CPUE of 634.7 fish summed over five tows. The largest single catch in Southeast Alaska was taken at the average tow depth of 28 m; the range of towing depths in this area was 14–130 m. Pacific herring and eulachon dominated the midwater catches in Southeast, respectively accounting for 83.7% and 11.0% of total CPUE. Herring was caught in each tow, and eulachon was caught in four of five tows. Herring was the most abundant species in three of five tows, and eulachon was the most abundant in the remaining two tows. The mean size of herring was 218±14 mm, and the mean length of eulachon was 134±30 mm. The mean length of the other six species was 261±110 mm.

Five species were captured by midwater tow in the Pribilof Islands (Table 16), i.e., Pacific cod, walleye pollock, fourhorn poacher, prowfish, and Pacific halibut. A total of 21,801 fish was caught, yielding a cumulative 10 min CPUE of 8358.4 fish summed over nine tows. The largest single catch was taken during a tow of 90 m average depth; the mean midwater tow depths in the Pribilof Islands ranged from 9 to 90 m. Each of the midwater tows in the Pribilofs was dominated by age-0 walleye pollock, which accounted for 99.9% of CPUE in every tow. The mean size of pollock was 31±6 mm. The mean length over the other four species was 43±18 mm.

Regional midwater tow CPUE of individual species was tested for significant differences. Two species had significantly higher CPUE in Southeast Alaska than in the Pribilofs region, i.e., Pacific herring ($F = 37.10$, $p<0.0001$) and eulachon ($F = 13.16$, $p<0.01$). Walleye pollock was the only species with lower CPUE in Southeast Alaska than in the Pribilofs ($F = 69.43$, $p<0.0001$).

Diet composition of predatory fish

Large predatory Pacific halibut and Pacific cod (N = 126) were examined for stomach contents from collections by baited longline (N = 106), baited hook and line (N = 19), and bottom trawl (N = 1; Table 17). Nine longline sets among the East Aleutians, Pribilofs, Central and West Aleutians captured 160 fish, primarily of yellow Irish Lord, Pacific halibut and Pacific cod. Each set caught from 0 to 34 fish. More halibut were caught than cod in the East and Central Aleutians, and more cod were caught than halibut in the Pribilofs and West Aleutians. Only halibut were retained from hook and line gear in the East and West Aleutians; the 16 stomachs retained from the Pribilofs may have been from either or both species. A single large cod was retained from bottom trawl catches for stomach analysis. From 23 to 48 fish were retained for stomach content analysis from each of the four regions examined, East Aleutians, Pribilofs, Central and West Aleutians.

Stomach contents of large Pacific halibut and Pacific cod were examined. Proportionally more Pacific cod than Pacific halibut contained prey (Table 18). Over the Aleutian regions, where predatory cod and halibut were examined separately, 11% of cod were empty, and 49% of halibut were empty. Half the fish examined from the Pribilofs were empty. Halibut and cod consumed both demersal and pelagic prey (Table 18).

Over the Aleutian regions, in order of decreasing frequency of occurrence, cod consumed unidentified fish (46%), crustaceans (40%), other benthic invertebrates (34%), cephalopods (23%), other demersal fishes (20%), small schooling fishes (11%), gadids (3%), and pleuronectids (3%). Over the Aleutian regions, the frequency of occurrence of halibut prey was unidentified fish (26%), gadids (19%), other benthic invertebrates (16%), crustaceans (14%), cephalopods (12%), small schooling fishes (9%), pleuronectids (2%), and other demersal fishes (2%). Fish from the Pribilofs consumed gadids (21%), crustaceans (13%), cephalopods (10%), pleuronectids (10%), other benthic invertebrates (8%), other demersal fishes (6%), unidentified fishes (4%), and seabirds (2%).

Both pelagic and demersal prey were consumed by predators in each region (Table 18, Figure 11). More cod in the East and Central Aleutians consumed crustaceans, other benthic invertebrates and other demersal fishes than in the West Aleutians. More cod in the East Aleutians ate small schooling fishes than in the Central or West Aleutians. Fewer cod in the East and Central Aleutians consumed unidentified fish than in the West Aleutians. Similar proportions of halibut within the East and Central Aleutians consumed cephalopods, crustaceans, other benthic invertebrates and unidentified fishes. A larger proportion of halibut in the East Aleutians ate gadids than in the Central Aleutians. The single halibut examined from the West Aleutians consumed only other benthic invertebrates, small schooling fishes, other demersal fishes and unidentified fishes.

