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NEARSHORE FISH AND MACROINVERTEBRATE COMMUNITIES OF ATTU ISLAND, ALASKA

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INTRODUCTION

In 1976, the Anchorage Field Station of the National Fish and Wildlife Laboratory, Fish and Wildlife Service (F&WS), initiated studies to document changes in the organization of nearshore marine communities corresponding with the growth of a sea otter population recently established on the northeastern coast of Attu Island, Alaska (Fig. 1). Investigators from the University of Washington's Fisheries Research Institute (FRI) have been involved in this program since its initiation, responsible for documenting the island's nearshore fish (and associated epibenthic macroinvertebrate) assemblages.

The assemblages of nearshore fishes in the Aleutians--their composition, relative abundance and standing crop, and the trophic relationships to other biotic elements in the community--appear to be both directly and indirectly related to intensity of sea otter predation, primarily by limiting nearshore herbivores (Palmisano and Estes 1975, Simenstad et al. 1977). Extensive studies of nearshore fish community structure at Amchitka Island, a system under intense sea otter predation since the late 1930's (Kenyon 1969), were performed by FRI investigators between 1967 and 1974 (*see* Simenstad et al. 1977 for summary). Nearshore fish data from a community with few or no sea otters, and thus herbivore-dominated, have not been available, however. The Attu investigations therefore present the opportunity to identify currently the relative status of nearshore fish assemblages which are not experiencing significant sea otter predation and, if continued over time, the future changes wrought by a steadily increasing sea otter population.

A preliminary survey at Attu in mid-July and August 1976 indicated significantly different fish assemblages, both in composition and relative abundance, compared with Amchitka (Simenstad and Nakatani 1977). Furthermore, when one considers the short time span of a viable sea otter population at Attu, there were surprisingly dramatic differences between both the fish and epibenthic macroinvertebrate assemblages found in the Chichagof Harbor area on the island's northeast coast and those in the

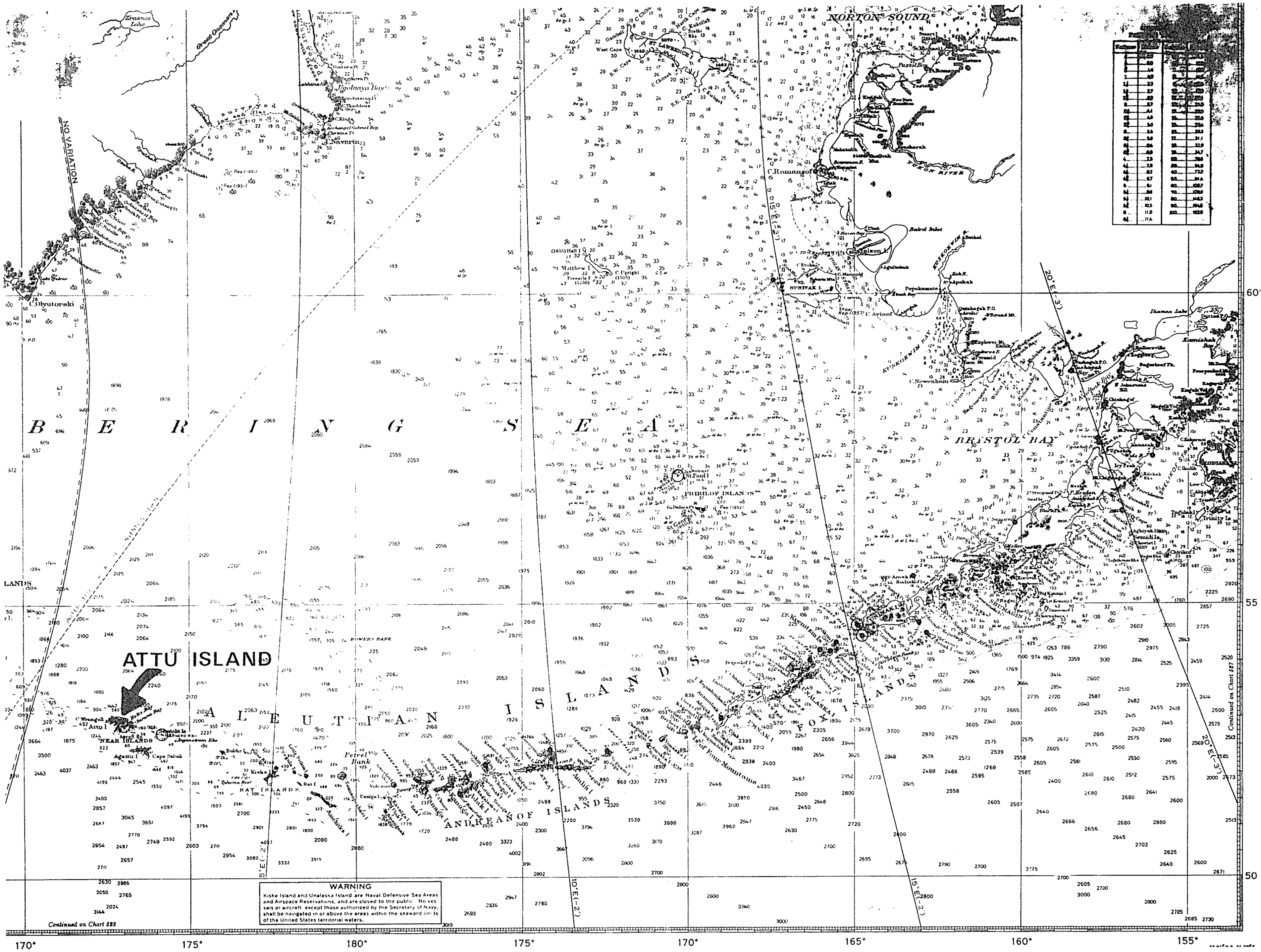

Fig. 1. Location of Attu Island at western end of Aleutian archipelago.

Massacre Bay area on the southeast side (Fig. 2). Attu's sea otter population appears to have spread from the Chicagof Harbor vicinity (Kenyon 1969, Estes and Smith 1973, J. Estes, unpublished data) but has yet to reach the Massacre Bay area. The catch-per-unit-of-effort (CPUE) for nearshore fish at Attu also were lower than those from comparable habitats at Amchitka. Furthermore, the epibenthic macroinvertebrate fauna of the Chichagof Harbor area, which has been subject to sea otter predation for about 10 years, is beginning to resemble that of Amchitka by the low abundance or absence of large pagurid and brachyuran crabs and octopuses.

In fact, two large brachyuran crabs (*Telmessus cheiragonus*, helmet crab, and *Erimacrus isenbeckii*) and the octopus, *Octopus dolfleini*, were not caught at all in the Chichagof Harbor area. The dominant herbivorous macroinvertebrate, sea urchin (*Strongylocentrotus polyacanthus*), was significantly larger (mean test diameter, 54.6 mm) in the Massacre Bay than around Chichagof Harbor (sample mean test diameters ranged from 20.7 to 23.4 mm) in the same depth zones.

The results of rock greenling (*Hexagrammos lagocephalus*) stomach contents analyses in 1976 also suggested that epibenthic crustaceans (mysids, amphipods) were less available and that brachyuran and anomuran crabs were more available in areas without significant sea otter predation.

The nearshore fish and epibenthic macroinvertebrate studies were continued in the summer of 1977. The specific objectives were to determine:

1) Species composition, life history composition, and relative abundance and standing crop (biomass) estimates for assemblages of nearshore fish and epibenthic macroinvertebrates associated with identifiable littoral and shallow sublittoral habitats in the Chichagof Harbor and Massacre Bay areas of Attu.

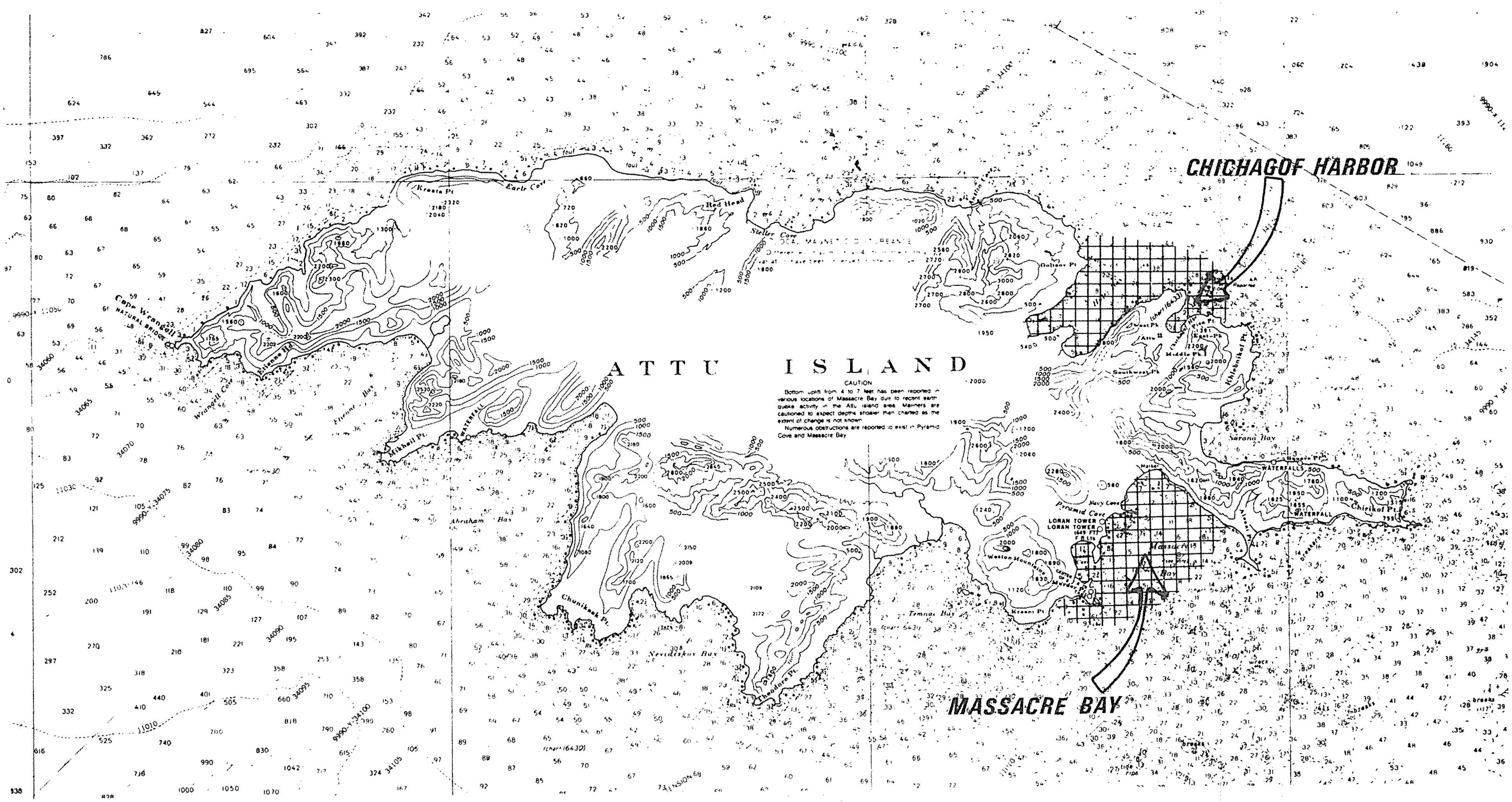

Fig. 2. Topographical map of Attu Island, indicating Chichagof Harbor and Massacre Bay sampling areas.

2) Food organisms and feeding behavior of principal fish (and, if possible, macroinvertebrate) species and associated trophic relationships with prey organisms.

3) The differences in the above statistics between the two nearshore study areas of Attu within and beyond the influence of sea otters.

4) The differences in fish assemblages and food web structures at Attu and those previously documented at Amchitka in comparable habitats and seasons.

In addition, several feasibility studies were planned, including: a) determining the dependence of nearshore fish upon the kelp bed habitat, and b) quantifying the abundance of detritus-feeding amphipods in different habitats and areas of differing sea otter predation.

This report presents the results of the 1977 survey at Attu and discusses the implications of the combined 1976-1977 findings.

METHODS AND MATERIALS

Sampling Period and Personnel

Charles Simenstad, Project Leader, and Robert Mayer, Student Helper, departed Anchorage, Alaska, for Attu Island on July 15, 1977. Fog at Attu prevented the scheduled flight from Shemya Island to Attu and 4 days were spent at the Shemya Air Force Base, until July 19, when the investigators were transported the final 38 miles to Attu. Sampling was conducted in the Massacre Bay area, July 20-30 and in the Chichagof Harbor vicinity, July 31-August 10. We could not sample on 4 days during that period because of inclement weather. Departure from Attu was on August 16, delayed 3 days because of thick fog.

Study Sites

Sampling in 1977 was concentrated in the Chichagof Harbor and Massacre Bay areas (Fig. 2). Visual (boat) surveys of the Attu coastline between Austin Cove on the northeast coast to Temnac Bay on the southwest side of Attu indicated that, although the distribution of sea otters has shifted from that observed in 1976, sea otters are still rare west of Alexai Point. Only one sea otter was observed within the Massacre Bay area in four surveys conducted in 1976-1977 (J. Estes, unpublished data). Thus, sea otter predation was still unimportant in the region of our Massacre Bay sampling area.

Only one study site, near Goltsov Point on the northern extremity of Holtz Bay, was added to those study sites sampled in 1976.

Sampling Techniques

Methodology used for fish and epibenthic macroinvertebrate collection was similar to that used during the 1976 Attu survey (Simenstad and Nakatani 1977) and during FRI's nearshore fish investigations at Amchitka Island (Simenstad et al. 1977). Tidepool fish assemblages were sampled by applying rotenone or quinaldine (97 percent diluted to 10 percent in alcohol) to tidepools which had been partially emptied (usually to < 25 percent of original volume) by hand, using buckets or by siphoning. Fish and epibenthic macroinvertebrate assemblages of the rocky shallow sublittoral habitat were sampled using 45.8-m x 1.8-m trammel nets. The assemblages characterizing sand or gravel habitats were sampled by trammel net and bottom longline and, at beach areas in these habitats, by 37-m beach seine. Detailed descriptions of these sampling gears and the techniques involved with each are given in Simenstad and Nakatani (1977).

In addition, for the first time in our Aleutian studies, we used a 4.9-m (head rope length) trynet (small otter trawl), with a 0.64-cm liner in the cod end, to sample for small or juvenile nearshore fishes and mobile epibenthic invertebrates found in the sand and gravel habitats of Massacre Bay and Casco Cove. Ten-minute tows were made in 5 m to 10 m of water parallel to and immediately adjacent to the beach.

All fish collections other than tidepool collections were made using a 5.2-m outboard motor boat. Traps were also devised to sample epibenthic amphipods. These consisted of four 2.4-liter plastic jars with inverted window screen cones at the mouth, strung on a nylon line approximately 20 cm apart. Three were baited with algae (*Fucus* sp. and *Alaria* spp.), fish (*Hexagrammos* sp.), and seal (*Phoca vitulina*) tissue and one was left unbaited as a control. The traps were attached to an anchor, lowered to the bottom approximately 6-8 m deep in a rocky near-shore area, and allowed to sit overnight before being retrieved in the morning. The amphipods caught in each jar were preserved in 10 percent buffered formalin for later enumeration and identification.

Sample Processing

All samples were processed as described in Simenstad and Nakatani (1977). Location, date, time, tide, weather, and oceanographic and other pertinent environmental information were recorded at the time of sampling. Each sample was sorted to species which, as a group, were enumerated and weighed. Individual total length and weight measurements were obtained for representative numbers (> 25, if available), by life history stage and size class, or each species; evidence of external disease, parasites, and abnormalities was also recorded. Sex, age data, and stomach contents samples were also obtained for predominant species. The stomach samples were labeled and preserved in 10 percent buffered formalin for processing in the FRI's Seattle laboratory.

All collection, catch, and individual specimen data, as well as the eventual stomach contents data, were directly recorded on NODC (format No. 100) computer coding forms and were summarized by existing computer programs especially designed for this manner and format of data; species were coded using NODC's 10-digit taxonomic code and a one-digit life history stage code.

Stomach Analyses

Stomach analyses were performed in the same way as in 1976 (Simenstad and Nakatani 1977). In the laboratory, the stomach samples were removed from the preservative, or from the preserved whole fish, and soaked in cold water for at least 2 or 3 hours before examination. The stomach was then identified according to information on the label and then processed. Processing involved taking a total (damp) weight (to nearest 0.1 g), removing the contents from the stomach and weighing (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 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 0.001 g). If a sorted taxon was represented by too many individuals to count, the number was estimated using a random grid-counting procedure.

