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NEARSHORE FISH COMMUNITIES OF
ATTU ISLAND, ALASKA

by

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INTRODUCTION

In 1976, the Anchorage Field Station of the National Fish and Wildlife Laboratory, U.S. Fish and Wildlife Service, initiated investigations of the nearshore marine communities of Attu Island, Alaska. The primary objective of this research was to determine the likely effects of an expanding sea otter (Enhydra lutris) population on the island's marine communities.

According to the available information, Attu Island was devoid of sea otters from the period of their extensive exploitation during the latter half of the 18th century¹ until 1956 when R.D. Jones (U.S. Fish & Wildlife) transferred five otters from Amchitka to Attu. Fisheries Research Institute biologist B.F. Jones reported an otter at Attu one-quarter mile off Chirikof Point three years later. Since that time the population has expanded to approximately 350 animals² distributed along the northeastern side of the island.

Aleutian nearshore fish assemblages--their composition, relative abundance and standing crop, and the trophic relationships to other elements in the community--appear to be both directly and indirectly influenced by sea-otter predation (Estes and Palmisano, 1974; Palmisano, 1975; Palmisano and Estes, 1974, 1977; Simenstad, et al., 1977). Documentation of benthic algae and invertebrate and nearshore fish community structure at Amchitka Island, where significant sea-otter predation has occurred since the mid-1930s (Kenyon, 1969), has been extensive since 1967 (see Lebednik and Palmisano, 1977; O'Clair, 1977; and Simenstad, et al., 1977, for summary). Although a similar information base for benthic algae and invertebrate

¹Federal protection of the sea otter was initiated in 1911.

²James Estes, USF&WS, personal communication.

communities exists for systems without abundant sea otters (Palmisano, 1975), the associated nearshore fish communities have not been studied. The Attu investigations presented the opportunity to observe and document the state of a nearshore fish community with little or no sea-otter predation and the changes resulting from expanding sea-otter predation.

The general objective of the initial investigation was to document the nearshore fish community at Attu, and to compare it with similar existing documentation from Amchitka. Specific research tasks included the following:

(1) Description of species composition, life history composition, and relative abundance and standing crop (biomass) for assemblages of nearshore fish and dominant macroinvertebrates associated with identifiable littoral and shallow sublittoral habitats.

(2) Description of food organisms and feeding behavior of principal fish species and associated trophic relationships with prey organisms in nearshore environs.

(3) Comparison of nearshore community structures within and outside the range of the sea otter at Attu.

(4) Comparison of documented fish assemblages at Attu with those previously encountered at Amchitka in similar habitats and seasons.

MATERIALS AND METHODS

In order to keep our data comparable to other studies as much as possible, we used the same collection methodology as was used at Amchitka. In the case of beach seining, we followed the standard techniques used in FRI's nearshore fish studies in Puget Sound for the Washington Department of Ecology and NOAA's Puget Sound MESA office.

Sampling Sites

Sampling efforts were concentrated in two general areas of Attu, the Chichagof Harbor area on the island's northeast side and the Massacre Bay area on the southeast side (Fig. 1). The sea otter appears to have spread from the Chichagof Harbor vicinity (Kenyon, 1969; Estes and Smith, 1973; J. Estes, personal communication) but has yet to populate the Massacre Bay area. Thus, these areas were chosen to represent the two extremes of sea-otter predation pressure at Attu.

Sampling Gear

Trammel Net. The trammel net is a set net with three parallel panels of net--a loosely hung, small-meshed panel hung between two large mesh panels. Fish encountering the net along the bottom continue to swim through the large mesh and strike the small-mesh netting, forming a bag through the large mesh panel on the opposite side. Small fish will also gill in the small-mesh net.

The trammel net used at Attu had the same dimensions as that used at Amchitka. The net was 45.8 m long and 1.8 m high with 50.8-cm standard mesh, #9 netting forming the outer panels and 5.1-cm standard mesh, #139 gillnetting forming the inner panel. The net's flotation and weight were increased from the Amchitka specifications to make the net stand upright under the effect of currents. A 1.3-cm polycore line with one "B-2" float at every seventh hanging made up the floatline and the leadline was of 34-kg leadcore.

Two nets were set consecutively at each sampling site, usually 15 to 20 m apart, in similar habitat (depth and gradient, kelp density, current alignment, etc.) in order to obtain replicate sets. Sets were made during daylight and usually fished 4 to 8 hours, although weather

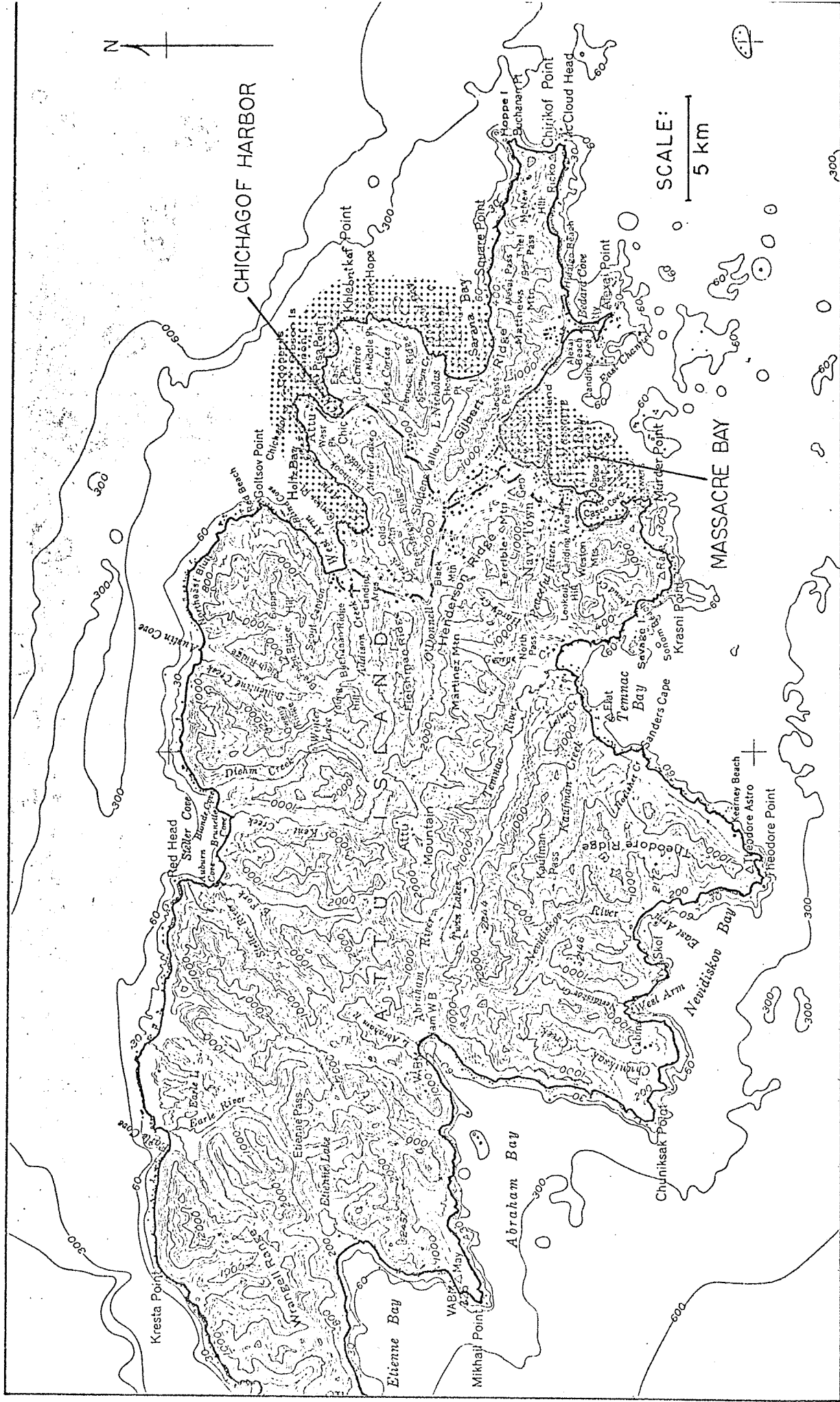


Fig. 1. Attu Island indicating principal sampling areas, July-August 1976.

conditions forced us to leave the nets set overnight on several occasions.

Beach Seining. A 37-m beach seine equipped with 18-m long, 3-mm mesh wings, and a 0.6m x 2.4m x 2.3m bag of 6-mm mesh, was utilized to sample nearshore fishes in cobble, gravel, and sand beach habitats. Where the beach gradient was steep enough, floats were added to the seine's floatline, and the net was fished so as to sweep only the surface water layer over the nearshore region. The net was set 30 m out from the beach off the bow of an outboard-powered skiff and retrieved to the beach at approximately 10 m/min. The lines attached to the poles at the end of each wing were initially hauled from positions 40 m apart until 20 m of line had been retrieved; the net was then closed down to a 12-m opening and the net retrieval was completed.

Bottom Longlines. Japanese salmon longlines, each with a 22.6-kg test vinylon main line, 138 m long with 49 evenly spaced (2.3-m interval) size-8 hooks on 1-m, 10-kg test monofilament leaders, were fished stretched along the bottom. Pieces of octopus (Octopus dofleini) were used as bait. Set durations averaged six hours, usually during daylight.

A heavy-duty 25-hook longline was also constructed to sample specifically for Pacific halibut, Hippoglossus stenolepis.

Crab Trap. An 86-cm diameter Taylor-type crab trap baited with fish carcasses was used to capture large, scavenging macroinvertebrates.

Rotenone. Rotenone was applied to isolated tidepools as a piscicide in order to capture tidepool fishes. The volume of each pool was reduced by manually bucketing the water out until the fish were concentrated in a shallow puddle. The rotenone was then added in paste form and the fish dipped out by hand as they responded to the rotenone. Tidepool volumes ranged from approximately 0.6 to 4.0 m², averaging about 1.7 m³.

Hand, Hook-and-Line, and Dipnet Collections. These incidental non-quantitative methods were used to obtain fishes not available through other methods--for example, schools of postlarval and small juvenile fishes swimming through kelp beds.

Collection Information

Location, date, time, tide, weather, and oceanographic and other pertinent environmental information was recorded at the time of sampling, and the sampling duration and area or volume were calculated. Water depth was determined by direct measurement in shallow areas and by fathometer in deeper areas. All information was initially recorded on computer-format forms (NOAA/EDS format No. 100).

Biological Information

All fish catches were processed soon after removal from the sampling gear. Each sample was sorted to species, enumerated, measured, and weighed. A count or proportional estimate of the total number and biomass was made for each species, as well as individual lengths (total length) and weight (to nearest 5 g) measurements, sex and age determination, stomach contents and evidence of external disease, parasites, or other external abnormalities for selected subsamples of important species.

All individual specimen data were initially recorded on computer-format forms (NOAA/EDS format No. 100). Principal sources of fish identification included Hart (1973), Wilimovsky (1958), and Andriyashev (1954).

Subsampling

The adopted sampling methods were designed to avoid the necessity of subsampling, but upon occasion catches were too large to process within a reasonable length of time. In these cases proportional subsampling was used.

Two conditions under which we subsampled were: (1) Subsampling the total catch for catch composition, abundance, and biomass estimates, and (2) subsampling within a species for abundance, biomass, and representative length, weight, sex, etc., information.

In subsampling the total catch in situ (in the net, on deck, etc.), the fish were well mixed. Then using a scoop or balance pan, we took uniform successive samples from the catch, retaining every tenth sample. The subsample was then sorted to species and life history stage and counted and weighed. The total catch was then estimated from the subsample proportion and the species/life-history ratios.

When an excessively large catch of one species was subsampled, all other species were removed and a minimum of 50 specimens (25 from each replicate) of each life history stage of the abundant species were taken randomly from the total. Any three data of (a) total count, (b) total weight, (3) subsample count, and (4) subsample weight were utilized to estimate the total number and biomass of that species and life history stage.

Stomach Analysis

All fish sampled for stomach contents were freshly measured and weighed before preservation, and life history stage and sex determined. For large specimens difficult to preserve whole, the stomach was removed by dissection from the abdominal cavity, cutting the esophagus as close to the pharynx as possible. The esophagus was tied off with string or wire with a waterproof label attached giving collection and haul number, date, and specimen number. The stomach was then cut away from the remaining digestive tract posterior to the pylorus. Fish preserved whole were similarly labelled by tying a string label through the gills. In whole

fish specimens the abdominal cavity was cut open to allow entrance of the preservative. All fish were preserved initially in 10% buffered formalin, and later were transferred to 70% alcohol if they were to remain unprocessed for long.

