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Forage Fish Assessment in Cook Inlet Oil and Gas Development Areas, 1997-1998

Prepared for MMS

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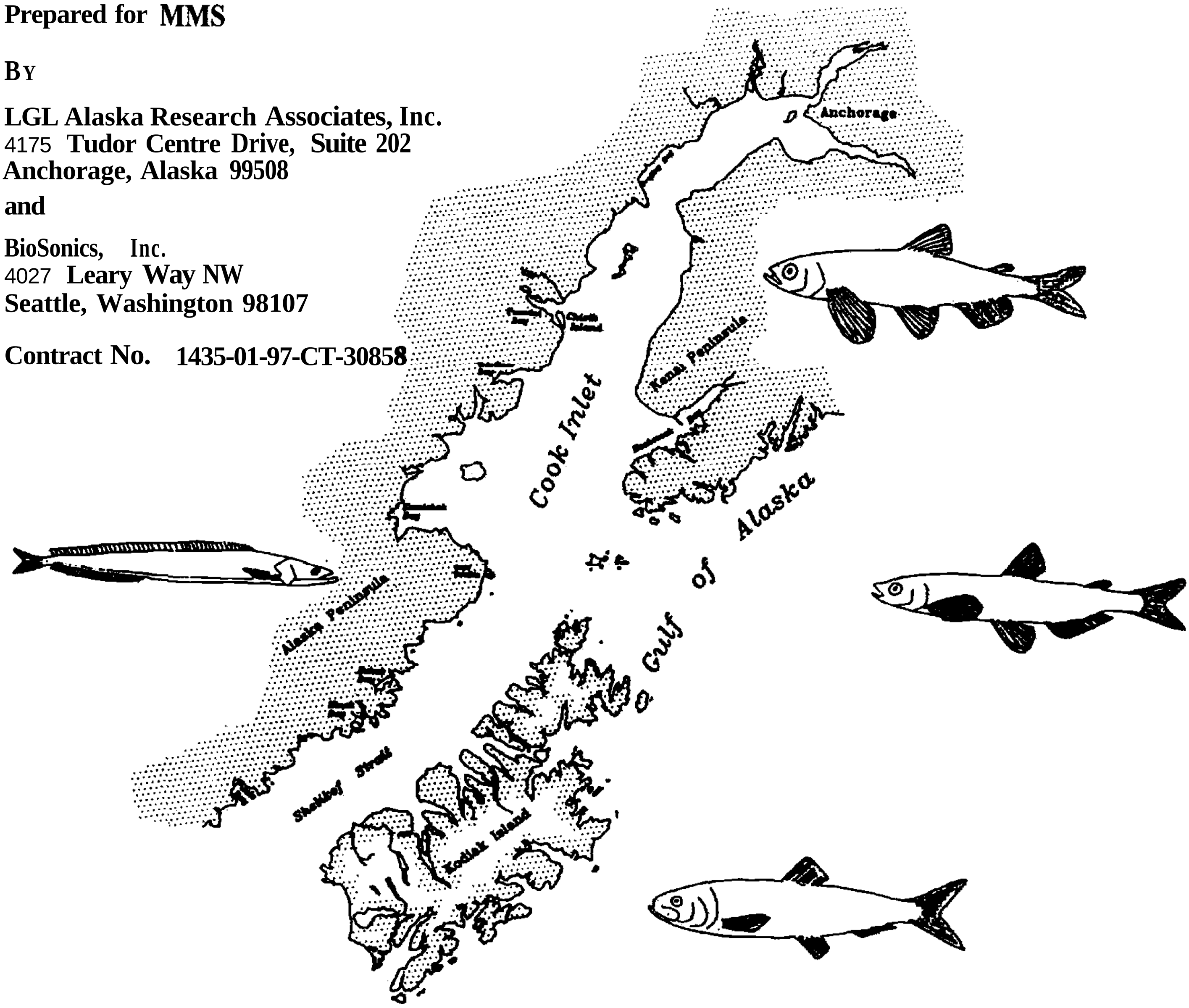

MMS U.S. Department of the Interior
Minerals Management Service
Alaska OCS Region

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1.0 INTRODUCTION

The U.S. Department of Interior, Minerals Management Service (MMS) contracted with LGL Alaska Research Associates, Inc. to conduct field and. laboratory studies of forage fish populations in lower Cook Inlet and Shelikof Strait, Alaska. These studies were conducted during summer 1997, spring 1998, and summer 1998. MMS objectives were to develop a database describing the seasonal abundance, biological characteristics, contaminant exposure, and ecological importance of forage fish in this region that could be used to assess the potential effects of future oil and gas development in the Cook Inlet/Shelikof Strait region. The objectives also included making recommendations for future monitoring of forage fish populations in this region.

Forage fish populations are considered key indicators of the health of the Cook Inlet/Northern Gulf of Alaska marine ecosystem. They include planktivorous species that serve as prey for seabirds (Sealy 197.5; Vermeer 1979; Divoky 1981; Drury et al. 1981; Warner and Shafford 1978; Springer et al. 1984; Baird and Gould 1985; Wilson and Manuwal 1986; Springer and Byrd 1989), marine mammals (Fiscus et al. 1964; Pitcher 1980, 1981; Lowery et al. 1989) and other fishes. In the Gulf of Alaska and Bering Sea, the dominant forage species are the Pacific herring *(Clupea pallasi)*, walleye pollock *(Theragra chalcogramma),* capelin *(Mallotus villosus)*, Pacific sand lance *(Ammodytes hexapterus)* and eulachon *(Thaleichthys pacificus)*.