Statistics

The Shannon-Wiener information statistic

$$H' = - \Sigma P_i \log_2 P_i,$$

where Pi is the proportion of numbers or biomass of the i^{th} species in the stomach sample, was used as an estimate of trophic diversity (Pielou 1966*a* and 1966*b*). H' incorporates both the number of prey taxa present and the evenness of the distribution (either numbers or biomass) among these taxa, and is relatively insensitive to sample size. It is appropriate only if the collection can be considered a random sample of a very large population and to include all taxa found in the population.

Pielou (1966*a*) proposed a measure to characterize diversity of random vegetation quadrats;

$$H = (^1/N)(\log_2 N! - \Sigma \log_2 Ni!)$$

where N_i = the number of i^{th} prey and N = total number of prey (Brillouin 1956). The use of this index has been extended by Hurtubia (1973) to describe the patchy distribution of prey organisms in a predator's diet;

$$H_p = \frac{1}{(z - t + 1)} \sum_{k=t}^{z} h_k$$

where H_p is the average prey diversity, t is the number of pooled stomachs sufficient to represent the trophic diversity of the predator population, z is the total number of stomachs, and h_k is the successive increment per individual.

Evenness of the prey spectra was represented by H/H_{max} where LNS = H_{max} and S is the total number of prey categories. This ratio has also been used to measure the breadth of the food niche (Levins 1968) and is calculated as such for rock greenling prey spectra using H_p/H_{max} (Hurtubia 1973).

In the presentation of the food habit data, a modification of Pinkas et al. (1971) "Index of Relative Importance" (IRI) has been utilized to rank the importance of prey organisms. The IRI values for prey taxa are displayed both graphically and in tabular form where sample size (n) $\geq$ 10. The three-axis IRI graphs illustrate frequency of occurrence (that proportion of stomachs containing a specific prey organism) plotted sequentially on the horizontal axis, and percentage of total abundance and percentage of total biomass plotted above and below the horizontal axis, respectively (Fig. 3). Prey taxa of differing stages of digestion (e.g., partly digested shrimp, "unidentified Natantia," as opposed to family, "Pandalidae," or species, "*Pandalus borealis*") are graphed separately.

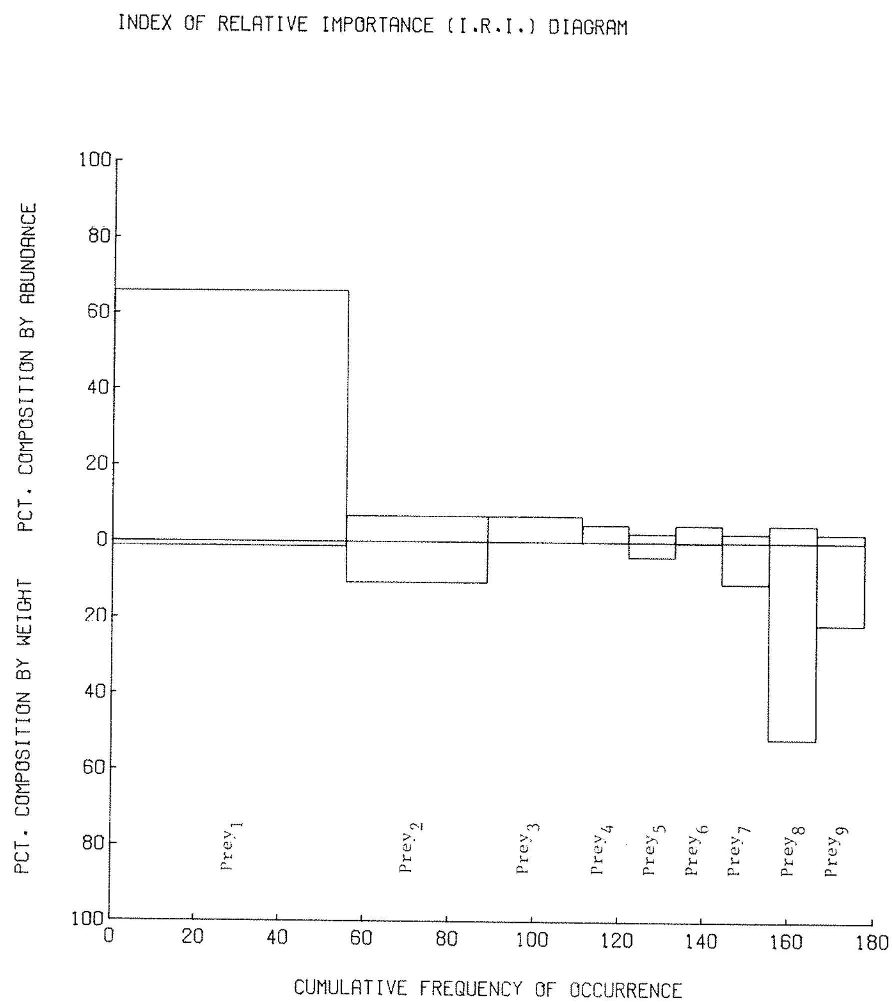

Fig. 3. Example IRI (Index of Relative Importance) diagram.

Table 1. Example computation of IRI values and percentages of total IRI from data illustrated in Fig. 1.

Prey Category	% Freq. of occurrence	% Numerical composition	% Gravimetric composition	Prey IRI	% Total IRI
1	55.56	65.91	1.22	3729.5	65.76
2	33.33	6.82	10.69	583.7	10.29
3	22.22	6.82	0.04	152.5	2.69
4	11.11	4.55	< 0.01	50.5	0.89
5	11.11	2.27	3.84	67.9	1.20
6	11.11	4.55	0.12	51.8	0.91
7	11.11	2.27	10.89	146.3	2.58
8	11.11	4.55	51.67	624.6	11.01
9	11.11	2.27	21.52	264.4	4.66

All prey groups, including those assigned to broad taxonomic level (family, order, class) because of advanced digestion, have been arranged from left to right by decreasing frequency of occurrence.

The IRI value was computed as follows:

$$\text{IRI} = \%\ \text{frequency of occurrence}_i\ [\%\ \text{numerical composition}_i + \%\ \text{gravimetric composition}_i]$$

and is equivalent to the area encompassed by the bar for each prey category *i* composing the IRI diagrams. In order to compare the IRI values between prey spectra with different sample sizes, the overall importance of general prey taxa (e.g., all shrimp, including "unidentified Natantia" and those identified to family and species, pooled) has been discussed as a percentage of the total combined IRI (areas) of the different prey taxa. Table 1 illustrates an example of the IRI values and percentages of total IRI generated from the data diagrammed in Fig. 3. The advantage of the IRI value is that numerically rare but high biomass prey (e.g., prey_8, Fig. 3); infrequently occurring but abundant or high biomass (when eaten) taxa; and numerically abundant or frequently occurring taxa (but which contribute little in the way of trophic input, e.g., prey_1, Fig. 3) do not dominate the more representative prey.

RESULTS

Collections

Twenty-six trammel net sets, nine tidepool collections, four trynet and longline collections, and two beach seine hauls were made during 1977 (Table 2). Trammel net collections in the Massacre Bay area were concentrated at Casco Point and Murder Point areas sampled in 1976, and new areas were sampled in the isolated rocky/kelp bed regions east of the West Channel (Fig. 4). Longlines were set in Massacre Bay proper. Trynet collections were made in Massacre Bay and Casco Cove: Beach seining was conducted at the head of Casco Cove. Tidepool collections

Table 2. Nearshore fish and epibenthic macroinvertebrates collected at Attu Island, July-Aug. 1977.

Collection number	Location	Area (M=Massacre Bay, C=Chichagof Hbr)	Date	Depth (m)	Duration (hr)	Oncorhynchus gorbuscha juv.	Salvelinus malma	Theragra chalcogramma juv.	Trichodon trichodon	Commandorella popovi	Bathymaster caeruleofasciatus	B. signatus	Anoplarchus purpurescens	A insignius	Phytichthys chirus	Pholis laeta	Ammodytes hexapterus	Hexagrammos lagocephalus	Sebastes ciliatus	Blepsias cirrhosus
Trammel net																				
07-02-1	Towers Rocks	M	7-20	6	5.4													3		
07-02-2	"	M	"	"	"													4		
06-01-1	Casco Pt.	M	7-22	5.5	6.5													12		
06-01-2	"	M	"	"	"													9		
06-01-3	"	M	7-23	6	5.3													16		
06-01-4	"	M	"	"	"													19		
10-01-1	West Channel	M	7-24	6	2.1													2		
10-01-2	"	M	"	"	"													3		
10-01-3	"	M	7-26	6	2.0													2		
10-01-4	"	M	"	"	2.3													6		
07-02-3	Towers Rocks	M	7-28	11	6.5													8		
07-02-4	"	M	"	9	"													8		
11-01-1	Pyramid Rocks	M	7-29	6	6.3													1		
11-01-2	"	M	"	"	"													4		
03-01-1	Harbor Rocks	C	8-1	6	5.3		1											4		
03-01-2	"	C	"	"	"		1											5		
12-01-1	Chicagof Pt.	C	8-2	8.5	5.2															
12-01-2	"	C	"	9	"													4		
01-11-1	Pisa Pt.	C	8-4	6	5.7													6		
01-11-2	"	C	"	8	"													7		
03-03-1	Outer Rocks	C	8-5	9	6.0															
03-03-2	"	C	"	8	"													6		
05-03-1	Goltsov Pt. (Holtz Bay)	C	8-6	6	3.8													21	3	
05-03-2	"	C	"	"	"													28	10	
12-02-1	Kennon Is.	C	8-9	6	4.8													2		
12-02-2	"	C	"	"	"													5		
25-Hook longline																				
08-02-1	Massacre Bay	M	7-21	28	13.0															
08-02-2	"	M	7-25	25	20.9															
08-02-3	"	M	7-27	25	16.3															
05-02-1	West Arm, Holtz Bay	M	8-6	12	105.8															
Trynet																				
06-03-1	Casco Cove	M	7-23	5.5	0.2													2		
06-04-1	"	M	"	7	0.2			2												
08-01-1	Massacre Bay	M	"	10	0.2															
08-01-2	"	M	"	6	0.2			12									1			1
Beach seine																				
06-05-1	Casco Cove	M	7-28	1	0.2	150	1										11	1		1
06-05-2	"	M	"	"	"	77	3		1								7	1		3
Tidepool (Rotenone and Quinaldine)																				
07-03-1	Murder Point	M	7-26	0.6	1															
07-03-2	"	M	"	"	1.4					1					1	7				
07-05-1	"	M	7-27	0.3	1						2		10	1		14				
07-06-1	"	M	"	0.5	0.5															
07-07-1	"	M	"	0.5	0.5								1		1	1				
09-02-1	Pyramid Cove	M	7-29	0.4	0.8								11			7				
09-03-1	"	M	"	0.3	0.5								7			4				
01-04-1	Pisa Point	C	8-1	0.5	1					1		1				1				
01-05-1	"	C	"	0.4	1					1		1	1			2				
Total						227	6	14	1	3	2	2	30	1	2	36	19	189	13	5

Collection number	Clinocottus acuticeps	C. embryum	Enophrys diceraus	Gymnocanthus sp. juv.	Hemilepidotus hemilepidotus	Myoxocephalus polyacanthocephalus	M. verrocosus (?)	Oligocottus maculosus	Sigmistes caulias	Agonidae unid.	Pallasina barbata	Liparis callyodon	Hippoglossus stenolepis	Lepidopsetta bilineata	Platichthys stellatus	Total fish	CPUE No. fish/hour	CPUE Grams/hr
07-02-1																3	0.56	435.2
07-02-2			1													5	0.93	565.9
06-01-1																12	1.85	747.1
06-01-2																9	1.38	691.2
06-01-3																16	3.02	1708.1
06-01-4																19	3.58	2443.2
10-01-1																2	0.95	476.2
10-01-2																3	1.43	1047.6
10-01-3																2	1.00	500.0
10-01-4																6	2.16	1132.6
07-02-3																8	1.23	513.1
07-02-4																8	1.23	578.9
11-01-1																1	0.16	63.5
11-01-2																4	0.63	318.1
03-01-1																5	0.94	314.7
03-01-2																6	1.13	830.2
12-01-1																0	0	0
12-01-2																4	0.75	330.9
01-11-1					1											7	1.23	903.2
01-11-2						1										8	1.40	873.2
03-03-1						1										1	0.17	17.5
03-03-2							1									7	1.17	674.5
05-03-1																24	6.32	2922.1
05-03-2																38	10.00	5474.4
12-02-1																2	0.42	201.0
12-02-2																5	1.04	801.9
08-02-1																0	0	0
08-02-2													1			1	0.05	1194.7
08-02-3																0	0	0
05-02-1													1			1	0.01	64.4
06-03-1					2	1										5	29.41	251.2
06-04-1				2												4	23.53	4.7
08-01-1																0	0	0
08-01-2				8	1	2				16	1		15	12		69	411.76	1499.4
																	No. fish/ m^2	Grams/ m^2
06-05-1				1		1				1				39	1	207	0.23	0.89
06-05-2				55		2				7		1		14		171	0.19	0.39
																	Fish/ m^3	Grams/ m^3
07-03-1						3										3	2.52	108.9
07-03-2	1					3	2					1				16	6.51	126.6
07-05-1		2				7	2					3				41	34.17	131.8
07-06-1		11							2			4				17	85.00	983.0
07-07-1									3			3				9	10.00	66.3
09-02-1	10					6						14				48	96.00	203.8
09-03-1								7				21				39	65.00	147.0
01-04-1					1		3		2			6				15	9.55	55.3
01-05-1	1				2	3	6									17	8.72	27.5
Total	12	13	1	66	7	30	14	7	7	24	1	53	17	65	1	868		

Collection number	Cryptochiton stelleri	Hyas lyratus	Oregonia gracilis	Scyra acutifrons	Telmessus cheiragonus	Phyllolithodes papillosus	Cryptolithodes typicus	Elassochirus tenuimanus	Unid. lithodid crab	Shrimp	Octopus dofleini	Evasteria troscheli	Henricia laeviuscula	Crossaster spp.	Leptasterias spp.	Pisaster brevispinus	Solaster sp.	Dendraster excentricus	Strongylocentrotus polyacanthus	Total macroinvertebrates	CPUE No. invertebrates/hour	CPUE No. sea urchins/hour	$\bar{X}$ diameter sea urchin test (mm)	Remarks
07-02-1				1		1						1							79	82	15.18	14.63	46.5	
07-02-2	1																		106	107	19.81	19.63	44.9	
06-01-1																			75	75	11.54	11.54	56.7	
06-01-2				1			1		1		1								42	46	7.08	6.46	54.1	
06-01-3	1				2	1					1	1	1						34	41	7.74	6.42	89.2	
06-01-4				1	9							2			1				86	99	18.68	16.20	62.8	
10-01-1													2	1	2				579	584	278.10	275.70	34.2	
10-01-2															1				231	232	110.98	110.00	38.8	
10-01-3											1								165	166	83.00	82.50	--	
10-01-4			1					1											211	213	92.61	91.70	--	
07-02-3			1												1				298	300	46.15	45.85	34.2	
07-02-4											1	2			1				248	252	38.77	38.15	36.6	
11-01-1			2									1			1	4			164	172	27.30	26.03		
11-01-2												5			1				159	165	26.19	25.24	57.7	
03-01-1																			~5	~5	--	--	~15-20	
03-01-2																			~5	~5	--	--	~15-20	
12-01-1		3		44								5			4				702	758	--	--	22.9	Net rolled, ineffective set
12-01-2																			58	58	11.15	11.15	26.5	
01-11-1												1		2	6				816	925	162.28	143.16	22.19	
01-11-2													2		8				2047	2007	360.88	359.12	21.43	
03-03-1						1							1	1	11				1100	1114	185.67	183.33	20.74	
03-03-2				3										1	5				735	744	124.00	122.5	22.08	
05-03-1															2				1278	1280	336.84	336.32	19.13	
05-03-2				1															1081	1082	284.74	284.47	19.72	
12-02-1															5		1		1083	1080	226.88	225.63	20.87	
12-02-2		1											2		6	1			885	895	186.46	184.38	23.15	
05-02-1																								Weather prevented timely pickup of longline
06-03-1					6					3										8	47.06	0	--	
06-04-1					7					42									1	50	294.12	5.88	68.1	
08-01-1										2								1		3	15.00	0	--	
08-01-2																				0	0.00	0	--	
07-03-1																			60					
07-05-1																			~175					
07-06-1																			27					
09-02-1																			6					
09-03-1																			65					
01-05-1																			~250					