In the laboratory, the stomach samples were removed from the preservative or the preserved whole fish and soaked in cold water for at least two or three hours before examination. The stomach was then identified according to information on the label and processed. Processing involved taking a total (damp) weight (to nearest 0.1 g) and removing the contents from the stomach and weighing the empty stomach, which gave a total contents weight (including unidentifiable material) by subtraction. Subjective numerical evaluations of the stomach condition or degree of fullness--scaled from 1 (empty) to 7 (distended)--and stage of digestion--scaled from 1 (all digested) to 5 (no digestion)--were made at this time. The stomach's contents were then sorted and identified as far as was practical, and the sorted organisms were counted and a total (damp) weight of each taxon obtained (to nearest 0.01 g). If a sorted taxon was represented by too many individuals to count, the number was estimated using a random grid counting procedure.

All stomach analysis data were recorded directly on NOAA/EDS format No. 100 computer forms.

Data Analysis

All data were processed using FORTRAN computer programs specifically written for the NOAA/EDS format record types, including statistical analyses of catch and stomach contents data.

RESULTS

Between July 9 and July 25, 1976, 22 trammel net, 2 beach seine, 6 bottom longline, 8 tidepool, and 2 hand collections of nearshore fish were made at Attu Island, resulting in an overall collection of 2,327 fish of 28 species (Tables 1 and 2). Figs. 2 and 3 show the comparable sampling sites concentrated in the Chichagof Harbor (Pisa Pt.) and Massacre Bay (Casco Pt.) areas only. In addition to sampling these two areas of emphasis, collections were made in the sandy bottomed embayments at Sarana Bay and Holtz Bay. Within the Chichagof Harbor area, sampling was stratified by depth and by habitat--e.g., rocky, exposed shoreline without kelp beds vs. protected embayment areas with kelp beds--in order to provide some qualitative indications of habitat associations.

A number of epibenthic macroinvertebrates were also captured with the trammel net (Table 3), the numbers of which may indicate their abundance in the shallow subtidal habitats.

Wilimovsky (1964), in the only comprehensive survey of Aleutian inshore fish fauna, lists 54 species from Attu Island. Our 1976 collections included 23 of these species, and added walleye pollock juveniles (Theragra chalcogramma), ribbed sculpin (Triglops pingeli), tubenose poacher (Pallasina barbata), and searcher (Bathymaster signatus) to the known nearshore fish fauna. The eelpout tentatively identified as Commanderella popovi may be the same as that reported by Wilimovsky.

The Attu Island fish fauna differs from Amchitka's nearshore fish fauna in several respects; however, differences in species composition in the two sampling areas at Attu--Chichagof Harbor and Massacre Bay--are not significant. The assemblage typical of exposed rocky shoreline at Amchitka

Table 1. Fish species collected during nearshore fish collections at Attu Island, Alaska, July 1976.

Scientific name	Common name
Class Osteichthys	
Order Salmoniformes	
Family Salmonidae	Salmon and trout
<i>Oncorhynchus gorbuscha</i> (Walbaum)	Pink salmon (juveniles)
<i>O. kisutch</i> (Walbaum)	Coho salmon (juveniles)
<i>O. nerka</i> (Walbaum)	Sockeye salmon (juveniles)
<i>Salvelinus malma</i> (Walbaum)	Dolly Varden (juveniles)
Order Gadiformes	
Family Gadidae	Codfishes
<i>Gadus macrocephalus</i> (Tilesius)	Pacific cod (juveniles)
<i>Theragra chalcogramma</i> (Pallas)	Walleye pollock (juveniles)
Family Zoarcidae	Eelpouts
<i>Commandorella popovi</i> (?)	
Order Perciformes	
Family Bathymasteridae	Ronquils
<i>Bathymaster signatus</i> (Cope)	Searcher
Family Stichaeidae	Pricklebacks
<i>Alectrias alectrolophus</i> (Pallas)	Stone cockscomb
<i>Anoplarchus purpureescens</i> (Gill)	High cockscomb
<i>Phytichthys chirus</i> (Jordan & Gilbert)	Ribbon prickleback
Family Pholidae	Gunnels
<i>Pholis laeta</i> (Cope)	Crescent gunnel
Family Ammodytidae	Sand lances
<i>Ammodytes hexapterus</i> (Pallas)	Pacific sand lance
Family Hexagrammidae	Greenlings
<i>Hexagrammos lagocephalus</i> (Pallas)	Rock greenling
<i>Pleurogrammus monoptyerygius</i> (Pallas)	Atka mackerel
Family Cottidae	Sculpins
<i>Clinocottus acuticeps</i> (Gilbert)	Sharpnose sculpin
<i>C. embryum</i> (Jordan & Starks)	Calico sculpin
<i>Enophrys diceraus</i> (Pallas)	Antlered sculpin
<i>Hemilepidotus hemilepidotus</i> (Tilesius)	Red Irish lord
<i>Myoxocephalus polyacanthocephalus</i> (Pallas)	Great sculpin
<i>Porocottus bradfordi</i> (Rutter)	
<i>Sigmistes caulis</i> (Rutter)	Kelp sculpin
<i>Triglops pingeli</i> (Reinhardt)	Ribbed sculpin
Family Agonidae	Poachers
<i>Pallasina barbata</i> (Steindachner)	Tubenose poacher

Table 1, cont'd

Scientific name	Common name
Family Cyclopteridae	Lumpfishes and snailfishes
<i>Liparis callyodon</i> (Pallas)	Spotted snailfish
Family Pleuronectidae	Righteye flounders
<i>Hippoglossus stenolepis</i> (Schmidt)	Pacific halibut
<i>Lepidopsetta bilineata</i> (Ayres)	Rock sole
<i>Platichthys stellatus</i> (Pallas)	Starry flounder

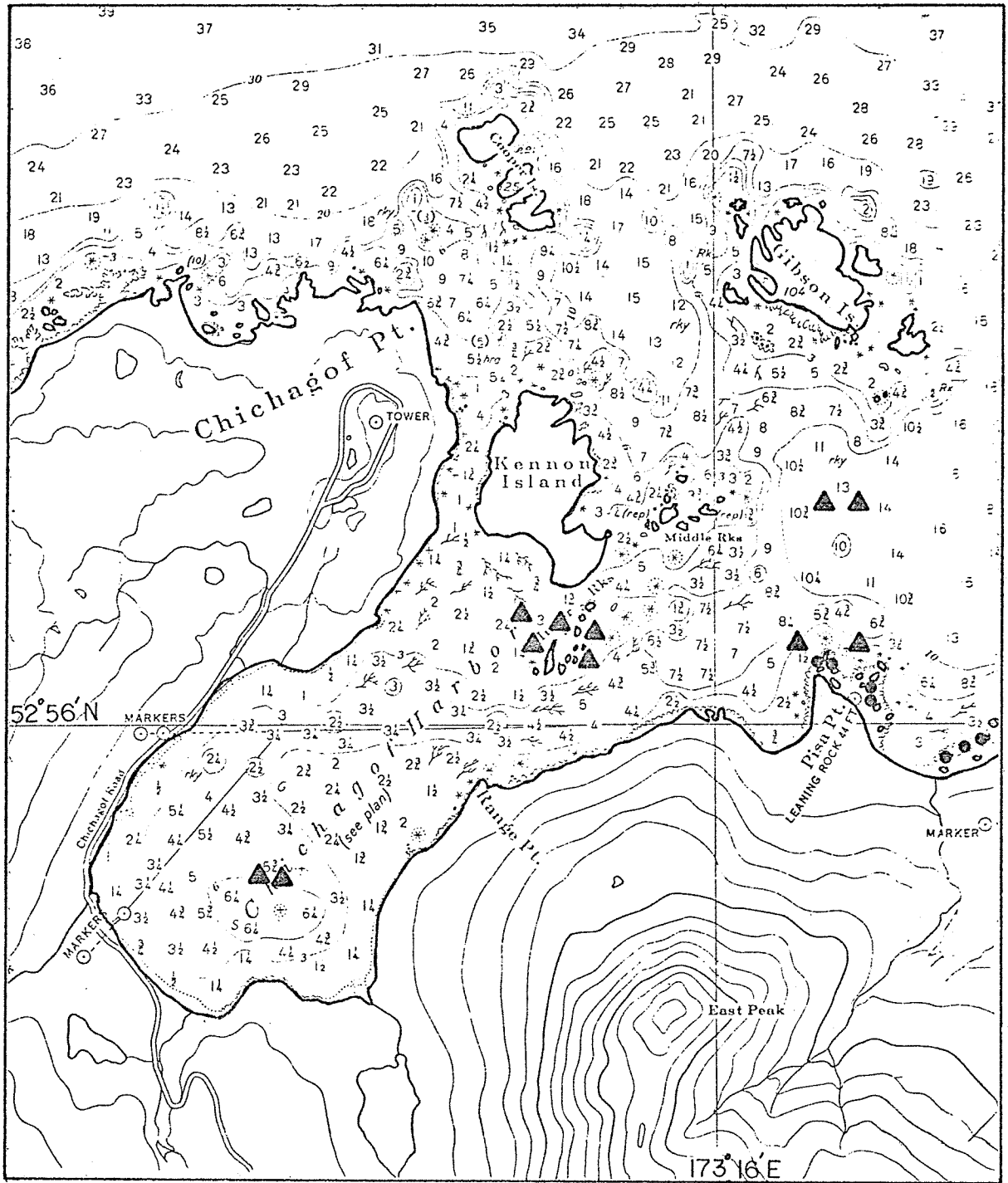


Fig. 2. Nearshore fish trammel net (▲) and tidepool (●) collection sites in Chichagof Harbor area, Attu Island, July 1976.

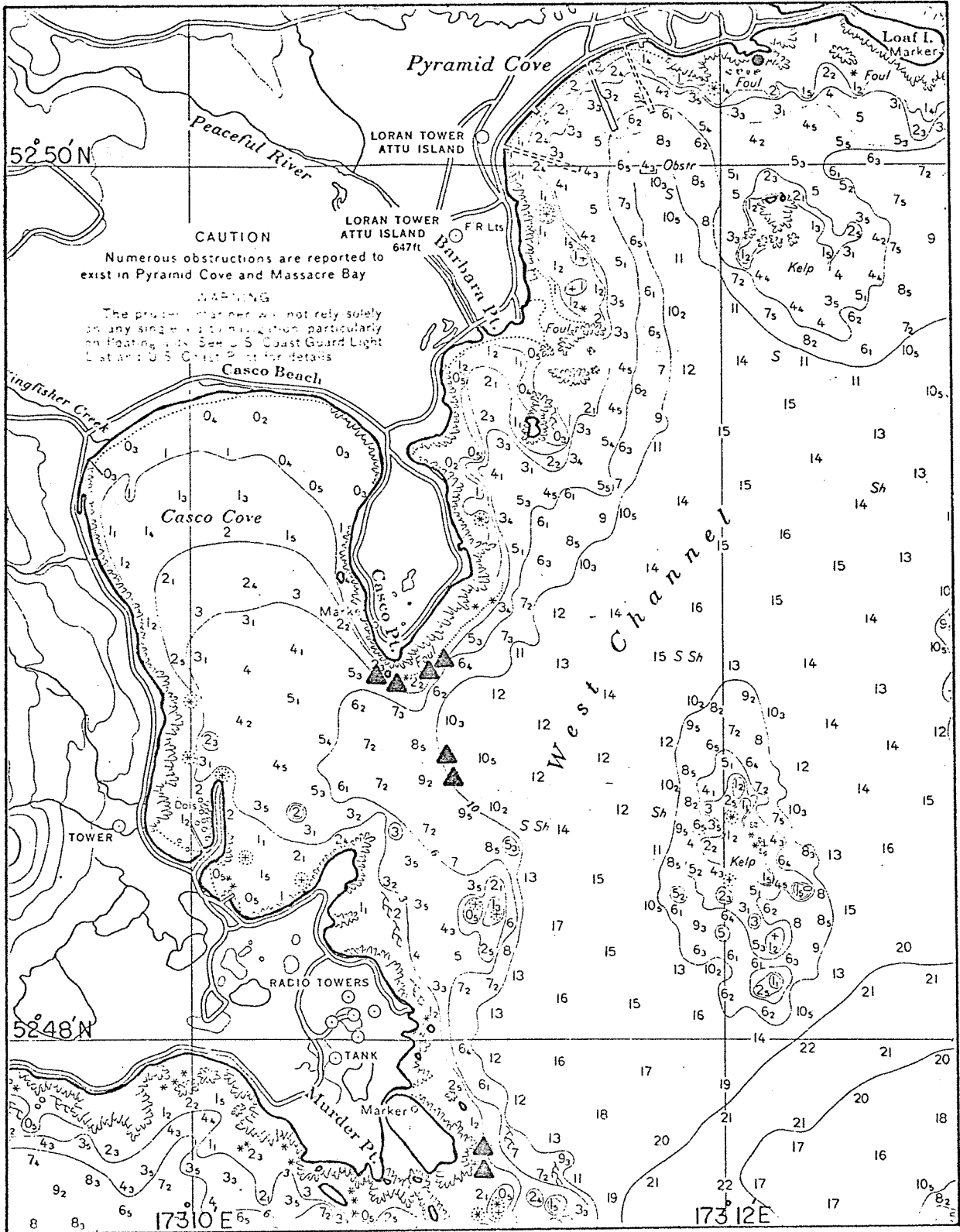


Fig. 3. Nearshore fish trammel net (▲) and tidepool (●) collection sites in Massacre Bay area, Attu Island, July 1976.