Disregarding predator species, the regional frequency of prey occurrence indicated crustaceans were consumed by halibut or cod 2–3 times more in the East (38%) and Central (24%) Aleutians than in the Pribilofs (13%) or West Aleutians (13%; Table 18). Gadids were consumed primarily by fish in the East Aleutians (31%) and Pribilofs (21%), and other small schooling fishes were consumed by fish in the East (23%) and West (9%) Aleutians.

The proportional number of prey consumed of each taxon is summarized (Table 19, Figure 11). Crustaceans accounted for the largest numbers of prey consumed by cod in the East and Central Aleutians, by halibut in the Central Aleutians, and by cod–halibut in the Pribilofs. The highest counts of prey were consumed of unidentified fishes by cod in the West Aleutians, small schooling fishes by halibut in the East Aleutians, and other benthic invertebrates by halibut in the West Aleutians.

Over the Aleutian regions (Figure 11), in order of decreasing proportional numbers taken of each prey taxa, cod consumed crustaceans (46%), fishes (combined fish taxa, 30%: unidentified fish, 22%; small schooling fishes, 3%; other demersal fishes, 3%; gadids, 1%), other benthic invertebrates (17%), and cephalopods (7%). Over the Aleutian regions, halibut consumed fishes (combined fish taxa, 57%: small schooling fishes, 26%; unidentified fishes, 14%; gadids, 13%; pleuronectids, 2%; other demersal fishes, 1%), crustaceans (26%), other benthic invertebrates (10%), and cephalopods (7%).

In the Pribilofs (Figure 11), fish consumed crustaceans (44%), fishes (combined fish taxa: 40%; gadids, 18%; pleuronectids, 13%; other demersal fishes, 6%; unidentified fishes, 3%), cephalopods (7%), other benthic invertebrates (7%), and seabirds (1%).

Within each region, there was considerable range in the size of predator fish examined for stomach contents. Suggested regional differences in prey consumption could be confounded by differences in diet between small and large fishes. The relatively small number of predators caught precluded meaningful analysis of diet composition by predator size group.

Size of fishes

Disregarding capture region, significantly different sizes of fishes were sampled by the bottom trawl, midwater trawl, and predatory halibut or cod ($F = 1448.35$, $p<0.0001$). Fishes collected by bottom trawl were smallest (10–651 mm, 70.5±76.7 mm), midwater fishes were of intermediate size (14–718 mm, 103.2±95.1 mm), and fishes consumed by halibut or cod were largest (22–498 mm, 146.7±118.9 mm) (Table 20). Fishes caught by bottom and midwater trawl were small relative to the size of pollock consumed by juvenile sea lions in the Gulf of Alaska (70–550 mm, mean = 208 mm, Merrick and Calkins 1996). The larger fishes consumed by halibut and cod are closer in size to fish consumed by juvenile sea lions.

Sizes of fishes captured with a single type of gear also varied significantly among and between regions. Fish caught by bottom trawl varied by region ($F = 35.59$, $p<0.0001$). Fishes caught by bottom trawl were larger in Southeast Alaska than all other regions, and fishes caught by bottom trawl in Central Aleutians were smaller than all other regions (Table 21). As noted previously, regional collections are confounded somewhat by sequential timing of sample collections. The collections in Southeast (June) may be prior to settling of age-0 groundfishes in that area, while sample collections in the Aleutians (west to east direction during June–July) and Pribilofs (July) may have taken place during or after the majority of settlement. However, sequential timing could not fully explain the observed differences in fish size, as fishes in the

Pribilof Islands were sampled the latest yet were approximately the same size as in the East and West Aleutians and significantly larger than the Central Aleutians.

Table 21. Differences in size of fish caught by bottom trawl among regions. Results of Tukey HSD test for unequal N. * = significance level of $\geq$0.05.