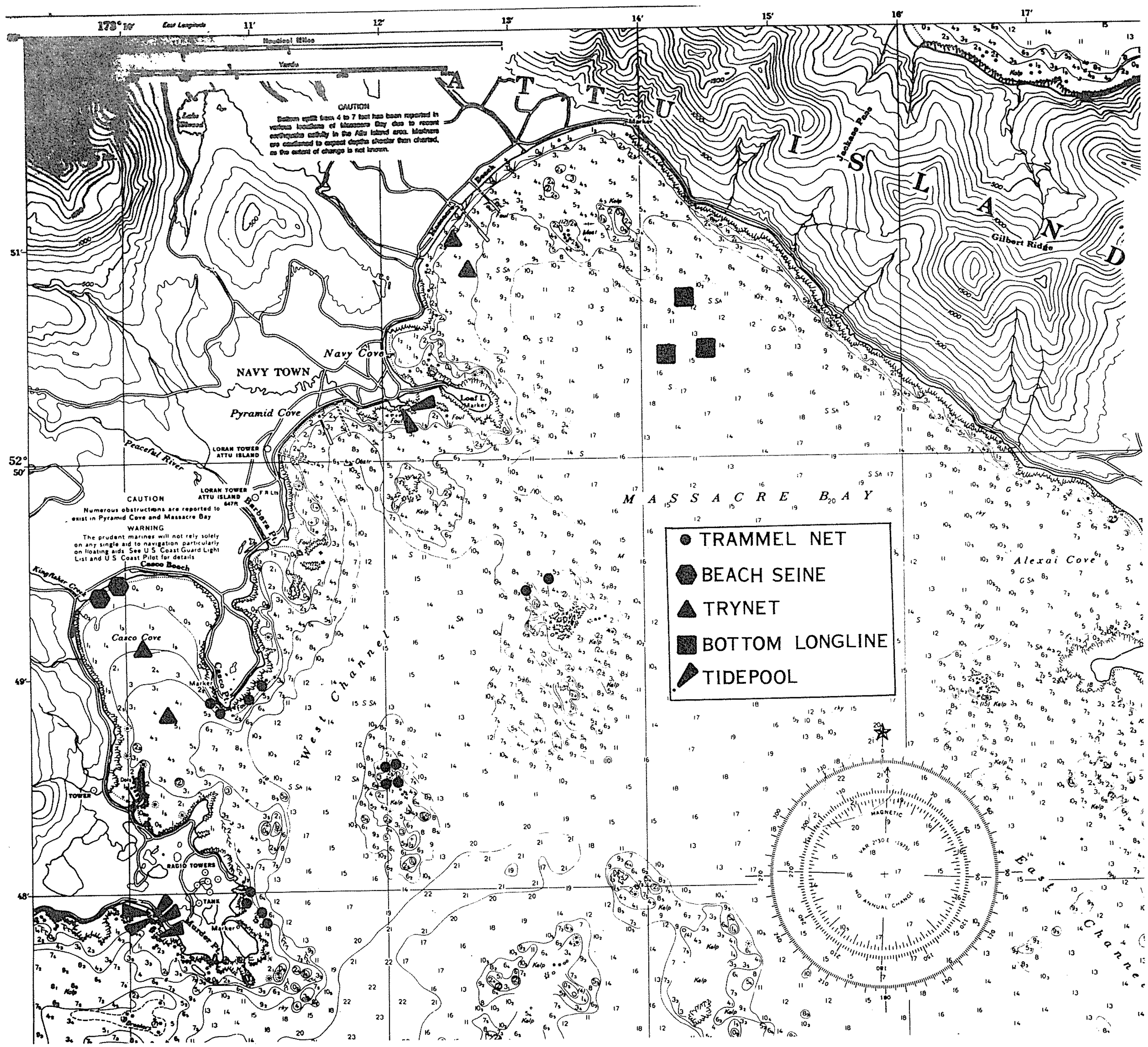

Fig. 4. Sampling sites, by method, in Massacre Bay vicinity of Attu Island, July-August 1977.

were made on the Pyramid Cove bench (sampled in 1976) and on the bench southwest of Murder Point. In the Chichagof Harbor vicinity, trammel net collections were made again at Pisa Point, and the inner harbor rocks: New sites included Middle Rocks, Outer Kennon Island, Chichagof Point and Goltsov Point in Holtz Bay (Fig. 5). Several longline sets were made in the west arm of Holtz Bay and two tidepools sampled in 1976 (designated Nos. 4 and 5) were resampled.

Catch Composition

A total of 868 fishes, representing 30 species, was collected, including eight species not captured during the 1976 sampling (Appendix Table 1) (Pacific sandfish, *Trichodon trichodon*, Alaska ronquil, *Bathymaster caeruleofasciatus*, slender cockscomb, *Anoplarchus insignius*, dusky rockfish, *Sebastes ciliatus*, silverspotted sculpin, *Blepsias cirrhosus*, juvenile sculpins, *Gymnocanthus* sp., warty sculpin, *Myoxocephalus verrocosus*, and possibly the Aleutian alligatorfish, *Aspidophoroides bartoni*). Of the newly reported species, Pacific sandfish and silverspotted sculpin have been reported from Attu; Alaskan ronquils have been reported from adjacent Agattu Island; and slender cockscombs, dusky rockfish, *Gymnocanthus* sp., warty sculpins, and Aleutian alligatorfish have been reported from Aleutian Islands outside the Near Island group. In addition, *Gymnocanthus* sp., warty sculpins and Aleutian alligatorfish have also been reported from the Western Pacific, either the Sea of Japan, Hokkaido and/or the Kurile Islands and Kamchatka (Wilimovsky 1964, Quast and Hall 1972).

Thirty-one species or taxa of epibenthic macroinvertebrates were coincidentally captured during the nearshore fish collections, totaling almost 12,400 individuals, the majority of which were sea urchins, sea stars and crabs (Table 2). Several species had not been reported in the 1976 collections, including the chiton, *Cryptochiton stelleri*, all the (trynet-caught) shrimps, the crabs, *Crytolithodes typicus*, *Cancer oregonensis*, and an unidentified lithodid, the sea stars, *Ceramaster*

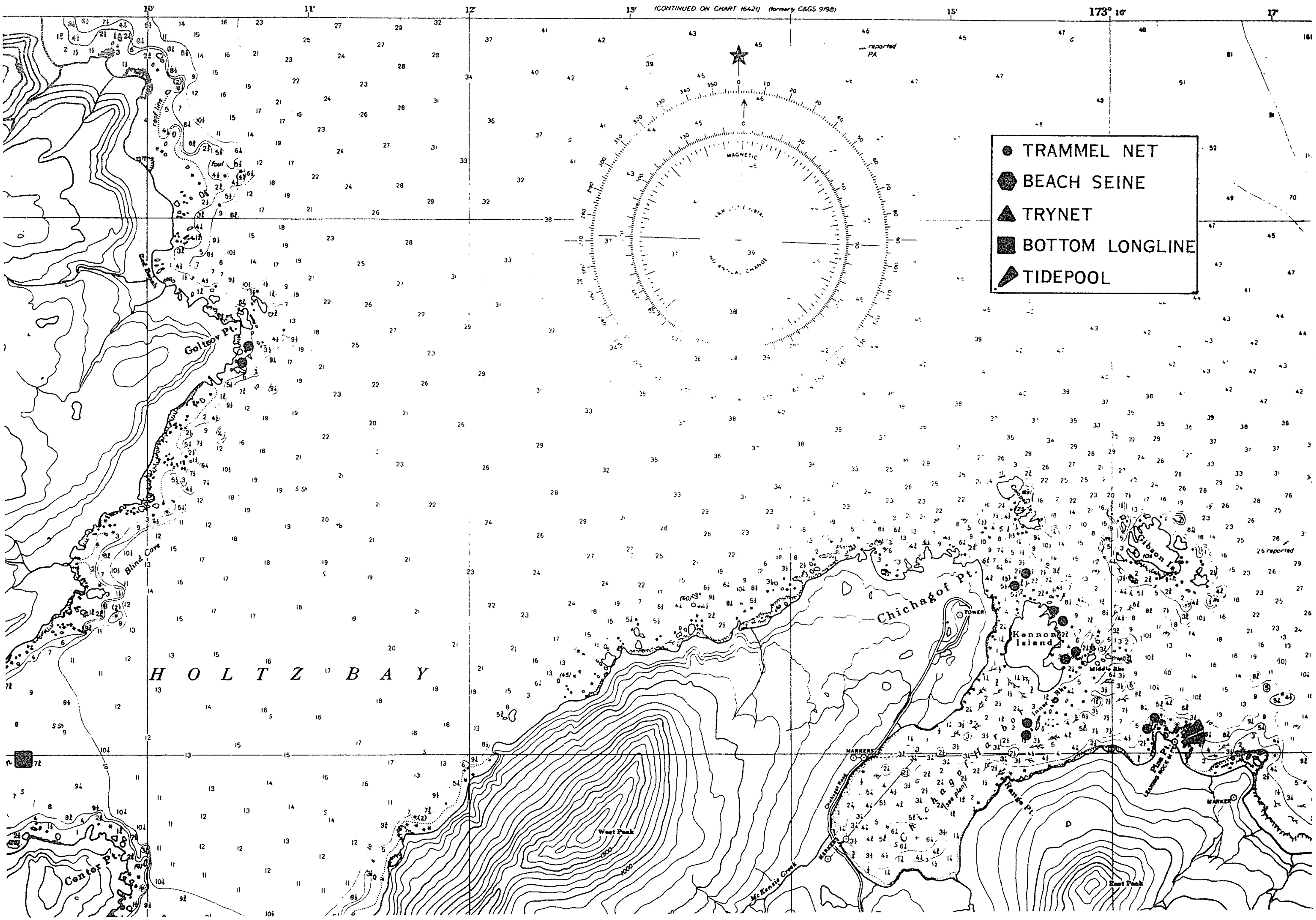

Fig. 5. Sampling sites, by method, in Chichagof Harbor vicinity of Attu Island, July-August 1977.

arcticus, *Crossaster diamesus*, *Pisaster brevispinus*, and *Solaster* sp., and the sand dollar, *Dendraster excentricus* (Appendix Table 2). The taxonomy of the sea stars collected in 1976, however, was not well established and the additional species may reflect the concerted identification effort applied to the specimens collected in 1977.

Only 14 of the 33 epibenthic macroinvertebrate species collected to date at Attu were reported during the 5 years of extensive sampling at Amchitka (Appendix Table 2 and O'Clair 1977). The occurrence of the shrimp species at the two islands is not comparable, however, because trynetting or trawling was not conducted nearshore at Amchitka. Even considering differences in taxonomic identification of the same species, there were several species which were found prominently at Attu but which were not found at all at Amchitka, including the crabs, *Phyllolithodes pappillosus*, *Hyas lyratus* and *Scyra acutifrons*, the sea stars, *C. arcticus*, *Evasterias troscheli*, *P. brevispinus* and *Solaster* sp., and a large holothurian, *Cucumaria* sp.

In addition to the epibenthic macroinvertebrates coincidentally collected by nearshore fish sampling methods, the amphipod traps effectively attracted scavenging gammarid amphipods. Traps baited with fish and seal remains were the most attractive, whereas algae-baited traps collected the fewest. Control (empty) traps had 8 to 20 times as many amphipods as those baited with algae and between 2 and 5 percent of the number collected by the fish- and mammal-baited traps (Table 3). These amphipod collections appeared to be composed almost entirely of the species *Anonyx multiarticulatus*.

Relative Abundance

The numbers of fish and epibenthic macroinvertebrates captured during the 1977 nearshore sampling are listed in Table 2. Relative abundances were calculated for fish as the number and biomass captured per unit of effort (CPUE by hours) for trammel net, trynet, and longline

Table 3. Amphipod trap collections, Attu Island, 1977.

Location	Date	Control		Algae		Fish		Mammal	
		No.	Wt(g)	No.	Wt(g)	No.	Wt(g)	No.	Wt(g)
Murder Pt. (rocky/kelp bed)	7-28	385	8.6	19*	0.3	19,900	607.5	21,900	904.6
Casco Pt. (rocky/kelp bed)	7-29	244	12.9	28**	0.2	***		5,300	349.8

*This trap also contained 18 *Littorina sitkana*, weighing 1.92 g.
**This trap also contained 1 idoteid isopod, weighing 0.003 g.
***This sample was lost in shipment back to Seattle but was similar in amphipod abundance to the trap baited with marine mammal remains.

collections. Number and biomass of fish were calculated per m^2 for beach seine collections and per m^3 for tidepool collections.

CPUE values from 1977 collections were generally consistent with those from the preliminary survey in 1976 (Simenstad and Nakatani 1977). Excluding the unusually large catch at Goltsov Point (Holtz Bay), CPUE's from Attu were significantly lower (at 99 percent level, t-test) than those reported from comparable* habitats at Amchitka (Table 4) (t = 13.63 for total fish/hour; t = 20.49 for total rock greenling/hour).

Catches during 1977 varied considerably among different sampling areas and habitats at Attu, but show a correlation between abundance of fish and the abundance of macroalgae (Table 4). For example, the highest catches (8.16 ± 2.16 fish/hour) originated from trammel nets set amidst thick kelp (*Alaria fistulosa*) at Goltsov Point. This is also one area of maximum sea otter density surveyed along Attu's northeast coast, with as many as 100 sea otters observed offshore in the west arm of Holtz Bay (J. Estes, personal communication). The Casco Point area on the southwest coast, which also has dense *Alaria* growth, correspondingly had the second highest mean CPUE values. CPUE, values in other comparable sampling areas included 1.06 ± 0.69 in sparse *Alaria* kelp beds of the West Channel 0.76 ± 0.42 in the outer Chichagof Harbor area (sparse to no kelp), and 0.65 ± 0.13 along the almost algaeless shoreline east of Murder Point.

Although the sampling techniques were not designed for collection of epibenthic macroinvertebrates, the catches (Table 2) may also indicate their abundances in shallow subtidal habitats. CPUE values for the numbers caught per hour of trammel net effort are summarized in Table 5. Catches were generally similar to those made in 1976 with the exception of Murder Point. This may be an effect of exposure, as the July 23, 1976, collections at Murder Point were made on the exposed tip of the

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*Rocky, exposed shoreline, 5-10 m in depth, 2- to 12-hour set duration during July-September.

Table 4. Summary of trammel net catch per unit effort (CPUE) by mean numbers and biomass (± one standard deviation) of total fish and rock greenling caught per hour at Attu Island, 1976 and 1977, as compared to Amchitka Island, 1971-72.

		No. sets	Catch per unit effort			
			Total fish		Rock greenling	
Location	Date	n	Number/hr	Grams/hr	Number/hr	Grams/hr
Amchitka Island						
IA2/3	71-72	14	9.02±2.02	*	8.80±2.17	*
Attu Island						
Chichagof Harbor area						
Pisa Pt.	1976	4	0.44±0.15	191.13±75.54	0.24±0.20	96.60±99.34
"	1977	2	1.32±0.12	888.20±21.21	1.14±0.13	722.19±31.39
Outer Rocks	1977	2	0.67±0.71	346.00±464.57	0.50±0.71	302.92±428.39
Kennon Island	1977	2	0.73±0.44	501.45±424.90	0.73±0.44	501.45±424.90
Chichagof Pt.	1977	1	0.75	330.9	0.75	330.9
Goltsov Pt.	1977	2	8.16±2.60	4198.25±1804.75	6.45±1.30	1911.18±2381.65
Massacre Bay area						
Casco Pt.	1976	4	2.65±0.29	1552.38±310.27	2.48±0.20	1502.29±326.95
"	1977	4	2.46±1.02	1397.40±839.02	2.46±1.02	1397.40±839.02
Murder Pt.	1976	2	0.69±0.16	340.03±101.21	0.59±0.29	301.47±155.74
"	1977	4	0.99±0.32	523.28±65.25	0.65±0.13	510.60±57.32
West Channel Rocks	1977	4	1.39±0.56	789.10±349.43	1.39±0.56	789.10±349.43
Pyramid Pt. Rocks	1977	2	0.40±0.33	190.80±180.03	0.40±0.33	190.80±180.03
All Attu	1976	10	1.35±1.14	955.49±753.08	1.20±1.12	699.83±724.44
	1977	21	1.25±0.85	715.38±551.02	1.22±0.85	693.26±550.19

*Total biomass values were not available for these trammel net data.

Table 5. Summary of comparable* trammel net catch per unit effort (CPUE) by mean numbers (± one standard deviation) of epibenthic macroinvertebrates caught per hour at Attu Island, 1971-1972.