An understanding of forage fish ecology can provide insights into the trophic ecology of the marine-based food web in the region. These fish form the nutritional basis for large populations of marine mammals, marine and coastal birds, and commercially-valuable populations of salmon, herring, and groundfish. In recent years, particular concern has centered on the decline of seabird populations in the region and the correlation this change might have with shifting populations of forage fish (e.g., Anderson et al. 1997; Logerwell and Hargreaves 1997; Maniscalco and Ostrand 1997; Ostrand et al. 1997).

The upwelling of marine water at the entrance to Cook Inlet creates a productive marine environment that supports from 2 to 3 million seabirds during summer (Piatt et al. 1998). These colonies are vital components of the southern Alaska coastal ecosystem and several related studies are ongoing in this area. These studies are attempting to gather information on the biological characteristics and feeding ecology of forage fish in lower Cook Inlet. The largest and most comprehensive of these is the Alaska Predator Ecosystem Experiment (APEX) which is funded by the Exxon Valdez Oil Spill Trustee Council. APEX is attempting to describe seabird population performance relative to forage fish distribution and abundance in Prince William Sound and Cook Inlet. The objectives of this study are to document the abundance of forage fish in lower Cook Inlet, to assess processes affecting forage fish distribution and abundance, and to relate these findings to production of several seabird populations which were affected by the 1989 Exxon Valdez oil spill. APEX studies include field sampling and hydroacoustic measurements of forage fish schools, proximate analyses of fish tissues, and assessments of seabird production relative to forage fish abundance and tissue condition.

Other studies in lower Cook Inlet include surveys by the Alaska Department of Fish & Game of herring and shrimp populations; seabird studies by the Alaska Coastal Maritime Refuge, U.S. Fish & Wildlife Service, primarily in the Barren Islands area, and a Pacific halibut stomach contents study related to forage fish abundance and composition (D. Roseneau, USFWS, pers. comm., 1998); contaminants monitoring and eutrophication studies by Cook Inlet Keeper; and some smaller studies by the National Park Service around St. Augustine Island and by the National Marine Fisheries Service relative to local marine mammal populations.

1.1 OBJECTIVES

The objectives of this study were to:

1. Identify and describe the seasonal variability of forage fish composition in Cook Inlet using age determination and length-frequency distribution;
2. Describe the relative biomass of forage fish species found in lower Cook Inlet;
3. Identify and describe proximate body composition of forage fish in lower Cook Inlet and describe any seasonal variability;
4. Identify and describe the results of P450A1 hydrocarbon (PAH) exposure analysis of forage fish and compare the Cook Inlet and Shelikof Strait findings;
5. Identify and describe the stomach contents of collected forage fish samples and compare the Cook Inlet and Shelikof Strait findings;
6. Identify and describe forage fish age classes determined from otolith analysis, and construct a length-frequency distribution for each forage fish species; and
7. Provide a baseline for and evaluate and correlate the above objectives to determine forage fish seasonal variability trends and make specific recommendations regarding the use of these data and methodologies in future fisheries monitoring.

2.0 STUDY AREAS

The overall objective of the present study was to survey major habitat types in each of two geographically different and geomorphologically unique areas fur seasonal use by forage fish, including the location and size of forage fish schools, exposure to hydrocarbons, and the biological characteristics (length, weight, age, diet, lipid content, etc.) of the species encountered. The two survey areas were the waters around Chisik Island located on the western shore of lower Cook Inlet and the waters along the western margin of Shelikof Strait from Cape Douglas south to Kukak Bay, located south of Cape Nukshak (Figure 1). Chisik Island is adjacent to Tuxedni Channel, a long, glacially-fed embayment bordered by extensive tidal flats, particularly along the mainland shore and around the northern tip of the island. Freshwater runoff enters the channel from several mountain streams flowing from the mainland and Chisik Island. Depths in the mid to lower reaches of the channel can reach 55 m. In contrast, the Shelikof Strait area is characterized by rocky reefs and small islets along a relatively open coast, although tidal flats occur in some of the more protected embayments.

Oceanographic conditions in Cook Inlet are strongly influenced by upwellings of cold, nutrient-rich waters along the margin of the Gulf of Alaska and the Alaska Coastal Current which flows into Cook Inlet from the southeast through the Barren Island entrance of the southern tip of the Kenai Peninsula (Figure 1). Waters around the Kodiak Island archipelago running southwest from the peninsula tend to be cold, marine and well mixed. Some of this flow sweeps northward along the eastern margin of Cook Inlet and there is also flow southward through the Shelikof Strait. By contrast, waters around Chisik Island tend to be warmer and less saline due to southerly flowing currents along the coast that bring water south from the head of the inlet (USDOI, MMS 1996; Reed and Shumacher 1986).