Table 3. Invertebrate species collected during nearshore fish collections, Attu Island, July 1976.

Class Amphinera

Ishnochiton sp.?

Class Gastropoda

Fusitriton oregonensis (Redfield)

Class Malacostraca

Order Decapoda

Suborder Brachyura

Erimacrus eisenbecki (Brandt)

Hyas lyratus (Dana)

Oregonia gracilis (Dana)

Scyra acutifrons (Dana)

Telmessus cheiragonus (Tilesius)

Suborder Anomura

Dermaturus mandti

Elassochirus tenuimanus (Miers)

Haplogaster grebnitzki

Pagurus hirsutiusculus (Dana)

P. kennerlyi (Stimpson)

Phyllolithodes papillosus (Brandt)

Class Cephalopoda

Order Octopoda

Octopus dofleini (Wülker)

Class Asteroidea

Ceramaster arcticus

Crossaster papposus (Linnaeus)

Evasterias sp. or *Asterias* sp.

Henricia sanguinolenta (?) (Müller)

Leptosterias spp.

Class Echinoidea

Strongylocentrotus polyacanthus (Agassiz & Clark)

Class Holothuroidea

Cucumaria sp.?

is dominated by rock greenling (Hexagrammos lagocephalus), red Irish lord (Hemilepidotus hemilepidotus), northern ronquil (Bathymaster caeruleofasciatus), silverspotted sculpin (Blepsias cirrhosus), great sculpin (Myoxocephalus polyacanthocephalus), and dusky rockfish (Sebastes ciliatus) (Simenstad, et al., 1977). Rock greenling, red Irish lord, and great sculpin are the only co-occurring species, and at Attu great sculpin are more numerous and occur as mature adults, a rare situation at Amchitka. Enophrys diceraus, the other common species of this assemblage at Attu, was not found during the seven years of intensive sampling at Amchitka.

The species characterizing the inshore/sand-gravel habitat at Amchitka were Pacific cod (Gadus macrocephalus), walleye pollock, Pacific halibut (Hippoglossus stenolepis), and Pacific sand lance (Ammodytes hexapterus). Of these species, only the Pacific sand lance was caught in appreciable numbers in this habitat at Attu, while rock sole (Lepidopsetta bilineata) and starry flounder (Platichthys stellatus) were more representative.

In the inshore epipelagic waters of Amchitka, Dolly Varden (Salvelinus malma), pink salmon (Oncorhynchus gorbuscha) as maturing adults, and Atka mackerel (Pleurogrammus monopterygius) were the predominant species. According to the beach seine catches at Attu (Sarana Bay), juvenile pink salmon, coho salmon (O. kisutch), sockeye salmon (O. nerka), and Dolly Varden predominated, with relatively few Atka mackerel. Adult pink salmon were also observed, though unsampled, at Chichagof Harbor just before we departed Attu in August. Pacific sand lance should also be considered a part of this assemblage.

High cockscomb (Anoplarchus purpurescens), crescent gunnel (Pholis laeta), sharpnose sculpin (Clinocottus acuticeps), silverspotted sculpin

(Blepsias cirrhosus), great sculpin, and spotted snailfish (Liparis callyodon) constituted the majority of the Amchitka littoral fish fauna. Great sculpin, high cockscomb, crescent gunnel, and spotted snailfish were also abundant in Attu's rocky littoral (tidepool) habitat but kelp sculpin (Sigmistes caulias), calico sculpin (Clinocottus embryum), and an unidentified zoarcid (eelpout), all unknown or uncommon in the Amchitka littoral fauna, were also predominant tidepool species. Porocottus bradfordi and stone cockscomb (Alectrias alectrolophus) were found at Attu but not at Amchitka. Ribbed sculpin was not found in Amchitka tidepools, although it was found offshore.

Overall, nearshore fish abundance at Attu is considerably different from that at Amchitka and is somewhat different between the Chichagof Harbor and Massacre Bay sampling areas. Comparison of trammel net catches in the exposed, rocky shoreline habitats indicates that fish abundance could be related to both sea-otter predation and the standing crop of macrophytic algae, the latter of course being indirectly related to sea-otter predation through the exploitation of the herbivorous sea urchin population. Directly comparable data from exposed, rocky shoreline habitats on both sides of Attu Island and from Amchitka Island (Table 4) indicate that the catch-per-unit-effort (CPUE in fish/hr) in non-kelp bed areas at Chichagof Harbor was about half of that within kelp beds and about a quarter of the CPUE from the Casco Point area which has no sea-otter predation. Overall, the trammel net CPUEs at Amchitka were much higher (as much as 44 times higher) than at Attu. There is a slight seasonal difference in sampling periods but most of the fish are resident species except Pacific cod, Atka mackerel, and smooth lumpsucker (Aptocyclus ventricosus). CPUE for rock greenling, the common dominant in all areas,

TRAMMEL NET FISH CATCHES

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Location	Date	Habitat	No. of sets	Depth (m)	Duration (hr)	C P U F		Species (CPUE)
						(fish/hr)	(grams/hr)	
ATTU ISLAND								
Pisa Pt.	11 July 1976	Exposed, rocky point	2	8	4.5	0.33±0.16	254.4±29.3	<i>Myoxocephalus polyacanthocephalus</i> (0.22) <i>Hexagrammos lagocephalus</i> (0.44)
"	"	"	2	8	11.5-12.5	0.54±0.03	127.9±15.8	<i>H. lagocephalus</i> (0.16, 0.34) <i>Hemilepidotus hemilepidotus</i> (0.32, 0.08) <i>Enophrys diceraus</i> (0.08, 0.08)
Chichagof Harbor		Outer bay, rocky/kelp bed	2	10-11	6.8	1.91±0.83	1383.7±640.0	<i>H. lagocephalus</i> (1.32, 2.50)
"		"	2	4-5	7.3	1.03±1.06	392.9±413.0	<i>H. lagocephalus</i> (1.78, 0.13) <i>Gadus macrocephalus</i> (0.13)
"		Inner bay, mud/gravel	2	12	7.1	0	0	--
Sarana Bay		Mid-bay, sand	2	24-33	5.9-6.3	0.57±0.14	130.2±23.6	<i>Pleurogrammus monopterygius</i> (0.33) <i>Lepidopsetta bilineata</i> (0.16, 0.31) <i>E. diceraus</i> (0.16) <i>G. macrocephalus</i> (0.15)
Gibson Is.	18 July 1976	Exposed, mid-channel	2	26	3.0-3.2	2.25±0.35	1415.1±109.5	<i>G. macrocephalus</i> (1.87, 1.00) <i>M. polyacanthocephalus</i> (0.62, 0.66) <i>L. bilineata</i> (0.33)

Casco Pt.	20 July 1976	Exposed, rocky point	2	7	4.0	2.88±0.18	1763.6±312.0	<i>H. lagocephalus</i> (2.50, 2.75) <i>L. bilineata</i> (0.25) <i>H. polyacanthocephalus</i> (0.25)
"	21 July 1976	"	2	8	6.0	2.42±0.12	1341.2±114.1	<i>H. lagocephalus</i> (2.33, 2.33) <i>H. polyacanthocephalus</i> (0.16)
Murder Pt.	23 July 1976	" (high exposure)	2	7-8	5.0-5.2	0.59±0.3	301.5±155.8	<i>H. lagocephalus</i> (0.38, 0.80)
Casco Pt.	24 July 1976	Exposed, mid-channel	2	22	16.0-16.1	0.16±0.13	46.3±59.3	<i>Triglops pingeli</i> (0.12) <i>Hippoglossus stenolepis</i> (0.06) <i>L. bilineata</i> (0.06) <i>H. polyacanthocephalus</i> (0.06)

ANCHITKA ISLAND								
IA-2	12-13 August 1972	Exposed, rocky point w/kelp bed	3	7-9	1.7-23.7	6.70±3.47		<i>H. lagocephalus</i> (10.5, 3.16, 5.29) <i>H. hemilepidotus</i> (0.37) <i>G. macrocephalus</i> (0.08) <i>Aptocyclus ventricosus</i> (0.04) <i>P. monopterygius</i> (0.58)
IA-2/3	16-24 August 1972	"	2	7-10	22.1-22.8	4.15±0.35		<i>H. lagocephalus</i> (1.97, 3.12) <i>G. macrocephalus</i> (1.62, 0.72) <i>H. hemilepidotus</i> (0.21, 0.40) <i>A. ventricosus</i> (0.04, 0.04) <i>P. monopterygius</i> (0.13)
"	31 Aug. 1972	"	2	16	2.0-2.2	8.00±3.54		<i>H. lagocephalus</i> (5.5, 10.0) <i>H. decagrammus</i> (0.45)
"	1 Sept. 1972	"	2	9-16	0.3-2.0	22.10±20.65		<i>H. lagocephalus</i> (36.66, 6.5) <i>G. macrocephalus</i> (0.50) <i>P. monopterygius</i> (0.50)
Sand Beach Cove	5 Sep. 1972	Inner shallow bay, sand	2	5-14	1.92	1.55±0.78		<i>H. lagocephalus</i> (1.04, 1.00) <i>Gymnocanthus galeatus</i> (1.04)
IA-2	22 Oct. 1972	Exposed, rocky point w/kelp bed	2	9-11	2.0-2.5	10.75±1.77		<i>H. lagocephalus</i> (9.00, 12.00) <i>Blepsias cirrhosus</i> (0.50)
"	25 Oct. 1972	"	3	8-9	2.0-2.1	9.07±1.45		<i>H. lagocephalus</i> (7.60, 10.50, 9.1)

Table 4. Nearshore fish catches from comparable trammel net collections at Attu and Amchitka islands.

averaged 0.31 fish/hr outside of kelp beds and 1.43 fish/hr inside kelp beds at Chichagof Harbor, 2.48 fish/hr in the Massacre Bay area of Attu, and 9.35 fish/hr at Amchitka Island under similar habitat, exposure, and depth ranges.

When the macroinvertebrates captured by the trammel net were identified and enumerated, distinct differences between the Chichagof Harbor and Massacre Bay epibenthic fauna were also found (Table 5). Although only sea urchins, Strongylocentrotus polyacanthus, of mean test diameters 20.7-23.4 mm were caught in the Chichagof Harbor vicinity, a great diversity of crustaceans, asteroids, holothurians, and molluscs were caught in the Massacre Bay region. In addition, the diameters of sea urchins from the same depth regions of Massacre Bay averaged 54.6 mm, significantly larger than those from the northeast side of the island amidst the island's sea-otter population

Stomach contents from 212 individuals of 18 species were analyzed for diet composition (Table 6). These include the numerically dominant species in Attu's nearshore fish assemblages; sampling emphasized the principal members of the exposed rocky shallow sublittoral habitat-- rock greenling, great sculpin, and red Irish lord.

