A SURVEY FOR SPAWNING FORAGE FISH ON THE EAST SIDE OF THE KODIAK ARCHIPELAGO BY AIR AND B0AT DURING SPRING AND SUMMER 1979

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INTRODUCTION

General Nature and Scope of Study

This project was designed to study aspects of forage fish biology along the eastside of the Kodiak Archipelago from Afognak Island to Sitkinak Island. The results of the project contribute to the data base necessary for an environmental impact statement required by law prior to Outer Continental Shelf (OCS) lease sales.

Specific Objectives

1. Determine the temporal and spatial distribution of spawning by nearshore pelagic forage fishes. Determine age, weight and length relationships of these fish species.
2. Identify spawning substrate commonly used by herring, capelin and other species encountered.
3. Determine density of herring and capelin spawn on substrate.

Forage fish are here defined as herring (*Clupea harengus*), sand lance (*Ammodytes hexapterus*) and any smelt (Osmeridae), which in this area includes the capelin (*Mallotus villosus*), eulachon (*Thaleichthys pacificus*) and surf smelt (*Hypomesus pretiosus*).

Relevance to Problems of Petroleum Development

Concern has been expressed over the impact of petroleum development on all finfish resources in the northern Gulf of Alaska, including the Kodiak shelf. Large scale damage to the major forage fish species would probably affect the ecosystem drastically and adversely. This study was funded primarily to assess forage fish vulnerability during a critical time, the spawning period.

Acknowledgements

The following persons contributed to the project: Nell Tsakrios, Kelly Meeusen and Dora Sigurdsson assisted in all aspects of field work, and Meeusen did tabulation and graphic work; Spencer Shaw, with Flirite Airways, piloted all surveys; Winn Brindel, Superintendent of Lazy Bay Cannery, allowed field personnel use of his facility; Joe Terebaso assisted in many ways on Sitkinak Island; Leroy Blondin contributed eulachon specimens and catch information; Jerry McCrary and Jim Blackburn (ADF&G, Kodiak) and Dr. Bill Arvey (ADF&G, Anchorage) edited the final report; Mr. Duane French provided sand lance information.

STUDY AREA

The study area (Figure 1) lies along the eastern shore of the Kodiak Archipelago, within the western Gulf of Alaska. The archipelago consists of Kodiak, Afognak and ten minor islands, from Shytak at the north to Tugidak at the south, with thousands of small islands and rocks. It extends through 2°20′ of latitude and is 260 km long.

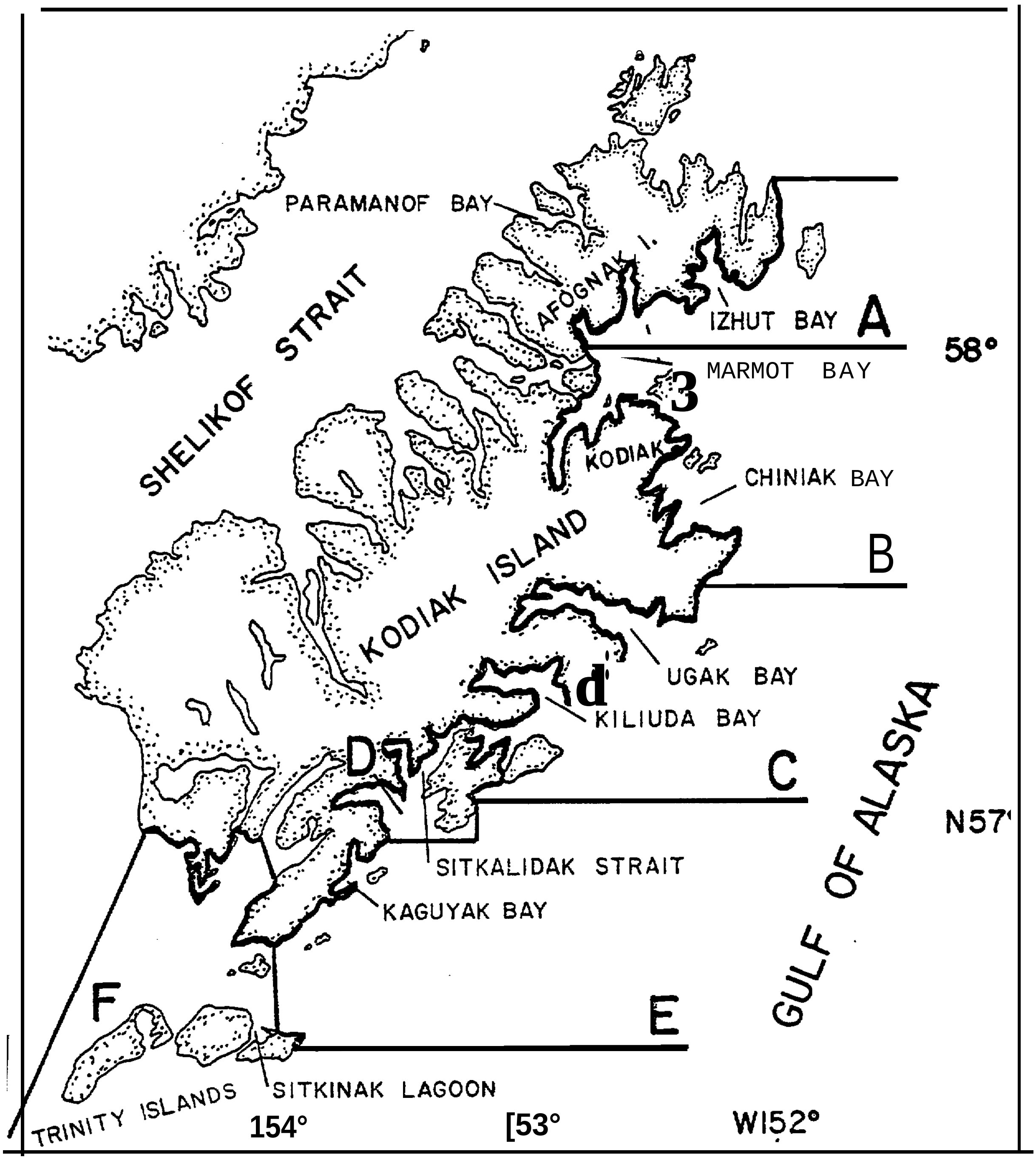


Figure 1. Kodiak Archipelago, Alaska. The study area for the 1979 OCS Forage Fish Project is outlined in black. Letters A-F represent census areas.

The coastline is convoluted with numerous bay systems. The 20meter (10 fathom) depth contour is generally within 2 - 4 km offshore, although in the Trinity Island group, it extends up to 16 km from shore. In most bays the bottom drops off sharply into troughs which are generally shallower than 200 m. There are numerous sheltered areas, which are advantageous for forage fish spawning. Eelgrass (Zostera marina) beds, common at the estuarine heads of bays throughout the study area, are important as shelter and substrate for spawning herring.

Although the Alaska Stream influences offshore currents, inshore currents along the east side of the archipelago are predominantly tidal, with velocities of 150 cm/sec or more, but with a vector average to the southwest of only 2.5 cm/sec (MacDonald 1979). Tidal amplitudes are in the range of 2 - 4 m. The tide usually floods to the north and ebbs to the south. Storms with high winds are common in the western Gulf of Alaska, especially in winter when sustained velocities can reach 50 to 75 knots (93 - 139 km/hr) with higher gusts. Wave action is severe. The effective fetch to the southwest is on the order of 1,850 km (1,000 nautical miles). Because of the dynamic nature of the water masses adjacent to this area, primary productivity is particularly high, hence conducive to the nurturing of a large biomass of forage fish.

CURRENT STATE OF KNOWLEDGE

Forage fish studies have been conducted by the ADF&G under OCSEAP funding since 1975. Initially the research area consisted of the southern and northeastern Bering Sea. Little was known about any aspect of northeastern Pacific and Bering Sea smelt at that time. In contrast to the smelt, a great deal of information concerning methods, natural history and basic biology existed for Pacific herring. Rounsefell (1929) worked extensively on the biology of herring in the northern Gulf of Alaska. In addition to Rounsefell, there was a wide literature base from three sources: 1) the British Columbia herring fishery, 2) studies in Puget Sound and 3) research and management materials from Southeastern and Southcentral Alaska. Herring fisheries have existed in these areas for nearly a century and it is beyond the scope of this contract to enter into an exhaustive literature review of this species.

There is no standing work on sand lance in the northeastern Pacific, outside of listing occurrence and length frequencies (Blackburn 1978; Harris and Hartt 1977). Various researchers have written on other populations of Ammodytes from around the world, and the best summary of life history information was given by Reay (1970). Trumble (1973) described the extensive commercial fisheries for sand lance in Europe and Japan, and mentioned that large, commercially-exploitable quantities probably exist in the northeastern Pacific, particularly the Gulf of Alaska.

Much has been written in the last decade on the impact of oil on herring and other marine fishes. Struhsaker (1977) exposed female herring to low levels of benzene, a soluble component of crude oils, and found that significant reduction occurred in survival of the ova, eggs, embryos and larvae. Exposure to benzene induced premature spawning, aberrant swimming behavior and disequilibrium in both sexes. Kuhnhold (1970) exposed cod, plaice and Atlantic herring to crude oils from different areas of the world and concluded that the effects on the eggs of these fish varied widely depending on the type of crude spilled. He observed that larvae of these species which remained in oil contaminated water had little chance of survival.

Mironov (1970) mentioned the highly toxic effects of oil pollution on marine fishes of the Black Sea, reiterating especially oil's adverse effects on eggs and larvae. Blumber (1969) stated that oil products are absorbed and incorporated into the lipids of fishes and cannot be readily eliminated as long as the animal lives.

The presence of forage fish species within the study area has been well documented during OCSEAP nearshore fish studies, (Blackburn 1978, Harris and Hartt 1977) and their importance as a food base for vertebrate predators has been established (Sanger, et. al. 1978; Baird and Hatch 1979; Krasnow et. al. 1979; Trumble 1973).

A short summary of life histories of forage fish occurring in the Kodiak Archipelago is presented in Table 1.

METHODS

Outline

There were several components to the study:

1) Aerial surveys to determine distribution and abundance of forage fish schools were flown by the project leader.

2) Ground surveys were conducted by two person teams which a) searched on extreme low tides for spawn deposited in areas of suitable intertidal habitat; b) captured forage fish in a number of ways and took length measurements and weights, collected otoliths and scales for ageing, and determined state of maturity by gonad examination.

3) Forage fish data were obtained from several sources other than fishing effort by ground crews: a) samples of herring were taken from commercial purse seine catches by the ground crews when the opportunity arose; b) fish samples were obtained from commercial shrimp trawl catches being unloaded at canneries; c) requests were placed in two newspapers and on two radio stations in the town of Kodiak from May 15 - May 31, asking that the public notify us of any forage fish spawning areas or activity known about or observed in the Kodiak vicinity.

Aerial Surveys

All aerial surveys began and ended in Kodiak City, which is in the northern third of the study area. The east side of the study area was divided into six aerial census areas, lettered A through F (Figure 1). The entire study area was never flown in a single survey due to observer fatigue and fuel limitations. Four to five hours of continuous observation was the maximum survey time. Survey routes were selected opportunistically depending upon weather conditions and logistic needs at the ground sites.

A Cessna 206 float plane was employed for all aerial surveys. Observations were made while flying along the shoreline at an altitude of 330 meters and a speed of 115 knots. Bays and points were rounded so that the actual distance flown was always greater than the straight line distance from the beginning to the end of each survey area. All schools were counted on the first "pass" of the day, a time lasting only a few minutes; this total count was the figure used for that day's survey. Length of survey area and fuel limitations were two elements which ruled out repeated "flybacks", except in those cases where direct counts and/or identification problems (e.g. is it a fish school, or a rock?) required more time than just the initial "pass" afforded the observer. The width of swath observed extended from the shore to approximately one kilometer offshore. The unit of analysis for aerial survey results is schools seen per kilometer flown, as in previous OCSEAP forage fish aerial surveys (Warner and Shafford 1979).

School sizes were broken into subjective categories: "small", "medium", and "large". Small schools are considered to be less than 5 metric tons in size, medium schools from 5 to 15 metric tons, and large schools greater than 15 metric tons. Observations were made through polarized sunglasses, and dictated into a cassette tape recorder. The data were later transcribed onto File Type 057 OCSEAP computer forms. A single flight was considered to be all aerial observations made during a calendar day.

Ground Surveys

Fish sampling and spawn surveys were conducted in five key areas within the study area: Izhut Bay, Chiniak/southern Marmot Bays, Sitkalidak Strait, Alitak Bay, and Sitkinak Lagoon. These key areas were chosen because of their accessibility and they adequately represent the northern, central and southern portions of the study area. There were two ground crews, each consisting of a biologist and a technician. One crew remained at Izhut Bay from May 5 to June 20, 1979. That crew returned to Kodiak town in late June and collected forage fish, primarily capelin, from shrimp trawl catches from Alitak Bay being unloaded at canneries. The other crew worked from Sitkalidak Island and vicinity from May 4 - June 3, in lower Alitak Bay and vicinity from June 4 - June 22, and at Sitkinak Island from June 23 - July 13, 1979. The project leader, Warner, worked intermittently in areas near the town of Kodiak accessible by road system, including Monashka, Chiniak and Ugak Bays, from May 1 - June 4 and June 12 - July 1, 1979.

Specimens were collected with the following gear: 1) monofilament, variable-mesh gill net (VMG), 13.5 m long, 3mdeep, in five panels of equal size having 13, 19, 25, 31 and 38 mm bar mesh size, respectively; 2) multifilament, variable-mesh gill net varying from30 - 40 m in length, from 3 - 5m deep, in five panels of bar mesh size 13 - 38 mm; 3) tapered beach seines 47 m long, ranging from 0.9 - 4 m deep, with panels of 13 and 38 mm mesh (stretch measure) on each wing, and a cod panel of 6 mm (Figure 2). In addition, dip nets were used for collecting spawning capelin and shovels for digging sand lance and spawn on beaches. All gear was deployed opportunistically at the discretion of crew leaders. Forage fish were measured to the nearest millimeter and weighed to the nearest gram. Herring were measured in standard length and all other fish in fork length (Eddy 1969). Gonad development was judged using the Hjort scale of maturity (Hjort 1914). The index relies mainly on the size of the gonad in reference to the body cavity of the specimen (Table 2).

Table 1.--General information on forage fish in the Kodiak Archipelago.

Species	Peak Spawning Time	Spawning Habitat	Common Nearshore School Size	Longevity (yr) Average	Longevity (yr) Maximum	Adult Size (in)	Commercial Use Alaska	Commercial Use World
Herring	April-May	On marine vegetation in sheltered bays	10 - 15 tons	6	14	8 - 10	Roe Bait Food	Roe Bait Food Meal Oil
Sand lance	October	Gravel beaches with mild surf	1 - 3 tons	3	5	4 - 7	None	Bait Food Meal Oil
Capelin	May-June	Gravel beaches with mild to moderate surf	25 - 500 tons	2	4	5	None	Bait Food Meal Oil
Surf smelt	May-March	Protected sand and gravel beaches[1]	Less than a ton	2 - 3	?	5 - 9	None	Food
Eulachon	May-June	Up rivers of small to major size	?	3	5	5 - 9	None	Food

[1] in Puget Sound, Schaefer (1936)

Table 2. Gonad maturity index.

Stage	Key Characteristics
I	Virgin herring. Gonads very small, threadlike, 2-3 mm broad. Ovaries wine red. Testes whitish or grey brown.
II	Virgin herring with small sexual organs. The height of ovaries and testes about 3-8 mm. Eggs not visible to naked eye but can be seen with magnifying glass. Ovaries a bright red color; testes a reddish grey color.
III	Gonads occupying about half of the ventral cavity. Breadth of sexual organs between 1 and 2 cm. Eggs small but can be distinguished with the naked eye. Ovaries orange; testes reddish grey or greyish.
Iv	Gonads almost as long as body cavity. Eggs larger varying in size, opaque. Ovaries orange or pale yellow; testes whitish.
v	Gonads fill body cavity. Eggs large, round; some transparent. Ovaries yellowish, testes milkwhite. Eggs and sperm do not flow, but sperm can be extruded by pressure.
VI	Ripe gonads; eggs transparent; testes white; eggs and sperm flow freely.
VII	Spent herring. Gonads baggy and bloodshot. Ovaries empty or containing only a few residual eggs. Testes may contain remains of sperm.
VIII	Recovering spents. Ovaries and testes firm and larger than virgin herring in Stage II. Eggs not visible to naked eye. Walls of gonads striated; blood vessels prominent. Gonads wine red color. (This stage passes into Stage 111.)

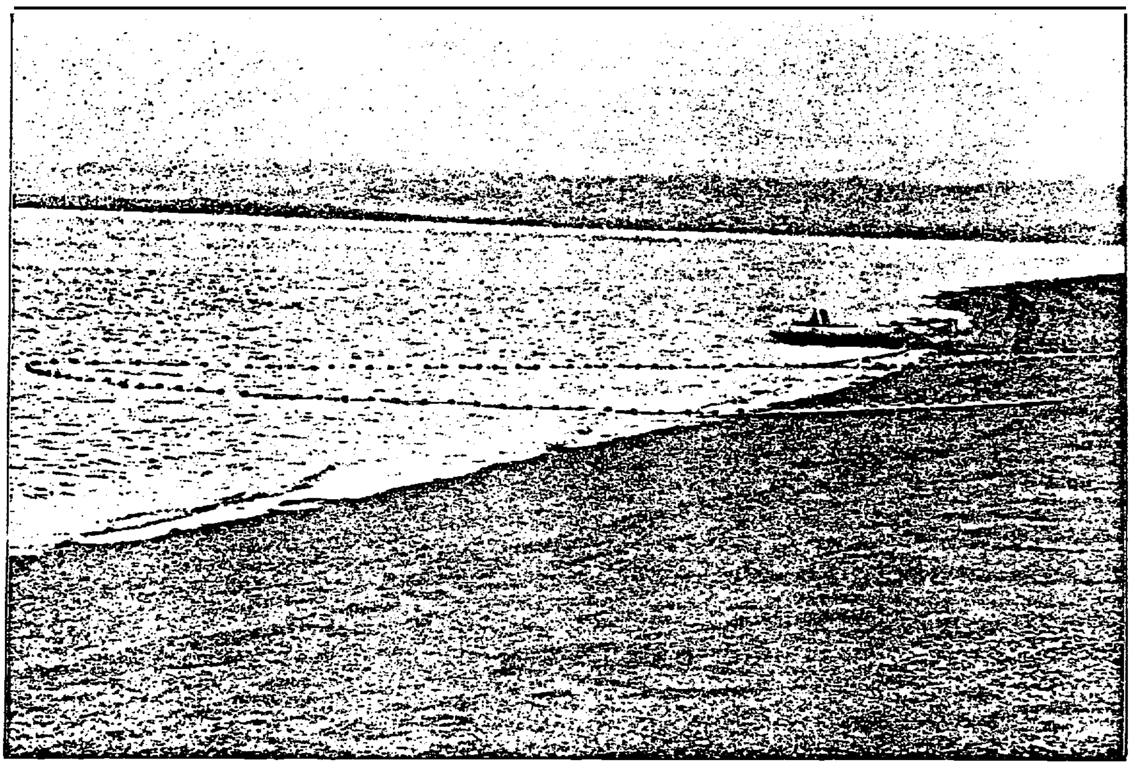


Figure 2 : Sampling for forage fish with Beach Seine, Trinity Islands, 1979.