			CPUE (mean number/hr)					
Location	Date	No. sets n	Sea urchins	Sea stars	Decorator crabs	*Telmessus*/ *Erimacrus* crabs	Octopus	Total epibenthic macroinvertebrates
Chichagof Harbor area								
Pisa Pt.	1976	2	404.50±119.50	0	0	0	0	404.50±119.50
"	1977	2	251.14±152.21	1.67±0.12	0	0	0	261.68±140.43
Outer Rocks	1977	2	152.92±43.01	1.58±0.82	0.33±0.24	0	0	154.09±44.67
Kennon Island	1977	2	205.01±29.17	1.56±0.44	0.60±0.56	0	0	206.67±28.58
Goltsov Point	1977	2	310.40±36.66	0.76±0.33	0.63±0.52	0	0	310.79±36.84
Massacre Bay area								
Casco Point	1976	3	8.86±4.93	0.17±0.14	1.50±1.77	0.53±0.63	0.17±0.14	13.75±3.54
"	1977	4	10.16±4.69	0.24±0.28	0.17±0.13	0.52±0.81	0.09±0.10	11.26±5.32
Murder Point	1976	2**	362.75	4.71	1.57	0	0	370.59
"	1977	4	29.57±14.84	0.20±0.19	0.13±0.18	0	0.04±0.08	29.70±14.66
West Channel Rocks	1977	4	139.98±51.20	0.71±1.13	0.11±0.22	0	0.13±0.25	141.17±92.02
Pyramid Rocks	1977	2	25.64±0.56	0.95±0.0	0.16±0.22	0	0	26.75±0.78

*Rocky, exposed shoreline, 5-10 m in depth, 2-12 hr set duration.
**Combined sample.

point (Simenstad and Nakatani 1977), whereas those made on July 20 and July 28, 1977, were located in a more protected location north of the point (Fig. 4). The differences in the relative abundances (CPUE's) of epibenthic macroinvertebrates were due principally to the differences in sea urchin abundances and are a function of the divergent size structures of the populations in the two sampling areas. The relationship between relative sea urchin abundance and mean test diameter takes the form of a negative power curve (Fig. 6).

$$y = 122.91\ x^{-0.31}$$

where y = sea urchin test diameter (mm), x = mean number of sea urchins per hour of trammel net set, with a coefficient of determination, $r^2 = 0.83$.

Similarly to the 1976 results (Simenstad and Nakatani 1977), there was a complete absence of large decapods (such as the true crabs, *Telmessus cheiragonus* and *Erimacrus eisenbecki*) and octopus in the Chichagof Harbor samples. Decorator crabs (such as *H. lyratus*, *S. acutifrons*, *Oregonia gracilis*, *P. papillosus* and *C. typicus*) were found in the Chichagof Harbor area in 1977, principally at Goltsov Point and Kennon Island where kelp beds were present. The abundances of sea stars were not tabulated in 1976, so comparisons with 1977 catches were not valid. Sea star catches in the trammel net collections were generally higher in the Chichagof Harbor vicinity, principally because of high numbers of *Leptasterias* spp., a relatively small sea star. The numbers of the larger predaceous starfish, such as *E. troschelii* and *P. brevispinus*, however, tended to be higher in the Massacre Bay sampling area.

Beach seine collections made at the north end of Casco Cove produced high numbers of juvenile pink salmon, Pacific sand lance, and juvenile sculpins (*Gymnocanthus* sp.?) and rock sole (Table 2). Trynet trawling in both Casco Cove and Massacre Bay indicated that juvenile walleye pollock, rock sole and Pacific halibut and small poachers (possibly the Aleutian alligatorfish) are the principal members of the fish assemblage

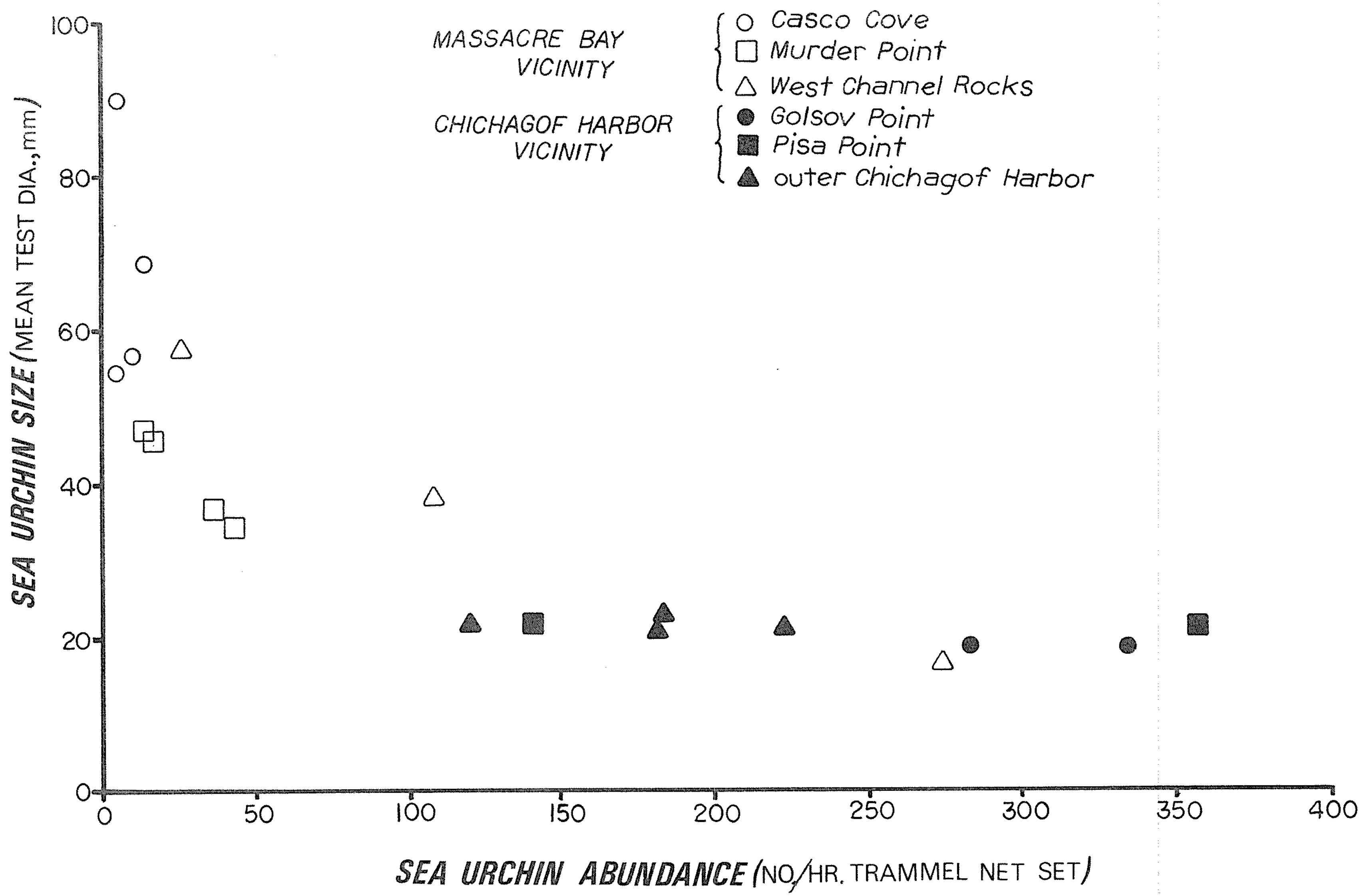


Fig. 6. Relationship between relative sea urchin abundance, as reflected in the trammel net catches, and the mean sea urchin test diameter.

occupying the shallow, sand-gravel habitat in that area. Neither beach seine nor trynet collections were performed at Amchitka, thus a comparison with Amchitka was not possible.

As in 1976, several adult Pacific halibut were caught on bottom longlines set in Holtz and Massacre bays.

Additional tidepool collections conducted in 1977 indicate that species composition and fish density vary considerably, usually with the abundance of macroalgae in the tidepool, and may change from year to year. Sculpins (family Cottidae, including *Hemilepidotus hemilepidotus*, *Myoxocephalus* spp., *Clinocottus* sp., *Oligocottus maculosus* and *Sigmistes caulias*) tended to predominate in tidepools which were well grazed by herbivorous sea urchins, chitons and limpets. In tidepools with fewer herbivores and denser macroalgae, pricklebacks (*Anoplarchus purpurescens* and *Phytichthys chirus*), gunnels (*Pholis laeta*) and snailfish (*Liparis callyodon*) were more prevalent. Correspondingly, *A. purpurescens*, *P. laeta*, and *L. callyodon* constituted the most frequently occurring, abundant species in the macroalgae-clogged tidepools at Amchitka (Simenstad et al. 1977). In general, tidepool fish density and standing crop estimates appeared to be higher in the Massacre Bay vicinity than at Chichagof Harbor (Pisa Point) but the comparability of the tidepools in the two areas may not be valid, owing to differing substrates, exposures and algal guilds.

Two tidepools sampled with rotenone in 1976 were resampled in 1977 (tidepools Nos. 4 and 5 at Pisa Point) with quinaldine. Lower fish densities and standing crops were found in both tidepools (Simenstad and Nakatani 1977, Table 2, page 13 versus Table 2, this report). Species composition, however, was similar with *Myoxocephalus* spp., *S. caulias*, and *C. popovi* predominating. Two tidepools sampled at Pyramid Cove (Nos. 09-02-01 and 09-03-1, Table 2) indicated species compositions (*L. callyodon*, *A. purpurescens*, and *P. laeta* dominating), fish densities ($80.5 \pm 21.92/m^3$) and standing crop values (175.4 ± 40.16 g/m^3) very similar to a tidepool sampled on the same littoral bench in 1976 (Nos. 09-01-01, Table 2, page 13 *in* Simenstad and Nakatani 1977).

Rock Greenling Population Structure

The contribution of nearshore fish, especially rock greenling, to the sea otter's diet at Amchitka has increased since first documented in the 1940's (Palmisano and Estes 1977, Estes et al., in press). It follows that the sea otter's size selective predation upon sea urchins (Estes and Palmisano 1974, Palmisano and Estes 1977) might also apply to the rock greenling populations, and that conversely, the population structure at Attu could represent the effects of low or no predation. This hypothesis was first examined using the length frequency distributions of rock greenling from comparable collections in 1977 at Attu and in 1971 and 1972 at Amchitka (Fig. 7). The distribution in the Massacre Bay vicinity shows a length mode in the 315-mm to 450-mm range, constituting 53 percent of the lengths; in the Chichagof Harbor vicinity, however, this mode represents only 11.6 percent. This mode is practically nonexistent in the distribution for Amchitka rock greenling, representing only 3.5 percent. Consequently, the length frequency distribution of Attu rock greenling (mean length = 314.37 mm, 1 S.D. = 8.79 mm) was significantly different from that of Amchitka rock greenling (mean length = 246.79, 1 S.D. = 4.25 mm) at the 5 percent level, but not significant at the 1 percent level, using the Mann-Whitney U-test.

The modes illustrated in Fig. 7 would appear to be distinct age classes. Unfortunately, we do not yet have age structure data for the Attu rock greenling population. Gorbunova (1962) illustrated age class modes for rock greenling from the east coast of Kamchatka with approximately 5 cm between years, showing 3+-year-old fish with lengths between 25.1 (male) and 25.8 cm (female); 4+, 29.8-30.7 cm; 5+, 36.1-35.6 cm; 6+, 40.2-41.4 cm; and 8+, 47.0-46.6 cm. Conversely, age structure data on Amchitka Island rock greenling indicated age 2 fish with an average length of 21.8 cm; age 3, 24.8 cm; age 4, 28.9 cm; age 5, 32.2 cm; age 6, 33.1 cm; age 7, 34.4 cm; and age 8, 33.9 cm (Simenstad, unpublished

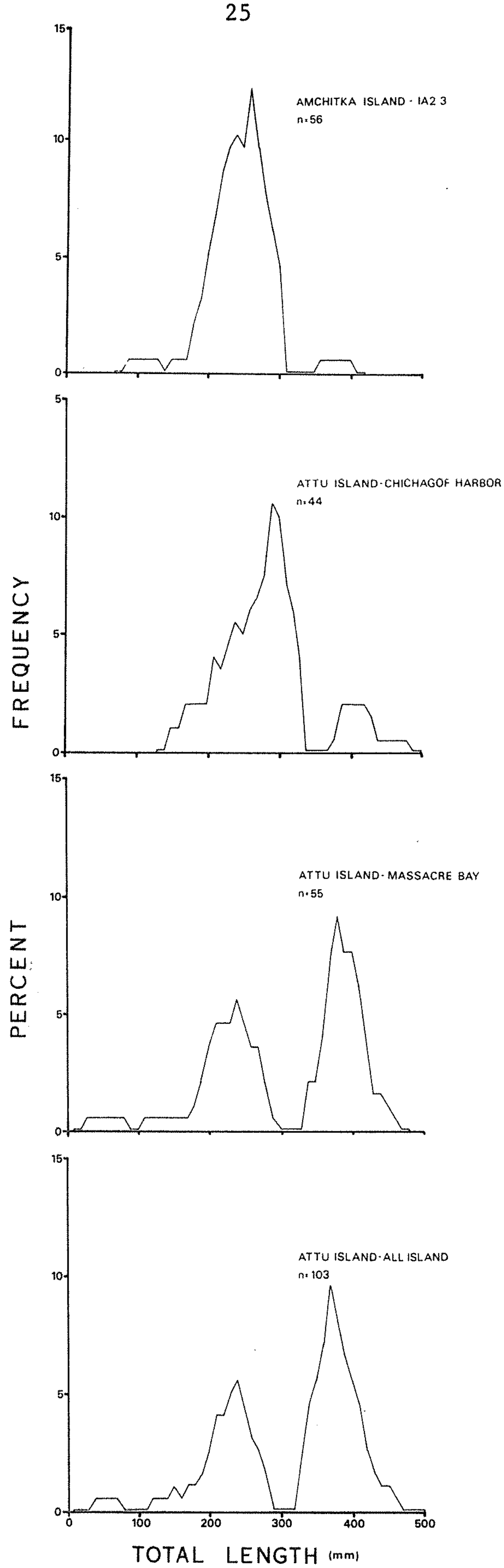


Fig. 7. Length frequency distributions of rock greenling from Amchitka and Attu islands. The distributions were smoothed by running averages of 5 cm.

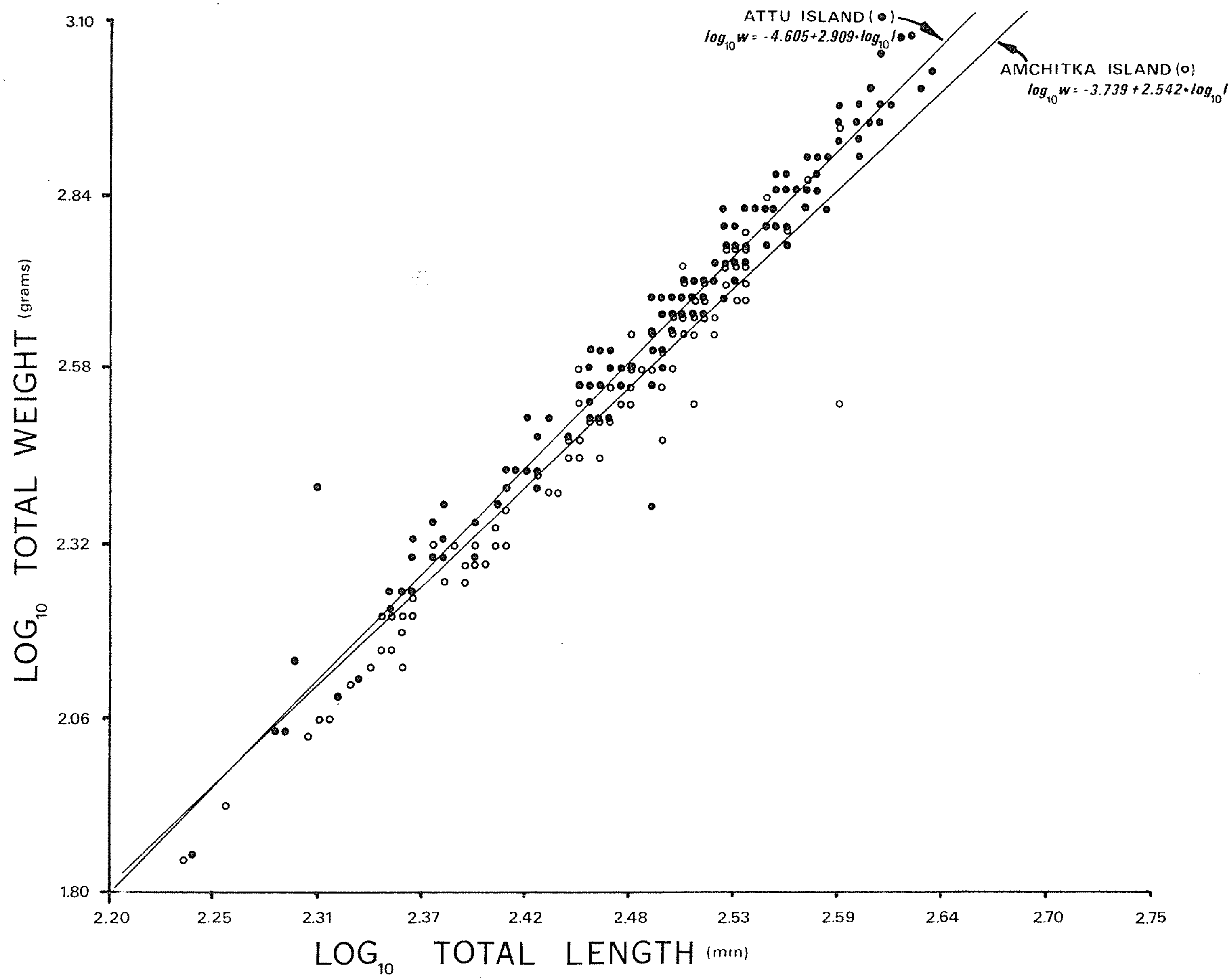


Fig. 8. Log length - log weight regressions of Attu and Amchitka island populations of rock greenling.