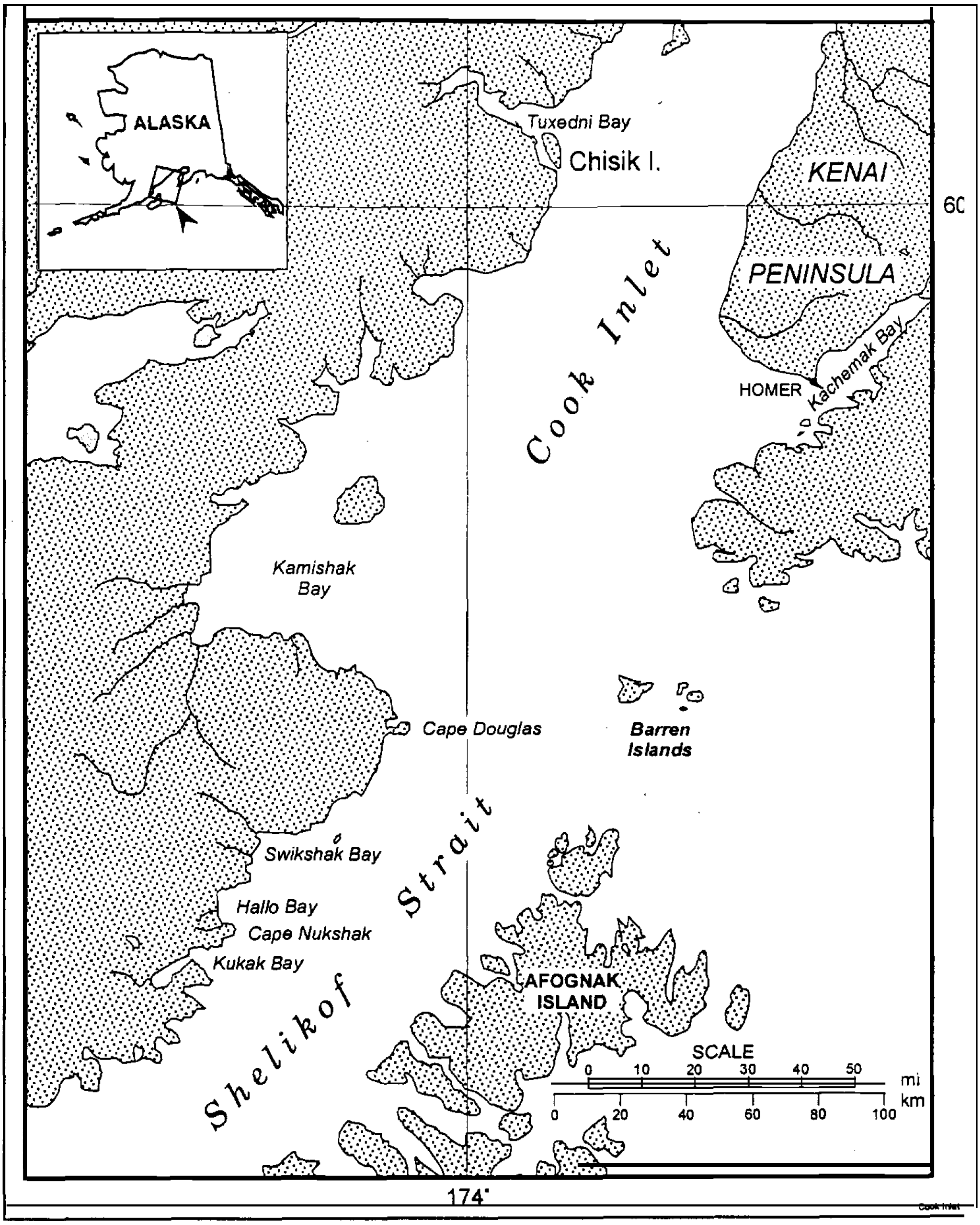


Figure 1. Map of the Cook Inlet/Shelikof Strait region of southern Alaska.

Sampling in Shelikof Strait occurred in July 1998, and was conducted at three separate locations: outer Kukak Bay, Hallo Bay, and Shakun Islets/Swikshak Bay. Kukak Bay was substituted for a planned sampling site near Cape Douglas, which was part of the original program plan. Weather conditions did not permit sampling near Cape Douglas. Sampling was conducted at Chisik Island during August 1997 and 1998, and in May 1998. Poor weather conditions during the August 1998 survey limited the amount of trawling that was conducted seaward of Chisik Island.

3.0 METHODS

3.1 FIELD METHODS

The basic sampling design used a hydroacoustic survey system to locate potential forage fish targets followed by midwater trawling to collect fish from the identified schools. Two boats were used so that midwater trawl sampling could be conducted immediately after obtaining the acoustic location of a school. The hydroacoustic vessel identified the location of the school via GPS (Global Positioning System) coordinates, and these data were then transmitted to the trawl vessel, which immediately sampled the school location. Vertical temperature and salinity (T/S) profiles obtained from CTD casts were also recorded in conjunction with hydroacoustic surveys. Shallow areas, reef areas, or close inshore areas were sampled by beach seine (on uniform bottoms) using a skiff to transport crews to these areas. No hydroacoustic surveys were conducted in conjunction with beach seining.

Sampling was completed during a series of cruises to the study areas. Sampling at Chisik Island occurred during a series of 5-day cruises in August 1997 and May and August 1998. Sampling of the Shelikof Strait study sites occurred during a 7-day cruise in July 1998.

Chisik Island lies in the mouth of Tuxedni Bay. Sampling included zigzag transects inside Tuxedni Channel and along the eastern shore of Chisik Island, with three 5 nmi transects offshore (Figures 2 and 3). Several sites were sampled in Shelikof Strait (Figure 4). Sampling at Kukak Bay was along a single transect across the outer bay (Figure 4). At Hallo Bay, two series of nearshore zigzag transects were sampled parallel to the shoreline (Figure 5.) And at the Shakun Islets/Swikshak Bay site, one series of zigzag transects were sampled roughly parallel to shore and between the islets (Figure 6).