In the following graphs, the Index of Relative Importance (I.R.I.) of Pinkas, et al. (1971), has been modified to illustrate each predator's prey spectrum in a single, composite form. The frequency of occurrence is plotted on the horizontal axis, decreasing from left to right. The percent numerical composition is plotted vertically above the horizontal axis, and the percent composition by biomass is plotted below the horizontal axis. Thus, the graph illustrates several aspects of a species' food habits. Frequency of occurrence and numerical composition indicate

ATTU ISLAND TRAMMEL NET INVERTEBRATE CATCHES

Location	Date	Habitat	No. of sets n	Depth (m)	Duration (hr)	CPUE (inverts/hr)	Species (CPUE)	\bar{X} size (mm)
Pisa Pt.	11 July 1976	Exposed, rocky point	2	8	4.5	404.5 ± 119.5	<i>Strongylocentrotus polyacanthus</i> (404.5)	20.7
Gibson Is.	18 July 1976	Expose, mid-channel	2	26	6.5	161	<i>S. polyacanthus</i> (161)	23.4
Casco Pt.	20 July 1976	Exposed, rocky point	2	7	4.0	58.0 ± 18.4	<i>S. polyacanthus</i> (14.25, 7.75) <i>Hyas/Pugettia/Oregonia</i> (2.25, 0.25) <i>Telmessus cheiragonus</i> (1.25, 0.25) <i>Evasterias</i> sp. (0.25, 0.25) <i>Octopus dofleini</i> (0.25, 0.25) <i>Phyllolithoides papillosus</i> (0.25) Holothurian (0.25)	57.8 24.2 91.0 297.5 1028.0 81.0 (1150 g)
"	21 July 1976	"	2	8	6.0	4.9	<i>S. polyacanthus</i> (4.58) <i>Telmessus</i> (0.08) <i>Hyas/Pugettia/Oregonia</i> (0.25)	55.2 103.0 17.3
Murder Pt.	23 July 1976	" (high exposure)	2	7-8	5.0-5.2	92.65	<i>S. polyacanthus</i> (90.7) <i>Hyas/Pugettia/Oregonia</i> (0.20) Unid. brachyuran crab #1 (0.10), #2 (0.10) <i>Ishmoehiton</i> sp. (0.20) Holothurian (0.10) <i>Fusitriton oregonensis</i> (0.10) <i>Evasterias</i> sp. (0.59) <i>Leptasterias</i> sp. (0.49) Unid. asteroid (0.10)	34.9 19.5 9.0 6.0 15.5 26.0 8.0 291.6 123.0 145.0
Casco Pt.	24 July 1976	Exposed, mid-channel	2	22	16.0-16.1	260.5 ± 68.6	<i>S. polyacanthus</i> (8.0, 4.68) <i>Erimacrus isenbeckii</i> (0.19, 0.63) <i>Telmessus</i> (0.75, 0.43) <i>Hyas/Pugettia/Oregonia</i> (0.19, 0.06) <i>Elassochirus tenuimanus</i> , <i>Pagurus kernerlyi</i> , and <i>P. hirsutiusculus</i> (3.79, 5.69) Unid. brachyuran crab #1 (3.79, 0.69), #2 (0.81, 1.30) <i>Evasterias</i> (0.25, 0.06) <i>Leptasterias</i> (0.12, 0.06) <i>Crossaster papposus</i> (?) (0.06) <i>Henricia</i> (?) (0.06) Unid. asteroid (0.43, 0.19)	70.5 81.1 76.2 15.0 12-20 27.1 29.5 306.2 64.0 82.0 61.0 363.4

Table 5. Macroinvertebrate catches from comparable trammel net collections at Attu Island, Alaska, July 1976.

Table 6. Nearshore fish samples analyzed for stomach contents and summary statistics, Attu Island, 1976.

Species	Sample size, n	No. empty stomachs	Stomach fullness index, \bar{x}	Contents digestion index, \bar{x}	Total contents weight, \bar{x}	Total contents abundance, \bar{x}	H' (abundance)	Shannon-Weiner diversity index H' (biomass)	Total number of prey categories
<i>Oncorhynchus kisutch</i> (juvs.)	9	0	5.3±1.0	4.4±0.9	0.8 ± 0.45	58.7± 78.8	2.41	2.95	15
<i>O. nerka</i> (juvs.)	26	0	5.3±1.4	4.8±0.6	0.23± 0.32	299.8±428.4	2.03	2.37	25
<i>Salvelinus malma</i> (juvs.)	10	0	3.3±1.8	5.0±0.7	0.47± 0.83	45.3± 45.3	2.43	1.67	9
<i>Gadus macrocephalus</i>	10	0	3.4±1.3	4.4±1.3	2.65± 4.01	13.9± 22.2	2.75	2.70	15
<i>Pleurongrammus monopterygius</i>	2	0	3.0±1.4	3.0±2.8	1.85± 1.01	4.5± 6.4	0.50	0.40	2
<i>Hexagrammos lagocephalus</i>	81	0	5.4±1.0	4.6±0.8	11.63±10.75	286.0±319.6	2.37	4.43	145
<i>Clinocottus embryum</i>	10	0	6.0±0.8	4.4±1.0	0.17± 0.12	98.8±110.4	1.22	3.67	22
<i>Enophrus dicerans</i>	2	0	1.0±0.0	0.5±0.7	3.18± 0.03	0.0	0.0	0.0	0
<i>Hemilepidotus hemilepidotus</i> (4 juveniles, 5 adults)	9	0	5.6±1.6	4.3±1.3	3.42± 4.13	12.8± 17.0	3.59	2.69	19
<i>Myoxocephalus polyacanthocephalus</i> (7 juveniles, 8 adults)	15	0	6.2±1.2	5.1±0.3	23.74±38.60	41.6± 55.1	3.33	3.46	37
<i>Triglops pingeli</i>	2	0	6.0±0.0	5.0±0.0	1.41± 1.24	9.5± 7.8	1.99	1.28	7
<i>Pallasina barbata</i>	3	0	6.0±0.0	5.0±0.0	0.09± 0.02	5.0± 1.0	0.0	0.0	1
<i>Bathymaster signatus</i>	10	0	6.3±0.5	5.0±0.0	0.47± 0.48	22.4± 8.0	1.28	1.49	11
<i>Phytichthys chirus</i>	1	0	5.0	5.0	0.03	12.0	1.19	0.46	3
<i>Photis laeta</i>	3	0	3.7±1.2	3.0±2.0	0.12± 0.2	10.7± 10.5	1.83	1.18	6
<i>Ammodytes hexapterus</i>	10	3	3.9±1.9	3.5±1.4	0.06± 0.10	59.7± 65.8	1.94	1.80	9
<i>Hippoglossus stenolepis</i>	3	0	2.7±2.1	5.3±0.6	11.78± 9.65	20.0± 29.6	2.23	1.59	8
<i>Lepidopsetta bilineata</i> (1 juvenile, 5 adults)	6	0	4.2±1.2	5.0±0.0	6.13± 8.58	8.0± 5.7	2.99	2.06	10

how often a certain prey was encountered and how many were consumed, whereas the biomass composition indicates the trophic contribution of the prey to the predator's diet.

Comparison with the food habits of Amchitka fishes is based upon data collected from 1968 to 1973 (Simenstad, 1971; Simenstad, et al., 1977, unpublished data).

Oncorhynchus kisutch, Juvenile Coho Salmon. Captured during beach seining at the head of Sarana Bay, the coho juveniles had fed mainly upon four epibenthic or surface prey--gammarid amphipods, mysids and mysid larvae, fish, and insects--with the smaller organisms (mysid larvae and insects) being the most commonly consumed prey (Fig. 4).

Oncorhynchus nerka, Juvenile Sockeye Salmon. Also captured during beach seining at the head of Sarana Bay, the sockeye juveniles (which probably entered the bay from fresh water that spring) had fed mostly on harpacticoid copepods, although larger gammarid amphipods, mysids, and fishes composed the majority of the ingested biomass (Fig. 5).

Salvelinus malma, Juvenile Dolly Varden. The Dolly Varden were caught with the other juvenile salmonids at Sarana Bay and had food habits common to both; harpacticoid copepods, gammarid amphipods, insects, and mysids constituted the most abundant prey items while the epibenthic gammarids and mysids constituted the greatest portion of the prey biomass. Fish contributed only a small portion of the overall prey composition (Fig. 6).

In comparison with the adult Dolly Varden caught at Amchitka, whose diet was composed principally of mysids and fishes, the juveniles at Attu had consumed more small harpacticoid copepods, which would be expected of the juveniles.

Oncorhynchus kisutch (juveniles)
n = 9

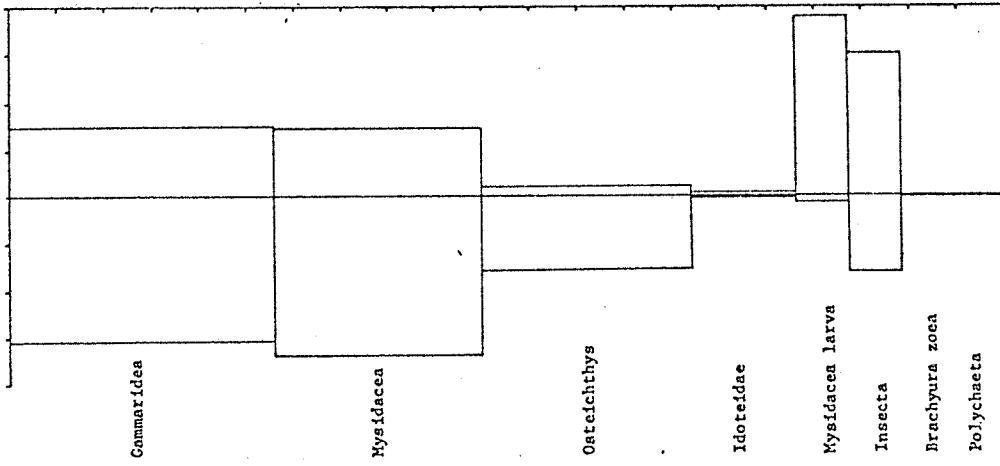


Fig. 4. Overall IRI spectrum for juvenile coho salmon. 1 division = 10%.

Oncorhynchus nerka (juveniles)
n = 26

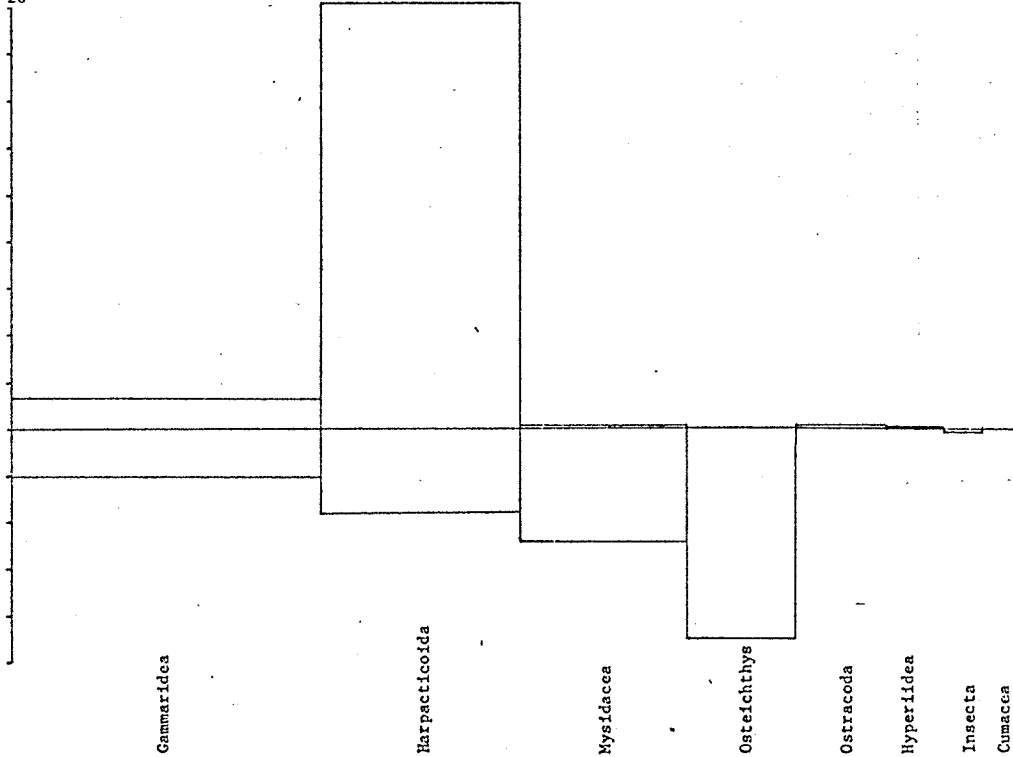


Fig. 5. Overall IRI spectrum for juvenile sockeye salmon. 1 division = 10%.