In order to facilitate the processing (i.e. measuring, weighing, gonad indexing, etc.) of potentially large samples of forage fish obtained by ground crews, each of the five key areas listed at the beginning of this section was considered a "district" for sampling purposes. The fishing season was broken into 10 sampling weeks, beginning on May 1 and ending on July 14. A sampling program was conducted separately for each week a ground crew was present in each of the five districts.

Every week, the initial one hundred specimens of each species taken in a district were all processed; after this, one out of 10 were processed. Every week, a minimum of 75 herring scales and 15 otoliths of each other forage fish species were collected in each district, and more if time permitted. VMG subsamples for processing were taken so as to correctly represent the proportion of fish caught by each panel in a particular set. Total counts or estimates of catches were recorded at all times.

Herring samples from commercial purse seine catches consisted of a bucket or two of fish dipped from the hold of a fishing vessel in a manner so as to equally represent the upper, middle and lower levels of fish in a hold. Care was taken to sample catches from only a single locality or single bay. Commercial samples were taken opportunistically, and were considered separate from the sampling program conducted each week in each district.

Spawn surveys were conducted on foot, or from a small boat during low tides. Searches for herring spawn were conducted on beaches as well as in eelgrass and kelp beds. Samples of substrate were dug and examined for capelin and other forage fish spawn. Presence, extent and density of spawn deposition were noted, and also substrate type utilized. Roe densities were judged using a subjective scale of indices. Data were recorded in the field notebooks and transferred to spawn survey computer forms in camp.

Laboratory Procedures

Herring were aged by the use of scales, the collection and preparation of which has been described previously (Warner and Shafford 1979; Barton, Warner and Shafford 1977). Otoliths dried in envelopes in the field were placed on black plastic otolith cards in 100% glycerin and read under a stereoscopic microscope. Sand lance otoliths were read immediately after glycerin immersion using reflected light. Smelt otoliths required. 1 - 3 hours in glycerin before clearing sufficiently to be read using reflected light, and transmitted light was used for verification in some cases. Each otolith was aged by two researchers, and only when the ages agreed were data used. All scales and otoliths were read employing the annulus method (Chuganova 1963; Scott 1973). The outside perimeter of the scale or otolith was counted as the last annulus, and "plus" growth noted when observed.

Data Formating

Data collected on ground surveys, i.e., specimen measurements and collected scales and otoliths, are on record and stored at the office of the ADF&G, Division of Commercial Fisheries, Kodiak, Alaska. As per contract agreement, all OCSEAP aerial survey data have been recorded on magnetic tape according to file type 057 format.

RESULTS

Aerial Surveys

The six census areas were surveyed for a total "in flight" time of 41 hours during 12 different flights. Ninety-two schools of forage fish were seen, 72 of which were not identified to species. Total coastline distance surveyed was 8,811 kilometers. Peak counts of schools seen per kilometer flown occurred in the Chiniak/Marmot Bay complex (census area B), which encompassed the City of Kodiak. Forty-eight percent of all schools counted were observed in this census area. The next highest was in Rolling Bay/Old Harbor (census area D) (Table 3).

Seventy-two percent of all schools fell in the "small" category, which is less than five tons. Biomass figures for forage fish schools are highly subjective and little emphasis is given them due to the imprecision involved.

A summary of aerial survey effort and results by time period are given in Table 4. Only two schools that were sighted were actually spawning, and the period of peak school counts (June 16 through June 30) occurred outside of the optimum spawning period documented by ground activities and catch data. No aerial surveys were flown during census period five (June 5 - June 15) due to inclement weather and aircraft logistic problems. Locations of school concentrations are given in Figure 3.

Eight schools of unusual size were observed on June 26, 1979 about 6 kilometers south of Old Harbor, Sitkalidak Straits (census area C). Field observations concerning this sighting were included in a memorandum to Jack Lechner, Regional Supervisor, ADF&G, Kodiak, Alaska. The following excerpts are taken from that memorandum:

> "On the evening of June 26, 1979 while involved in an aerial survey on my ongoing OCS forage fish project I observed eight extraordinarily large schools of forage fish in Sitkalidak Straits. I was then (aloft in a Cessna 206) at an altitude of 3,500 feet (1,250 meters).....(I) circled the schools numerous times, watching them move and "split" off from one another, often returning to their original shape while the pilot and I watched . . ..The depth of the water (in the area where schools were seen) was 65 fathoms, hence calculating the volume of a cone* . . . ..this would make each school a volume of 2,720,025 cubic yards of sea water. Large concentrations of capelin have been found within a few kilometers during shrimp surveys, and it is my opinion that the biomass of forage fish 1 observed would be a minimum of 8,500 tons and a maximum of 15,000 tons, though I feel these estimates to be conservative. . ..The Sitkalidak schools I observed on June 26, 1979 were the largest aggregation of forage fish I've observed during the past 3-1/2 years. (Warner, interdepartmental memo, 1979).

During subsequent surveys in this area, no schools were again sighted. Despite observer confidence in the species identification of their sight-schools, there are no empirical data from ground crews to make the identification definite.

*It has been observed during acoustic surveys that herring and capelin form cone or "plume" shaped schools, the narrow portion of the "cone" being closest to the surface.

Table 3. Summary of aerial survey effort and results by census area, April-July, 1979.

Census Area	Shoreline Length (Km)	Times Flown	Total Km Flown	Schools Sighted	Schools/Km
A	212	4	848	5	.006
B	320	6	1,920	4 5	.023
C	356	8	2,848	15	.005
D	112	5	560	12	.021
E	106	3	318	3	.009
F	331	7	2,317	12	.005
Totals:	1,437	33	8,811	92	.0104

Table 4. Summary of aerial survey effort and results by census period, April-July, 1979.

Period	Km Flown	Schools 'Sighted	Schools/Km
1 (4/1-4/14)	1,255	1	.008
2 (4/15-4/30)	0	0	0
3 (5/1-5/14)	1,320	26	.0197
4 (5/15-5/31)	1,204	11	.0091
5 (6/1-6/14)	0	0	0
6 (6/15-6/30)	4,239	51	.0120
7 (6/12-6/18)	793	3	.0038
Totals:	8,811	92	.0117

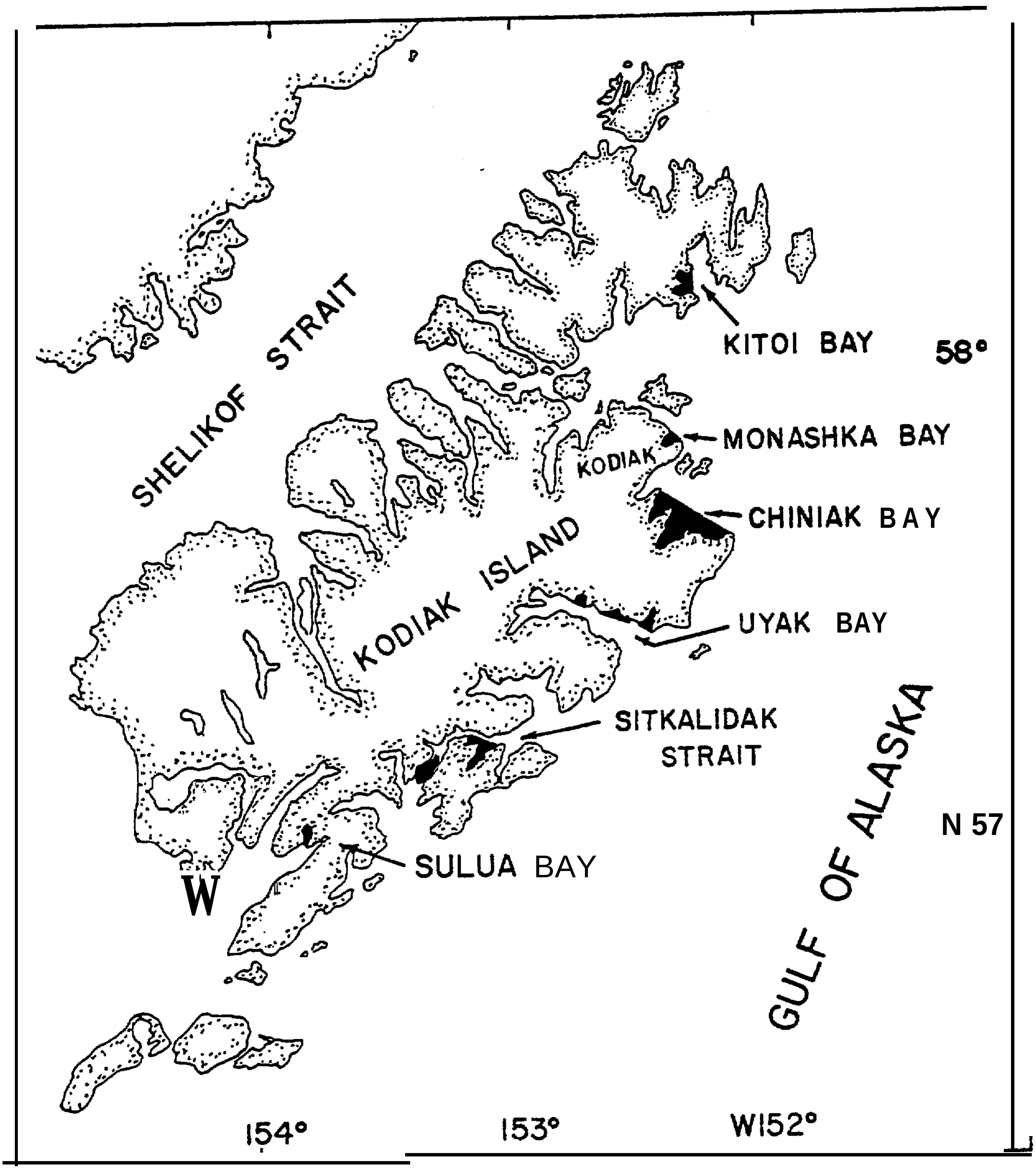


Figure 3. Areas of forage fish school concentrations (black shading) sighted during 1979 aerial surveys.

Spawn Surveys

A total of 125 spawn surveys was conducted at 38 locations (Figures 4 and Table 5). Capelin spawn was located at Monashka Bay, Pillar Creek Beach, and Kalsin Bay (census area B) during the last six days of May. No capelin spawn was found outside these areas. Herring spawn was found at Woman's Bay on June 28 and Pasagshak Bay on May 30 (census area B); Amee Bay on May 20, Barling Bay on May 10, and Three Saints Bay on May 20 (census area D). Spawning herring were observed from the air in Woman's Bay and Sulua Bay. The former observation was made on June 28 and included actually observing milt. The latter observation was made on May 23. Eulachon spawned in Kalsin River during the last week of May. Specimens of eulachon collected by sports fishermen were given to project biologists and subsequent examination disclosed the fish to be flowing, i.e. male and female sex products running freely from the vents.

Capelin spawning substrate results are discussed in the capelin section. Herring spawn was always found on eelgrass with one exception, and that was at Pasagshak Bay where it was found on Desmarestia (hair kelp) washed up along a 200 meter long area in the high tide zone. in a survey conducted 48 hours after the collection of spawning eulachon from Kalsin River, the substrate size was found to be 5 mm to 15 mm and composed of rough stream gravel. During the 48 hour period between the catching of the eulachon and the survey, extreme high water made it impossible . to locate spawn or spawned-out eulachon.

Habitat types of sites examined for herring and capelin spawn in the Sitkalidak Island area are shown in Figures 5 and 6. The Sitkalidak area was considered to be representative of the rest of the study area, and more effort in mapping habitat type was expended there than in other areas during post season data analysis. Half the sites where herring spawn or spawning was observed occurred in the Sitkalidak Strait area. Although no capelin spawn was found in the Sitkalidak area, suitable beaches were common.

Pacific Herring

A total of 3,328 herring from five census areas (A, B, C, D, F) on the east side of Kodiak and Afognak Islands were measured, and of these 1,368 were aged. Spawn ready or ripe herring were found in all five areas. Spawn on substrate was found in three of the areas (B, C, D).

Herring caught with VMG in the widely separate areas of Izhut Bay and Sitkalidak Island showed similar mean length at age (Table 6), though different age compositions. At Sitkalidak Island three year old invidivuals dominated while at Izhut Bay five year olds were most numerous (Figures 7 and 8). Herring caught with power purse seine at these two sites were also dissimilar in age composition but showed similar mean lengths at age (Figure 9).

Overall, purse seine results yielded specimens from five census areas: Izhut Bay, Sitkalidak Island, Woman's Bay, Kiliuda Bay, and Sulua Bay (Table 7). VMG results yielded specimens from three census areas, though in area F (Izhut Bay, Sitkalidak Island and Alitak Bay) so few were captured (less than 12) as to make tabularization meaningless. Most herring processed for this study were from three and six years old; 72 percent of all VMG captured herring fell in this bracket, while 95 percent of purse seine herring fell within these four age groups. The youngest herring captured by VMG was 1 year old, while the oldest was 1?. Samples of herring captured by purse seine showed the youngest was 2 years old, and the oldest 10.

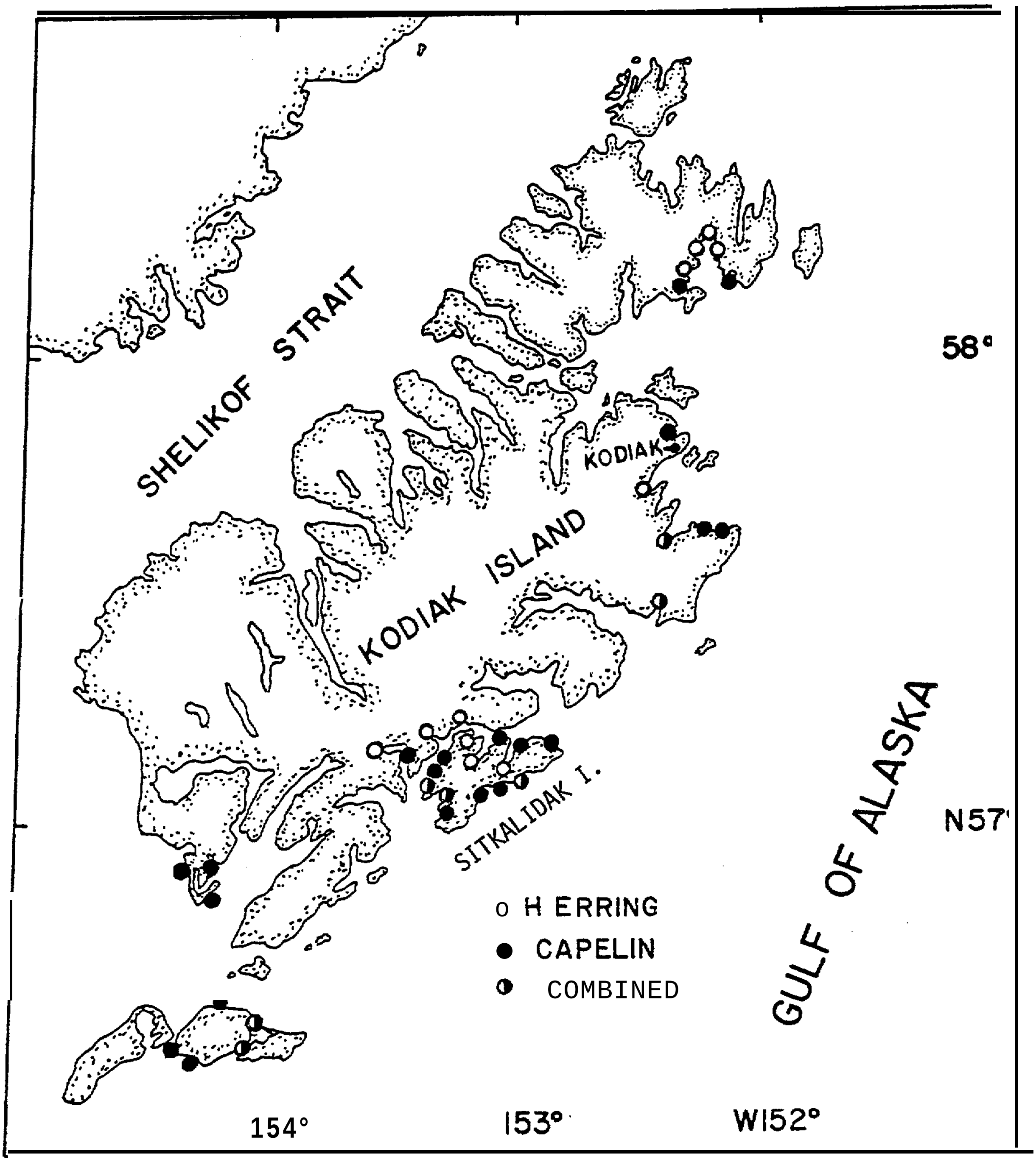


Figure 4. Forage fish spawn survey sites, 1979.

Table 5. Total number of ground surveys for spawning herring and capelin by area, and survey period.