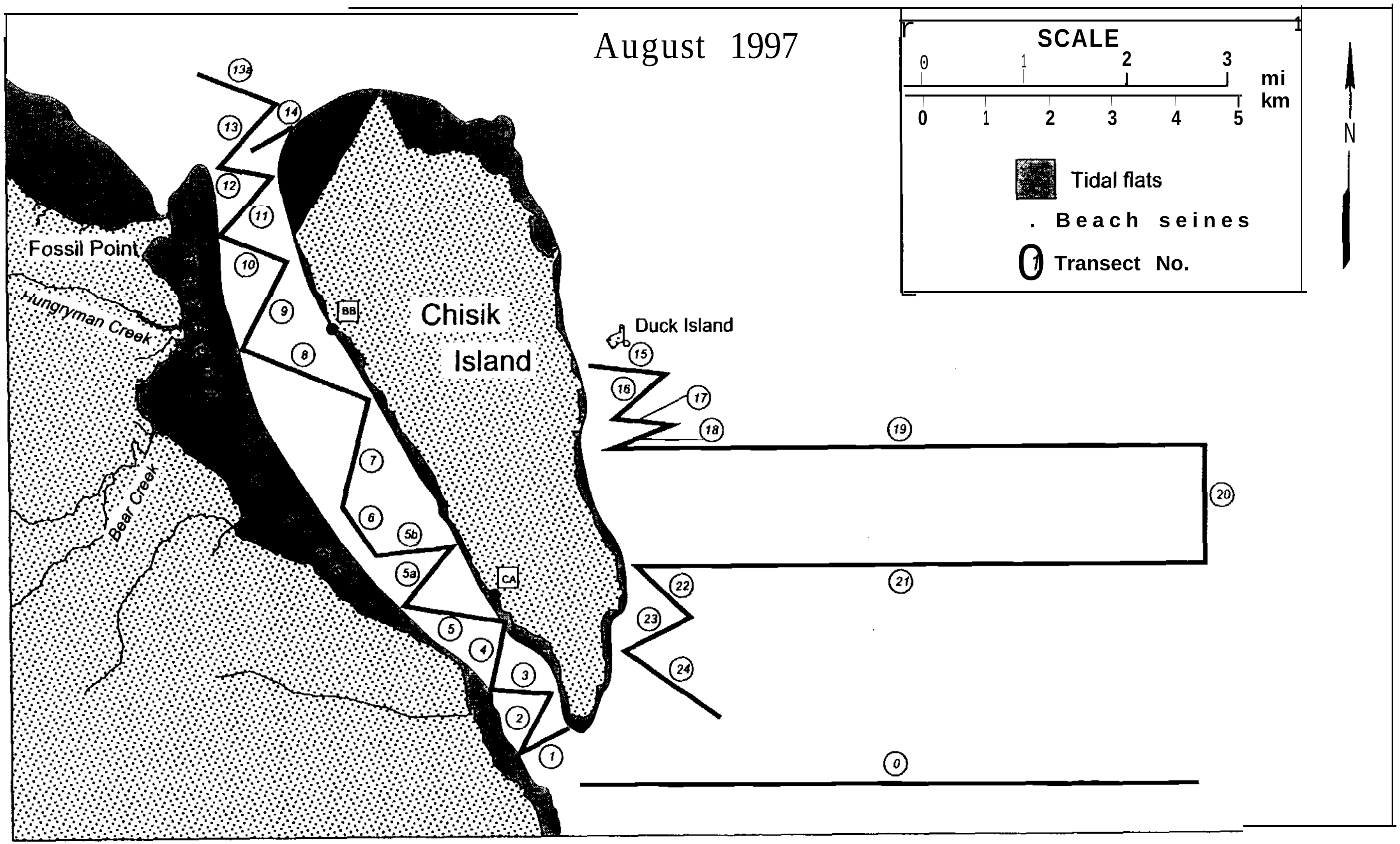


Figure 2. **Hydroacoustic transects and beach seine sites surveyed at Chisik Island from 11 to 13 August 1997.**