Salvelinus malma (juveniles)
n = 10

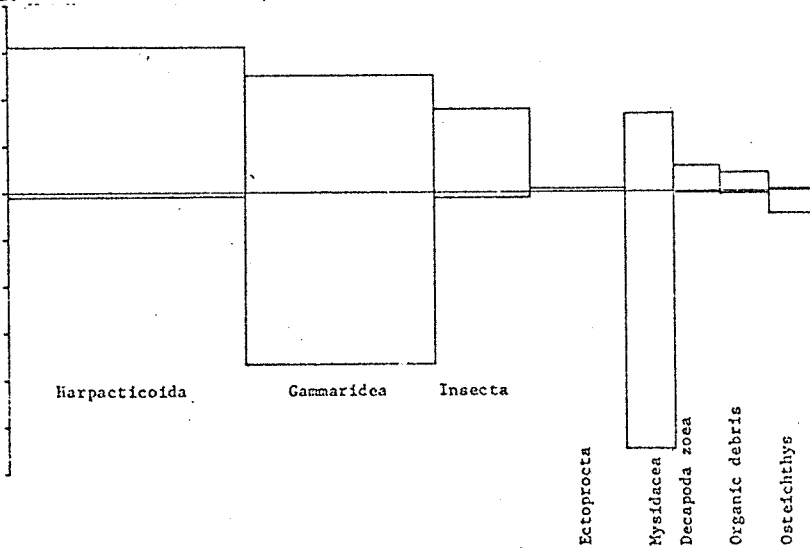


Fig. 6. Overall IRI spectrum for juvenile Dolly Varden. 1 division = 10%.

Gadus macrocephalus, Juvenile Pacific Cod. Caught principally in the 26-m trammel net sets off Pisa Point, juvenile Pacific cod consumed five major prey taxa--gammarid amphipods, isopods (Pentidotea stenops), fish (including Ammodytes hexapterus), polychaetes, and holothuroideans (sea cucumbers), the latter four of which, especially fishes, constituted the majority of the prey biomass (Fig. 7).

Few juvenile Pacific cod were caught at Amchitka. Adults at Amchitka had fed on decapod crustaceans, gammarid amphipods, polychaetes, and fish, the latter (mostly Gymnocanthus galeatus) forming 50-75% of the prey biomass.

Pleurogrammus monopterygius, Atka Mackerel. Two Atka mackerel caught at Sarana Bay had consumed gammarid amphipods and one juvenile octopus (Octopus dofleini?). This is a different diet from the Atka mackerel caught at Amchitka, which fed mostly on mysids; however, the low sample size will not permit such comparison.

Hexagrammos lagocephalus, Rock Greenling. The most common nearshore fish at Attu Island as well as at Amchitka Island, rock greenling had the most diverse prey spectrum of any nearshore fish (Fig. 8). Gammarid amphipods completely dominated the prey composition. Gastropods (Littorina sp.), polychaetes, chitons (Tonicella lineata, Mopalia ciliata), leptostracans (Nebaliacea), caprellid amphipods, isopods (Pentidotea stenops, Synidotea bicuspidata), crabs (Hyastyratus, Deumaturus mandti, Pugettia gracilis, Paguridae, Haplogaster grebnitzki), and fish (Pholis sp., Hexagrammos lagocephalus, Stichaeidae, Hemilepidotus hemilepidotus, Commanderella popovi, Sigmistes caulias) composed the other dominant prey. Algae, rocks, and organic debris also occurred incidentally in the greenling stomachs.

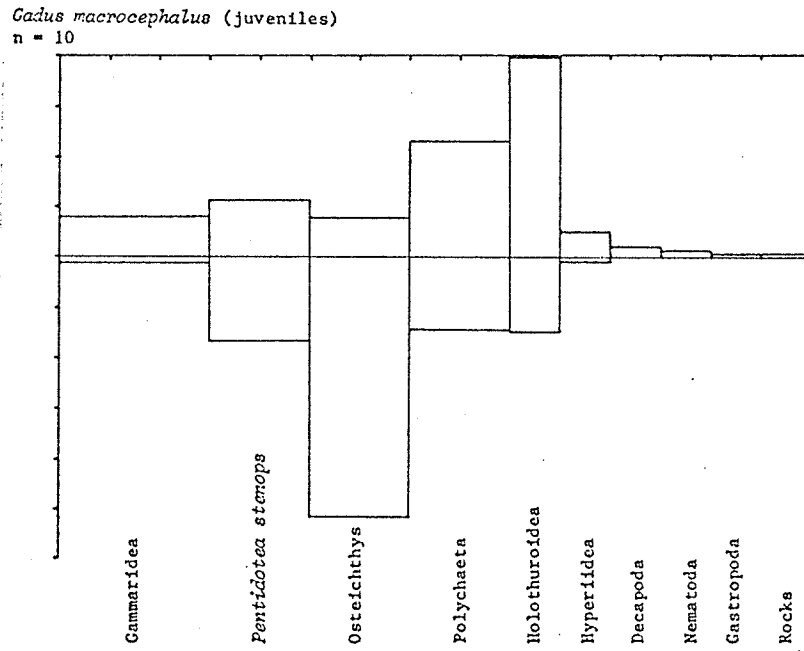
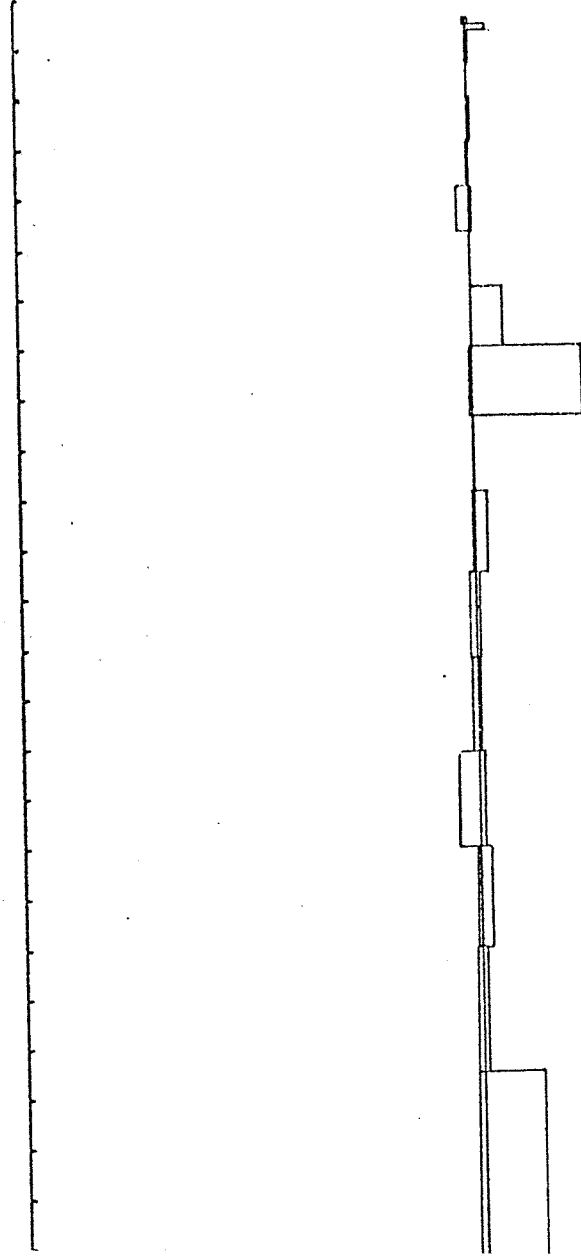


Fig. 7. Overall I.R.I. spectrum for juvenile Pacific cod. 1 division = 10%.

Polychaeta
Rocks
Polyplocophora
Organic debris
Nebaliacea
Caprellidea
Isopoda
Ectoprocta
Reptantia
Oateichthys
Pelecypoda
Oateichthys-eggs
Harpacticoida
Tunicata
Hematozoa
Trematoda
Tanaidacea

ing. 1 division = 10%.



Percent frequency of occurrence of the dominant prey items (Fig. 9) at Amchitka³ and Attu indicated surprisingly similar diets for rock greenling, with a few notable exceptions. Rock greenling at Attu Island had consumed no mysids or sipunculids but had consumed noticeably more leptostracans, crabs, tunicates, and bryozoans. Despite a greater sample size from Amchitka Island, the numerical prey composition of rock greenling at Amchitka was more abbreviated than at Attu.⁴ Gastropods and mysids were a numerically larger portion of the diet of Amchitka rock greenling (Fig. 10). Pelecypods may also have been more important to rock greenling at Attu than at Amchitka.

Food habits of rock greenling from the Chichagof Harbor and Massacre Bay areas of Attu Island may support the hypothesis that the absence or presence of sea otters alters the food web contributing to the rock greenling population. Figs. 11 and 12 illustrate the I.R.I. prey spectra for rock greenling from the two areas. Since rock greenling have omnivorous food habits, these data suggest obvious differences in the prey organisms available on the northeast and southeast sides of the island. Gammarid amphipods were taken less frequently in the Massacre Bay area, whereas polychaetes, crabs (*Brachyura*), and fish were generally more important in the diet of rock greenling in that area. This was also suggested in the Shannon-Weiner diversity indices (H') for the diet composition between the two areas. Chichagof Harbor greenling prey spectrum had an H' of 1.60

³Amchitka Island data are from Simenstad (1971) and Simenstad, et al. (1977).

⁴The prey biomass data from Amchitka are not detailed enough to include in an I.R.I. plot.

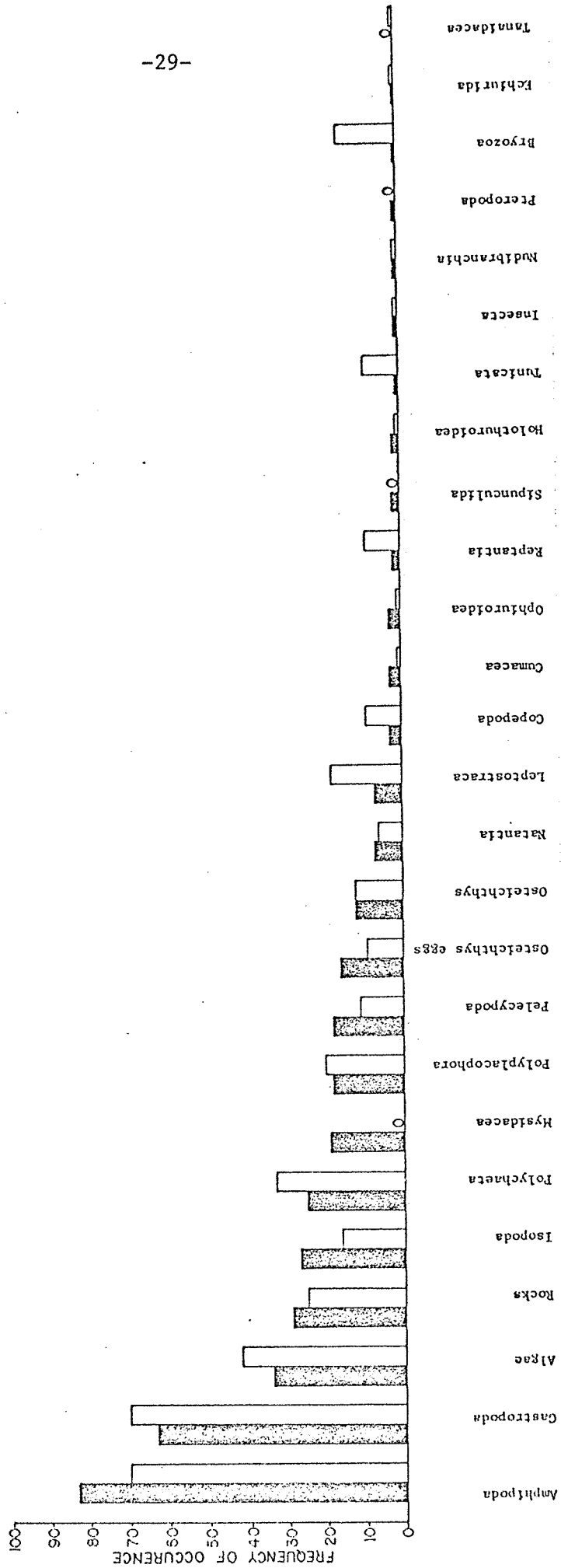


Fig. 9. Frequency of occurrence of principal prey items of rock greenling collected at Amchitka (solid bars) and Attu (hollow bars). Amchitka Island data are from Simenstad (1971) and Simenstad, et al. (1977).