	May					June				July	
Area & Sp.	1-7	8-14	1s-21	22-28	29 - 4	5-11	12-18	19-25	26 - 4	5-13	Total
A.											
Herring	4	7	2	9	2	1	0	0	0	0	25
Capelin	0	4	0	4	1	10	8				27
B											
Herring	0	0	0	0	0	0	0	0	0	0	0
Capelin	0	0	0	1	1	3					5
C											
Herring	2	7	11	1	0	0	0	0	0	0	21
Capelin	0	0	1	9	3	1					14
D											
Herring	0	1	0	0	1	0	1	0	0	0	3
Capelin	0	0			3	3	5				11
E											
Herring	0	0	0	0	0	0	0	0	0	0	0
Capelin	0	0									0
F											
Herring	0	0	0	0	0	0	0	0	0	4	4
Capelin	0	0						2	13	0	15
Totals	6	19	14	24	11	18	14	2	13	4	125

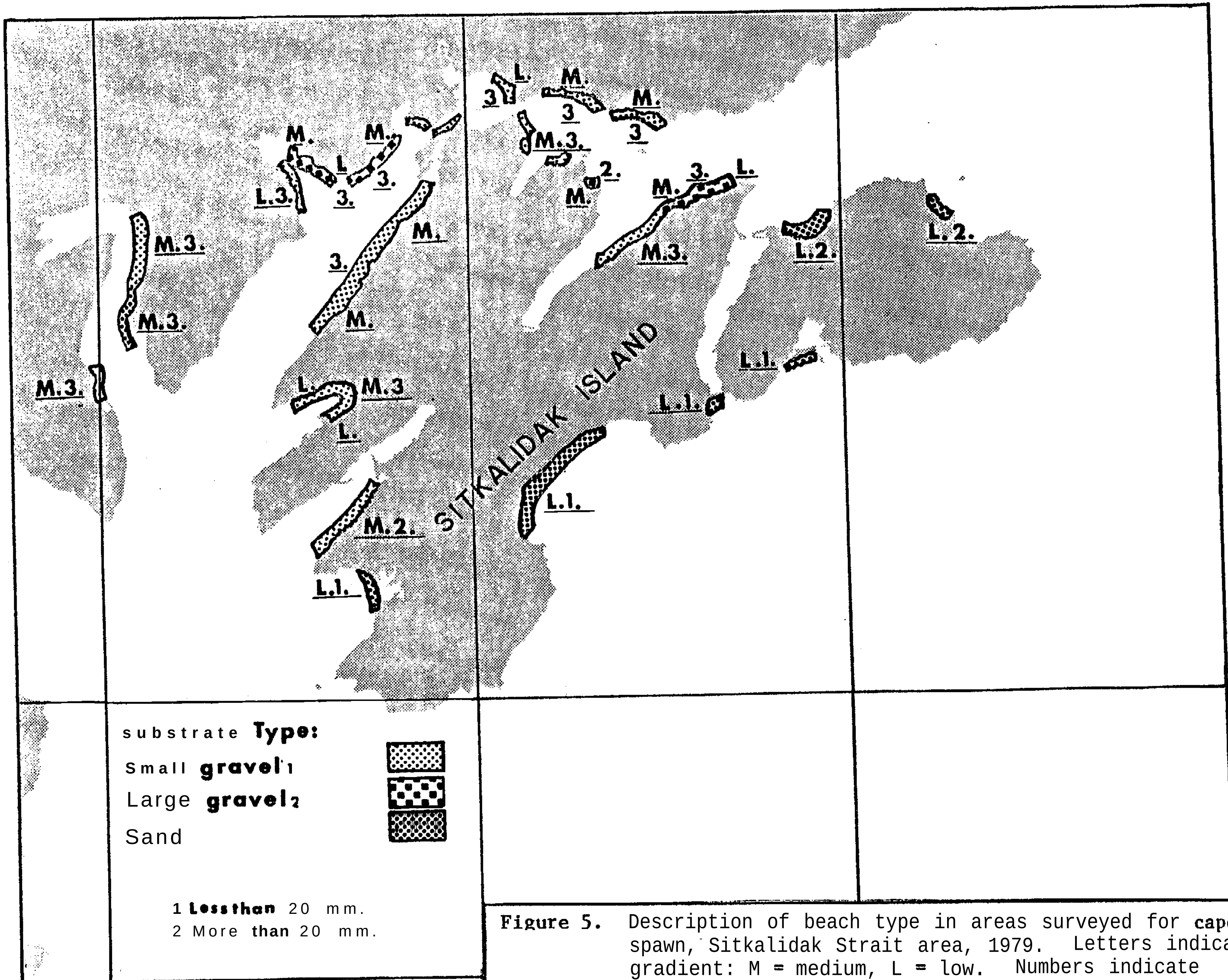


Figure 5. Description of beach type in areas surveyed for **capelin** spawn, Sitkalidak Strait area, 1979. Letters indicate gradient: M = medium, L = low. Numbers indicate predominant surf condition: 1 = heavy, 2 = medium, 3 = light.

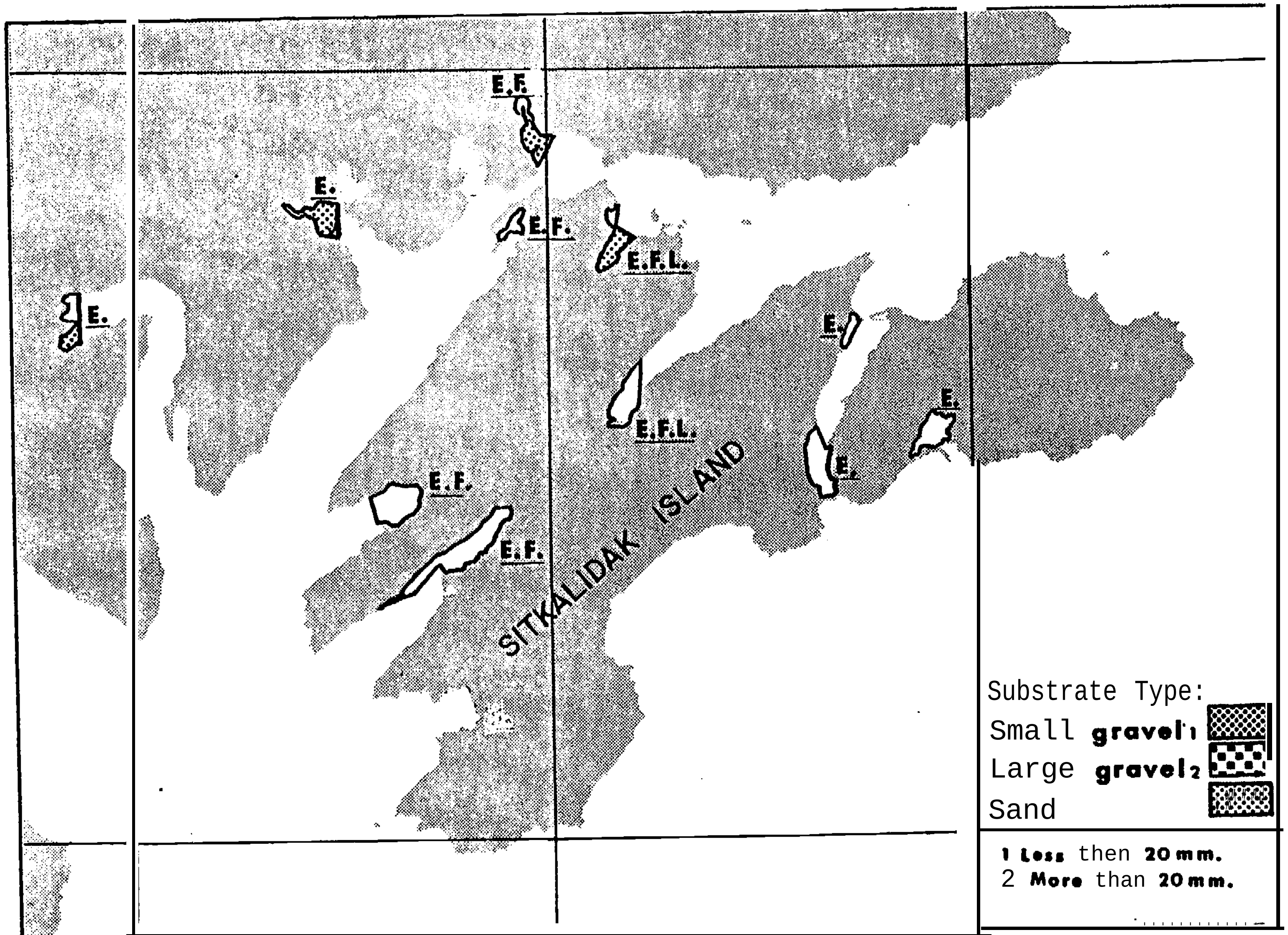


Figure 6. Intertidal areas surveyed for herring spawn, Sitkalidak Isla area, 1979. Letters indicate dominant plant species: E = eelgrass (Zostera), F = Fucus, L = Laminaria. Stippling indicates where light herring spawn deposition was observed.

Table 6. Mean lengths and ranges (mm) of herring at age: captured by variable mesh gill net at 2 sites east side of Kodiak Archipelago; May - June, 1979, (number of fish in parenthesis).

Area	Age in Years					
	1	2	3	4	5	6
Izhut Bay[1]						
Mean		173 (88)	200 (32)	222 (22)	230 (80)	239 (29)
Range		148-187	170-219	193-257	178-273	214-281
Sitkalidak Island[2]						
Mean	116 (5)	178 (33)	208 (111)	217 (41)	234 (67)	239 (29)
Range	110-119	164-200	168-246	187-251	202-259	210-258
	7	8	9	10	11	12
Izhut Bay						
Mean	245 (6)	265 (8)	270 (3)	267 (2)	264 (1)	--
Range	236-271	255-279	260-285	265-270	264	—
Sitkalidak Island						
Mean	260 (2)	--	265 (8)	262 (2)	--	--
Range	256-264	--	243-275	258-266	--	--

[1]Overall sample *size* at Izhut Bay = 271.

[2]*Overall sample size* at Sitkalidak Island = 298.

Table 7. Mean lengths and ranges in mm of herring at age: captured by commercial purse seine at various sites, east side of Kodiak Archipelago May - June 1979 (number of fish in parentheses).

Area	Age in Years 1	2	3	4	5	6	7	8	9	10	Sample Size
Izhut Bay											
Mean	--	--	198(3)	220(12)	227(43)	234(4)	240(1)	255(2)	--		(65)
Range	--	--	187-209	209-230	204-247	222-244	240	244-267	--		
Sitkalidak Is.											
Mean	--	177(7)	198(88)	198(12)	218(7)	--	--	--	--	259(1)	(115)
Range	--	160-215	162-215	174-211	199-246	--	--	--	--	259	
Womants Bay											
Mean	--	165(13)	192(174)	193(23)	208(6)	213(1)	--	--	--		(217)
Range	--	153-195	146-216	176-216	189-220	213	--	--	--		
Kiliuda Bay											
Mean	--	178(7)	204(121)	212(22)	223(26)	234(6)	223(1)	--	247(1)		(184)
Range	--	169-189	170-236	190-239	201-240	204-260	223	--	247		
Sulua Bay											
Mean	--	--	183(24)	199(27)	211(49)	220(17)	218(1)	--	--		(118)
Range	--	--	171-215	175-229	187-241	194-245	218	--	--		

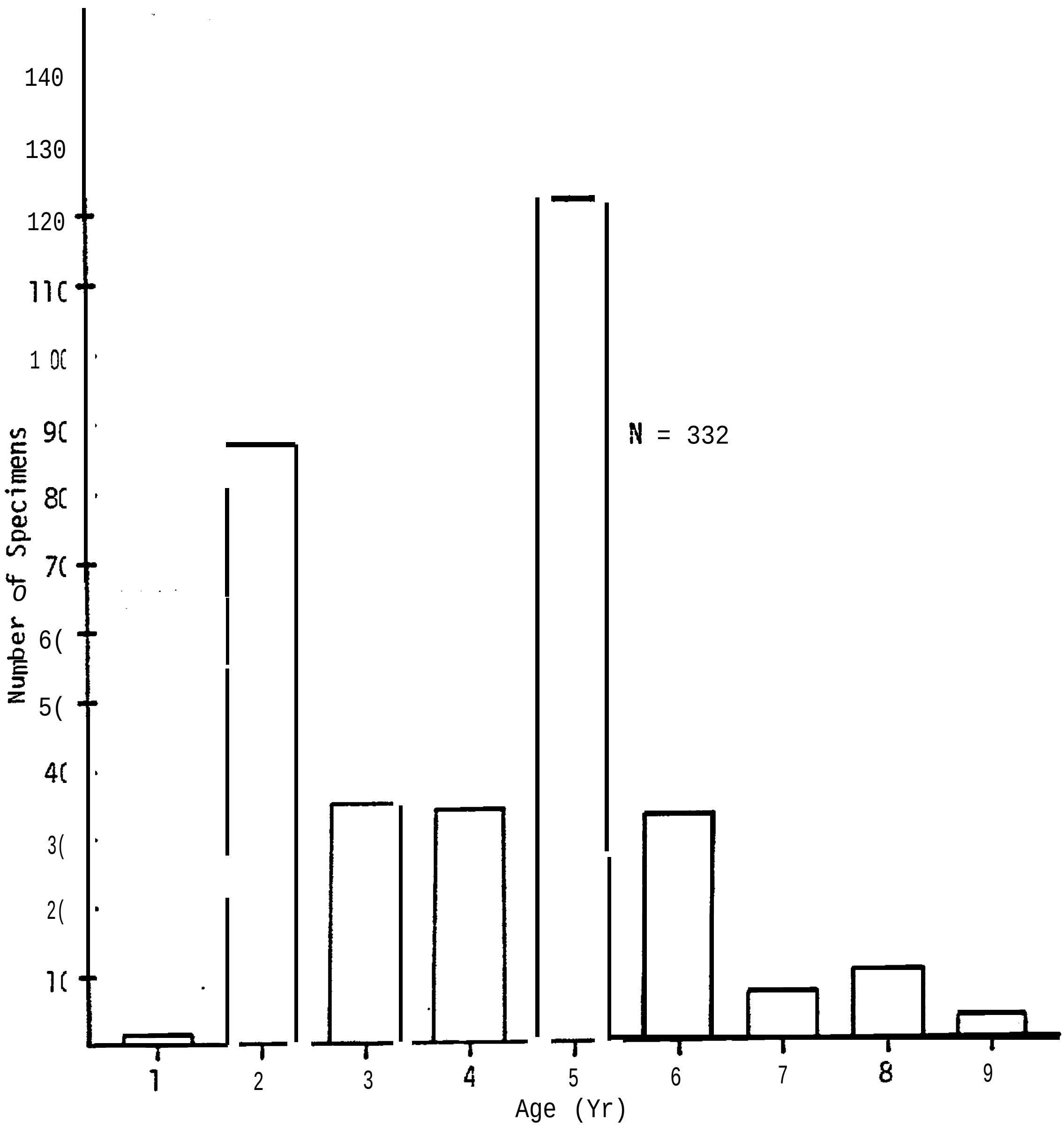


Figure 7. Age-frequency distribution of herring (*Clupea harengus pallasi*) captured by variable mesh gill net, Izhut Bay, May-June, 1979.

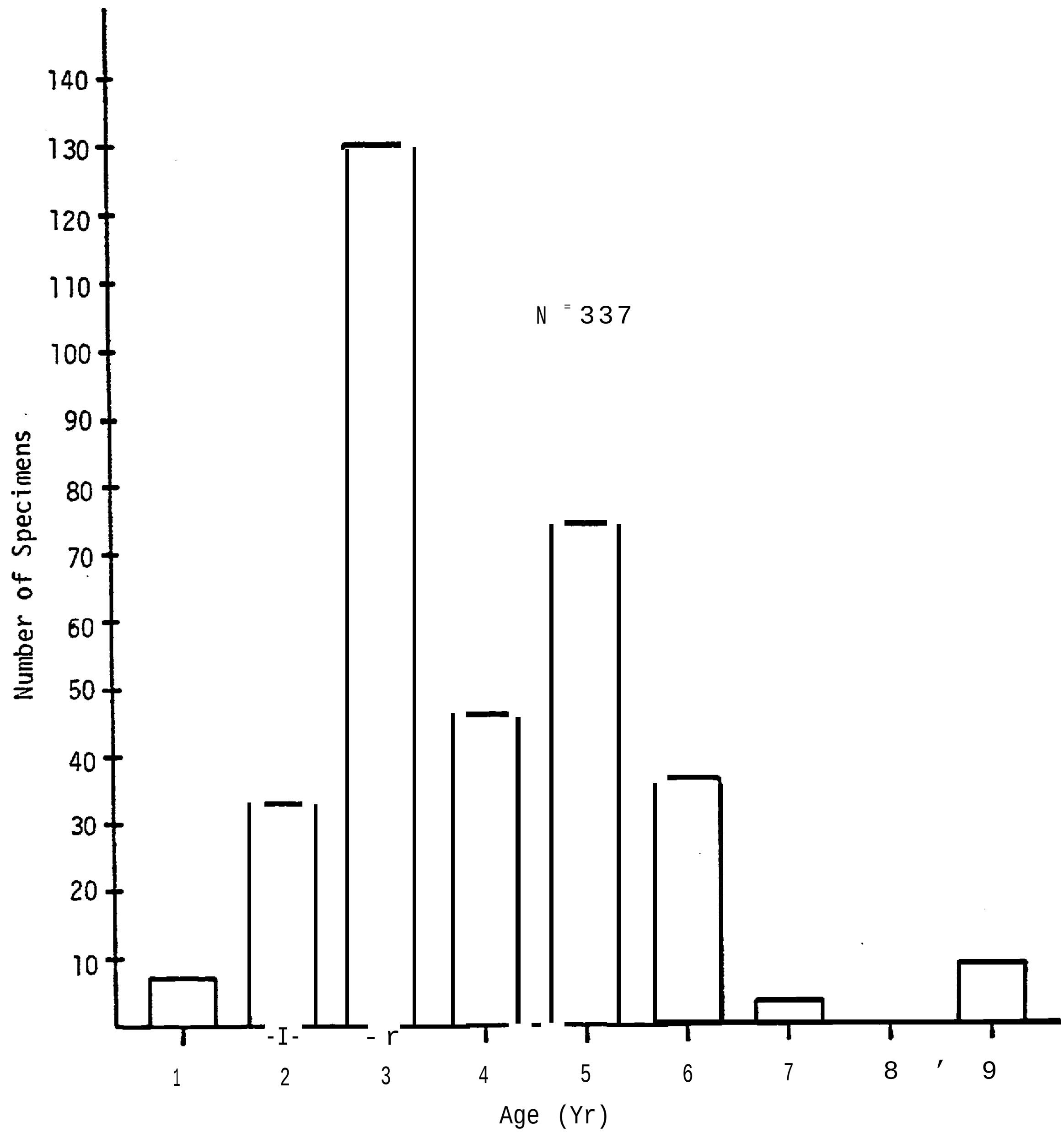


Figure 8. Age-frequency distribution of herring (*Clupea harengus pallasi*) caught by variable mesh gill net, Sitkalidak Island, May-June, 1979.