	Mean length (mm)	East Aleutians	Pribilofs	Central Aleutians	West Aleutians
Southeast	113.3	<0.0001*	<0.0001*	<0.0001*	<0.0001*
East Aleutians	74.0		0.9969	0.0024*	0.9999
Pribilofs	75.6			0.0021*	0.9907
Central Aleutians	58.6				0.0002*
West Aleutians	73.4				

Fishes caught in Southeast Alaska by midwater trawl were larger than were caught in the Pribilofs (Table 20; F = 2490.51, p<0.0001). Fishes consumed by halibut or cod also varied among regions (F = 53.06, p<0.0001); they were larger in the Pribilofs than the East, Central or West Aleutians (Table 22).

Table 22. Differences in size of fish consumed by Pacific halibut or Pacific cod among regions. Results of Tukey HSD test for unequal N. * = significance level of $\geq$0.05.

	Mean length (mm)	Pribilofs	Central Aleutians	West Aleutians
East Aleutians	97.9	0.0002*	0.7129	0.2533
Pribilofs	385.4		0.0002*	0.0003*
Central Aleutians	42.5			0.0622
West Aleutians	178.0			

Sampling problems

The main problems encountered during sampling were due to vessel differences between Southeast and western regions, lack of gear and data in some regions, dissimilar habitats, rough bottom topography around rookeries and resulting sampling gear limitations.

There was a significant difference among regional towing speeds at bottom trawl sites (Table 1: F = 12.94, p<0.0001). The average towing speed in Southeast Alaska (92.8±32.23 m/min), the one region sampled with a different vessel, was significantly faster than the towing speed in each other region (Table 23: p<0.01). There were no significant differences in towing speed among the other regions, which were all sampled from the same vessel. During towing speeds both similar to and faster than speeds in other regions, CPUE in Southeast Alaska was consistently low (Figure 12). No relationship between towing speed and CPUE was detected in any region.

Table 23. Differences in tow speed among regions. Results of Tukey HSD test for unequal N. * = significance level of >0.05.

	Mean tow speed (m/min)	East Aleutians	Pribilofs	Central Aleutians	West Aleutians
Southeast	92.8	0.0001*	0.0093*	0.0004*	0.0001*
East Aleutians	45.1		0.9765	0.4603	0.9999
Pribilofs	52.0			0.9939	0.9874
Central Aleutians	56.8				0.6265
West Aleutians	46.1				

All gear and data were not available during each cruise. Midwater trawl tows were collected during all cruises, however midwater trawl data were available to us only from Southeast Alaska and the Pribilofs, and not from the East, Central, or West Aleutians. Hydroacoustics gear was not available aboard the F/V *Tracey Ann* for sampling in Southeast Alaska, and although hydroacoustics data were collected during cruises in the Aleutians and Pribilofs, the data were not available to us. Longlines baited to collect predatory groundfishes were set only in the Aleutian and Pribilof Islands because gear was not available aboard the F/V *Tracey Ann* to sample in Southeast Alaska. Stomach contents of Pacific halibut and Pacific cod examined in the Pribilofs were not distinguished as to predator species. As the prey taxa consumed by these two species were somewhat different in the East, Central, and West Aleutians (Figure 11), we consider stomach contents from the Pribilofs to be confounded by the lack of predator species.

There were considerable differences among trawlable habitats available near rookeries. The small meshed bottom trawl used in quantitative collections of juvenile groundfishes was rarely deployed with success over steep slopes or substrates containing gravel or cobble. Untrawlable or marginal areas containing rocky pinnacles and large-grained substrates were common near all rookeries and severely restricted sampling. In particular, steep slopes and rocky pinnacles precluded trawling in depths <80 m in the Southeast region.

Bottom trawls, midwater trawls, and predatory fishes each sampled fishes within a large range of sizes, yet average lengths of fishes caught by these methods were smaller than were found in the stomachs of juvenile sea lions in the mid-1980's (Merrick and Calkins 1996). Thus, the lengths of fishes in our catches do not reflect the lengths of fish targeted by sea lions. However, the species compositions of demersal and pelagic communities provided by this research can serve as an index for the availability of potential prey species in subsequent years.

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