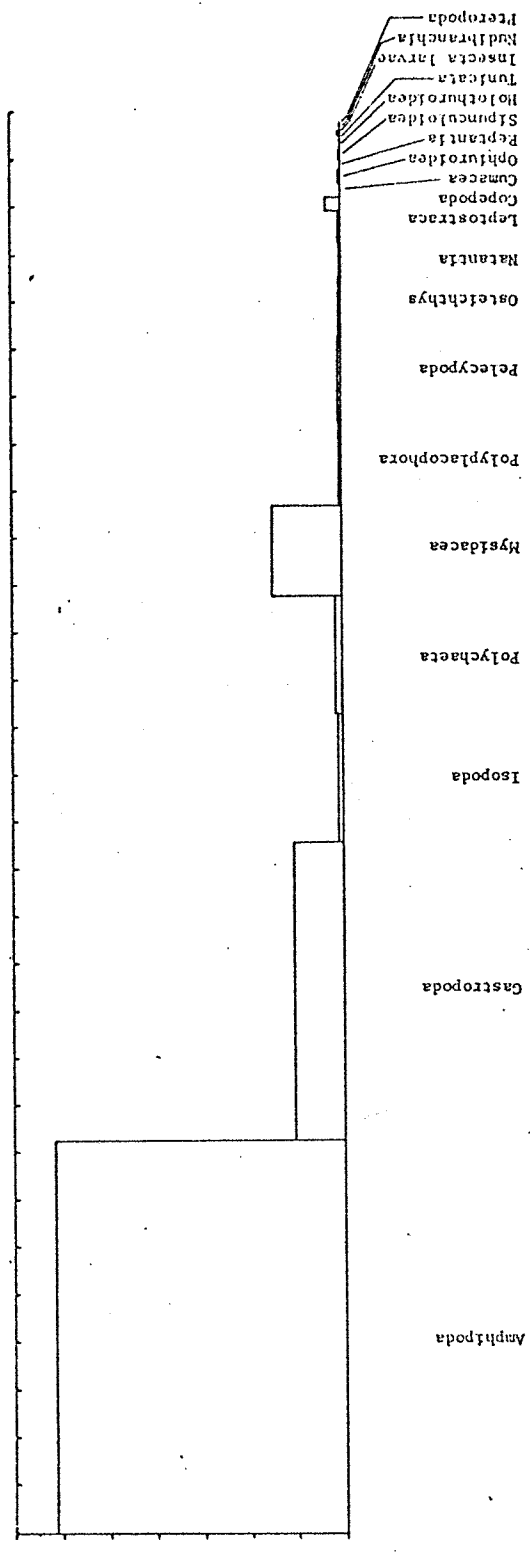


Fig. 10. Percent numerical composition of principal prey items of rock greenling at Amchitka Island, 1968-1970 (data from Simenstad, 1971, and Simenstad, et al., 1977).

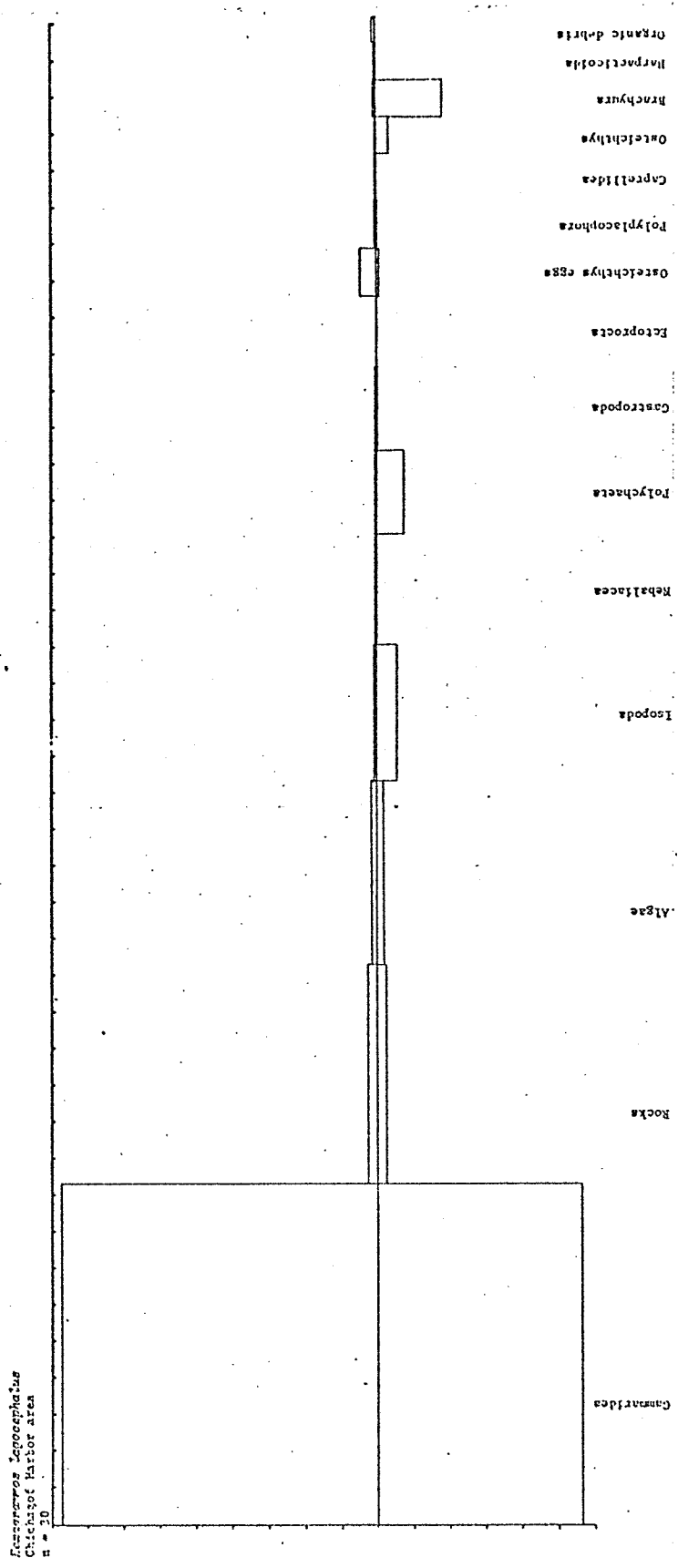


Fig. 11. Overall I.R.I. spectrum for rock greenling at Chichagof Harbor, Attu Island. 1 division = 10%.

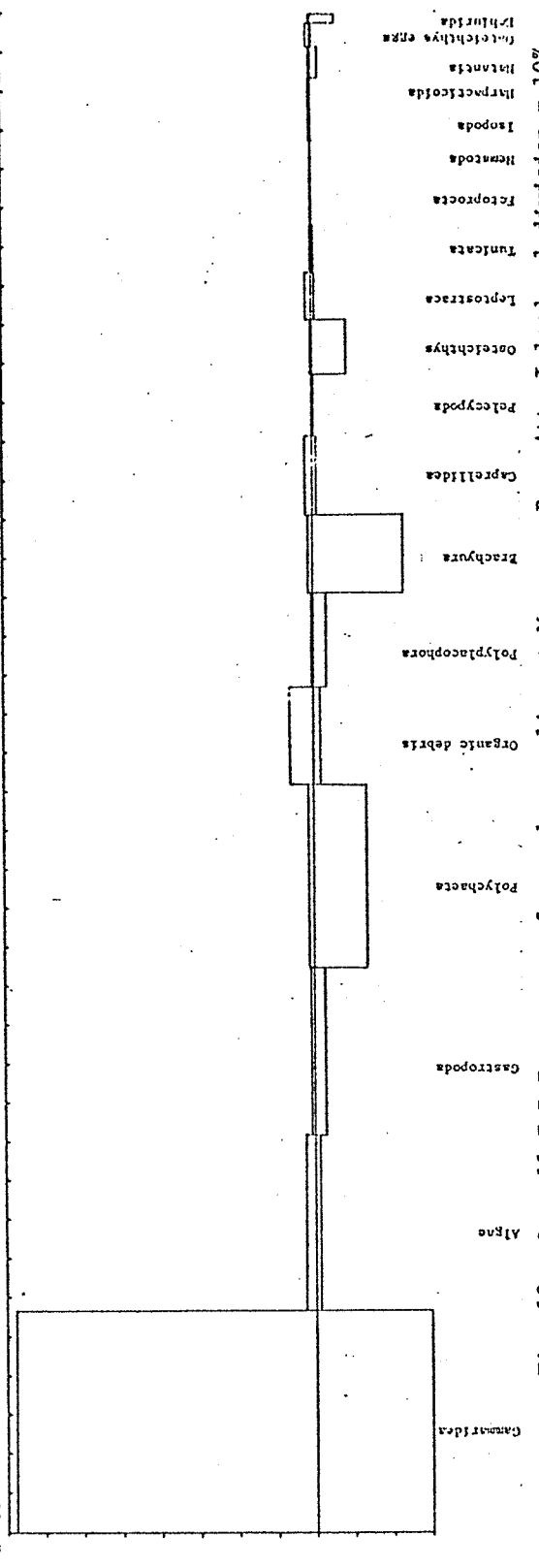


Fig. 12. Overall I.R.I. spectrum for rock greenling at Massacre Bay, Attu Island. 1 division = 10%.

for numerical composition and an H' of 2.97 for biomass composition while the Massacre Bay rock greenling prey spectrum was represented by an H' of 2.72 for numerical composition and 4.79 for biomass composition. The numerical composition portion of Chichagof Harbor prey spectrum (Fig. 11) is not identical to that of Amchitka Island (Fig. 10); gastropods and mysids are still more representative at Amchitka than at Attu in addition to the higher percentage of amphipods in the Attu prey spectra.

Clinocottus embryum, Calico Sculpin. One of the most abundant tidepool fishes in the Pisa Point area, this small sculpin fed rather uniformly on a variety of epibenthic and benthic prey, especially barnacle cirri, gammarid amphipods, gastropods (Littorina spp.), fish eggs, isopods (including Gnorimosphaeroma oregonense), and insect larvae (Fig. 13).

Harpacticoid copepods and gammarid amphipods had composed the major prey taxa for C. embryum in the tidepools of Amchitka Island.

Enophrys diceraus, Antlered Sculpin. The two specimens of this sculpin were nearly empty and contained only unidentified material. No E. diceraus from Amchitka were examined as it was extremely rare in the nearshore fish catches.

Hemilepidotus hemilepidotus, Red Irish Lord. Red Irish lord at Attu Island had an I.R.I. prey spectrum emphasizing benthic epifauna, especially ophiuroids, gammarid and caprellid amphipods, tunicates, isopods (Gnorimosphaeroma oregonense), and brachyuran crabs (Pugettia gracilis, Haplogaster grebnitzki, and Dermaturus mandti). Ophiuroids and crabs provide most of the prey biomass (Fig. 14).

Red Irish lord in Amchitka Island's nearshore waters also concentrated upon ophiuroids and gammarid amphipods but preyed upon shrimp instead of crabs.