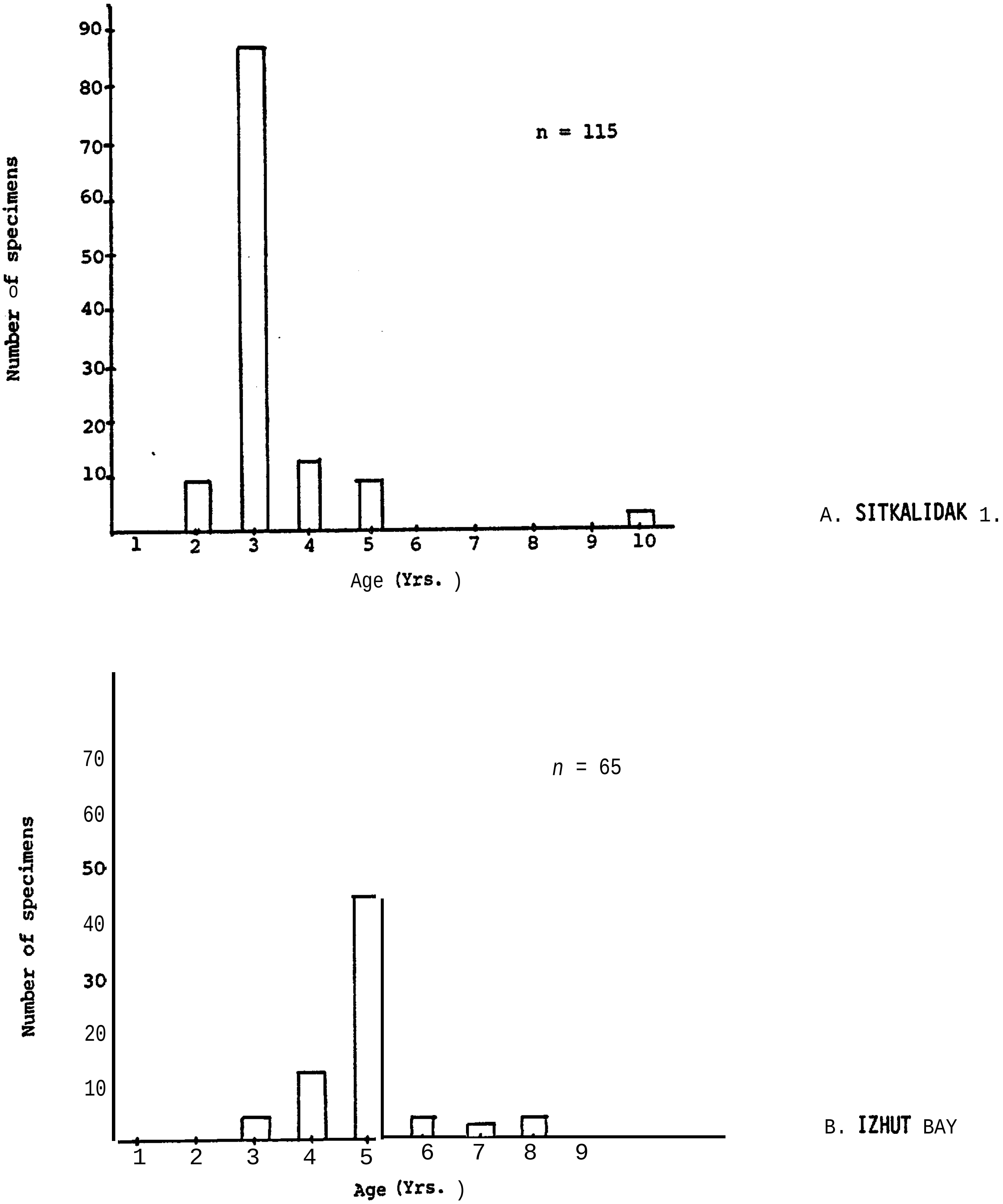


Figure 9. Age-frequency distribution of herring (*Clupea harengus pallasi*) captured by power purse seine at Sitkalidak (A) and Izhut Bay (B), 1979.

Inspection of herring gonads showed that most specimens mature at age two or three though sexual maturity is essentially complete in Kodiak/Afognak area herring by age four. Ninety percent of 2year old herring from Izhut Bay reached gonad index 4 or greater, contrasted to Sitkalidak Island where only half of the two year olds were mature. A summary of gonad index values at age is given in Table 8.

Sand Lance

Table 14 shows the sexual maturity of each age class in summer, based on degree of gonad development. Most lance (74%) were of gonad index I. Few of the fish exceeded index III, and none attained index V. 'There were no indications of summer spawning.

In the fall of 1980, well after the first draft of this report had been prepared, the authors received from Mr. Duane French an account of extensive intertidal spawning by sand lance on the south shores of Ban Island and Paramanof Bay, on the west side of Afognak Island (Figure 1). He collected two specimens, one of each sex, on October 9. Both were in spawning condition, as were most other sand lance he examined on the beaches. There was roe in the gravel on Ban island, and a cloud of milt which filled a cove 0.4 km wide on the shore of Paramanof Bay. During the three days (October 8 - 10, 1980) which Mr. French spent in Paramanof Bay, sand lance remained adjacent to gravel beaches of the same type utilized in summer. They schooled at high tide (the largest schools estimated at 2 - 3 tons) swimming back and forth at the mouths of small freshwater streams. At low tide, the fish were scattered across the surface of the gravel, heavily preyed upon by crows and gulls. There were many thousands of sand lance exposed to the air, especially in small, relatively moist rivulet-depressions, At the touch, the sand lance became quite active and even exuded sex products. Apparently actual spawning took place at high tide. A few juvenile herring were among the sand lance, indicating their presence in the schools, as reported similarly by Kühlmann and Karst (1967) for A. tonianus and A. lanceolatus. Schools of sand lance were observed in a brackish lake on the southeast shore of Ban Island. The lake, fed by a freshwater stream and probably receiving saltwater only on extreme high tides, drained across the gravel beach during ebb tide. Sand lance spawned in this drainage despite the strong freshwater influence.

Mr. Jerry McCrary of the Alaska Department of Fish and Game dug sand lance at extreme low tide on October 25, 1980 from beaches at Pillar Creek and Shahafka Cove, all near the town of Kodiak. From a sample of 40 ranging in length from 67 - 150 mm and in age from class 1 - 3, seven fish were in spawning condition. These ranged from 128 - 130 mm in length; two were of age class 3 and five from age class 2. Of the remaining, 21 of age class I and five of age class 2 were of gonad index III or less. Thus, Kodiak sand lance mature at age class 2, though some may mature at age class 3.

Sand lance occurred in forty-five percent of 38 beach seine sets from three widely separate areas: Izhut Bay, Sitkalidak Strait and Sitkinak Lagoon. It was the numerically dominant species in the overall beach seine catch (Tables 9, 10, and 11). Frequency of occurrence and CPUE was greatest in Sitkalidak Strait (54% and 986.4 fish/set) and at least in southwestern Alitak Bay (11% of 18 sets and 0.1 fish/set). Catch results from Sitkinak Island (44% and 43.2 fish/set) and Izhut Bay (38% and 75.9 fish/set) were similar.

Table 8. Hjort relative gonad index at age for herring (*Clupea harengus pallasi*) captured by variable mesh gill net at 2 sites, east side of Kodiak Archipelago, May - June, 1979.

Sitkalidak Island

Index	Age in Years											Total
	1	2	3	4	5	6	7	8	9	10	11	
1	4	1	0	0	0	0	0	0	0	0	0	5
2	1	9	1	0	3	0	0	0	0	0	0	14
3	0	1	9	0	0	0	0	0	3	0	0	13
4	0	15	67	19	24	20	1	0	1	0	0	147
5	0	4	48	25	43	10	3	0	2	0	0	135
6	0	0	1	0	1	1	0	0	0	0	0	3
7	0	0	3	1	3	4	0	0	2	0	0	13
8	0	0	0	0	0	0	0	0	0	0	0	0
Totals	5	30	129	45	74	35	4	0	8	0	0	330

Izhut Bay

Index	Age in Years											Total
	1	2	3	4	5	6	7	8	9	10	11	
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	0	0	1	0	0	0	0	0	0	2
4	0	7	5	16	33	4	0	3	1	0	0	69
5	0	44	29	15	66	21	6	3	1	1	0	186
6	0	0	4	2	16	7	1	2	1	0	0	33
7	0	15	1	1	7	1	0	2	0	1	1	29
8	0	23	1	0	0	0	0	0	0	0	0	24
Totals	0	90	40	34	123	33	7	10	3	2	1	343

Table 9. Summary of beach seine catch, Izhut Bay, May 7 - June 19, 1979. Figures represent 16 sets. X = presence indicated.

Species	Frequency of Occurrence in Sets	% Frequency of Occurrence	Total Number Caught	CPUE (Fish/Set)
Chum salmon fry	I	6	15	0.9
Pink salmon fry	11	69	556+	34.8+
Dolly Varden	2	13	6	0.4
Sand Lance	6	38	1,214	75.9
Sculpins	5	31	11	0.7
Sculpin fry	1	6	X	--
Flounders	2	13	12	0.8

Table 10. Summary of beach seine catch, Sitkalidak Strait, May 7 - June 20, 1979. Figures represent 13 sets.

Species	Frequency of Occurrence in Sets	% Frequency of Occurrence	Total Number Caught	CPUE (Fish/Set)
Herring	1	8	3	0.2
Chum salmon fry	1	8	25	.9
Pink salmon fry	7	54	240+	8.5+
Unid. salmon fry	1	8	1	0.1
Dolly Varden	4	31	19+	1.5+
Unidentified fry	2	8	7	0.5
All Pricklebacks	2	8	1	0.2
Sand Lance	7	54	12,823	986.4
Greenlings[1]	8	62	88+	6.8+
Sculpins[2]	9	69	121	9.3
Silverspotted sculpin	1	8	77	5.9
adult	1	8	2	0.2
fry	1	8	75	5.8
Tubenose poacher	1	8	1	0.1
Flounders	1		1	0.8

[1] Includes at least 35 whitespotted greenling; also, unidentified greenling fry were present in two sets.

[2] Includes 25 unidentified sculpin fry in one set and the silverspotted sculpins listed subsequently.

Table 11.--Summary of beach seine catch, Sitkinak Lagoon, June 25 - July 2, 1979. Figures represent 9 sets.

Species	Frequency of Occurrence in Sets	Percent Frequency of Occurrence	Total Number Caught	CPUE (Fish/Set)
King salmon smelt	3	33	6	0.7
Pink salmon fry	2	22	69	7.7
Chum salmon fry	1	11	4	0.4
Dolly Varden	3	33	12	1.3
Whitespotted greenling	1	22	1	0.1
Greenling fry	4	44	5,006	556.2
Sand lance	4	44	389	43.2
Great sculpin group	5	55	15	1.7
Staghorn sculpin	2	22	2	0.2
Starry flounder	1	11	1	0.1
Rock sole	1	1 1	2	0.2

At Sitkalidak Strait, sand lance were seined exclusively over beaches of coarse sand 1 - 4 mm in diameter, or fine gravel 5 - 10 mm in diameter, or combinations of the two, with larger pebbles or finer sand commonly present. Sand lance substrate was invariably well drained and well washed, bearing little or no mud. Throughout the study area, beaches of this type were generally dark gray, being derived predominantly from slate. Generally, beaches in bights or coves seemed preferred to beaches on small islands or exposed beaches in straits. Also, moderately long beaches with mild slopes seemed preferred to tiny beaches. In Izhut Bay, the Chiniak-Marmot Bay area and Alitak Bay, sand lance were seined over or found buried in beaches similar to those in the Sitkalidak area.

At Sitkinak Lagoon, sand lance were dug by hand during extreme low tides from gravel bars near the north entrance to the lagoon. The substrate was a loose mixture of fine and coarse slate sand with fine slate gravel to 15 mm in diameter. The f?at bars drained via broad, shallow channels ranging from 2 - 15 mm deep and up to 1 mwide. The sand lance were concentrated in and adjacent to these channels.

In no part of the study area were sand lance found buried in beaches of fine, light colored sand, or in sand-mud mixture, several of which were examined by digging at extreme low tides on Sitkalidak Island (Seal Cove, Partition Cove, Ocean Beach, Rolling Bay) and Sitkinak Island (north and south spits). At Sitkinak Island, sand lance were seined above a beach of hard, light colored sand overlaid with varying amounts of fine gravel on the lagoon side shore of the main northern spit which forms the entrance to Sitkinak Lagoon. They were also seined along the steep hard beach of fine sand on the lagoon side of the southern spit, from a tidal current of 3 - 4 knots. Sand lance were never caught or observed along the seaward shores of the spits.

Length measurements were taken on 1,308 sand lance from three census areas: Izhut Bay, Sitkalidak Strait and Sitkinak Lagoon. Length frequencies are" presented in Figure 10, and mean lengths at age in Table 12. A growth curve for sand lance at Sitkinak Lagoon is shown in Figure 11, The length frequency histograms from Izhut Bay and Sitkalidak Strait are almost identical and unimodal, but that from Sitkinak Lagoon is bimodal. The mean lengths at age of the Izhut Bay and Sitkalidak Strait samples are not significantly different, as the means are close and the ranges overlap. Using standard error of the difference between two means (Arkin and Colton 1956) we found the mean lengths at age of the Sitkinak and Sitkalidak Strait samples to be significantly different at the 99.7 confidence level (Table 13).

Three hundred eighty-eight sand lance were aged. Six age classes (O - 5) were found. Very few class O fish were caught between May 7 and July 12. A single set made in Narrow Strait a few kilometers from the city of Kodiak on July 22 yielded only age class O fish, The mean length of a sample of 40 was 53.8 mm.

The age frequency distributions resulting from the beach seine samples were similar in all areas, with age class 1 predominant. age class 2 much less frequent, and age classes 4 and 5 infrequent (Figure 12). In no area did age class 3 occur in the beach seine samples. The age frequency of the beach seined sample at Sitkinak Lagoon was much different from that of the sample dug from the gravel (Figure 12C). Age class 3 was strong in the gravel sample, and age class 2 was much stronger than in the seine sample. The mean lengths at age from the two samples were not significantly different at the 99.7 confidence interval, though only classes 1 and 2 could be compared.

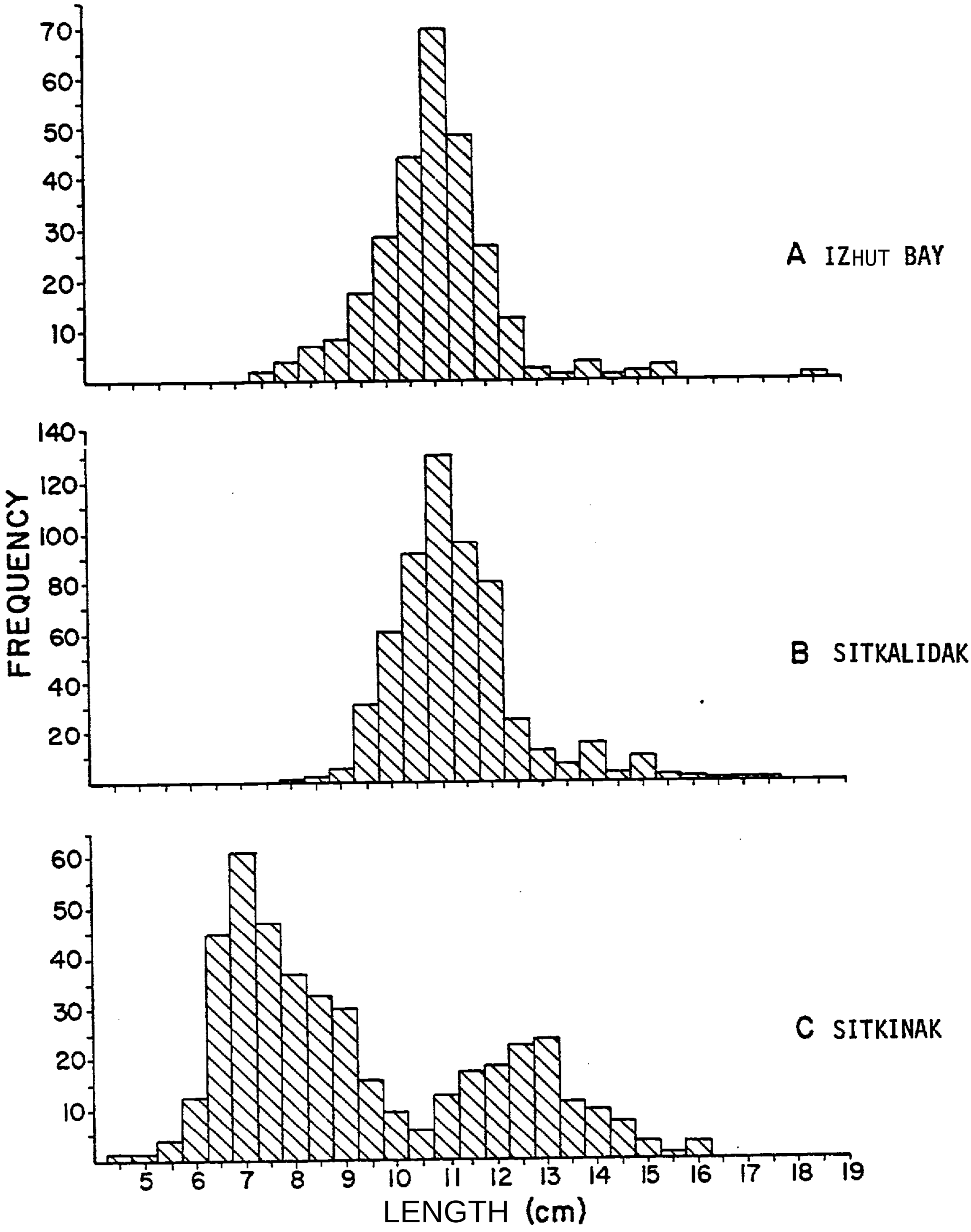


Figure 10. Length- frequency distributions of sand lance (*Ammodytes hexapterus*) sampled A.) by beach seine at Izhut Bay, May-June, 1979. n = 278. B.) by beach seine at Sitkalidak Strait, May-June, 1979. n = 579. C.) by beach seine and digging at Sitkinak Lagoon, June-July, 1979. n = 451.