Table 6. Mean condition factor, $K = \frac{W}{L^3}$, of rock greenling populations at Amchitka and Attu islands.

Sampling area	Sample size n	$\bar{K}$(±1 S.D.)
Amchitka Island - IA2/3	103	$1.37 \times 10^{-5} \pm 7.80 \times 10^{-6}$
Attu Island - Chichagof Hbr.	86	$1.08 \times 10^{-5} \pm 4.75 \times 10^{-6}$
Massacre Bay	83	$1.06 \times 10^{-5} \pm 4.62 \times 10^{-6}$
Combined	169	$1.07 \times 10^{-5} \pm 4.69 \times 10^{-6}$
Attu Island combined		
$\geq$300 mm	120	$8.27 \times 10^{-6} \pm 1.76 \times 10^{-6}$
$<$300 mm	49	$1.64 \times 10^{-5} \pm 4.72 \times 10^{-6}$

which through intraspecific food competition turn a lower proportion of their prey biomass into growth than do the younger, "middle-aged" fish at Amchitka.

The von Bertalanffy growth equation (von Bertalanffy 1938, 1957; Walford 1946; Beverton and Holt 1957) for the rate of fish length increase over time

$$L_t = L_\infty(1 - e^{-K(t - t_o)})$$

where

L_∞ = maximum length attainable

K = growth coefficient, e.g., rate at which length approaches L_∞

t_o = (hypothetical) time at which the fish would have been zero size was fitted for the Amchitka greenling population

$$L_t = 338.62\ (1 - e^{-0.639(t - 1.96)})$$

the only length-age data existing at this time. From these growth coefficients the total instantaneous mortality

$$Z = \frac{K(L_\infty - \bar{L})}{(\bar{L} - L_c)}$$

where

$\bar{L}$ = mean length in catch

L_c = mean length when first available in nearshore environment (Ricker 1971) was equal to 0.313. Age data, determined from otoliths, will be obtained from Attu in 1978. These data will allow calculation of growth and mortality coefficients for the Attu rock greenling population. If the value for Z is significantly lower for Attu than determined for Amchitka, the difference may be a usable estimate of the mortality affected by Amchitka's sea otter population.

Food Habits

Two hundred thirty-two stomach samples of 18 fish species were collected in 1977 and analyzed in FRI's Seattle laboratory (Table 7). As in the 1976 collections, the specimens examined in 1977 represented the principal members of Attu's exposed rocky sublittoral and littoral (tidepool) habitats.

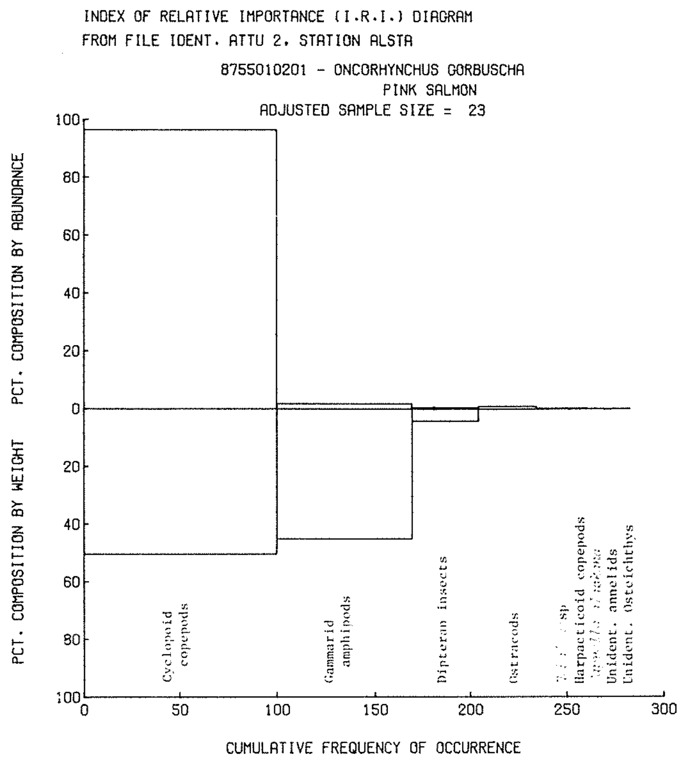
Prey composition is summarized by principal taxa in Appendix Table 3.

Oncorhynchus gorbuscha, Juvenile Pink Salmon

Although not abundant in the 1976 collection, because of their cyclic life history, juvenile pink salmon were predominant in the Casco Cove beach seine collections in 1977. Calanoid copepods and gammarid amphipods dominated their diet (Fig. 9), composing almost 90 percent of the total prey IRI.

Salvelinus malma, Juvenile Dolly Varden

Juvenile Dolly Varden were captured both in Casco Cove beach seine and inner Chichagof Harbor trammel net collections. Gammarid amphipods were the principal food organism, both numerically and gravimetrically. Fish (cottids) comprised just over 20 percent of the total prey biomass. Juvenile Dolly Varden from the 1976 collections at Sarana Bay had preyed more upon harpacticoid copepods and mysids in addition to gammarid amphipods (Simenstad and Nakatani 1977); they were, however, much smaller fish than those in the 1977 collections.



Prey item	Freq. of occurrence	Numerical composition	Gravimetric composition	Prey I.R.I.	% Total I.R.I.
Cyclopoida	100.00	96.51	50.31	14681.7	80.93
Gammaridae	69.57	1.78	45.04	3256.7	17.95
Diptera	34.78	0.44	4.31	164.9	0.91
Ostracoda	30.43	0.90	0.09	30.3	0.17
Nebalia sp.	26.09	0.19	0.08	6.9	0.04
Phaeophyta	4.35	0.06	0.01	0.3	0.00
Harpacticoida	4.35	0.03	0.01	0.2	0.00
Caprella alaskana	4.35	0.03	0.13	0.7	0.00
Annelida	4.35	0.03	0.01	0.2	0.00
Osteichthys	4.35	0.03	0.01	0.2	0.00

Fig. 9. Prey spectrum of juvenile pink salmon, Attu Island, Alaska, July-August 1977.

Sebastes ciliatus, Dusky Rockfish

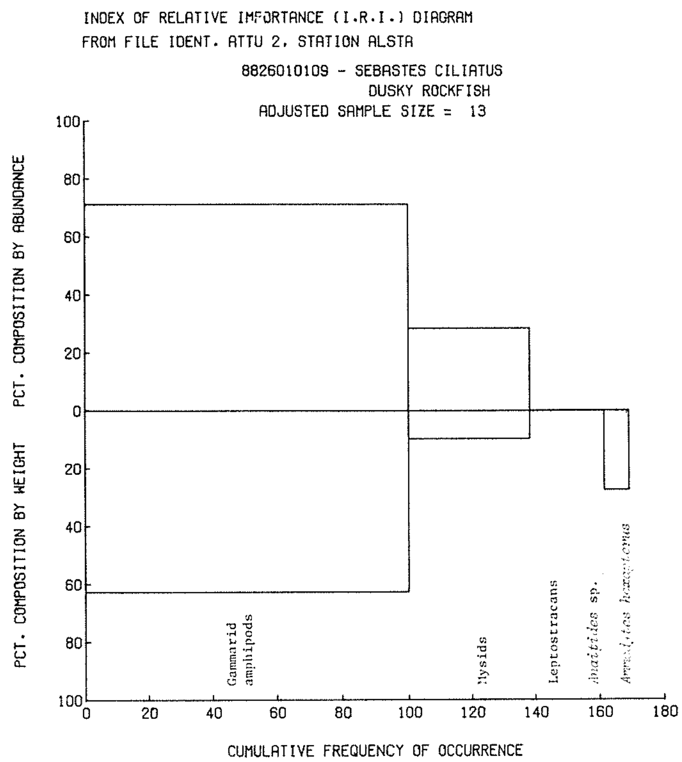
Adult dusky rockfish were caught for the first time at Attu in the 1977 trammel net collections at Goltsov Point. Gammarid amphipods comprised the majority (89 percent) of the IRI prey spectrum, with lesser contributions by mysids and Pacific sand lance (Fig. 10). Dusky rockfish at Amchitka had a similar prey spectrum (Simenstad et al. 1977) although mysids were more important than amphipods in the diets at Amchitka.

Hexagrammos lagocephalus, Rock Greenling

As the dominant nearshore fish at both Attu and Amchitka islands, the rock greenling provided the largest sample available for stomach analyses. Gammarid amphipods (just over 60 percent of the total IRI dominated the prey spectrum of rock greenling collected during 1977) (Fig. 11) as they did in 1976 (Simenstad and Nakatani 1977). Polychaete annelids, caprellid amphipods (*Caprella alaskana*), crabs (*Dermaturus mandti*, *H. lyratus*, *S. acutifrons*, *P. papillosus*, and *T. cheiragonus*), chitons (*Tonicella lineata*), fish eggs (predominantly Hexagrammidae), algae (Phaeophyta), and gastropods (*Baleis* sp., *Littorina* sp., and *Velutina laevigata*) comprised the prey of secondary importance. The only notable differences discernible between the 1976 and 1977 rock greenling prey spectra were the greater contribution by caprellid amphipods, mysids, and fish eggs in the 1977 spectrum versus the greater contribution by gastropods in the 1976 spectrum.

Clinocottus acuticeps, Sharpnose Sculpin

Gammarid amphipods (73 percent of the total IRI) constituted the principal prey of this common tidepool sculpin, supplemented by bivalves, flabelliferan isopods, and bivalve nauplii. Sharpnose sculpins at Amchitka had fed almost exclusively on gammarid amphipods (Simenstad et al. 1977).

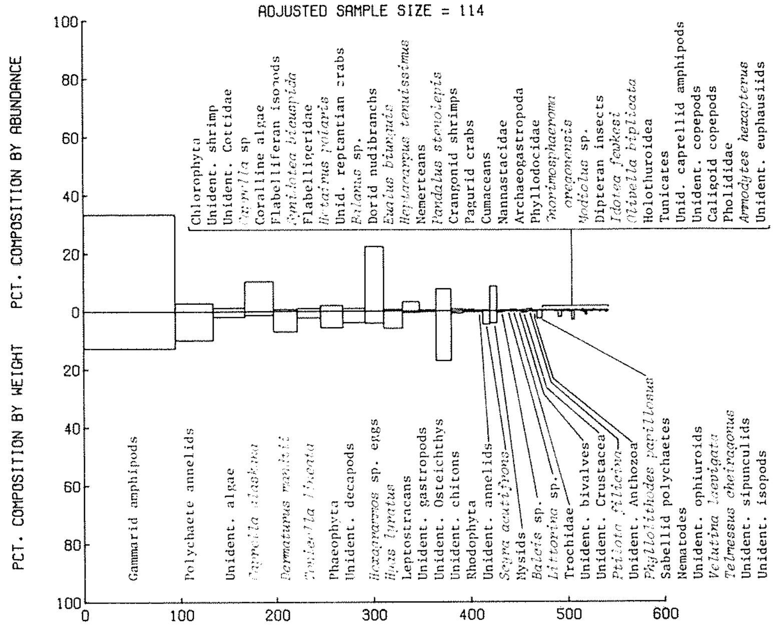


Prey item	Freq. of occurrence	Numerical composition	Gravimetric composition	Prey I.R.I.	% Total I.R.I.
Gammaridae	100.00	71.27	62.74	13401.2	88.86
Mysidacea	38.46	28.48	9.64	1466.2	9.72
Malacostraca phyllocarida	7.69	0.06	0.01	0.6	0.00
Nematoda	7.69	0.06	0.00	0.5	0.00
Anaitides sp.	7.69	0.06	0.09	1.2	0.01
Ammodytidae	7.69	0.06	27.51	212.1	1.41

Fig. 10. Prey spectrum of dusky rockfish, Attu Island, Alaska, July-August 1977.

INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. ATTU 2, STATION ALSTA

8827010102 - HEXAGRAMMOS LAGOCEPHALUS
ROCK GREENLING
ADJUSTED SAMPLE SIZE = 114



Prey item	Freq. of occurrence	Numerical composition	Gravimetric composition	Prey I.R.I.	% Total I.R.I.
Gammaridae	94.74	33.43	12.70	4370.4	60.60
Polychaeta	39.47	2.83	9.92	503.4	6.98
Unid.	33.33	1.29	2.00	109.8	1.52
Caprella alaskana	29.82	10.34	1.37	349.4	4.84
Dermaturus mandti	24.56	0.64	7.04	188.8	2.62
Tonicella lineata	24.56	1.01	2.34	82.2	1.14
Phaeophyta	22.81	1.91	5.71	173.8	2.41
Eucarida-Decapoda	22.81	0.94	3.97	112.0	1.55
Hexagrammidae	19.30	22.16	4.22	509.0	7.06
Hyas lyratus	19.30	0.55	5.97	125.8	1.74
Malacostraca phyllocarida	17.54	3.15	0.50	63.9	0.89
Prosobranchia-Gastropoda	16.67	0.35	0.26	10.1	0.14
Teleostei	15.79	7.54	17.16	389.9	5.41
Polyplacophora	12.28	0.69	0.83	18.7	0.26
Rhodophyta	11.40	0.50	0.30	9.1	0.13
Annelida	8.77	0.17	0.36	4.7	0.07
Scyra acutifrons	7.02	0.19	4.71	34.4	0.48
Mysidacea	7.02	8.41	4.31	89.3	1.24
Balcis sp.	7.02	0.16	0.46	4.4	0.06
Littorina sp.	7.02	0.12	0.10	1.5	0.02
Trochidae	6.14	0.31	0.20	3.1	0.04
Bivalvia	5.26	0.07	0.11	0.9	0.01
Crustacea	5.26	0.28	0.67	5.0	0.07
Ptilota filicina	5.26	0.53	0.27	4.2	0.06
Anthozoa	5.26	0.06	0.25	1.6	0.02
Phyllolithodes papillosus	5.26	0.09	2.78	15.1	0.21
Sabellaridae	4.39	0.12	0.06	0.8	0.01
Nematoda	4.39	0.05	0.00	0.2	0.00
Ophiuroida	4.39	0.05	0.03	0.4	0.01
Velutina laevigata	3.51	0.06	0.18	0.8	0.01
Telmessus cheiragonus	3.51	0.09	2.30	8.4	0.12
Sipunculidae	2.63	0.07	0.33	1.1	0.01
Isopoda	2.63	0.09	0.09	0.5	0.01
Chlorophyta	2.63	0.14	0.15	0.8	0.01
Natantia	2.63	0.08	0.22	0.8	0.01
Cottidae	2.63	0.04	3.29	8.8	0.12
Caprella sp.	2.63	0.22	0.02	0.6	0.01
Corallinacea	1.75	0.06	0.03	0.2	0.00
Flabellifera	1.75	0.02	0.02	0.1	0.00
Synidotea bicuspida	1.75	0.03	0.13	0.3	0.00
Flabelligeridae	1.75	0.32	0.06	0.7	0.01
Hetairus polaris	1.75	0.04	0.52	1.0	0.01
Reptantia	1.75	0.08	1.53	2.8	0.04
Balanus sp.	0.88	0.01	0.00	0.0	0.00
Nudibranchia-Doridoidea	0.88	0.01	0.11	0.1	0.00
Eualus biunguis	0.88	0.01	0.08	0.1	0.00
Heptacarpus tenuissimus	0.88	0.01	0.11	0.1	0.00
Nemertea	0.88	0.01	0.00	0.0	0.00
Pandalus stenolepis	0.88	0.01	0.23	0.2	0.00
Crangonidae	0.88	0.02	0.11	0.1	0.00
Paguridae	0.88	0.01	0.04	0.0	0.00
Cumacea	0.88	0.28	0.04	0.3	0.00
Nannastacidae	0.88	0.01	0.00	0.0	0.00
Archaeogastropoda	0.88	0.02	0.02	0.0	0.00
Phyllodocidae	0.88	0.02	0.00	0.0	0.00
Gnorimosphaeroma oregonensis	0.88	0.02	0.03	0.0	0.00
Modiolus sp.	0.88	0.01	0.08	0.1	0.00
Diptera	0.88	0.01	0.00	0.0	0.00
Idotea fewkesi	0.88	0.03	0.42	0.4	0.01
Olivella biplicata	0.88	0.01	0.10	0.1	0.00
Holothuroidea	0.88	0.01	0.08	0.1	0.00
Urochordata	0.88	0.01	0.04	0.0	0.00
Caprellidae	0.88	0.10	0.02	0.1	0.00
Copepoda	0.88	0.01	0.00	0.0	0.00
Caligoida	0.88	0.04	0.00	0.0	0.00
Pholididae	0.88	0.01	0.49	0.4	0.01
Ammodytes hexapterus	0.88	0.01	0.42	0.4	0.01
Euphausiacea	0.88	0.01	0.09	0.1	0.00

Fig. 11. Prey spectrum of rock greenling, Attu Island, Alaska, July–August 1977.