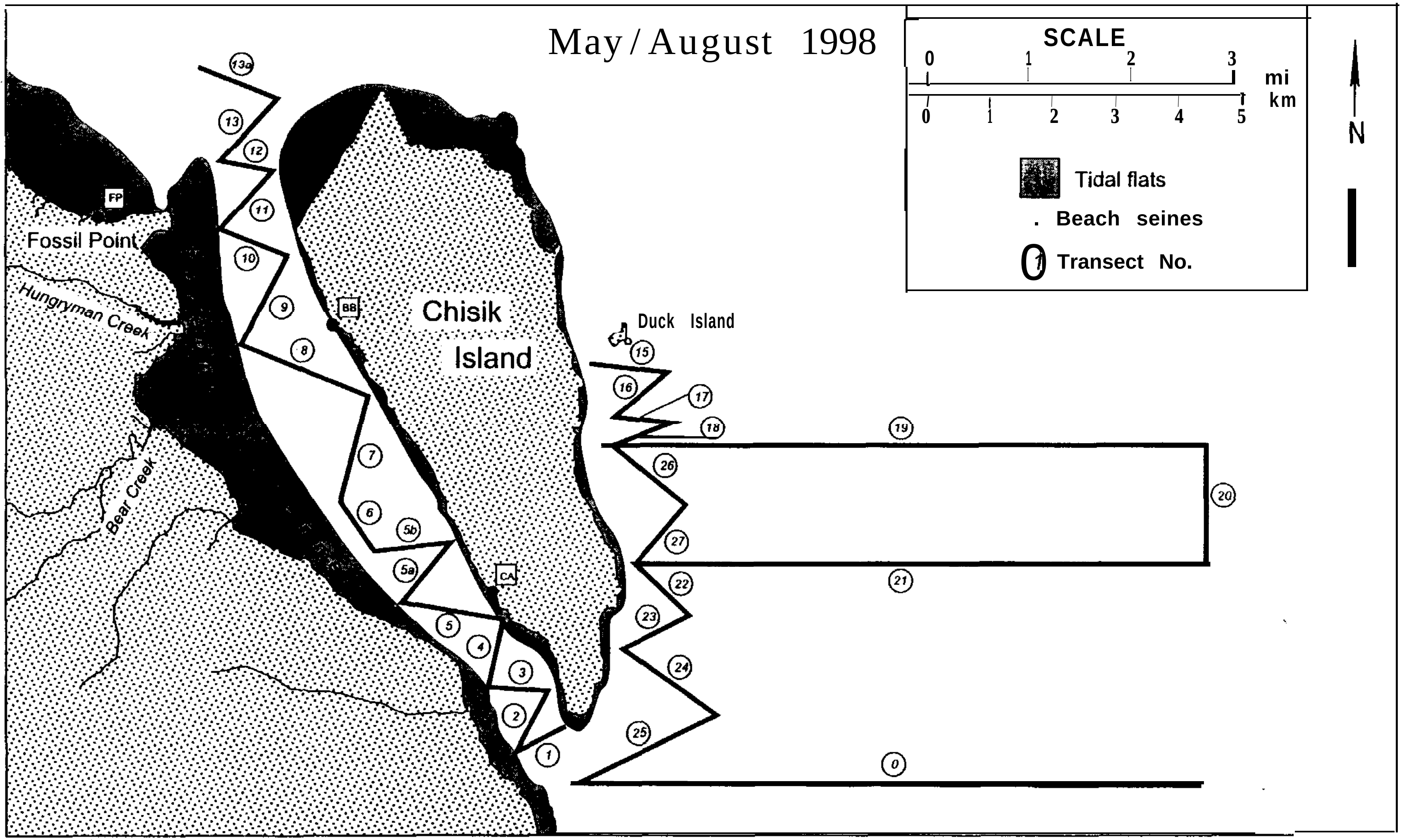


Figure 3. Hydroacoustic transects and beach seine sites surveyed at Chisik Island from 12 to 15 May 1998 and from 2 to 4 August 1998.

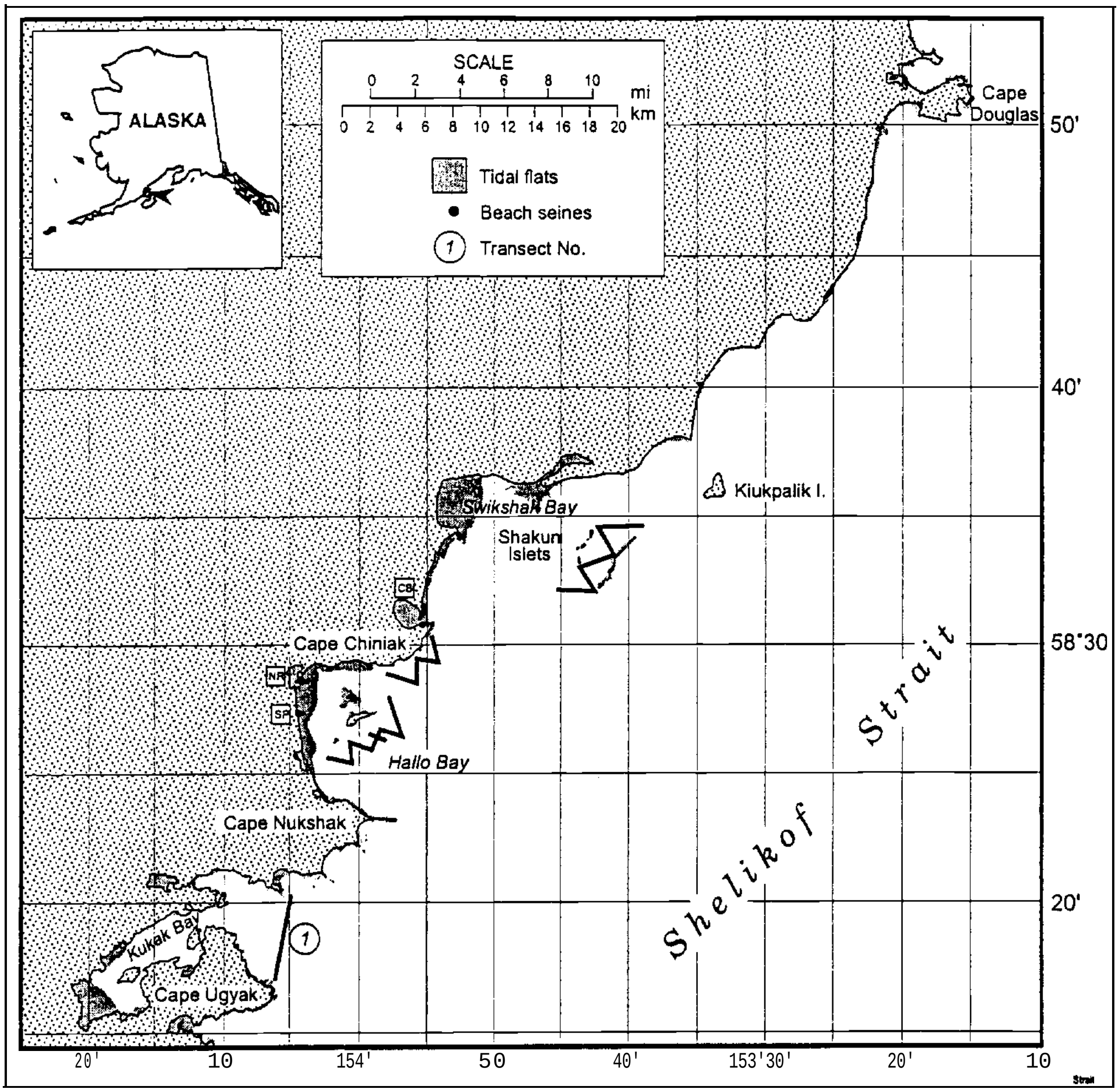


Figure 4. Hydroacoustic transects and beach seine sites surveyed in Shelikof Strait from 26 to 28 July 1998. Transect numbers for the Hallo Bay and Swikshak Bay areas are shown on Figures 5 and 6.