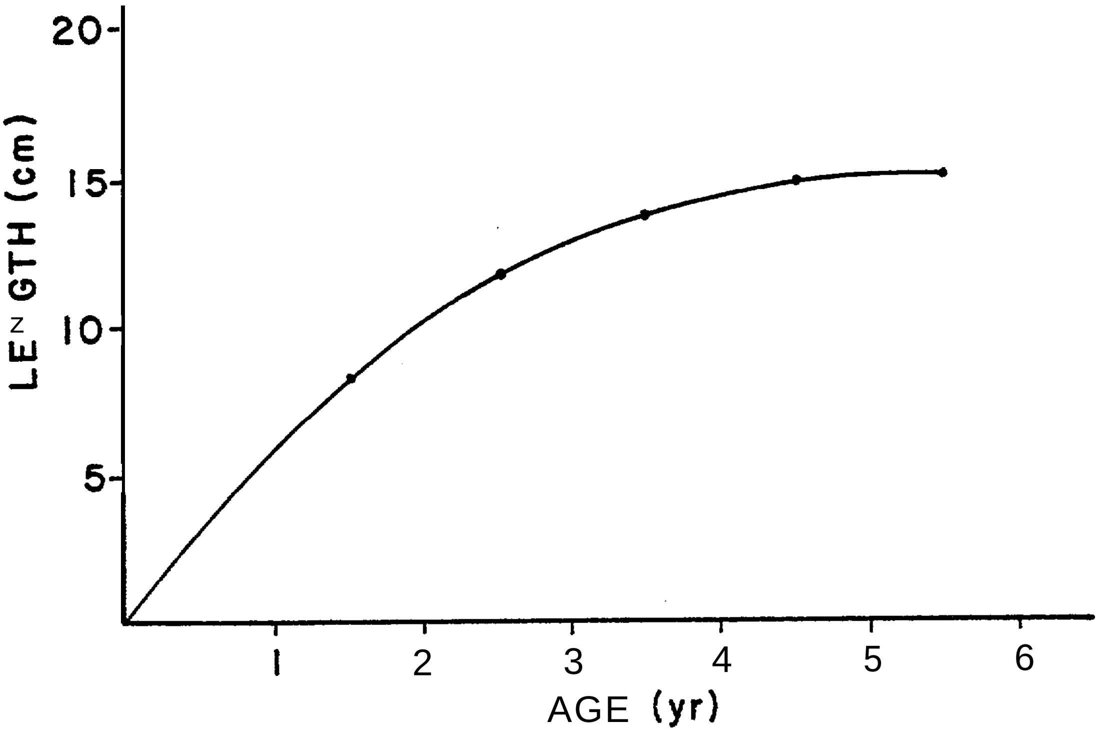


Figure 11. Growth curve of sand lance (*Ammodytes hexapterus*) at Sitkinak Lagoon. Points represent mean length at age class of fish taken in late June-early July, 1979.

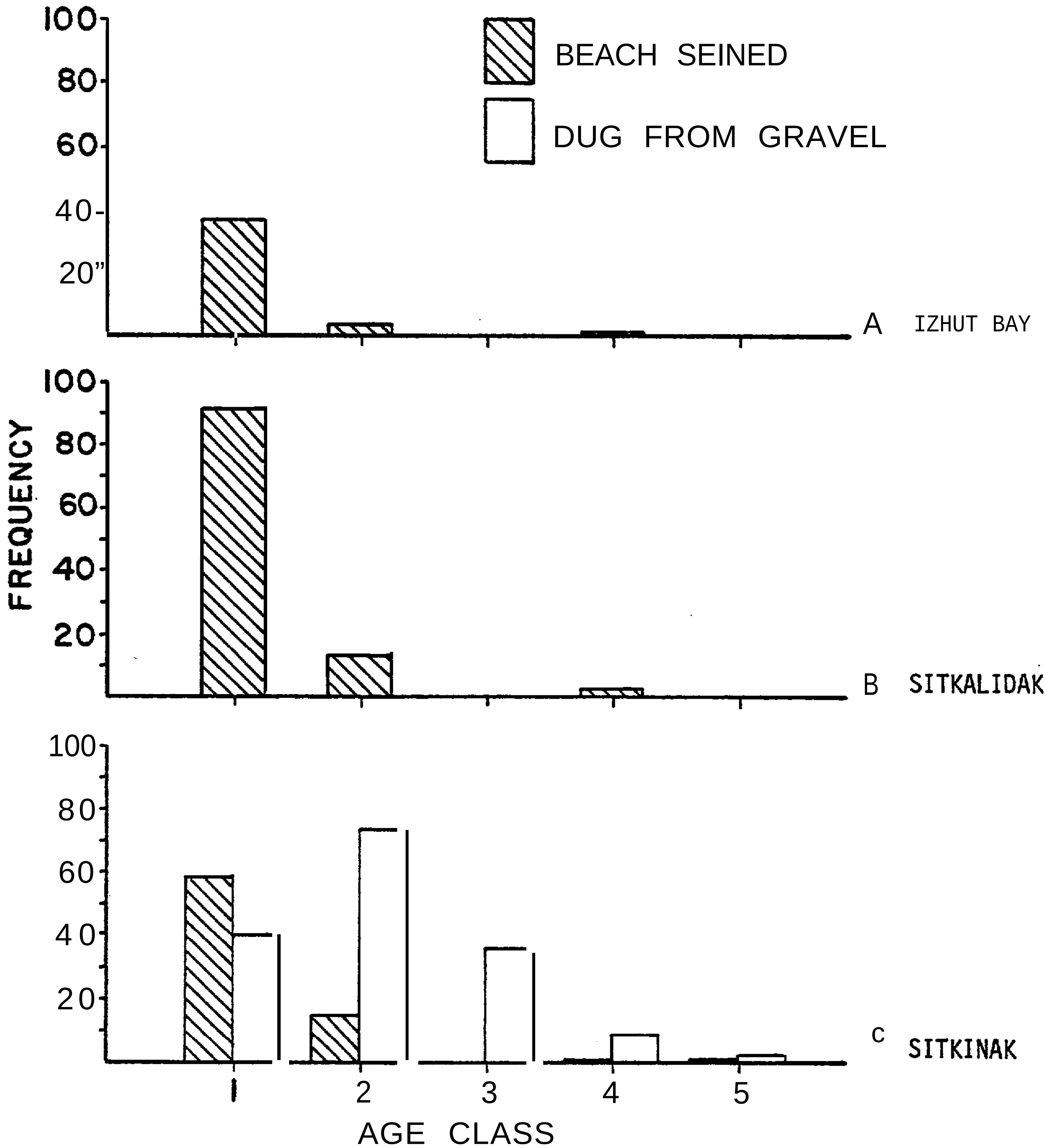


Figure 12. Age-frequency distributions of sand lance (*Ammodytes hexapterus*) sampled A.) by beach seine at Izhut Bay, May-June, 1979. n = 42. B.) by beach seine at Sitkalidak Strait, May-June, 1979. n = 109. C.) by beach seine (n = 76) and digging (n = 161) at Sitkinak Lagoon, June-July, 1979.

Table 12.--Means, followed by ranges, of body length (mm) at age class of sand lance from the east side of the Kodiak Archipelago, May-June, 1979. Mean lengths at age class of Barents Sea sand lance (*A. hexapterus marinus*) given by Andriyashev (1954) are presented for comparison. Numbers of individuals in the Kodiak samples are given in parenthesis.

Area	Age Classes					
	0	1	7	3	4	s
Izhut Bay n = 42		114.8 104-130 (37)	139.0 128-135 (4)		189.0 189 (1)	
Narrow Strait n = 40	53.8 49-60					
Sitkalidak Island n = 109		113.2 90-136 (02)	135.9 103-158 (14)		171.7 169-175 (3)	
Sitkinak Island n = 237		82.1 61-118 (98)	117.1 65-140 (90)	133.9 111-164 (36)	146.5 133-160 (lo)	1s0.3 133-161 (3)
Offcoast of Murman	95	116	135	159	(166)	---
Offcoast of Novaya Zemlya	64	75	81	94	104	---

Table 13. Significance of the difference between mean lengths (mm) at age between Sitkinak and Sitkalidak sand lance, and between sand lance captured by two capture methods at Sitkinak Island.

Year Class	Samples Compared	Difference In Means	3(D)[1]
I	Sitkalidak/Sitkinak	31.1	4.5
11	Sitkalidak/Sitkinak	18.8	13.6
Iv	Sitkalidak/Sitkinak	25.2	10.2
I	Sitkinak (Seined/Dug)	3.1	6.8
11	Sitkinak (Seined/Dug)	13.6	16.9

[1] Standard error of the difference between two means.

Casual field observations during this study showed predation by Dolly Varden, coho salmon and other species to be common (Table 15). The only information collected on sand lance food habits came from the examination of 115 fish dug at Sitkinak Island. Eighty-seven percent contained amphipods only; 13% were empty.

Capelin

Capelin spawn was detected only at two sites, both within Monashka Bay (census area B). Actual spawning was witnessed at one of those locations (Monashka Beach) by a project biologist. Spawn ready, or spawned out capelin were captured in four census areas: Izhut Bay, Monashka Bay, Sitkalidak Island and Alitak Bay. Through public interviews conducted after media announcements, capelin spawnings were found to have been annual at Roslyn Beach in Chiniak Bay (census area B) for a minimum of 25 years.

Spawning capelin were observed at a small beach at Monashka Bay at 11:45 p.m. on May 28, 1979 at high tide. During the spawning period an offshore wind blew at a 45 degree angle to the shore at less than 3 knots, and the surf was less than half a meter in height. The characteristic "cucumber" odor of smelt was noted when the observer was yet 200 meters from the spawning beach. Tens of thousands of capelin could be seen riding on the crest of each incoming wave, then retreating as the wave receded. The fish appeared unafraid of activities on the beach; however, they did avoid the lights used by fishermen and observers. There were few females in the large samples of fish taken by project personnel; this paucity of spawning females was previously noted by Warner and Shafford (1979). Sports fishermen present were interviewed and reported that on May 29, 1979 capelin spawned on the same beach for four hours, continuing past high tide and until dawn. A similar description of capelin spawning behavior was recorded at Pillar Beach (census area B) in 1977 (Ibid. 1979).

Inspection of the Monashka Beach site on the low tide following spawning revealed large quantities of roe 1 - 3 meters below (i.e. seaward from) where spawning activities had been observed the previous night (Figure 20), The gravel substrate in the spawning area was 2 - 20mm in diameter and spawn had been washed into the substrate to a depth of 0.5 to 240 mm. Roe was white and about .75 mm in diameter. The density of deposition varied considerably, though levels usually exceeded 60 ova per .25 square meter of beach surface. Highest estimated densities were one hundred times that level. Predation on the deposited roe by amphipods was intense but unquantified. No spawning mortality was noted.

On the morning of May 29, 1979 the beach at Pillar Creek, which is approximately 5 kilometers from Monashka Beach (census area B), was also inspected for spawn deposition. Apparent spawning mortality of approximately a thousand individual male capelin was noted along the high tide line. Capelin spawn was also located by project personnel at this beach, and deposition features were identical to those on Monashka Beach.

A total of 620 capelin was taken from four census areas: Izhut Bay, Monashka Bay, Sitkalidak Island, and Alitak Bay. A total of 352 of these specimens was aged. Age 1 fish predominated in samples from the northern range of the study area (census areas A and B), whereas in the southern range (census areas C and F) age class 2 capelin dominated (Figures 17 and 18). A relationship between age and

Tab le 14. Sand lance gonad index (Hjort Scale) by age class, all areas, 1979. Table shows number of individuals, (n = 351).

Gonad Index	Age Class I	II	111	IV	v
I	215	40	4	-	-
11	3	32	14	7	2
111		17	10	3	1
IV			1	2	-

Table 15. Summary of miscellaneous observations of sand lance taken as prey along the east side of the Kodiak Archipelago in summer, 1979.

Date	Locality	Data
5/30/79	Sitkalidak Strait	A large Dolly Varden contained 15 sand lance.
6/20/79	Alitak Lagoon	Twelve large Dolly Varden sampled. One contained three sand lance and neried polychaetes; four contained neried polychaetes; seven were empty.
6/16/79	Moser Bay	Several captured Dolly Varden contained a few sand lance each.
6/21/79	Akhiok Bay	Sand lance in two of three _Myoxocephalus_ sampled. .
6/25/79	Sitkinak Lagoon	One Dolly Varden contained 40 sand lance.
6/27/79	Sitkinak Lagoon	Six sand lance in a _Mvoxocephalus_, one of seven of that genus and the genus _Leptocottus_ which were sampled.
6/28/79	Sitkinak Lagoon	Of three Dolly Varden sampled, there were two sand lance in one and four in another.
7/11/79	Sitkinak Lagoon	In a night beach seine set using a lantern as an attractant, one of three Dolly Varden caught contained two sand lance.
8/20/'79	Buskin River Vicinity	The stomachs of three coho salmon were filled with sand lance.

size was not apparent (Figure 19). Body lengths ranged between 93 and 149 mm (Figures 13 through 16), and the single year class dominance is apparent from these length frequencies. Few capelin taken were smaller than 100 mm and all were mature. All capelin examined showed strong sexual dimorphism, which is characteristic of the species.

Eulachon

Spawn ready eulachon were collected from three census areas: A, B and F (Izhut Bay, Kalsin Bay and Alitak Bay respectively). Maturity indices of the Kalsin Bay eulachon are shown in Table 16, Forty seven of these fish were spawning or had spawned, while 54 were in a pre-spawning condition. All these specimens were collected in fresh water, Eulachon samples from Alitak Bay were obtained from commercial shrimp vessels, Spawn ready eulachon were found along with pre-spawning specimens; however, gonad samples and body measurements were unuseable due to compaction in the vessel holds, Seven spawn ready eulachon were captured in Izhut Bay"within a few kilometers of each other between May 24 and May 28. One eulachon was captured at Sitkalidak Island on May 30, and it was in a pre-spawning condition.

One hundred eight eulachon were collected and measured, and of this number 70 were aged. Eulachon from Izhut Bay were all 3years old. Eulachon from Kalsin River were mostly 2 years old (Figure 22). Otoliths from eulachon taken at Alitak Bay were lost during processing and the age of the eulachon specimen from Sitkalidak was unknown.

Lengths of Kalsin River eulachon ranged from 175 mm to 220 mm (Figure 21), and were bimodal (Figure 21). Lengths of Izhut Bay eulachon ranged from 195 mm to 219 mm. The ratio of males to females in the Kalsin River eulachon was six to one. Insufficient data exist in other areas to project a meaningful sex ratio.

Surf Smelt

No spawning surf smelt, nor deposited spawn of surf smelt were found during this study. Six specimens of this species were caught, and three of these were in spawn ready condition.

The six surf smelt caught in this study were taken at Sitkalidak Strait (2), and Izhut Bay (4). Five of these fish were aged at 2 years and one at 3 years. Mean body size of these specimens was 192 mm in length and 89 grams in weight.

Miscellaneous Species and Catch per Unit of Effort (CPUE)

A total of twenty-two taxa of non-forage fish was collected (Table 17). Frequency of occurrence and CPUE of Dolly Varden was consistent (38 - 45% and .05 - .08 fish per hour respectively in gill net) in all areas (Tables 18, 19, 20, 21 for gill net catches, and Tables 9, 10, 11 and 22 for beach seine catches). The catch figures for other species caught by VMG were similar at Izhut Bay and Sitkalidak Strait. The frequency of greenling was 35% and 34% at these two localities respectively; cod 12% and 19%; flounders 8% and 15%. At Sitkinak Island, there was a much greater frequency of sculpins (80%) and flounders (50%) and a much greater CPUE for these groups.

Table 16.--Frequency distribution of gonad index for eulachon taken in the Kalsin River on May 27, 1979. N = 85

Gonad Index	Frequency of Occurrence	Percent Frequency of Occurrence
3	7	8
4	39	46
5	9	11
6	9	11
7	21	25

Table 17.--List of all miscellaneous species caught during forage fish investigations, Kodiak/Afognak Islands, 1979 OCSEAP research

Species Common Name	Scientific Name	Abundance
Pink salmon (fry)	Oncorhynchus gorbuscha	High
Chum salmon (fry)	Oncorhynchus keta	Moderate
King salmon (smelt)	Oncorhynchus tshawytscha	Low
Dolly Varden	Salvelinus malma	Moderate
Pacific cod	Gadus macrocephalus	Low
Threespine sticklebacks	Gasterosteus aculeatus	Low
Greenling (fry)	Hexagrammos	High
Rock greenling	Hexagrammos logocephalus	Low
Whitespotted greenling	Hexagrammos stelleni	Low
Masked greenling	Hexagrammos octogrammus	Low
Silverspotted sculpin	Blepsias cirrhosus	Low
Pacific staghorn sculpin	Leptocottus armatus	Low
Great sculpin (fry)	Myoxocephalus polyacanthocephalus	Moderate
Sturgeon poacher	Agonus acipenserinus	Low
Tubenose poacher	Pallasina barbata	Low
Pricklebacks	Stichaeidae	Low
Snake prickleback	Lumpenus sagitta	Low
Crescent gunnel	Pholis laeta	Low
Sole & Flounders	Pleuronectidae	Moderate
Rock sole	Lepidopsetta bilineata	Low
English sole	Parophrys vetulus	Low
Starry flounder	Platichthys stellatus	Low

Table 18. Summary of variable mesh gill net catch, Sitkinak Island, June 25 - July 5, 1979. (Eight sets in estuary on Tugidak Passage; all other sets on Sitkinak Lagoon.) Figures represent 20 sets, 363 net hours.