Clinocottus embryum, Calico Sculpin

The calico sculpin, also a common member of the rocky tidepool fish assemblage at Attu, had a dramatically different prey spectrum from its congener, the sharpnose sculpin. The chiton, *Cryptochiton stelleri*, comprised 92 percent of the total IRI but barnacle appendages dominated numerically. Gammarid amphipods occurred frequently in the diet but comprise only 4 percent of the total IRI. The incidence of *C. stelleri* is the only significant difference in the two otherwise comparable prey spectra from 1976 and 1977 collections (Simenstad and Nakatani 1977) and may represent subtle differences in the prey organisms available in different tidepools.

Enophrys diceraus, Antlered Sculpin

One antlered sculpin had consumed two sea urchins, comprising 88 percent of the total prey biomass, and two pieces of algae.

Hemilepidotus hemilepidotus, Red Irish Lord

Ophiuroids (*Ophiopholis aculeata* and *Diamphodia* sp.) and sea urchins were the dominant prey organisms in the stomach of a red Irish lord caught at Pisa Point. Red Irish lord from the 1976 collections at Attu had also concentrated their feeding upon ophiuroids but gammarid and caprellid amphipods, tunicates, isopods and brachyuran crabs were also important (Simenstad and Nakatani 1977).

Myoxocephalus polyacanthocephalus, Great Sculpin

The four great sculpins examined from 1977's collections fed principally upon crabs (*H. lyratus*, *S. acutifrons* and *Dermaturus mandti*; 66 percent of total number of prey, 90 percent of prey biomass) and fish (sculpins and snailfish); amphipods composed 20 percent of the total number of prey. Crabs were a more important component of the diet of these specimens than those examined in 1976 (Simenstad and Nakatani 1977) and dramatically different from the diet of Amchitka great sculpins, which, being smaller, fed principally upon gammarid amphipods (Simenstad et al. 1977).

Myoxocephalus verrucosa, Warty Sculpin

This sculpin was identified for the first time in the Attu collections in 1977 and was not reported from Amchitka (Simenstad et al. 1977); because of its similarity to the great sculpin. However, the 1976 and earlier Amchitka collections may have included specimens of *M. verrucosa*.

Gammarid amphipods were the most numerous prey organisms (73 percent IRI) but crabs (*H. lyratus* and *P. pappillosus*) contributed the bulk of the prey biomass (78 percent).

Sigmistes caulis, Kelp Sculpin

This common tidepool sculpin appeared to feed specifically upon barnacle cirri (75 percent of total number of prey items) though gammarid amphipods (60 percent of total prey biomass) and chitons (*C. stelleri*, 13 percent of total prey biomass) provided the majority of the prey biomass.

Trichodon trichodon, Pacific Sandfish

Gammarid amphipods were the predominant (both numerically and gravimetrically) prey in the stomach of one Pacific sandfish captured at Casco Cove.

Anoplarchus insignis, Slender Cockscomb

One specimen of *A. insignis* had six polychaetes in its stomach.

Anoplarchus purpurescens, High Cockscomb

High cockscombs were one of the most common fishes found in tidepools with abundant macroalgae. Polychaete annelids (including Capitellidae) and oligochaetes were their most important prey; combined, they provided 87 percent of the total IRI (Fig. 12). Gammarid amphipods, nematodes, gastropods, and bivalves were of secondary importance.

Amphipods dominated the diet of high cockscombs at Amchitka Island (Simenstad et al. 1977).

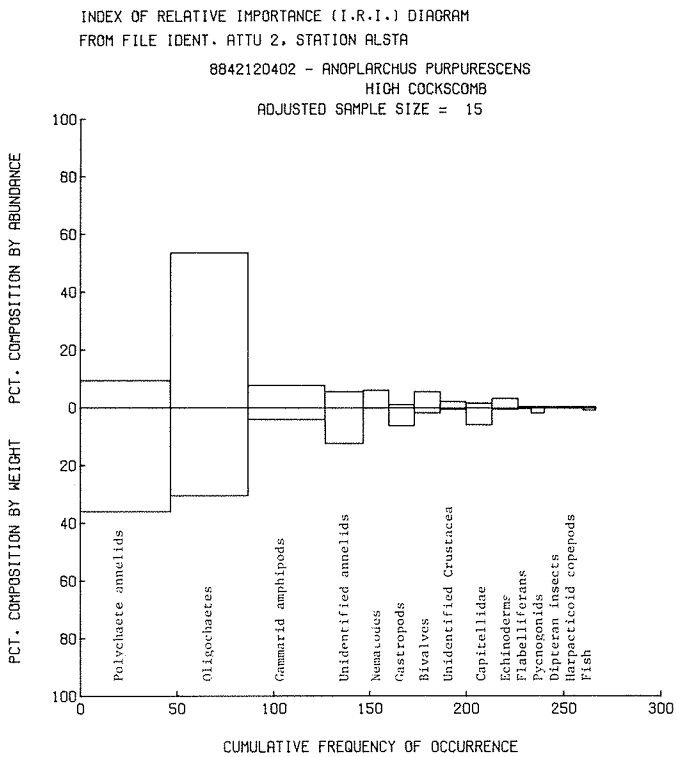
Pholis laeta, Crescent Gunnel

Another common tidepool fish, crescent gunnels from the 1977 collections fed primarily upon harpacticoid copepods (63 percent frequency occurrence, 71 percent total number of prey) but which only comprised a small proportion (8 percent) of the total prey biomass. Gammarid amphipods, polychaete annelids, and unidentified fish and crustaceans, though neither as numerous nor as common, formed most of the prey biomass.

The few crescent gunnels examined from the 1976 Attu collections and from Amchitka had consumed more gammarid amphipods and idoteid isopods.

Ammodytes hexapterus, Pacific Sand Lance

Cyclopoid copepods were both numerically (96 percent) and gravimetrically (85 percent) the most important prey for Pacific sand lance captured at Casco Cove; gammarid amphipods provided most of the remaining prey biomass. This dietary composition differs from Pacific sand lance caught at Sarana Bay in 1976, which had consumed principally harpacticoid and calanoid copepods and larvaceans (Simenstad and Nakatani 1977), and those at Amchitka, which fed almost exclusively upon calanoid copepods (Simenstad et al. 1977).



Prey item	Freq. of occurrence	Numerical composition	Gravimetric composition	Prey I.R.I.	% Total I.R.I.
Polychaeta	46.67	9.50	36.00	2123.1	31.13
Oligochaeta	40.00	53.63	30.43	3362.3	49.29
Gammaridae	40.00	7.82	4.09	476.6	6.99
Annelida	20.00	5.59	12.21	356.0	5.22
Nematoda	13.33	6.15	0.04	82.5	1.21
Prosobranchia-Gastropoda	13.33	1.12	6.21	97.7	1.43
Bivalvia	13.33	5.59	1.71	97.3	1.43
Crustacea	13.33	2.23	0.45	35.8	0.52
Capitellidae	13.33	1.68	5.79	99.5	1.46
Echinodermata	13.33	3.35	0.43	50.4	0.74
Flabellifera	6.67	0.56	0.21	5.2	0.08
Pycnogonidae	6.67	0.56	1.71	15.2	0.22
Diptera	6.67	0.56	0.02	3.9	0.06
Harpacticoida	6.67	0.56	0.02	3.9	0.06
Teleostei	6.67	0.56	0.02	3.9	0.06
Unid.	6.67	0.56	0.64	8.0	0.12

Fig. 12. Prey spectrum of high cockscomb, Attu Island, Alaska, July-August 1977.

Platichthys stellatus, Starry Flounder

The stomach of the only adult starry flounder caught in 1977 contained two gammarid amphipods. Starry flounder were not examined in 1976 and were not found at Amchitka at all.

Hippoglossus stenolepis, Pacific Halibut

Four Pacific halibut stomachs contained unidentified fish which comprised 57 percent of the total prey numbers and 99 percent of the prey biomass. Unidentifiable bivalves comprised the remaining prey items. No Pacific halibut stomachs were examined in 1976. Pacific halibut found in Amchitka's inshore waters also fed primarily upon fish (*L. bilineata, G. galeatus*, and *A. hexapterus*) secondarily upon brachyuran and lithodid crabs (Simenstad et al. 1977).

Attu Island Nearshore Food Web

A preliminary representation of the food web structure among dominant members of Attu's nearshore fish community was assembled from the 2 years of stomach contents analyses (Fig. 13). Although this may not be strictly comparable to the results from the 7 years of extensive research at Amchitka, several differences in the prey resources and trophic flow are evident between the two nearshore communities.

The most obvious difference between the food web structure of Amchitka's nearshore fish community (Simenstad, Isakson and Nakatani 1977, Fig. 8b) and the food web structure at Attu is the higher contribution by brachyuran and anomuran crabs which made no contribution to any fish occupying the nearshore, rock-algae habitat at Amchitka. Pacific cod and Pacific halibut were the only nearshore fish at Amchitka to feed on crabs, and then only incidentally ($<$ 25 percent total prey biomass) upon two large crabs, *T. cheiragonus* and *Chionoecetes bairdi*. At Attu, however, the dominant members of the rocky, shallow sublittoral habitat--

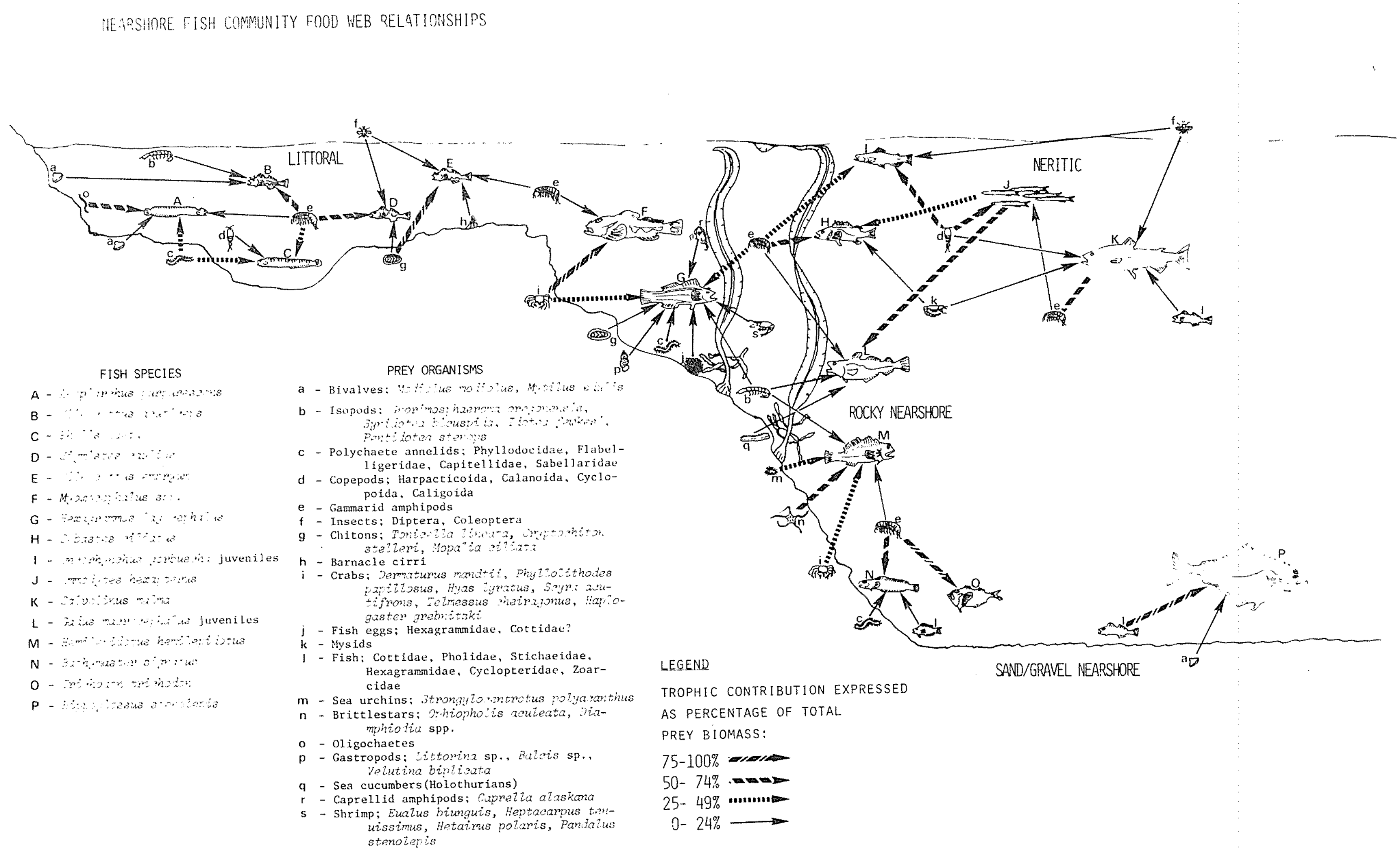


Fig. 13. Food web relationships among dominant nearshore fishes at Attu Island, Alaska.

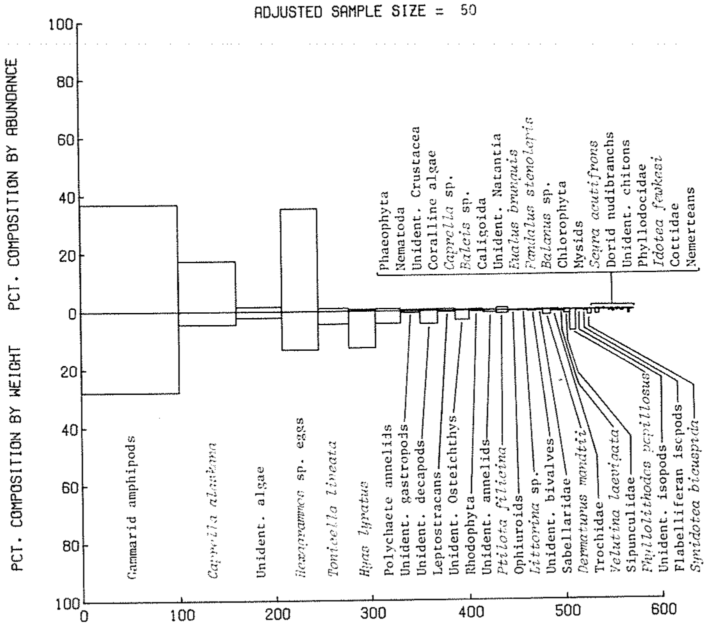
rock greenling, red Irish lord and *Myoxocephalus* sp. sculpins--fed upon small crabs (listed on Fig. 13) to a significant degree. Although still a common prey organism for many fish, gammarid amphipods did not appear to contribute to nearshore fish diets at Attu in the proportion they had at Amchitka; similarly, mysids were not an important food resource for many fish.

Measurement of Trophic Diversity Using Rock Greenling Prey Spectra

Hurtubia (1973) described the use of prey composition of generalistic predators to measure trophic diversity, treating each stomach as a sampling unit synonymous to a randomly placed quadrat or bottom grab. Rock greenling, because they feed opportunistically in a "grazing" manner upon benthic and epibenthic macroinvertebrates (Simenstad 1971), represent a predator aptly suited to Hurtubia's analysis. Although competition for food resources between sea otters and rock greenling probably is not significant, it could be hypothesized that the variable densities of sea otters in Attu's nearshore waters indirectly determine the composition and diversity of the epibenthic fauna available as prey to rock greenling. Potential indirect effects of sea otter predation on rock greenling prey resources predation could include: a) reduction of spawning stocks of adult macroinvertebrates reducing recruitment of juveniles; b) reduction of herbivore populations, releasing macroalgae guilds to dominate shallow sublittoral substrate space to the detriment of some invertebrate assemblages; c) increased habitat for rock greenling to lay their eggs; and d) increased algal detritus input into the near-shore environs which, in turn, supports higher populations of detritus-utilizing macrocrustaceans such as mysids and gammarid amphipods.