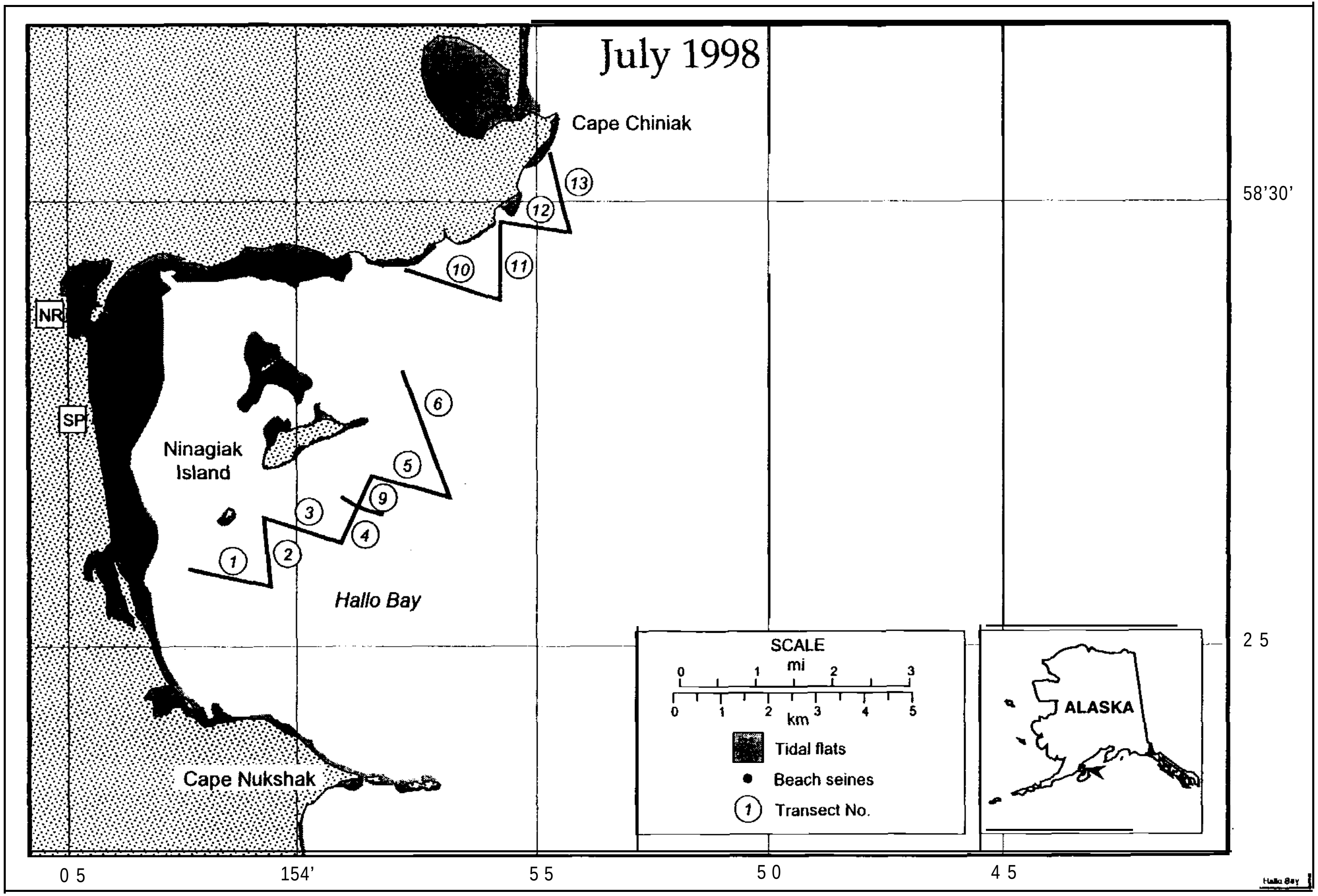


Figure 5. Hydroacoustic transects and beach seine sites surveyed at Hallo Bay on 27 July 1998.