Clinocottus embryum
n = 10

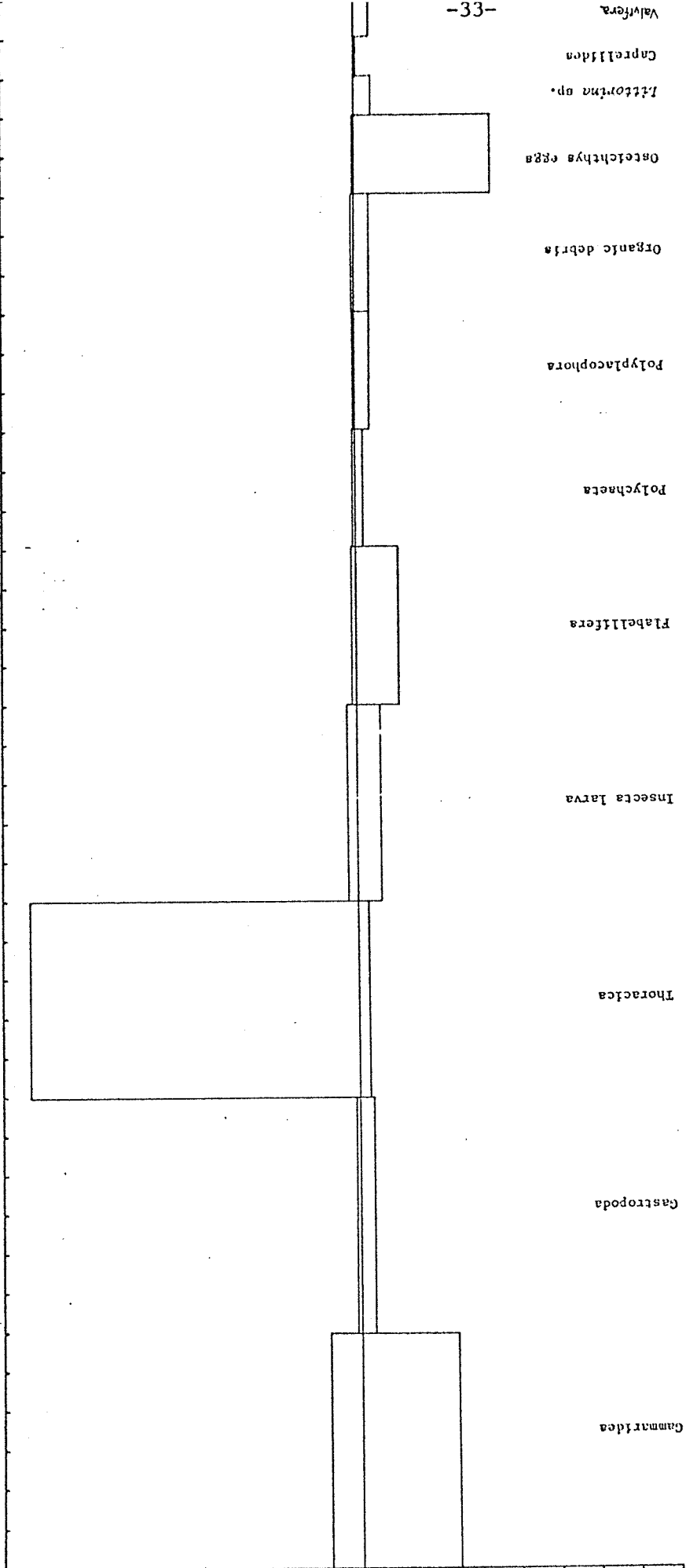
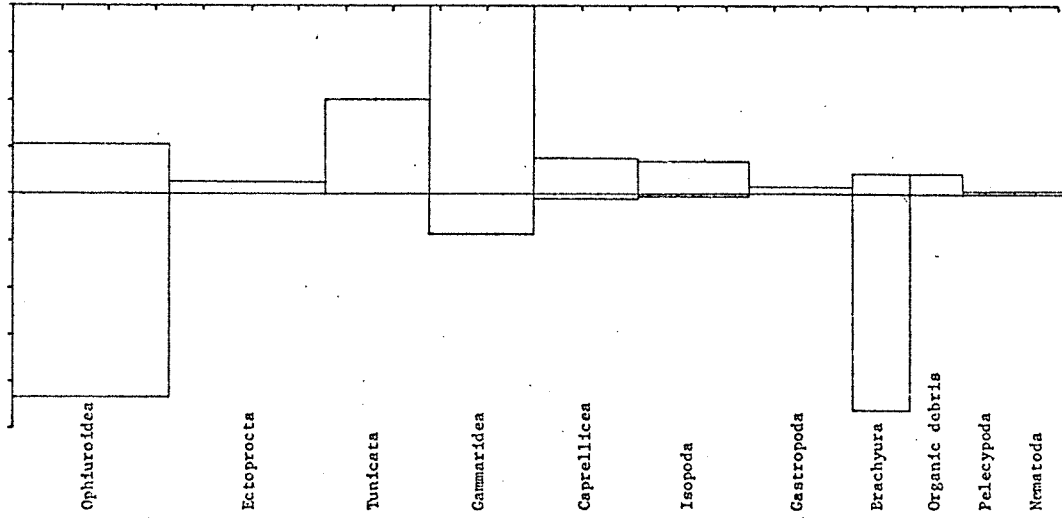


Fig. 13. Overall I.R.I. spectrum for calico sculpin. 1 division = 10%.

Hemilepidotus hemilepidotus
n = 9



Myczocephalus polyacanthocephalus
(7 juveniles, 8 adults)
n = 15

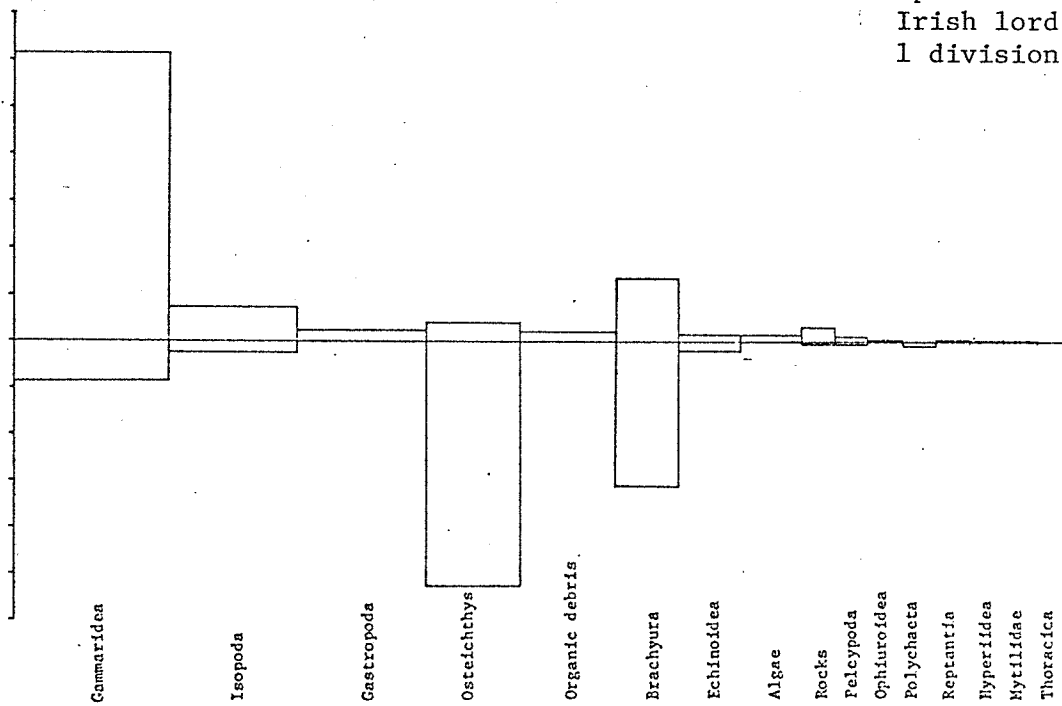


Fig. 14. Overall IRI spectrum for red Irish lord.
1 division = 10%.

Fig. 15. Overall IRI spectrum for great sculpin.
1 division = 10%.

Myoxocephalus polyacanthocephalus, Great Sculpin. Adult great sculpin were much more abundant at Attu than in the Amchitka nearshore fish communities, although the juveniles were a common member of the tidepool assemblages at Amchitka Island. Gammarid amphipods, isopods (Gnorimosphaeroma oregonense and Pentidotea stenops), fish (Hemilepidotus hemilepidotus, Ammodytes hexapterus, Gymnocanthus sp., and Pholis sp.), and brachyuran crabs (Pugettia gracilis, Dermaturus mandti) constituted the principal prey organisms (Fig. 15). Fish and crabs made up over 75% of the total ingested biomass (Fig. 15). This prey spectrum is similar to that of Amchitka Island great sculpin, although there, gammarid amphipods supplied 50-75% of the prey biomass. These fish, however, were typically smaller than those analyzed from Attu Island.

Triglops pingeli, Ribbed Sculpin. Two Triglops pingeli had eaten gammarid amphipods, shrimp (Crangon sp.), fish (Hemilepidotus hemilepidotus), polychaetes, and pelecypods.

Pallasina barbata, Tubenose Poacher. Three Pallasina barbata had consumed only mysids.

Bathymaster signatus, Searcher. As at Amchitka Island, gammarid amphipods almost completely dominated the prey spectrum for searcher caught at Attu Island, with only minor contributions by leptostracans (Nebaliacea), polychaetes, and fish (Fig. 16).

Phytichthys chirus, Ribbon Prickleback. The one ribbon prickleback stomach collected at Attu Island contained eight gammarid amphipods (92.6% of total prey biomass), three leptostracans (Nebaliacea), and one small pelecypod.

Pholis laeta, Crescent Gunnel. Three crescent gunnel examined from Attu Island had consumed gammarid amphipods (59.4% numerical composition, 96.9% biomass consumption), harpacticoid copepods, idoteid isopods, and

polychaetes. This prey composition was similar to Amchitka Island crescent gunnel which preyed mainly upon gammarid amphipods and secondarily upon isopods, polychaetes, gastropods, and pelecypods.

Ammodytes hexapterus, Pacific Sand Lance. Pacific sand lance caught near shore in Sarana Bay at Attu Island had commonly consumed harpacticoid and calanoid copepods and larvaceans (chaetognaths). Gammarid amphipods, though not common in the total stomach sample, also represented a significant portion of the prey biomass (Fig. 17). Polychaete annelids, though common in the stomach sample, were not abundant nor did they constitute an important contribution to the prey biomass.

Although the sample size for Pacific sand lance collected at Amchitka Island is not adequate for reliable interpretation of that species' food habits, it appears that they feed principally upon calanoid copepods.

DISCUSSION

Bearing in mind the brief, limited nature of the nearshore fish and macroinvertebrate sampling at Attu Island, as compared to five years of comprehensive sampling at Amchitka Island, we noted several differences in the nearshore communities. Some of these differences may be attributable to the status of the sea-otter population about Attu Island.

Of the 28 nearshore fish species collected at Attu Island in July 1976, six were species unrecorded or rare to the collections from Amchitka Island. Commanderella popovi, the eelpout, and Porocottus bradfordi and Sigmistes caulias, the small cottids found in Pisa Point tidepools, were all unknown at Amchitka Island; these probably represent varying and patchy zoogeographic distributions rather than effects of different nearshore community structures. Commanderella popovi was the only species of those recorded at Amchitka and Attu islands which represented an Asiatic