The quantitative composition of rock greenling diets from the Chichagof Harbor and Massacre Bay areas of Attu is illustrated in Figs. 14 and 15, respectively, and summarized by major prey taxa in Table 8. Results of this comparison lend support to the hypothesis in that: 1) anomuran crabs and unidentifiable decapods were more important in Massacre Bay greenling diets; 2) gammarid and caprellid amphipods were

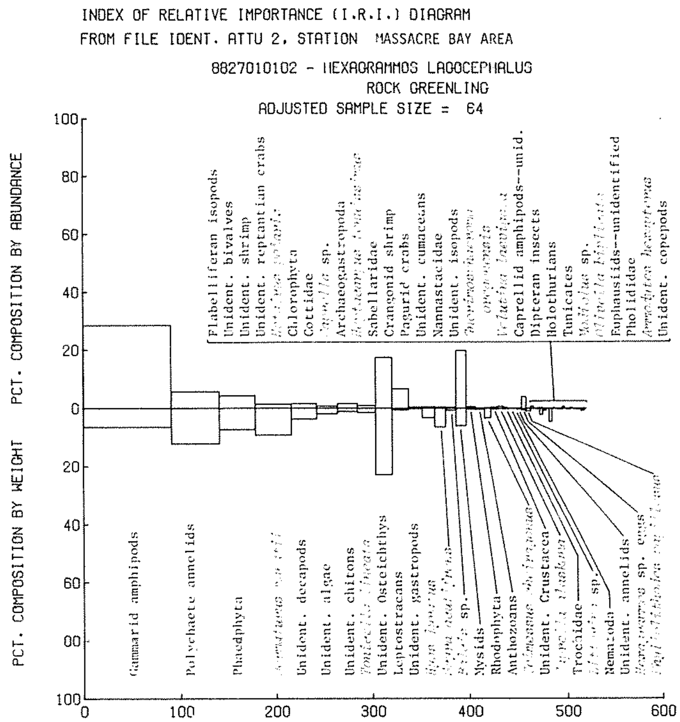
INDEX OF RELATIVE IMPORTANCE (I.R.I.) DIAGRAM
FROM FILE IDENT. ATTU 2, STATION CHICHAGOF HARBOR AREA
8827010102 - HEXAGRAMMOS LAGOCEPHALUS
ROCK GREENLING
ADJUSTED SAMPLE SIZE = 50



CUMULATIVE FREQUENCY OF OCCURRENCE

Prey item	Freq. of occurrence	Numerical composition	Gravimetric composition	Prey I.R.I.	% Total I.R.I.
Gammaridae	100.00	36.99	27.87	6486.7	59.73
Caprella alaskana	60.00	17.45	4.53	1318.6	12.14
Unid. algae	48.00	1.70	2.15	184.6	1.70
Hexagrammidae eggs	38.00	35.44	13.30	1852.3	17.06
Tonicella lineata	32.00	1.06	4.49	177.6	1.64
Hyas lyratus	28.00	0.60	12.72	372.9	3.43
Polychaeta	26.00	0.78	4.33	132.7	1.22
Prosobranchia-Gastropoda	20.00	0.32	0.61	18.5	0.17
Eucarida-Decapoda	18.00	0.49	4.56	91.0	0.84
Malacostraca phyllocarida	18.00	0.57	0.40	17.3	0.16
Teleostei	14.00	0.28	3.20	48.8	0.45
Rhodophyta	14.00	0.49	0.24	10.3	0.09
Annelida	14.00	0.21	0.69	12.7	0.12
Ptilota filicina	12.00	0.92	0.93	22.2	0.20
Ophiuroida	10.00	0.09	0.11	2.0	0.02
Littorina sp.	10.00	0.14	0.20	3.4	0.03
Bivalvia	8.00	0.09	0.31	3.2	0.03
Sabellaridae	8.00	0.18	0.19	2.9	0.03
Dermaturus mandti	8.00	0.11	1.59	13.5	0.12
Trochidae	8.00	0.25	0.40	5.1	0.05
Velutina laevigata	6.00	0.05	0.50	3.3	0.03
Sipunculidae	6.00	0.12	1.14	7.6	0.07
Phyllolithodes papillosus	6.00	0.09	7.24	44.0	0.40
Isopoda	4.00	0.12	0.18	1.2	0.01
Flabellifera	4.00	0.04	0.07	0.4	0.00
Synidotea bicuspida	4.00	0.05	0.43	2.0	0.02
Phaeophyta	4.00	0.16	1.70	7.4	0.07
Nematoda	4.00	0.04	0.00	0.2	0.00
Crustacea	4.00	0.19	1.46	6.6	0.06
Corallinacea	4.00	0.11	0.09	0.8	0.01
Caprella sp.	2.00	0.28	0.04	0.7	0.01
Balcis sp.	2.00	0.02	0.01	0.1	0.00
Caligoida	2.00	0.07	0.01	0.2	0.00
Natantia	2.00	0.04	0.45	1.0	0.01
Eualus biunguis	2.00	0.02	0.28	0.6	0.01
Pandalus stenolepis	2.00	0.02	0.78	1.6	0.01
Balanus sp.	2.00	0.02	0.01	0.1	0.00
Chlorophyta	2.00	0.21	0.36	1.1	0.01
Mysidacea	2.00	0.04	0.03	0.1	0.00
Scyra acutifrons	2.00	0.02	0.42	0.9	0.01
Nudibranchia-Doridoidea	2.00	0.02	0.40	0.8	0.01
Polyplacophora	2.00	0.02	0.02	0.1	0.00
Phyllodocidae	2.00	0.04	0.01	0.1	0.00
Idotea fewkesi	2.00	0.05	1.44	3.0	0.03
Cottidae	2.00	0.02	0.15	0.3	0.00
Nemertea	2.00	0.02	0.00	0.0	0.00

Fig. 14. Prey spectrum of rock greenling captured in the Chichagof Harbor area of Attu Island, Alaska, 1977.



Prey item	Freq. of occurrence	Numerical composition	Gravimetric composition	Prey I.R.I.	% Total I.R.I.
Gammaridae	90.63	28.56	6.52	3179.6	48.50
Polychaeta	50.00	5.64	12.20	891.8	13.60
Phaeophyta	37.50	4.29	7.35	436.5	6.66
Dermaturus mandti	37.50	1.37	9.27	399.1	6.09
Eucarida-Decapoda	26.56	1.54	3.73	140.1	2.14
Unid. algae	21.88	0.75	1.94	58.7	0.90
Polyplacophora	20.31	1.61	1.16	56.3	0.86
Tonicella lineata	18.75	0.94	1.46	45.0	0.69
Teleostei	17.19	17.44	22.84	692.3	10.56
Malacostraca phyllocarida	17.19	6.67	0.54	123.9	1.89
Prosobranchia-Gastropoda	14.06	0.39	0.12	7.1	0.11
Hyas lyratus	12.50	0.48	3.22	46.2	0.70
Scyra acutifrons	10.94	0.43	6.46	75.4	1.15
Balcis sp.	10.94	0.36	0.65	11.1	0.17
Mysidacea	10.94	19.82	6.06	283.1	4.32
Rhodophyta	9.38	0.51	0.33	7.8	0.12
Anthozoa	9.38	0.14	0.35	4.6	0.07
Telmessus cheiragonus	6.25	0.22	3.24	21.6	0.33
Crustacea	6.25	0.39	0.35	4.6	0.07
Caprella alaskana	6.25	0.65	0.09	4.6	0.07
Trochidae	4.69	0.39	0.12	2.4	0.04
Littorina sp.	4.69	0.10	0.06	0.7	0.01
Nematoda	4.69	0.07	0.00	0.3	0.01
Annelida	4.69	0.12	0.23	1.6	0.02
Hexagrammidae	4.69	4.05	0.51	21.4	0.33
Phyllolithodes papillosus	4.69	0.10	0.96	4.9	0.08
Flabelligeridae	3.13	0.75	0.09	2.6	0.04
Bivalvia	3.13	0.05	0.02	0.2	0.00
Natantia	3.13	0.14	0.13	0.9	0.01
Reptantia	3.13	0.19	2.16	7.3	0.11
Hetairus polaris	3.13	0.10	0.74	2.6	0.04
Chlorophyta	3.13	0.05	0.07	0.4	0.01
Cottidae	3.13	0.07	4.57	14.5	0.22
Caprella sp.	3.13	0.14	0.00	0.5	0.01
Archaeogastropoda	1.56	0.05	0.03	0.1	0.00
Heptacarpus tenuissimus	1.56	0.02	0.16	0.3	0.00
Sabellaridae	1.56	0.05	0.00	0.1	0.00
Crangonidae	1.56	0.05	0.15	0.3	0.00
Paguridae	1.56	0.02	0.06	0.1	0.00
Cumacea	1.56	0.65	0.06	1.1	0.02
Nannastacidae	1.56	0.02	0.00	0.0	0.00
Isopoda	1.56	0.05	0.06	0.2	0.00
Gnorimosphaeroma oregonensis	1.56	0.05	0.04	0.1	0.00
Velutina laevigata	1.56	0.07	0.04	0.2	0.00
Caprellidae	1.56	0.24	0.02	0.4	0.01
Diptera	1.56	0.02	0.00	0.0	0.00
Holothuroidea	1.56	0.02	0.12	0.2	0.00
Urochordata	1.56	0.02	0.06	0.1	0.00
Modiolus sp.	1.56	0.02	0.12	0.2	0.00
Olivella biplicata	1.56	0.02	0.14	0.3	0.00
Euphausiacea	1.56	0.02	0.13	0.2	0.00
Pholididae	1.56	0.02	0.69	1.1	0.02
Ammodytes hexapterus	1.56	0.02	0.60	1.0	0.01
Copepoda	1.56	0.02	0.00	0.0	0.00

Fig. 15. Prey spectrum of rock greenling captured in Massacre Bay area of Attu Island, Alaska, 1977.

Table 8. Quantitative contribution of major prey taxa to the diets of rock greenling in the Chichagof Harbor and Massacre Bay areas of Attu Island, Alaska, 1977.

	Gammarid Amphipods	Caprellid Amphipods	Algae	Fish Eggs	Chitons	Brachyuran Crabs	Annelids	Gastropods	Unidentifiable Decapods	Leptostracans	Fish	Ophiuroids	Bivalves	Anomuran Crabs	Sipunculids	Isopods	Unidentifiable Crustacea	Shrimp	Mysids	Anthozoans
Chichagof Harbor Region n = 50																				
Max. F.O.	100.00	60.00	98.00	38.00	32.00	28.00	26.00	20.00	18.00	18.00	14.00	10.00	8.00	8.00	6.00	4.00	4.00	2.00	2.00	0.00
% Abundance	36.99	17.73	5.02	35.44	1.08	0.62	1.21	0.80	0.49	0.57	0.30	0.09	0.09	0.20	0.12	0.26	0.19	0.08	0.04	0.00
% Biomass	27.87	4.57	11.08	13.30	4.51	13.14	5.22	2.12	4.56	0.40	3.35	0.11	0.31	20.74	1.14	2.12	1.46	1.51	0.03	0.00
% Total IRI	59.73	12.15	2.07	17.06	1.74	3.44	4.29	0.39	0.84	0.16	0.45	0.02	0.03	0.52	0.07	0.06	0.06	0.03	0.00	0.00
Massacre Bay Region n = 64																				
Max. F.O.	90.63	6.25	37.50	4.69	20.81	12.50	50.00	14.06	26.56	17.19	17.19	0.00	3.13	37.50	0.00	3.13	6.25	3.13	10.94	9.38
% Abundance	28.56	1.03	5.60	4.05	2.55	1.13	5.81	1.38	1.54	6.67	17.55	0.00	0.07	1.49	0.00	0.85	0.58	0.31	19.82	0.14
% Biomass	6.52	0.11	9.69	0.51	2.62	12.92	12.43	0.16	3.73	0.54	28.70	0.00	0.14	10.29	0.00	0.19	2.51	1.18	6.06	0.35
% Total IRI	48.50	0.09	7.69	0.33	1.55	2.18	13.62	0.33	2.14	1.89	12.88	0.00	0.00	6.17	0.00	0.04	0.18	0.05	4.32	0.07

somewhat more important in the Chichagof Harbor greenling diets; and 3) eggs of rock greenling were also more prevalent in the Chichagof Harbor greenling diets. There were some inconsistencies; brachyuran crabs were approximately equally represented in both prey spectra and mysids were more prevalent in Massacre Bay greenling diets.

Rock greenling diets from the two areas were noticeably different both in terms of the richness of the prey taxa (measured by S, the total number of prey categories including different life history stages), and the diversity and evenness; however, the diversity and evenness of the prey biomass were similar (Table 9). In all cases, the diets of rock greenling in the vicinity of Chichagof Harbor were less diverse. Because of the patchy nature of prey populations, total diversity of the prey population can be estimated by pooling stomachs at random, one at a time, until reaching a stability point, t (Hurtubia 1973), and the average stomach contents diversity values computed by pooling data after H_t. This method, as applied to the Attu rock greenling stomach samples, suggests differences in the prey diversity in the regions with and without sea otters (Fig. 16). The apparent asymptotes and t values appear close to the end of the curves; thus, a slight change in diversity may occur beyond those values. Setting the apparent values of t = 46 for Chichagof Harbor and t = 61 for Massacre Bay, the corresponding H_p values are 2.51 and 3.55, respectively; corresponding niche breadth values, H_p/H_{max}, are 0.59 for Chichagof Harbor and 0.79 for Massacre Bay.

Curves of the mean number of prey organisms per stomach versus the pooled number of stomachs (Fig. 16), suggest that, despite a less diverse prey spectra, rock greenling in the Chichagof Harbor region had consumed more organisms per individual than did those about Massacre Bay. As the greenling at Massacre Bay were slightly larger than those at Chichagof Harbor, these differences cannot be accounted for by a positive predator size-ration size relationship and may therefore reflect inherent differences in the epibenthic prey communities available to rock greenling in the two areas.

Table 9. Diversity values for prey spectra of Massacre Bay and Chichagof Harbor rock greenling, 1977.

	Massacre Bay	Chichagof Harbor
Sample size, n	64	50
Diversity		
Number of prey categories, S	89	70
Shannon-Wiener diversity indices, H"		
Abundance	3.61	2.51
Biomass	4.61	4.23
Brillouin diversity index, H	3.56	2.47
Evenness		
Shannon-Wiener		
Abundance	0.80	0.59
Biomass	1.03	1.00
Brillouin	0.79	0.58

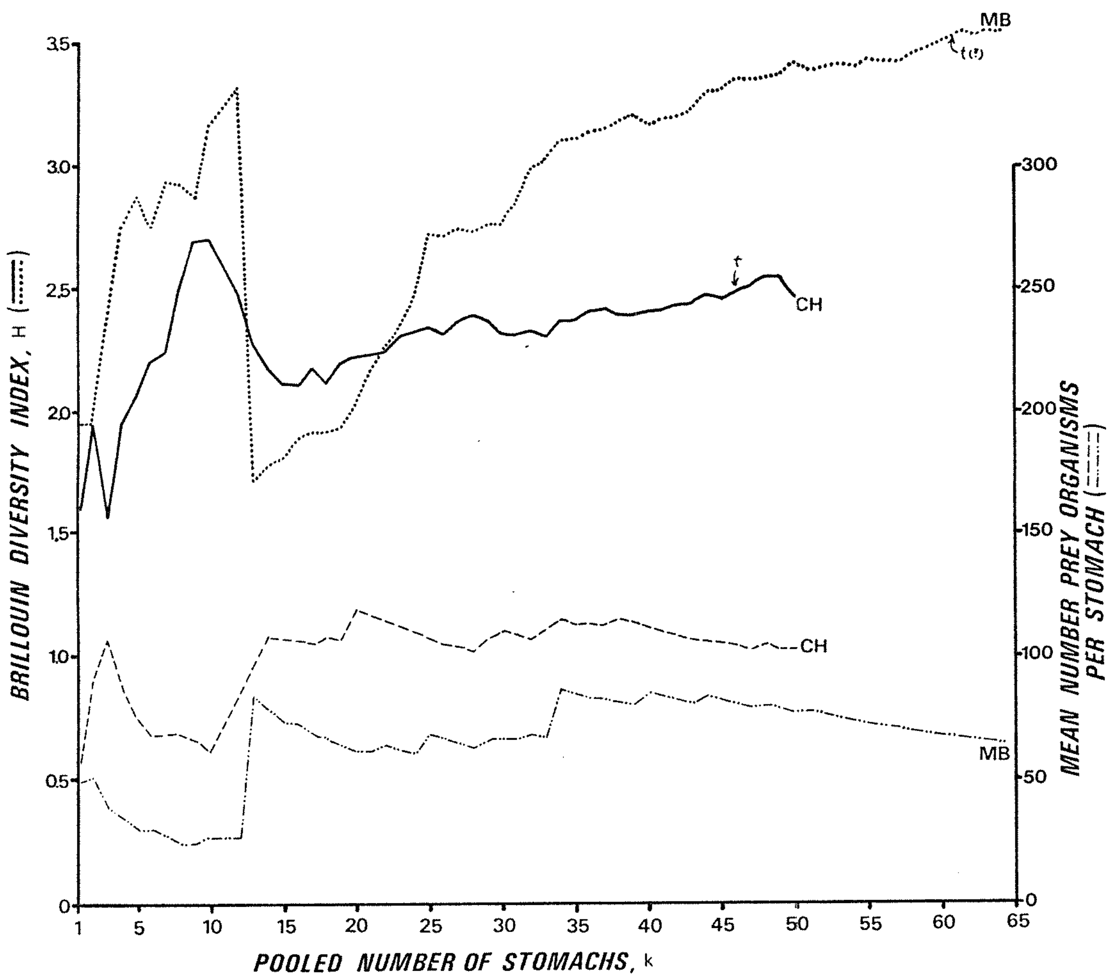


Fig. 16. Curves of Brillouin diversity index, H and mean number prey organisms per stomach versus the number of pooled stomachs for rock greenling at Massacre Bay (MB) and Chichagof Harbor (CH), Attu Island, Alaska, 1977. The point t shows the pooled number of stomachs necessary to stabilize the curves.