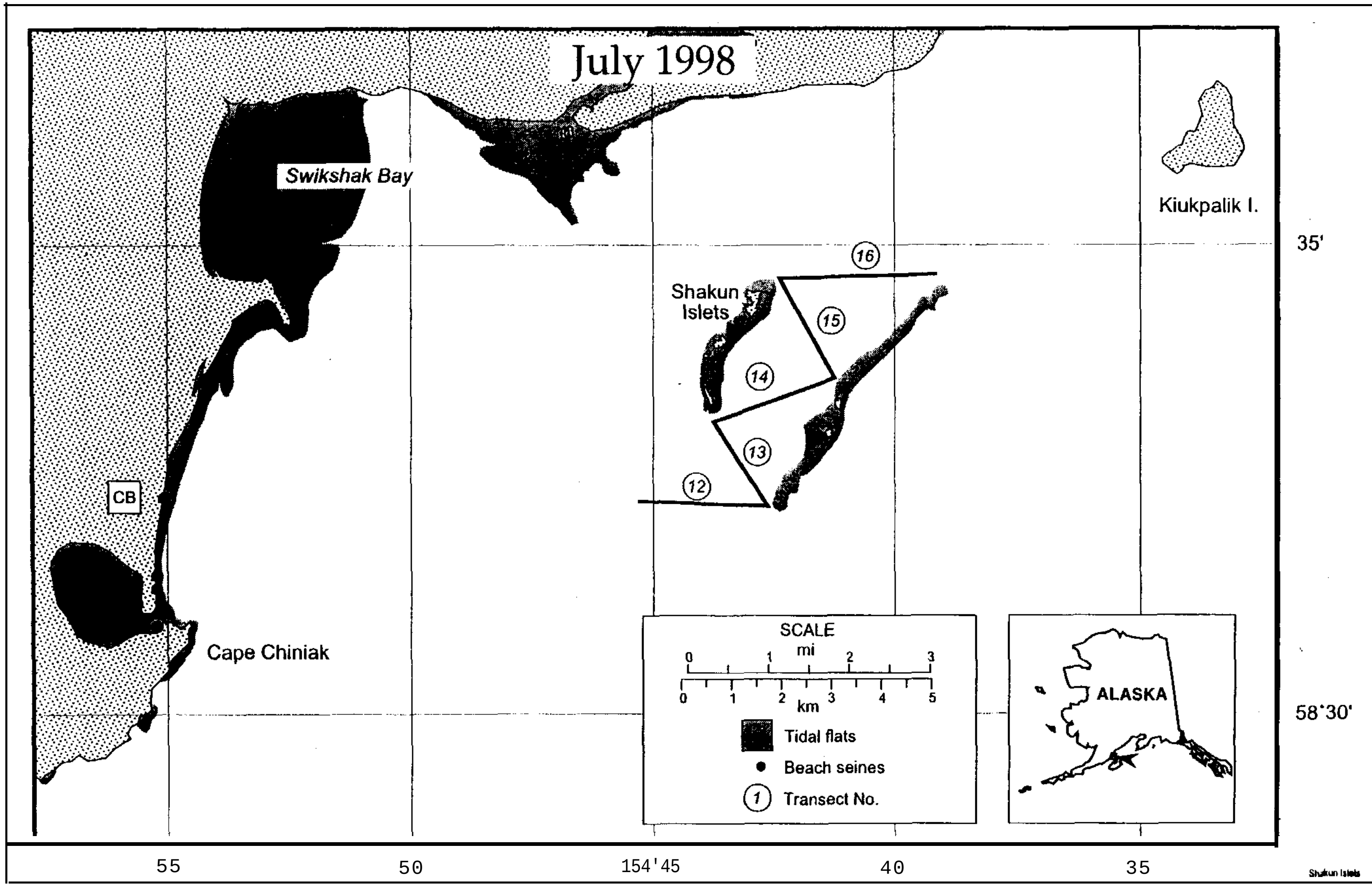


Figure 6. Hydroacoustic transects and beach seine sites surveyed at Shakun Islets on 28 July 1998.

No offshore transects were completed at the Shelikof Strait study sites because of poor weather conditions.

Beach seining also was completed at all study sites except Kukak Bay in Shelikof Strait. Beach seining was conducted where shoreline and surf conditions permitted. Beach seine sites are shown on Figures 2-6.

3.1.1 Hydroacoustic Surveys

One objective of this study was to determine forage fish school dimensions, composition, and position in the water column. All hydroacoustic data collected on each transect during each sampling cruise were saved on computer hard drives and backup diskettes for later processing in the BioSonics, Inc. offices. When detected, fish schools appeared as visible aggregations of targets. Schools were sampled by trawl, and fish species, length, weight, and other data were obtained. These data and hydroacoustic data collected from the schools were used to calculate a biomass estimate for schools.

Hydroacoustic survey methods followed general guidelines described in Forbes and Nakken (1972), Thome (1983), MacLennan and Simmonds (1992), Brandt (1996), and others. Because forage fish school characteristics were the focus of this study, all sampling was conducted during daylight when schooling behavior was strongest and as conducted by other investigators (Haldorson et al. 1996).

Forage fish schools were located along pre-established transects. Two vessels were used, one to hydroacoustically locate schools and delineate their size, and a second vessel to sample (i.e., trawl) the school to "ground truth" the acoustic system. Vessels included a 38-ft aluminum boat, Launch 1273 (May and August 1998) provided by MMS; a 40-ft National Park Service vessel, *the WV Brown Bear* (August 1997, July 1998) and a chartered commercial drift gillnet salmon fishing boat, the *F/V Cutwater*

(August 1997, July and August 1998). A 44-ft chartered sport fishing vessel, the *F/V Born Free*, also was used on one cruise (May 1998).

Sampling included hydroacoustic searching along both nearshore and offshore transects in each study area. At the Chisik Island sampling site, nearshore sampling included transects inside Tuxedni Channel ("inner") and along the east side of Chisik Island ("outer") as well as three offshore transects. Offshore transects were attempted during the Shelikof Strait sampling effort, but weather precluded sampling offshore.

No forage fish schools were encountered along the nearshore transects sampled in Shelikof Strait, and one school was observed and sampled on a single offshore transect near Chisik Island (Table 1). Thus, the forage fish school assessment for this study essentially is based on nearshore sampling at the Chisik Island study site. Additional samples of forage fish species were collected in all areas, except Kukak Bay in Shelikof Strait, by beach seine.