Species	Frequency of Occurrence in Sets	% Frequency of Occurrence	Total Number Caught	Average Number Per Set	CPUE (Fish/net hr.)
King salmon (smelt)	2	10	2	0.1	0.01
Dolly Varden	9	45	18	0.9	0.05
Threespine sticklebacks	1	5	1	0.1	0.01
Whitespotted greenling	5	25	13	0.7	0.04
Great sculpin group	3	15	14	0.7	0.04
Pacific staghorn sculpin	16	80	165	8.3	0.50
Starry flounder	10	50	29	1.5	0.08
Rock sole	2	10	7	0.4	0.02
All Sculpins	16	80	179	9.0	0.50
All Flounders	10	50	36	1.8	0.10

Table 19. Summary of variable mesh gill net catch, Sitkalidak Strait, May 4 - July 3, 1979. Figures represent 53 sets, 716 net hours.

Species	Frequency of Occurrence in Sets	% Frequency of Occurrence	Total Number Caught	Average Number Per Set	CPUE (Fish/net hr.)
Herring	33	62	2,023	38.2	2.83
Chum salmon (smolt)	1	2	1	0.1	0.01
Dolly Varden	24	45	56	1.1	0.08
Surf smelt	3	6	4	0.1	0.01
Capelin	9	17	81	1.5	0.11
Eulachon	1	z	z	0.1	0.01
Cod[1]	10	19	53	1.0	0.07
Greenling[2]	18	34	90	1.7	0.12
Sculpins	13	25	51	1.0	0.07
Flounders[3]	8	15	21	0.4	0.03

[1]Includes at least 27 Pacific cod.

[2]At least Rock greenling, Masked greenling and Whitespotted greenling were identified.

[3]Includes at least Rock sole, English sole and Starry flounder.

Table 20. Variable mesh gill net catch at Rodman Beach in Alitak Bay, Kodiak, June 18 - 20, 1979.

SPECIES	SET NUMBER 87	93	94	96	TOTAL
Staghorn sculpin				2	2
Great sculpin			3	5	8
Sturgeon poacher		3	1	5	9
Snake prickleback				2	2
Silverspotted sculpin		2			2
Pacific cod		2			3
Whitespotted greenling		1	2		3
Dolly varden	1		5	23	29
Herring		1	3	2	6
Hours of soak time	10	12	9	14	45
Total fish per set	1	9	14	40	64

Table 21. Summary of variable mesh gill net catch, Izhut Bay, May 7 - June 20, 1979. Figures represent 52 sets, 1,131 net hours.

Species	Frequency of Occurrence in Sets	% Frequency of Occurrence	Total Number Caught	Average Number per Set	CPUE (Fish/net hr.)
Herring	35	67	1,432	27.5	1.27
Dolly Varden	20	38	80	1.5	0.07
Surf smelt	2	4	2	0.1	0.01
Capelin	10	19	81	1.6	0.07
Eulachon	6	12	11	0.2	0.01
Cod	6	12	6	0.1	0.01
Pricklebacks	1	2	2	0.1	0.01
Rockfish	1	2	1	0.1	0.01
Greenling	18	35	69	1.3	0.06
Sand lance	1	2	1	0.1	0.01
Sculpins	5	10	8	0.2	0.01
Flounders	4	8	7	0.1	0.01

Sets of over 30 hours soak time were omitted from this summary.

Table 22. Beach seine catch, west shore **Alitak** Lagoon (sets 88-92) and **Rodman** Reach (95).

SPECIES	SET NUMBER 88	89	90	91	92	95	TOTAL
Pink salmon	17		10	50	30	1	108
Chum salmon	2						2
King salmon		2	1	2			5
Dolly varden	2				10		12
Crescent gunnel						4	4
Great **sculpin**			1	5	2	3	30
Whitespotted **greenling**						3	3
Greenling species						1	1
Greenling fry	1	2		3			6
Staghorn **sculpin**						1	1
Sand lance			1				1
Unid. Sculpin fry	1						1
Total fish per set	23	23	13	60	42	13	174

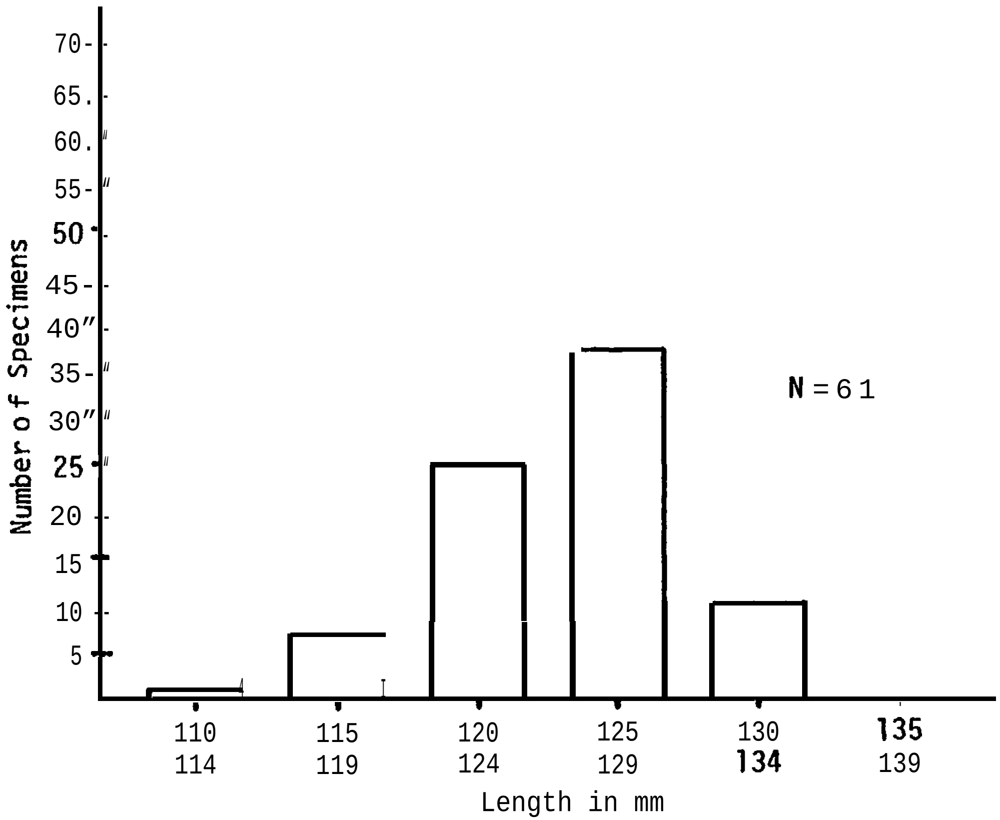


Figure 13. Length-frequency distribution of capelin (*Mallotus villosus*) captured by variable mesh gill net, Izhut Bay, 1979.

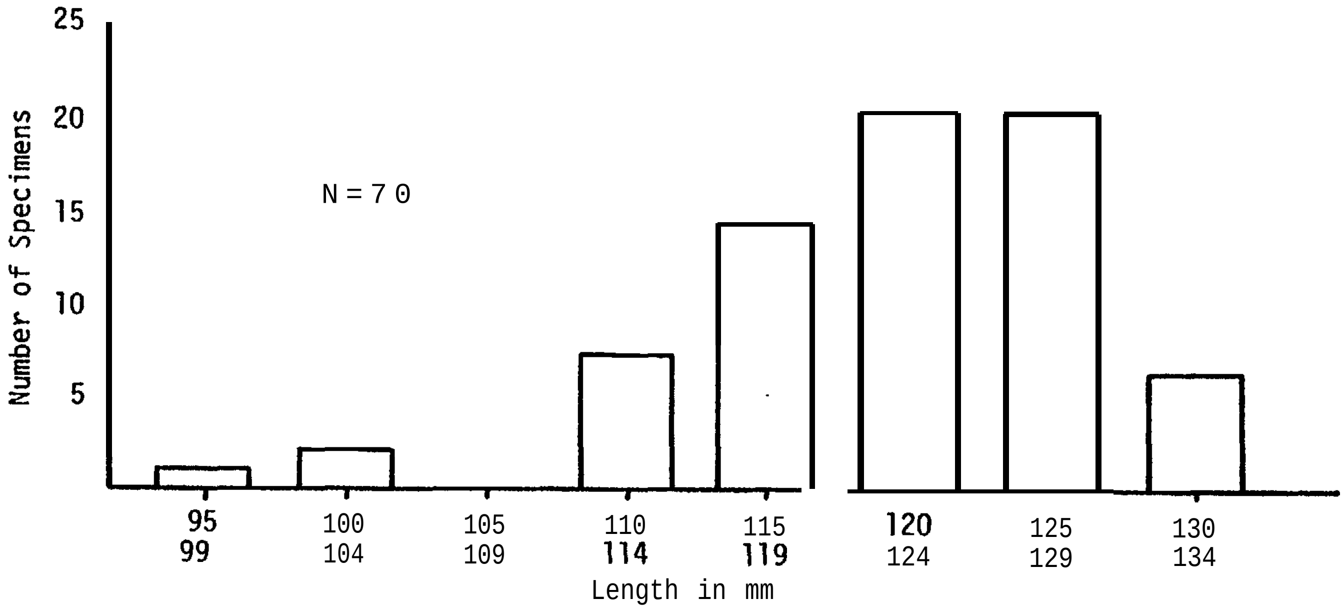


Figure 14. Length-frequency distribution of spawning capelin (*Mallotus villosus*) recovered from beach, Monashka Bay, 1979.

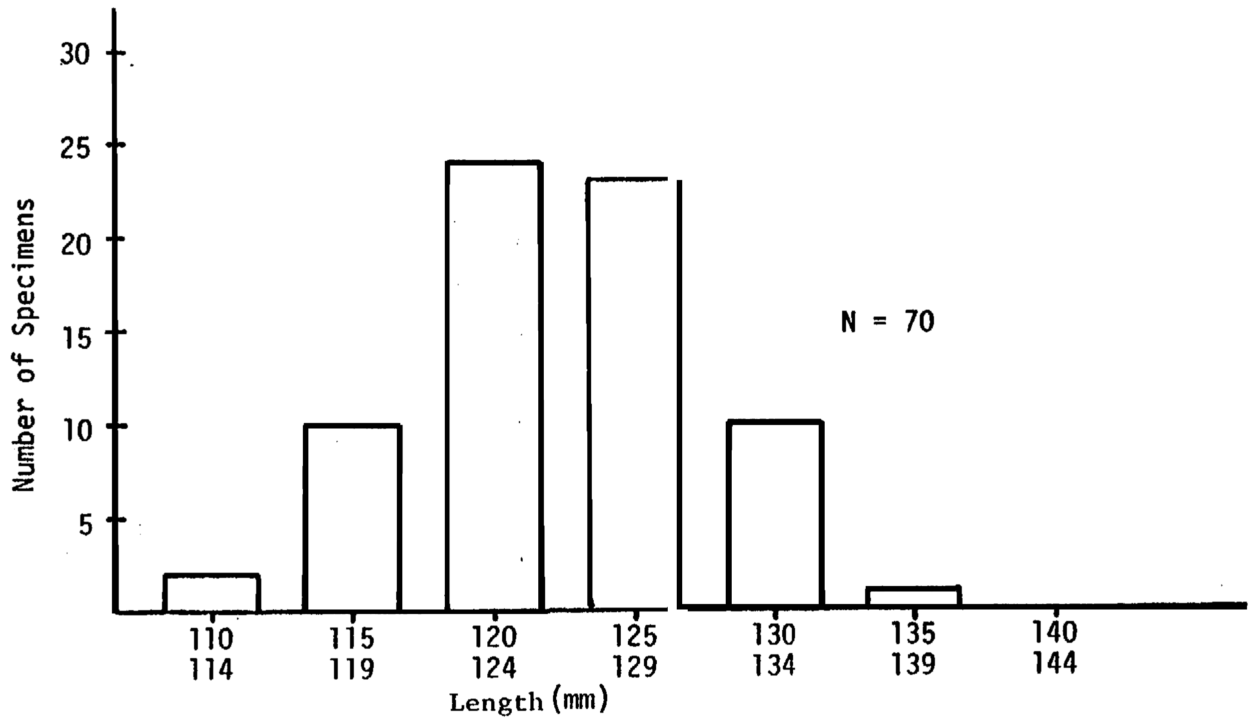


Figure 15. Length-frequency distribution of capelin (*Mallotus villosus*) captured by variable mesh gill net, Sitkalidak Island, May-July 1979.

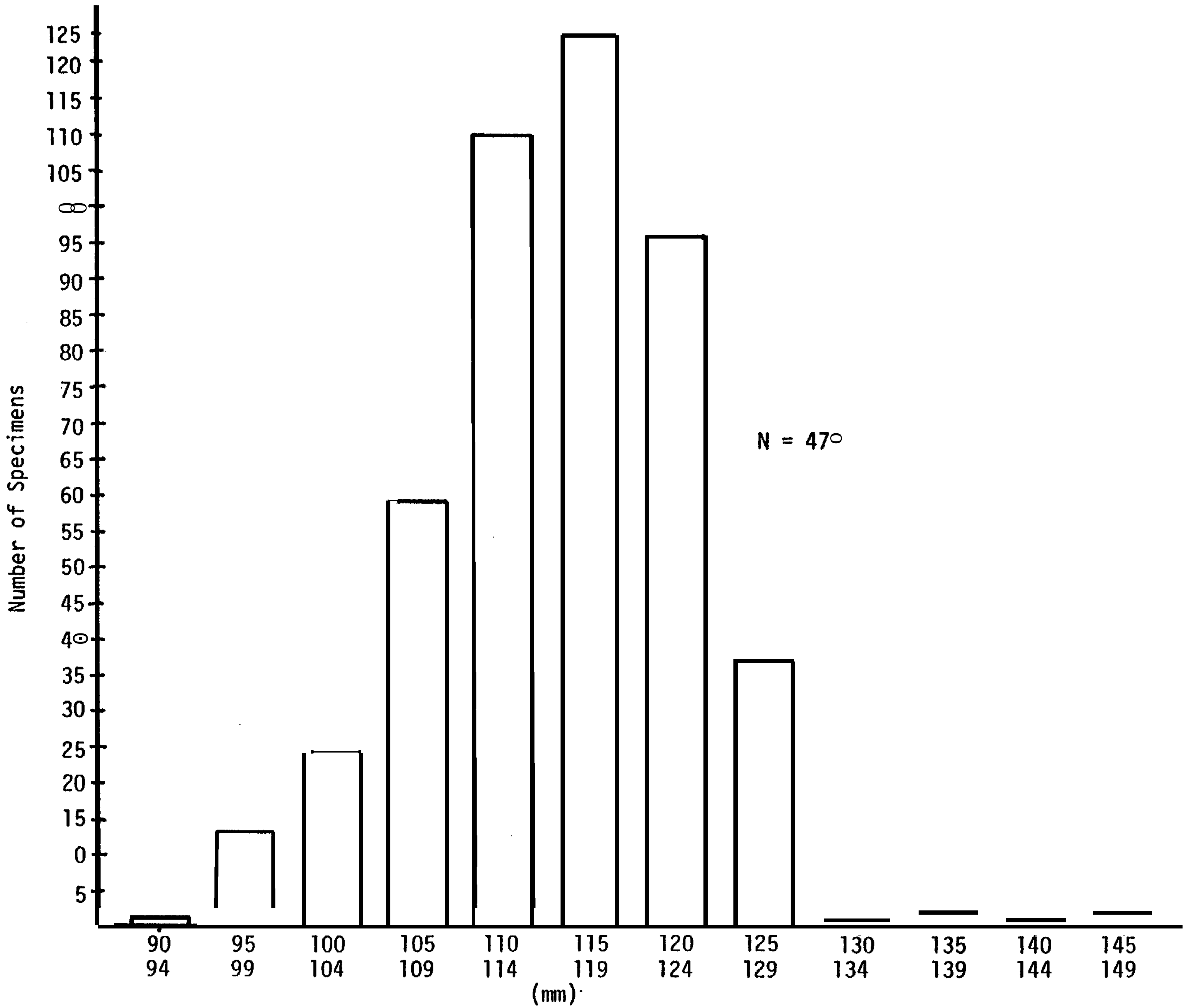


Figure 1 Length-frequency distribution of capelin (*Mallotus villosus*) caught by commercial otter trawl, June 1979, Alitak Bay.

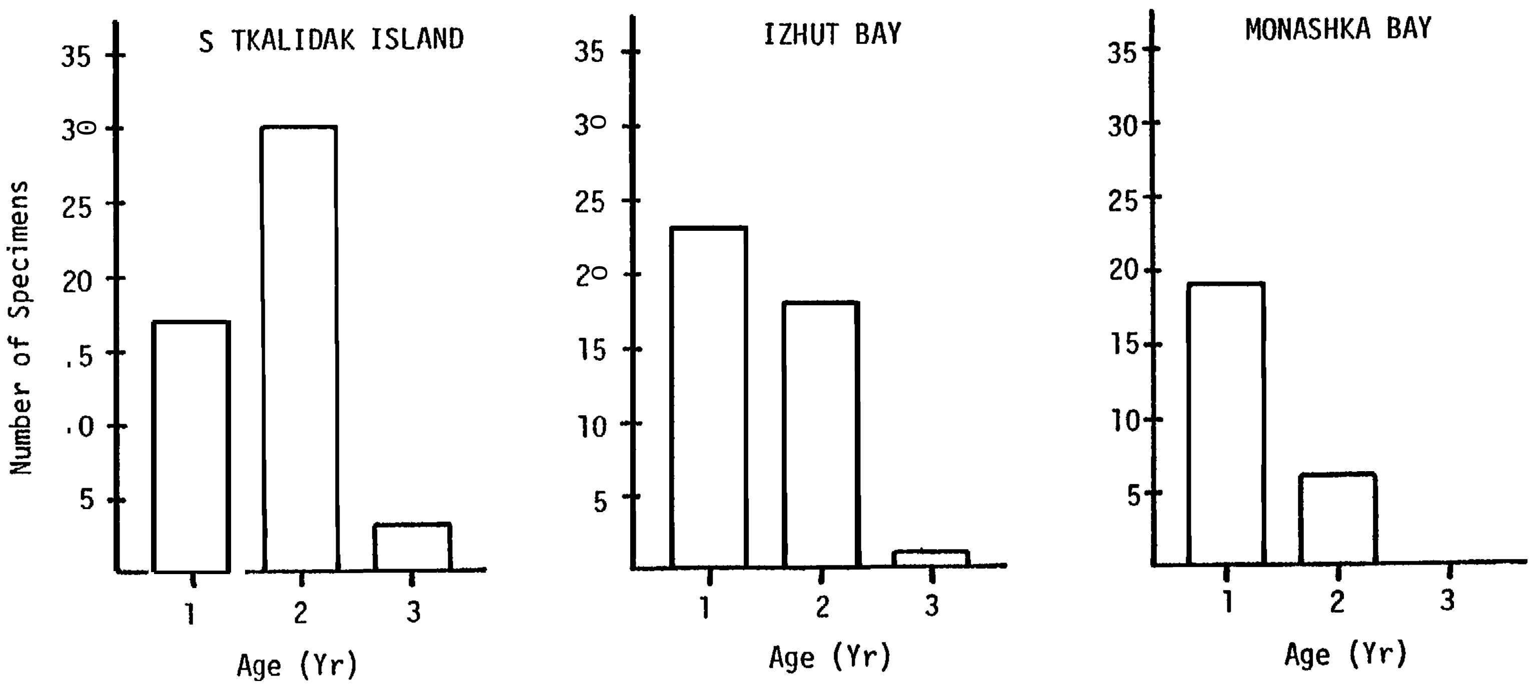


Figure 17. Age-frequency distribution of capelin (*Mallotus villosus*) captured at various sites along the east side of the Kodiak Archipelago, May-July, 1979. Capelin from Sitkalidak Island and Izhut Bay were caught by variable mesh gill net, capelin from Monashka Bay were recovered by hand from the beach.