DISCUSSION

Although the taxonomic compositions of the nearshore fish communities at Amchitka compared to the two regions sampled at Attu are not dramatically different, the density of nearshore fish is significantly higher at Amchitka. These conclusions are based upon CPUE data from trammel net sampling. Actual estimates of density and standing crop, however, are extremely difficult to obtain from this type of sampling because the effective fishing area of the net cannot be readily estimated. With some estimate of the effective area sampled by the trammel net, catches of the dominant nearshore species, rock greenling, could potentially be utilized to compare nearshore fish productivity at the different habitats and islands under different sea otter predation regimes.

Two tasks proposed for 1978 will help estimate greenling abundance and biomass per unit area. One would be quantitative SCUBA-diver observation along subtidal transects (Miller et al. 1977, and Moulton 1977); however, this may be difficult because of the greenling's ability to hide in the algal understory, thus preventing an accurate visual estimate of the total greenling available to the set net. A second experiment, though more complicated, would provide a direct calibration of the fishing power of the net, assuming that rock greenling are relatively territorial (Simenstad 1971). A trammel net will be fished daily for short periods of time (2 hours), and the rock greenling caught will be measured, tagged, and released. When the catches began to contain a consistent percentage of tagged fish, it may be assumed that the greenling within that net's effective fishing area were adequately marked. At this time a second net will be set at varying distances from the primary trammel net location with the idea that the largest distance producing tagged fish in the adjacent net's catches is the limit of the net's fishing range, assuming low tag loss, tagging mortality, and alteration in behavior of tagged fish. This will depend on random directional movement of greenling around the sampling site, so it would be necessary to fish the second net in several different directions from the initial net.

A positive relationship between rocky nearshore fish and the *Alaria* kelp bed habitat in the Aleutians is apparent from the difference between fish catches within and without the kelp beds. Studies by Quast (1968), Leaman (1976) and Moulton (1977) suggest that the relationship between rocky nearshore fish assemblages and kelp beds in the northeastern Pacific is not strong. At this time, however, there has not been a successful experiment to test this relationship nor the integrity of the fish populations associated with specific kelp bed habitat. Such an experiment was attempted in July 1977 but was stopped because of inclement weather, and will be attempted again in summer 1978. The experiment involves choosing two distinct but adjacent kelp patches to be continuously sampled with trammel nets and the captured rock greenling measured, tagged, and released. If a reasonably high and constant ratio of tagged to untagged fish is attained, it will be assumed that the greenling occupying the kelp patches are adequately marked. At that time SCUBA-equipped divers will manually remove all algae from one kelp patch by cutting them free at the holdfasts. Trammel net sampling will continue at both sites to document: 1) differences in rock greenling CPUE between the experimental (cleared) and control sites; and 2) appearance of tagged greenling from the experimental site in the catches at the control site. SCUBA transect surveys will also be conducted to see if greenling are actually reduced in abundance or just better able to detect the nets. Results of these experiments will help establish the importance of physical habitat to the standing stock of Aleutian nearshore fishes.

The potential impact of sea otter predation upon the population structure of rock greenling has only recently been determined. The implications of the size selective predation, which is evident even between the two sampling areas at Attu, involve both a threshold limit to the standing stock of greenling and, given any food density-dependent limitation, increased production from an age structure limited to younger, faster growing fish. This effect is analogous to the effect of maximizing yield by regulated fishing of a stock of fish compared to an unexploited stock. Age structure data from Amchitka have provided an estimate of total mortality, which includes both "natural" mortality and that imposed by sea otter predation ("fishing" mortality). Age data gathered at Attu during the next field season will enable us to estimate the "natural" mortality component under no sea otter predation pressure (Massacre Bay) and under increasing predation (Chichagof Harbor). The complicated interactions between increasing sea otter predation upon rock greenling and an expanding kelp bed habitat and subsequently increasing detritus food base must be considered when evaluating the total impact of the return of the sea otter to Attu's nearshore community.

The Attu versus Amchitka food web analysis and the utilization of rock greenling diet spectra as an indication of the diversity and availability of small benthic and epibenthic macroinvertebrates have shown some surprising differences which may be attributed to shallow sublittoral community changes caused by the resurgence of the sea otter in the western Aleutians. Larger sample sizes of rock greenling will be required from Attu in the next field season in order to confirm the asymptotic level of the prey diversity curves. An ultimate goal would be to return to Amchitka Island and obtain corresponding greenling stomach samples which we could analyze in the same way as we have the Attu samples. At this stage, however, it appears that the trophic resource base of rock greenling at Amchitka and Attu are quite different and that more subtle differences exist in areas of sea otter abundance at Attu, despite the short time since the otter appeared there.

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APPENDICES

Appendix Table 1. Fish species and number of each collected during nearshore fish sampling at Attu Island, Alaska, 1976 and 1977.

Scientific name	Common name	1976	1977
Class Osteichthys			
Order Salmoniformes	Salmon and trout		
Oncorhynchus gorbuscha Walbaum	Pink salmon juv.	3	227
O. kisutch Walbaum	Coho salmon juv.	9	
O. nerka Walbaum	Sockeye salmon juv.	356	
Salvelinus malma Walbaum	Dolly Varden juv.	15	6
Order Gadiformes			
Family Gadidae	Codfishes		
Gadus macrocephalus Tilesius	Pacific cod juv.	12	
Theragra chalcogramma Pallas	Walleye pollock juv.	1	14
Family Zoarcidae	Eelpouts		
Commandorella popovi (?)	--	34	3
Order Perciformes			
Family Trichodontidae	Sandfishes		
Trichodon trichodon Tilesius	Pacific sandfish		1
Family Bathymasteridae	Ronquils		
Bathymaster caeruleofasciatus Gilbert and Burke	Alaskan ronquil		2
B. signatus Cope	Searcher	5	2
Family Stichaeidae	Pricklebacks		
Alectrias alectrolophus Pallas	Stone cockscomb	3	
Anoplarchus purpurescens Gill	High cockscomb	10	30
A. insignius Gilbert and Burke	Slender cockscomb		1
Phytichthys chirus Jordan and Gilbert	Ribbon prickleback	4	2
Family Pholidae	Gunnels		
Pholis laeta Cope	Crescent gunnel	10	36
Family Ammodytidae	Sand lances		
Ammodytes hexapterus Pallas	Pacific sand lance	1550	19
Family Hexagrammidae	Greenlings		
Hexagrammos lagocephalus Pallas	Rock greenling	104	189
Pleurogrammus monopterygius Pallas	Atka mackerel	2	
Family Scorpaenidae	Scorpion fishes		
Sebastes ciliatus Tilesius	Dusky rockfish		13
Family Cottidae	Sculpins		
Blepsias cirrhosus Pallas	Silverspotted sculpin		5
Clinocottus acuticeps Gilbert	Sharpnose sculpin	1	12
C. embryum Jordan and Starks	Calico sculpin	35	13
Enophrys diceraus Pallas	Antlered sculpin	3	1
Gymnocanthus sp.	Juveniles		66
Hemilepidotus hemilepidotus Tilesius	Red Irish lord	9	7
Myoxocephalus polyacanthocephalus Pallas	Great sculpin	73	30
M. verrocosus (?)	Warty sculpin (Russ.)		14

Appendix Table 1. Fish species and number of each collected during nearshore fish sampling at Attu Island, Alaska, 1976 and 1977, continued

Scientific name	Common name	1976	1977
Oligocottus maculosos Girard	Tidepool sculpin		7
Porocottus bradfordi Rutter	--	4	
Sigmistes caulias Rutter	Kelp sculpin	26	7
Triglops pingeli Reinhardt	Ribbed sculpin	2	
Family Agonidae	Poachers		
Pallasina barbata Steindachner	Tubenose poacher	3	1
Unidentified, possibly *Aspidophoroides bartoni*			24
Family Cyclopteridae	Lumpfishes and snailfishes		
Liparis callyodon Pallas		44	53
Family Pleuronectidae	Righteye flounders		
Hippoglossus stenolepis Schmidt	Pacific halibut	3	17
Lepidopsetta bilineata Ayres	Rock sole	6	65
Platichthys stellatus Pallas	Starry flounder	1	1

Appendix Table 2. Epibenthic macroinvertebrates collected incidentally during nearshore fish collections, Attu Island, 1977 and 1978.

	1976	1977	Amchitka
Class Amphineura			
Cryptochiton stelleri Middendorff		x	x
Schizoplax sp.	x		x
Class Gastropoda			
Fusitriton oregonensis Redfield	x		x
Class Malocostraca			
Order Decapoda			
Suborder Natantia			
Argis crassa Rathbun		x	
Crangon alaskensis Lockington		x	
Eualus pusiolus Kroyer		x	
Heptacarpus flexus Rathbun		x	
Spirontocaris polaris		x	
S. spina Sowerby		x	
Suborder Reptantia			
Section Anomura			
Dermaturus mandti Brandt	x	x	x
Cryptlithodes typicus Brandt		x	x
Elassochirus tenuimanus Miers	x	x	x
Hapalogaster grebnitzki Schalfeew	x		x
Phyllolithodes papillosus Brandt	x	x	
Unidentified Lithodidae		x	
Section Brachyura			
Cancer oregonensis Dana		x	x
Chionoectes bairdi Rathbun	x	x	x
Erimacrus eisenbecki Brandt	x		x
Hyas lyratus Dana	x	x	
Oregonia gracilis Dana	x	x	x
Scyra acutifrons Dana	x	x	
Telmessus cheiragonus Tilesius	x	x	x
Class Cephalopoda			
Order Octopoda			
Octopus dofleini Wulker	x	x	x
Class Asteroidea			
Ceramaster arcticus		x	
Crossaster diamesus		x	
C. papposus Linnaeus	x	x	
Evasterias troscheli Stimpson	x	x	
Henricia leviuscula Stimpson	x	x	x
Leptasterias alaskensis Verrill	x	x	x
L. groenlandica	x	x	
Pisaster brevispinus Stimpson		x	
Solaster sp.		x	
Class Echinoidea			
Dendraster excentricus Eschscholtz		x	x
Strongylocentrotus polyacanthus Agassiz & Clark	x	x	x
Class Holothuroidea			
Cucumaria sp.	x		?

Appendix Table 3. Principal prey taxa of nearshore fishes collected at Attu Island, Alaska, July-August 1977. Top value is percent frequency of occurrence, second value is percent numerical composition, and third value down is percent gravimetric composition. Unidentifiable and digested material was not included.

	Sample size, n	Algae	Anthozoans	Nemerteans	Nematodes	Polychaeta annelids	Oligochaetes	Pycnogonids	Unidentified gastropods	Snails	Nudibranchs	Chitons	Bivalves	Bivalve larvae	Unidentified crustaceans	Barnacles	Ostracods	Unidentified copepods	Harpacticoid copepods	Calanoid copepods	Caligoid copepod eggs	Cyclopoid copepods
Oncorhynchus gorbuscha	23	4.30 0.06 0.01				4.30 0.03 0.01											30.40 0.90 0.09		4.30 0.03 0.01	100.00 96.51 50.31		
Salvelinus malma	4																					
Sebastes ciliatus	13				7.70 0.06 0.01	7.70 0.06 0.09									7.70 0.06 0.01							
Hexagrammos lagocephalus	114	22.80 3.14 6.46	2.60 0.06 0.24	0.90 0.01 0.01	4.40 0.05 0.01	33.09 3.46 10.39			4.40 0.36 0.27	5.30 0.65 1.02	0.90 0.01 0.11	18.40 1.69 3.17	4.40 0.08 0.18		17.50 3.43 1.17	0.90 0.01 0.01		0.90 0.01 0.01			0.90 0.04 0.01	
Clinocottus acuticeps	6												16.67 7.89 12.99	16.67 5.26 3.30								
Clinocottus embryum	7								14.30 0.40 0.19	14.30 0.40 0.02		42.90 6.00 91.64				57.10 83.60 1.96						
Enophrys diceraus	1	100.00 50.00 11.68																				
Hemilepidotus hemilepidotus	1	100.00 4.35 0.46																				
Myoxocephalus polyacanthocephalus	4					25.00 1.11 0.13				25.00 1.11 0.01												
Myoxocephalus verrucosus	6	16.67 1.56 0.29											16.67 3.12 0.19		16.67 1.56 0.01							
Sigmistes caulias	5											20.00 2.00 12.99	20.00 1.00 2.00		40.00 13.00 5.00	20.00 75.00 3.00						
Trichodon trichodon	1																					
Anoplarchus insignis	1					100.00 100.00 100.00																
Anoplarchus purpurescens	15				13.30 6.15 0.04	26.67 16.77 54.00	13.33 53.63 30.42	6.67 0.56 1.71	6.67 1.12 6.21				13.33 5.59 1.71		6.67 2.24 0.45				6.67 0.56 0.02			
Pholis laeta	8	12.50 0.55 0.63				12.50 0.55 42.90									25.00 9.84 10.09		12.50 0.55 0.06		62.50 71.04 7.76			
Ammodytes hexapterus	8														12.50 0.41 4.98							12.50 95.53 84.72
Platichthys stellatus	1																					
Hippoglossus stenolepis	4				25.00 14.29 0.01								25.00 28.57 1.09									

	Mysids	Cumaceans	Isopods	Gammarid amphipods	Caprellid amphipods	Euphausiids	Unidentified decapods	Shrimp	Hermit crabs	Crabs	Insects	Sipunculids	Unidentified echinoderm parts	Sea cucumbers	Brittlestars	Sea urchins	Tunicates	Fish	Fish eggs
Oncorhynchus gorbuscha		26.10 0.19 0.08		47.80 1.78 45.04	4.30 0.03 0.13						34.80 0.44 4.31								
Salvelinus malma	25.00 8.76 4.64	50.00 2.14 1.38		50.00 88.68 71.66							25.00 0.21 1.91							25.00 0.21 21.41	
Sebastes ciliatus	23.10 28.48 9.64			69.20 71.27 62.75														7.70 0.06 27.51	
Hexagrammos lagocephalus	4.40 8.40 4.11	0.90 0.29 0.04	2.60 0.19 0.68	59.60 33.42 12.70	15.80 10.67 1.41	0.90 0.01 0.09	19.30 0.94 3.98	2.60 0.17 1.27	0.90 0.01 0.04	17.50 1.65 24.33	1.80 0.07 0.03			0.90 0.01 0.08			0.90 0.01 0.04	8.80 0.47 20.61	19.30 29.29 4.95
Clinocottus acuticeps			33.33 7.89 10.39	66.70 78.95 72.72															
Clinocottus embryum				71.40 5.20 4.04							14.30 4.00 2.12								
Enophrys diceraus																100.00 50.00 88.32			
Hemilepidotus hemilepidotus															100.00 60.87 50.15	100.00 21.74 48.32			
Myoxocephalus polyacanthocephalus				75.00 20.00 0.60				25.00 1.11 0.50	25.00 1.11 0.36	25.00 65.56 90.01								25.00 3.33 1.64	
Myoxocephalus verrucosus				50.00 73.44 14.96						16.67 9.37 77.94								16.67 1.56 3.92	
Sigmistes caulias				40.00 2.00 68.93							20.00 7.00 8.09								
Trichodon trichodon		100.00 10.00 0.07		100.00 90.00 99.33															
Anoplarchus insignis																			
Anoplarchus purpurescens			6.67 0.56 0.21	26.67 7.82 4.10							6.67 0.56 0.02		13.33 3.35 0.43						6.67 0.57 0.02
Pholis laeta				37.50 15.29 29.66														12.50 0.55 8.20	
Ammodytes hexapterus				12.50 3.66 10.14	12.50 0.41 0.17														
Platichthys stellatus				100.00 100.00 100.00															
Hippoglossus stenolepis																		50.00 57.14 98.91	