Pathyaster signatus
n = 10

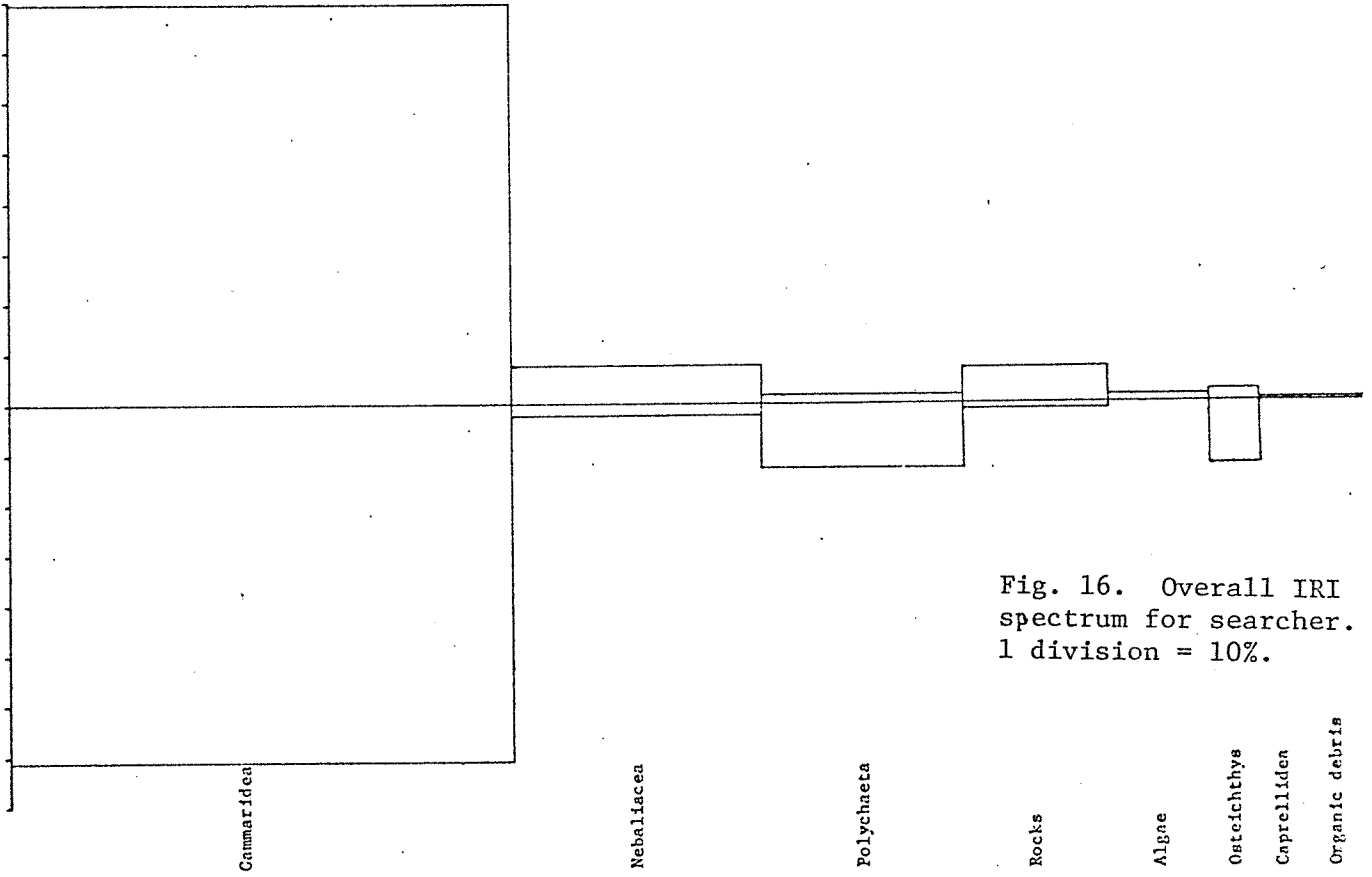


Fig. 16. Overall IRI spectrum for searcher. 1 division = 10%.

Ammodytes hexapterus
n = 10

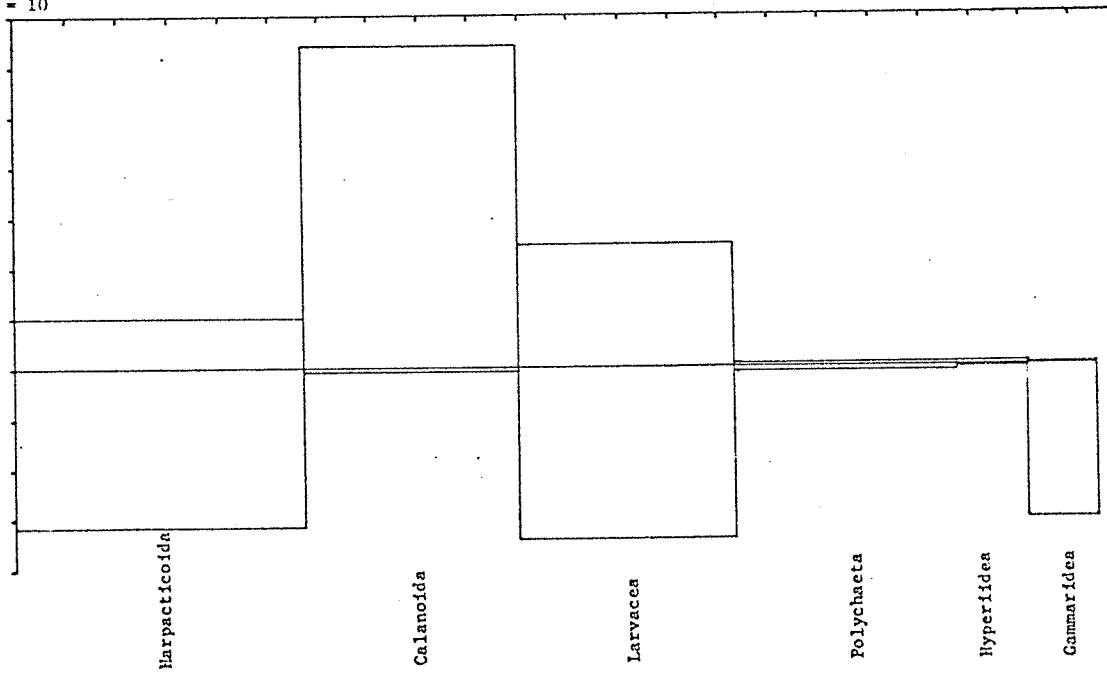


Fig. 17. Overall IRI spectrum for Pacific sand lance. 1 division = 10%.

nearshore species at the eastern extremity of its reported distribution. The stone cockscomb (Alectrias alectrolophus) is a small prickleback found in Attu tidepools which was rarely found at Amchitka Island and should also fall into the zoogeographic category. Several species, however, were common in Attu's nearshore community which may exist there solely because of the low density or absence of the sea otter; these included the antlered sculpin (Enophrys diceraus), the great sculpin (Myoxocephalus polyacanthocephalus), and the starry flounder (Platichthys stellatus). The latter species was unreported at Amchitka Island and the two sculpins were very rarely caught there as adults in the nearshore waters. Furthermore, while juvenile great sculpin were abundant in Amchitka's tidepools, there was no corresponding abundance of adults in the shallow subtidal region. Rock sole (Lepidopsetta bilineata) also tended to be more common in the Attu Island catches than in the Amchitka catches. All these species represent potential prey items for the sea otter, and their occurrence may be a function of the low predation pressure from the Attu Island sea-otter population. It is impossible to verify this hypothesis, however, until we have spent some time sampling the densities of these prey species as the Attu Island sea otters continue to increase and their influence spreads around the island. A trend toward the Amchitka Island nearshore fish community composition would support this argument.

More significant are the densities of nearshore fish (especially rock greenling) and epibenthic macroinvertebrates at the two sampling areas at Attu Island as compared to Amchitka Island. In some respects, the macroinvertebrate fauna of the Chichagof Harbor area, which has seen sea-otter predation for some ten years, is beginning to resemble that of Amchitka Island--generally depleted of large macroinvertebrates, pagurid

and brachyuran crabs and octopuses, which are preferred food items of the sea otter. When the exposed rocky subtidal habitat in the Chichagof Harbor area was sampled, the fish CPUEs were dramatically lower than at comparable areas at Amchitka Island (Table 4). The principal difference between these habitats at the two islands is, of course, the lack of dense Alaria fistulosa kelp beds at Attu Island. Indeed, when the relatively sparse kelp beds just inside Chichagof Harbor were sampled, the CPUE was higher but still did not approach the norm for Amchitka. This implies that the Alaria kelp beds provide important habitat for fishes such as rock greenling, and that expansion of the kelp beds on the northeastern coast would result in a proportional increase in the standing stock of associated nearshore fishes. The difference between fish CPUEs at the two sampling areas at Attu Island, though highly variable, also implies that the sea otter may limit some of the nearshore fish populations. This condition would theoretically change as the kelp beds expanded and the nearshore habitat became more advantageous for nearshore fish, both from the standpoint of protection and spawning substrate, and through the production of algal detritus utilized by their principal prey organisms.

Similar sampling at Casco Point indicated generally higher CPUE for nearshore fish as well as dramatically more abundant and diverse macro-invertebrates (Table 5), regardless of the abundance of macroalgae. This suggests that in the brief time the sea otter has foraged along the northeastern coast of Attu, this predation pressure has already depleted the populations of their principal prey species, especially the large decapods and molluscs. Our data on the test diameters of the sea otter's principal prey organism, the sea urchin (Strongylocentrotus polyacanthus) (Table 5), also suggest that size-selective predation by the sea otter is beginning to show its effect in the Chichagof Harbor area.

Although the data are inconclusive, there is a suggestion of differences in the prey resources available for nearshore fishes in communities with and without sea otters as seen in comparisons between Amchitka and Attu islands. In areas without significant sea-otter predation, the stomach contents data imply that detritivorous epibenthic crustaceans are absent (mysids) or reduced (amphipods) and brachyuran and anomuran crabs are more available to epibenthic or epibenthic-feeding fishes. Simenstad (1971) indicated no significant differences in prey composition of rock greenling among different areas and habitats at Amchitka Island. Considering the omnivorous food habits of this species, some differences between Amchitka's and Attu's prey resources may be real. At this time, differences in prey composition from the two sampling areas at Attu are not great enough to imply that significant changes in prey resources have occurred in the ten years since the sea otter returned to Attu Island.

This discussion has posed several interpretations of Attu Island's recent ecological history with the return of the sea otter. Because all of these deductions were made on the basis of one month's intensive but limited sampling, the major assumption that the data are representative of the overall Attu Island nearshore community is tentative. Verification of these hypotheses depends upon continued close documentation of the algal, invertebrate, fish, and sea-otter components of the nearshore community.

Literature Cited

- Andriyashev, A.P. 1954. Fishes of the northern seas of the USSR. Zool. Inst. USSR Acad. Sci. No. 53, Israel Prog. Sci. Trans. TT63-11160 (1964). 617 pp.
- Estes, J.A., and L.S. Smith. 1973. Amchitka bioenvironmental program, research on the sea otter, Amchitka Island, Alaska, final report, October 1970 - December 1972. Atomic Energy Comm., Prime Contract No. AT(26-1)-520.
- Estes, J.A., and J.F. Palmisano. 1974. Sea otters: Their role in structuring nearshore communities. *Science* 185:1058-1060.
- Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Bd. Canada Bull. 180, 740 pp.
- Kenyon, K.W. 1969. The sea otter in the eastern Pacific Ocean. U.S. Dept. Interior, Bur. Sport Fisheries and Wildlife, N. American Fauna No. 68, 352 pp.
- Lebednik, P.A., and J.F. Palmisano. 1977. Ecology of marine algae. Chapt. 17 in M.L. Merritt and R.G. Fuller, editors, The environment of Amchitka Island, Alaska. U.S. ERDA TID-26712. (In press)
- O'Clair, C.E. 1977. Marine invertebrates in rocky intertidal communities. Chapt. 18 in M.L. Merritt and R.G. Fuller, editors, The environment of Amchitka Island, Alaska. U.S. ERDA TID-26712. (In press)
- Palmisano, J.F. 1975. Sea otter predation: Its role in rocky intertidal community structure at Amchitka and other Aleutian Islands. Ph.D. thesis, Univ. Washington, Seattle. 207 pp.
- Palmisano, J.F., and J.A. Estes. 1977. Community interactions involving the sea otter in the western Aleutian Islands, Alaska. Chapt. 22 in M.L. Merritt and R.G. Fuller, editors, The environment of Amchitka Island, Alaska. U.S. ERDA TID-26712. (In press)
- Pinkas, L., M.S. Oliphant, and I.L.K. Iverson. 1971. Food habits of albacore, bluefin tuna, and bonito in California water. Calif. Fish and Game, Fish Bull. 152:1-105.
- Simenstad, C.A. 1971. The feeding ecology of the rock greenling, Hexagrammos lagocephalus, in the inshore waters of Amchitka Island, Alaska. M.S. thesis, Univ. Washington, Seattle. 131 pp.
- Simenstad, C.A., J.S. Isakson, and R.E. Nakatani. 1977. The marine fish communities of Amchitka Island, Alaska. Chapt. 19 in M.L. Merritt and R.G. Fuller, editors, The environment of Amchitka Island, Alaska. U.S. ERDA TID-26712. (In press)

Wilimovsky, N.J. 1958. Provisional keys to the fishes of Alaska.
Unpublished manuscript, U.S. Fish and Wildlife Service, Juneau,
Alaska. 113 pp.

Wilimovsky, N.J. 1964. Inshore fish fauna of the Aleutian archipelago.
Science in Alaska, Proc. 14th Alaskan Science Conference. Pp. 172-190.