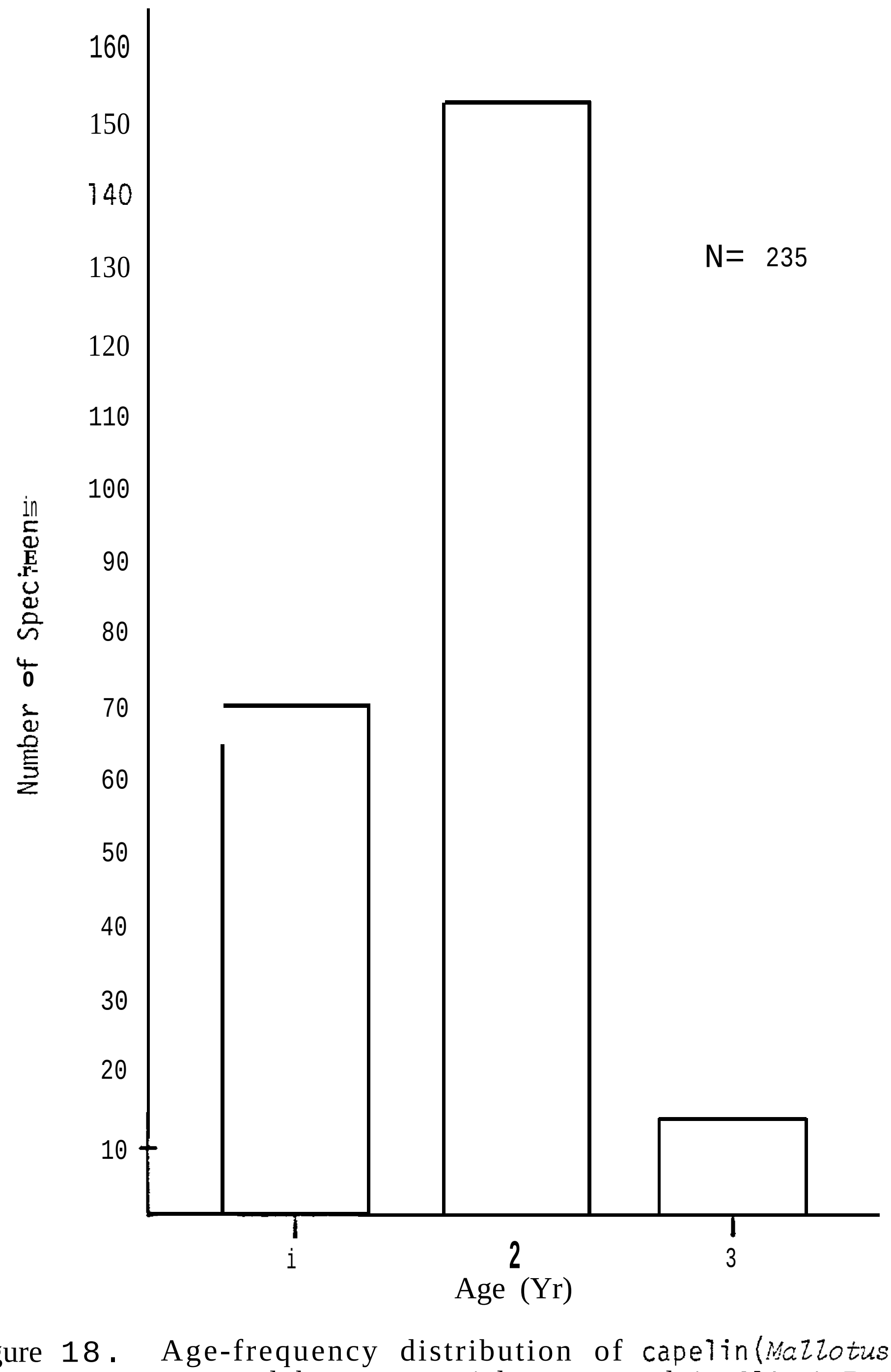


Figure 18. Age-frequency distribution of capelin (*Mallotus villosus*) captured by commercial otter trawl in Alitak Bay, June, 1979.

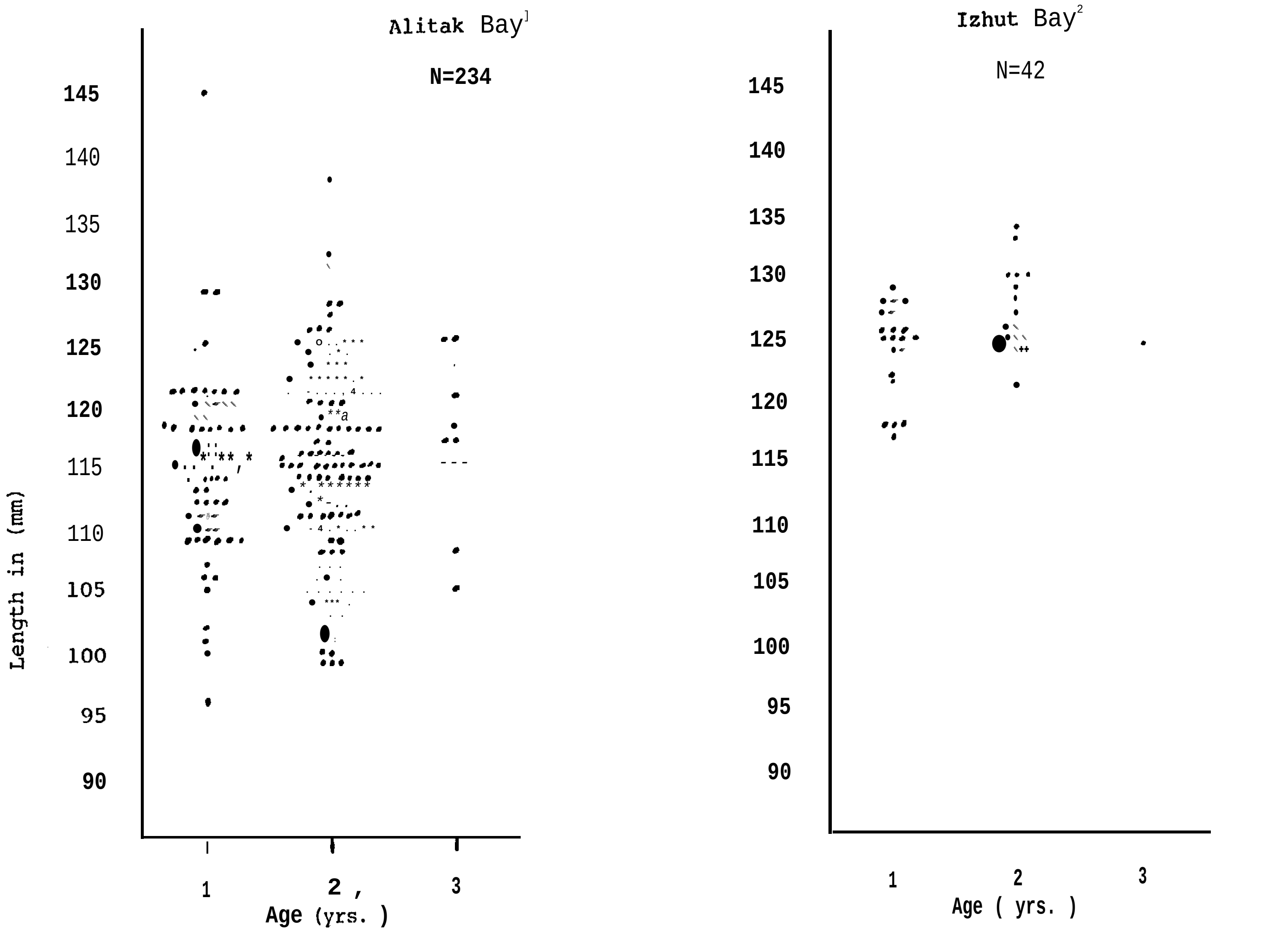
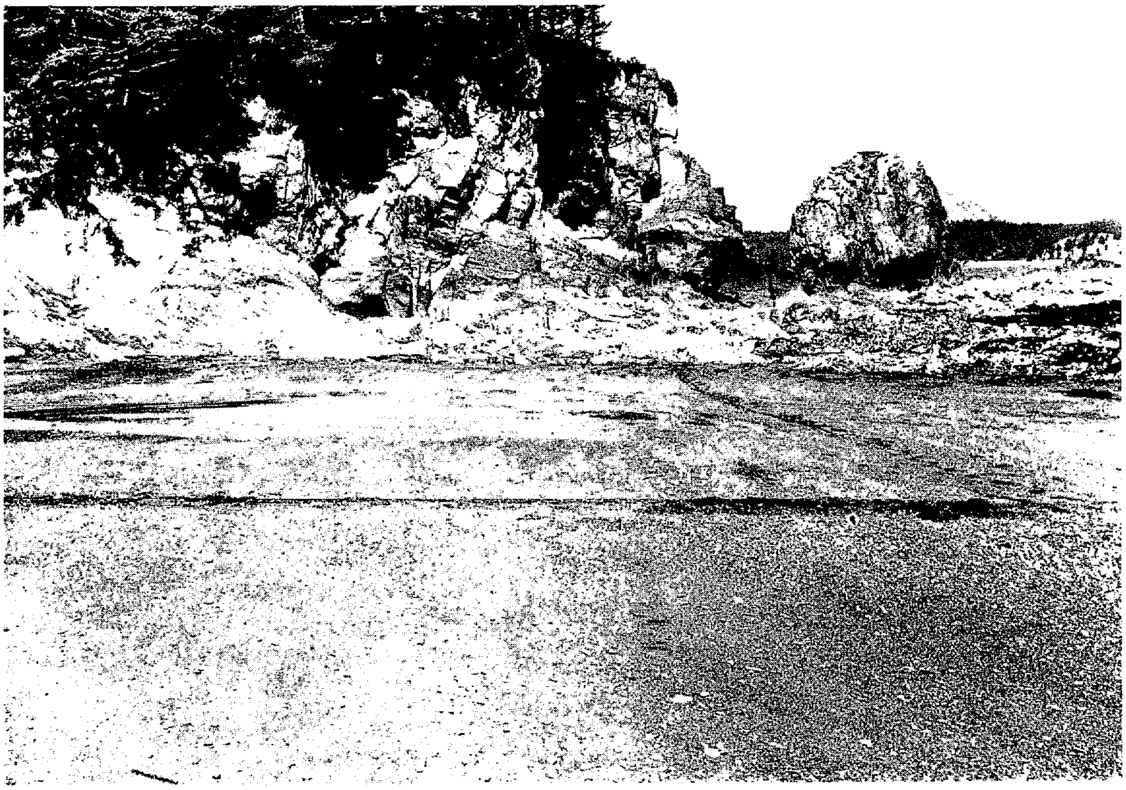
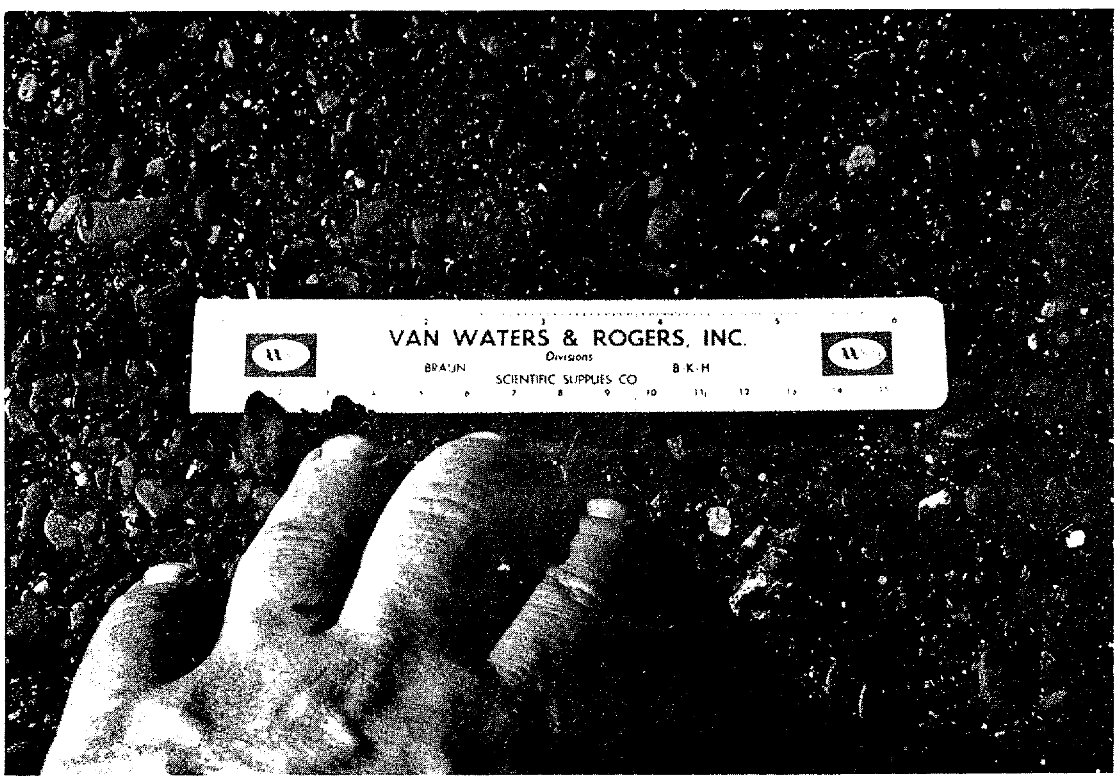


Figure 19. Length-frequency distribution, by age group, of capelin (*Mallotus villosus*) captured by commercial otter trawl[1] and variable mesh gill net[2] at two sites on the east side of the Kodiak Archipelago, May-June, 1979. Dots represent individuals.

Figure 20.



a. Beach area where capelin spawning was observed, May 1979.



b. Typical capelin spawning substrate. Monashka Bay, Kodiak Island. 1979.

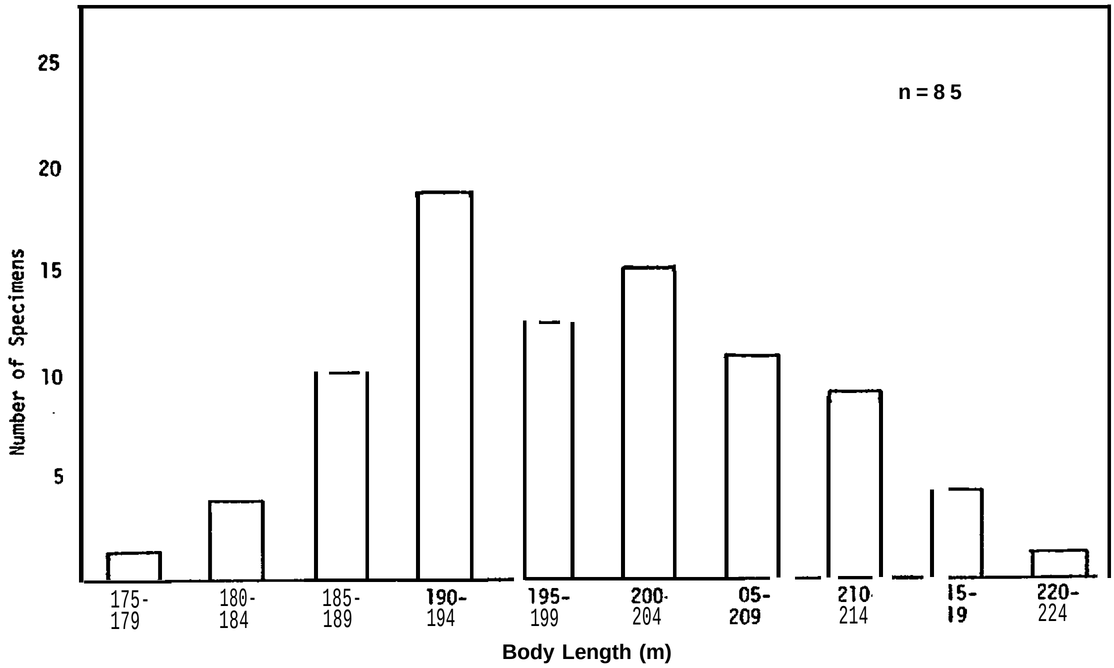


Figure 21. Length-frequency distribution of eul achon (*Thaleichthys pacificus*) caught by dip net at Kalsin River, Kodiak Island, May 1979.

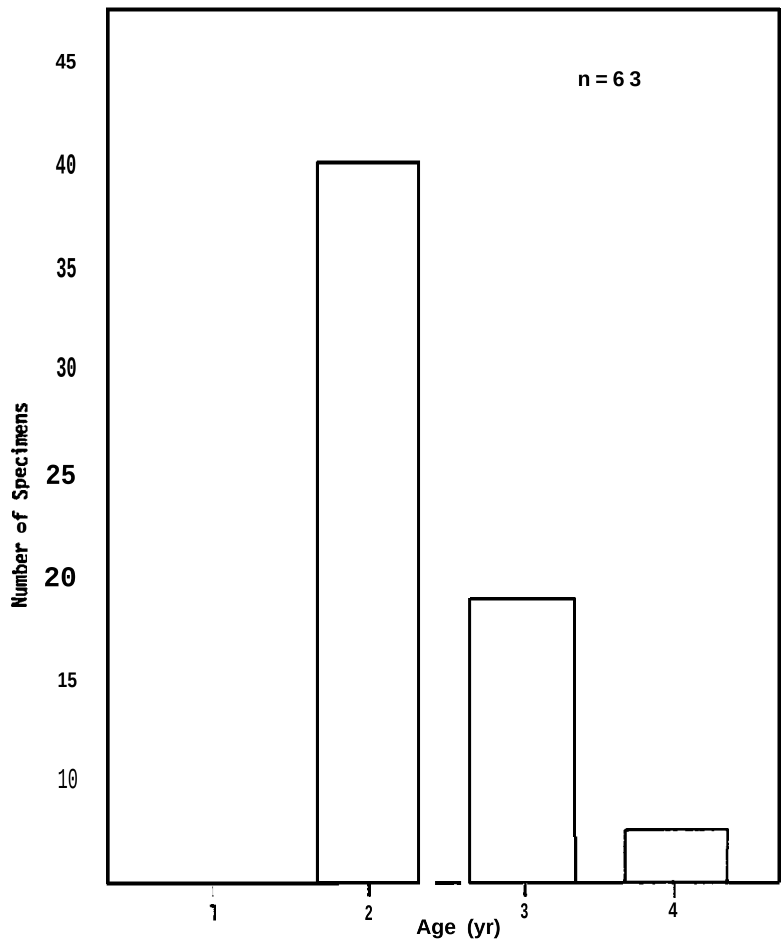


Figure 22. Age-frequency distribution of spawning eulachon (*Thaleichthys pacificus*) "p "'ted from the Kal sin River, Kodiak Island, May 1979.

The average catch of non-forage fish species in VMG at Sitkinak (12.6 fish/set) was much less than at Izhut (32.9 fish/set). Catches of pink salmon fry in beach seines were consistently high in all areas. The frequency of occurrence of sculpins was high in all areas.

DISCUSSION

Aerial Surveys

All observations made during aerial surveys are subjective except for the counts of schools sighted. School size, either from a standpoint of biomass or area is highly subjective and a function of observer experience. It is the opinion of the senior author that school size, as judged from the air is an extremely fluid parameter, i.e. that frequently an observed school's size will vary within minutes by, often times, a factor of 2. Species composition of a school and distinguishing a fish school from non-fish subsurface objects is often difficult because of turbulence, turbidity, light conditions, fatigue or a combination of all these factors. Statements derived solely from aerial surveys must, therefore, be severely limited in scope if no other form of data (i.e. ground surveys, fishing results, etc.) exist for a given study zone.

Aerial observations of forage fish schools in the Kodiak area were more difficult than OCSEAP aerial surveys conducted in the Bering Sea by the same observer. The highly convoluted shoreline of Kodiak and Afognak Islands made air turbulence a decisive factor on every survey, i.e. meaning that some portions of a census area simply-couldn't be surveyed safely and were passed over until weather conditions improved. Also, many more subsurface objects, which appear similar to fish schools were sighted, hence, prudence had to be employed. In the final analysis, few schools were counted unless movement was observed directly or indirectly.

Too few hours were dedicated to aerial surveys, considering the study area size, but in spite of this, aerial survey indications of high forage fish density correlated well with ground results. Few schools were seen in the Trinity Islands; these results, we feel, accurately describe a situation there; e.g. that the forage fish species studied during this project do not rely on this area for nearshore spawning during the summer months. Aerial surveys indicate that forage fish are active in areas only where shelter is afforded from violent open ocean conditions.

The importance of aerial surveys in a spawning study is limited; sighted schools cannot be determined as to spawning state and activity except in instances where milt is observed in the water, or digging in substrate is observed. Finally, actual ground activities must be conducted to confirm any aerial observations concerning spawning. There is no substitute for actually finding fertilized ova *in situ*.

Pacific Herring

Herring are a significant component of the spawning forage fish community along the east coast of the Kodiak Island Archipelago in the spring and summer of the year. Generally, they require secluded bays within larger bays with eelgrass and kelp substrate on which to spawn. Herring begin spawning in early spring of the year, often as early as mid to late April.' During their spawning cycle they are subject to commercial fishing pressure.

Herring are the longest lived of the forage fishes Included in this study, and individual specimens of over 10 years of age have been identified. Assuming a sexual maturity at 2 or 3 years of age, a 10 year old herring could have completed seven to eight spawning cycles. This longevity has direct petroleum impact relevance. The more spawning cycles an individual year class can complete, the less likelihood that an entire population could be obliterated by an oil spill during a single year, as that population of fish is not dependent on a single year-class for sustaining itself. How quickly and ably a herring school would avoid a spill area is not known. The *toxic* effects of crude oil and refined oil products on egg and young of this genus have been demonstrated in other studies. Adult physiological reaction to crude oil has been shown to vary in impoundment studies.

Nearshore spills, depending on drift direction would have a high probability of having adverse effect on eelgrass and algae substrate on which herring depend for proper spawning. Because of the toxicity of these substances to the eggs, a bay or inlet subjected to a petroleum spill would, in the opinion of these researchers, be rendered useless for herring spawning. Petroleum spills during the spring of the year probably would subject herring to the highest degree of risk. It is possible that an entire year-class of eggs or larvae could be annihilated by an oil spill.

Sand Lance

Sand lance were abundant at each of three widely separate localities on the east side of the Kodiak Archipelago in summer, though seine catches varied greatly with time and location. Harris and Hartt (1977) similarly found sand lance to be the numerically dominant fish species in the nearshore zone in summer in Alitak, Kaiugnak and Ugak Bays, all on the east side of the archipelago. They also noted a variability in catches, which indicates a highly clustered distribution. Frequency of occurrence and catch per unit effort were highest in Sitkalidak Strait and lowest in southwestern Alitak Bay. Harris and Hartt (1977) found fewer lance in the southwestern portion than in the rest of Alitak Bay. They obtained sand lance at all tide stages, though we found seining much more productive at mid to high tide than at low tide. The factors determining local distribution are poorly understood (Reay 1970), though they include diurnal behavior and tide stage in some populations of Ammodytes.

The presence of Kodiak sand lance in the brackish lake on Ban Island indicates a tolerance to low salinity, as has been observed in some other species within the genus (Ibid.) We commonly found sand lance in the gravel at stream mouths, and Mr. French specifically mentioned schooling near stream mouths and small freshwater outlets during spawning. Freshwater influence, therefore, seems to a greater or lesser extent related to local distribution.

The habitat in which sand lance bury themselves in summer and spawn in fall is very similar or identical to that utilized by capelin, i.e., beaches of coarse sand and fine gravel:

The adequacy of the beach seine as a sampling tool for sand lance is in doubt as evidenced by the differences in age frequencies of beach seined samples and those dug from gravel at Sitkinak Island (Figure 12). Kühlmann and Karst (1967) reported the segregation of A. tobianus into schools of fish of a similar size. While such behavior might account for differences in age-frequency between the samples, it does not explain why schools of older, larger fish were never caught by beach seine.

Kodiak Archipelago sand lance show a number of similarities to the subspecies Ah. marinus in the Barents Sea, discussed by Andriyashev (1954), Mean lengths at age of Barents Sea/Murman and Sitkalidak Strait samples are nearly identical (Table 12). Mean lengths of the Novaya Zemlya and Sitkinak Lagoon samples are among the smallest in the genus, judging from the summary of mean lengths at age for various species given by Reay (1970). Kodiak sand lance attain age class 5; Barents Sea sand lance age class 4. Kodiak sand lance mature at age classes 2 and 3; Barents Sea sand lance at age class 3. Kodiak sand lance spawn intertidally in October, then disappear from the nearshore zone. They possibly bury themselves in the substrate in deeper water, as is the case with some other species in winter (Ibid.). They may continue to spawn for a month or two in deeper water, though this is purely speculation. Barents Sea sand lance move offshore in October and spawn in depths of 25 - 100 m from November - February.

Kodiak sand lance age class determination was based upon the assumption of January or February hatching dates. Blackburn (1978) back-calculated these dates for sand lance in Cook Inlet, the mouth of which lies 50 km north of the Kodiak Archipelago. Given October spawning in the archipelago, eggs possibly hatch by the end of December. The effective hatching date might still be January or February, as some autumn spawning Ammodytes are known to overwinter as larvae, spending 3 - 5 months in that stage (Reay 1970 after Kändler 1941).

The observations and specimens contributed by Mr. Duane French constitute, as far as we know, the first spawning record for Ammodytes in the northeastern Pacific Ocean. The spawning took place at the beginning of the first spring tide series in October. Specimens in spawning condition were also obtained at the peak of the second spring tide series in October. Whether or not spawning took place during the rest of that month is unknown.

Sand lance are most susceptible to oil impact from May - October, as an undetermined proportion of the population is present in the nearshore zone at that time. In summer both larvae and adults occur in the pelagic and mesopelagic zones of bays as well as in nearshore zones (Harris and Hartt 1977). October is probably a particularly sensitive time, as sand lance appear on beaches in greater densities than at any other time of the year to spawn. Barents Sea sand lance migrate to deeper water in autumn (Andriyashev 1954), and it is assumed that Kodiak sand lance also take part in this type of migration. They are absent from the intertidal from November to mid April. It would be speculative to make any statements about the long-term effects of an oil spill. It can be said, however, that if sand lance were eliminated from, or drastically reduced along, theeast side of the archipelago, the consequences on various vertebrate predators would be marked, either by a decrease in their productivity or greatly increased usage of other prey species such as capelin.

This study has made original contributions concerning the basic biology of sand lance in the eastern Pacific, especially the information on longevity, growth, age structure and reproduction. It has been demonstrated that beach seining alone is inadequate for reliably sampling sand lance populations. Future research should pay careful attention to sampling techniques.

Capelin

Because of the large concentrations of capelin found in the area of Sitkalidak Straits (census area C) during shrimp surveys by ADF&G biologists, this area was expected *to* produce extensive observations of spawning capelin and spawn deposition.

The negative results in Sitkalidak Straits were a surprise to project personnel. Interviews concerning spawning capelin at the village of Old Harbor (located on the dividing point of census areas C and D) failed to reveal any native residents who could recall capelin runs.

Ancillary data from projects occurring after the contractual end of this project indicate that capelin biomass in the Sitkalidak area is high. Winter shrimp cruises completed by the ADF&G in January of 1980 again revealed dense concentrations of capelin. Prior to this, trawl catches of six to nine tons (per one mile tow) throughout an area of approximately 10 square miles (McCrary. pers. comm., 1979) have been common.

Spawn surveys conducted at locations where capelin had been observed spawning only six hours before often revealed that locating spawn was difficult. Capelin spawn was difficult to find because of two basic reasons: 1) The area where the fish spawn is not where the ova subsequently become deposited in the substrate. The fertilized ova become buried considerably seaward of the spawning location, depending on the slope of the beach. 2) Once the area of spawn deposition was located, a slow cautious examination was required before individual ova became evident to the naked eye. Once the observer began sighting individual ova, the subsequent sightings of other ova became easier. Because of these experiences in looking for capelin spawn, the job of giving adequate coverage to dozens of beaches in an area the size of Sitkalidak Island became more formidable than anticipated. A two man crew (which was the field complement in census area C and D), looking for capelin spawn on beaches where they hadn't seen spawning capelin, became a hit and miss proposition.

This study, and others in the Bering Sea, show that capelin rarely live longer than four years, and more commonly two or three years. Research in these areas indicate capelin spawn mainly once, sometimes twice, and rarely three times during their lifetime. Atlantic capelin also have this characteristic (Templeman 1948). It would follow that the biomass of capelin in different areas would have the distinct potential of being cyclic, i.e. reaching high numbers in some years, yet almost absent during others, as is true with this species in the Barents Sea.

Investigators world-wide regard the capelin as a spring spawner with spawning confined to certain high tide cycles in mid-to late spring. However, there is evidence that in Alaska the capelin spawning period is longer than previously estimated (Warner and Shafford 1979). Capelin spawning has been observed in August in Prince William Sound by marine mammal biologists (Hall, pers. comm. 1979). Larvae less than 20 mm in length have been captured in Cook Inlet during August, and two distinct body length modes of larvae 20mm apart were found there (Blackburn 1978). Blackburn hypothesized that spawning occurred over an extended time period. If this were the case, it would explain the variable mean length at age results for capelin in 1979.

If the duration of capelin spawning exceeded the time period previously accepted, the time of hatch and subsequent metamorphosis of larvae into the adult stage at 12 to 16 months, would take place over a long period of time. Ageing capelin, therefore, would be difficult because of the varying amounts of summer growth prior to the formation of the first visible annulus.

Like herring, capelin would be the most vulnerable to petroleum spills during the nearshore spawning portion of their life cycle. Adverse impact to capelin stocks along the study area would likely carry over quickly to vertebrate populations which depend on these fish for food. It is established that capelin are the most important prey species for marine birds inhabiting this area. Capelin predominate in the summer diet of sooty and short-tailed shearwaters, black-legged kittiwakes, tufted puffins and common murres. These five species comprise most of the numbers and biomass of the marine bird community in the Kodiak area in spring and summer (Sanger et. al. 1978}. Similar results were obtained for marine birds in the Izhut Bay area on Afognak Island (Krasnow et. al. 1979).

Eulachon

The importance of eulachon as a forage fish in the study area is uncertain. During other OCSEAP research along the east coast of Kodiak Island, eulachon were listed as an occasional member of-the nearshore finfish community (Blackburn 1978). Our study showed them to be of minor significance compared to herring, capelin and sand lance, although catches during 1980 shrimp research cruises resulted in consistent numbers of this species in deep, (i.e. more than 50 meters) nearshore waters along the study area.

Eulachon have a life history in the Kodiak area similar to that of more southern populations. They are an anadromous smelt, ascending rivers to spawn in the spring. In Chiniak Bay they utilize Kalsin River, and in Marmot Bay, Pillar Creek. Both of *these* rivers have runs dating back at least seven years (Blondin, pers. comm.). These two systems were examined soon after the eulachon had spawned in 1979, but no carcasses were found. It is not known if adults all die after spawning, although it is assumed in the literature that some survive (Smith and Saalfield 1955). Our surveys of the two spawning streams indicate that post-spawning adults live at least long enough to swim back into the sea. Although four year old fish from Kalsin River were examined, it could not be determined if these were repeat spawners. Eulachon in Kalsin River were spawn ready; a few fish accompanying ripe spawners were not close to spawning condition.

Eulachon in Alaska may attain high population densities some years (Warner and Shafford 1979). Runs have been described of such magnitude that they clog a river system and pollute the mouth of the river with organic waste resulting from the decomposition of dead fish (Ibid.). Such anecdotal information of strong runs is lacking in the study area,

Eulachon, once up a spawning river, would be unaffected by a petroleum spill, though their access into or from the river might be impeded, and larvae returning to the sea could be affected.

Surf Smelt

Although few surf smelt were caught during this study, we feel that this only superficially indicates a low population density. Though there is no secondary evidence to indicate a high density of surf smelt (i.e. stomach contents from bird/mammal research), historical observations show that this species can reach high population levels in the Chiniak/Marmot Bay area.

During commercial fishing activities in the winter of 1966-67 more than 10 metric tons of surf smelt were landed in Kodiak in a period of six weeks (Warner ADF&G field notes). These were subsequently marketed as “silver smelt” in local markets, which were unable to handle the glut of fish. At that time, surf smelt congregated by the hundreds of tons in Kodiak’s small boat harbor.

From the scanty information obtained in this study and from what is known of other populations, the following statements can be made: The surf smelt does not presently seem to be of high population density in summer along the east side of the Kodiak Archipelago. Undetermined numbers of these fish apparently spawn during summer months, and possibly during other seasons. Detailed spawning habitat demands are unknown.

Miscellaneous Species

Adult Dolly Varden and pink and chum salmon fry are ubiquitous and fairly abundant in the nearshore zones in summer along the east side of the Kodiak/Afognak Island area. The catch of miscellaneous species at Izhut Bay and Sitkalidak Strait reinforces the conclusion that the fish community structure in these two areas is similar. That these areas differ from Sitkinak Lagoon is evidenced by: 1) morphometric differences in the sand lance populations; 2) occurrence of all forage fish species in the former localities, but not in Sitkinak Lagoon; 3) similarities in frequency of occurrence of non-forage fish species at the former localities but not at the latter,

CONCLUSIONS

The following conclusions have been derived from the results of this study:

1. Capelin spawn commonly in the nearshore areas of Chiniak, Monashka and Pasagshak Bays.
2. Capelin spawn was found to be moved and buried by surf some distance seaward from where spawning occurred.
3. Capelin utilize pebble/gravel beaches of mild to moderate slope for spawning during spring high tides.
4. Chiniak Bay yielded the highest density of schools of forage fish along the east side of the Kodiak Archipelago, with Sitkalidak Straits being a close second.
5. Sand lance are an abundant part of spring/summer nearshore catches.
6. Sand lance spawn in the autumn of the year in the nearshore zone.
7. Herring utilize eelgrass for spawning substrate.
8. Eulachon spawn in a river system which empties into Chiniak Bay.
9. Eulachon can live as long as 4 years in the study area.
10. Sand lance can live to an age of five years.
11. The mean length at age data of Sitkinak Island sand lance was different from that at Sitkalidak Island and Izhut Bay, suggesting that these two areas harbor different stocks of sand lance.

12. Beach seining caught different sizes and ages of sand lance than did digging, hence, each method alone is inadequate to fully sample sand lance stocks in the study area.

13. Surf smelt were a minor forage fish species in the study area in 1979.

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ADDENDUM

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The reference to Blumber (1969) on page 4 is out of date. More recent work indicates fish exposed to petroleum in water, sediment, and food supply readily take up hydrocarbons (Varansi and Malins, 1977) and these hydrocarbons accumulate in tissues such as those of the liver, brain, and muscle (Collier et al., 1980; Dixit and Anderson, 1977). However, metabolism and excretion progressively reduce the body burden so that hydrocarbons are not always detected (Malins and Hodgins, 1981). How quickly fish can detect petroleum hydrocarbons depends on the species, the tissue where hydrocarbons are concentrated. and other factors such as temperature and salinity. For example, severely contaminated longnose killifish, (Fundulus similus) smear to be completely free of petroleum hydrocarbons after 200 hours in clean water (Neff and Anderson, 1976).

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