The acoustic signal detects the swim bladder in fish, and thus gives a trace of the size of fish in the school. However, many species of forage fish are similar sized, and net sampling was used to verify species present. The hydroacoustic equipment was pre-calibrated in the laboratory before each cruise, and was field-calibrated after mounting on the vessel. A BioSonics, Inc. technician operated the hydroacoustic equipment on all cruises.

Digital echo sounders were used for hydroacoustic data collection in both years of sampling. A BioSonics Model DT4000, 130 kHz, single-beam (6 degree) echo sounder was used in the August 1997 survey, while the 1998 surveys were conducted with a Model DT6000, 200 kHz, split-beam (6 degree) sounder. Both echosounders generated comparable data on forage fish targets. Latitude and longitude data were collected with a Furuno differential GPS and written to acoustic data tiles in real time. Acoustic data,

Table 1. Locations of sampled forage fish schools near Chisik Island, 1997-1998.

Date	Forage Fish School Location: Nearshore Transects * Outer	Nearshore Transects * Inner	Offshore Transects	Depth (m)	Forage Fish School Composition
0811 1/97		X		30	Herring & surf smelt
08/1 1197		X		6	Herring & surf smelt
0811 1/97		X		2	Herring & longfin smelt
08/12/97	X			22	Herring & surf smelt
08/12/97		X		15	Herring
08/12/97		X		6	Herring
08/12/97		X		12	Herring & surf smelt
08/12/97		X		10	Herring & surf smelt
05/12/98			X	10	Herring
05/13/98	X			5	Herring & sand lance
05/13/98	X			5	Herring & sand lance
05/13/98	X			32	Eulachon & sand lance
05113198	X			32	Eulachon & sand lance
05/14/98		X		8	Eulachon & juv. pollock
05/14/98		X		5	Eulachon & herring
05/14/98		X		7	Eulachon & herring
05/14/98		X		12	Eulachon & juv. pollock
05/14/98		X		11	Eulachon & juv. pollock
05115198		X		7	Eulachon & tomcod
05/15/98		X		6	Herring (1)
05/15/98		X		10	Eulachon & herring
08/02/98		X		35	Longfin smelt & tomcod
08/02/98		X		42	Longfin smelt & eulachon
08/02/98		X		20	Eulachon
08/02/98		X		20	Eulachon & longfin smelt
08/02/98		X		20	Eulachon
08/02/98		X		22	Eulachon
08/03/98		X		40	Eulachon & Iongfin smelt
08104198		X		40	Eulachon & longfin smelt
08/04/98		X		45	Eulachon & longfin smelt
08/04/98		X		20	Eulachon
08/04/98		X		50	Longfin smelt & juv. pollock

* Nearshore transects: outer = east side of Chisik Island; inner = Tuxedni Channel

including all collection parameters, were stored directly to a Pentium PC computer hard drive during the survey. The transducer was fixed to a pipe mount attached to the boat railing about mid-ships, from which it was suspended vertically into the water, aiming downward, 0.75 to 1 meter beneath the water surface. The echo sounder surface unit and computer were located in the ship's cabin and powered by the ship's 120 VAC electrical system. A Nav Trek computer-based navigation system was used in 1998 to display the vessel track and mark fish school locations in real time.

Acoustic data were collected to a maximum depth of 50 meters, which exceeded the greatest water depth in most of the study areas. In some locations known to be shallower, the maximum range was 30 or 40 meters. Other settings used during the surveys included a ping rate of 5 pings per second (most transects), a pulse width of 0.4 millisecond (msec), and a data collection threshold of -70 dB (most transects; range used was -66 to -80 dB) with 40 Log R time varied threshold.

Acoustic data files were processed using BioSonics Visual Analyzer 4.0 software to measure locations and dimensions of all fish aggregations (schools and layers) encountered. In addition, density (number/m^3) and biomass (kg/aggregation) were also estimated by echo integration for schools or layers that were sampled by trawling. *In situ* estimates of target strength for scaling echo integration were determined by EMS deconvolution in 1997 and by the split-beam method in 1998. Mean biomass per individual target and the proportion of acoustically estimated biomass attributed to forage fish were based on the weight of organisms in the trawl catch.

Initially, echograms were created at two scales for visual examination preliminary to further analysis. Echograms were made with one transect per printed page to show patterns over whole transects, and echograms were also made with 1,000 pings per page for closer examination of fish groups. Locations of fish groups (depth and ping range) were marked on echograms, and each data range so indicated was echo integrated using

Visual Analyzer V4.0 software. For each fish aggregation, results of this processing included starting and ending location (latitude and longitude), top and bottom depth, and average bottom depth beneath the school. Overall mean density (number/m'), mean density in the portion of the water column where fish were'detected (number/m'), and mean back scattering cross-section were also computed for aggregations that were also sampled by trawl. Fish groups were noted in the data record as schools if they were too tightly packed for recognition of many individual targets, and as layers if most individuals were discernible.

Other characteristics of fish aggregations were computed in Excel spreadsheets. Lengths of schools and layers were calculated from initial and final latitude and longitude coordinates using a Pythagorean method with a factor of 0.4972 minutes latitude per minute of longitude. School widths were determined in a similar fashion from measurements made on cross-transects.

3.1.2 Trawl Sampling

When fish schools were acoustically identified, the second vessel equipped with a midwater trawl sampled a portion of the school to obtain specimens for species identification and other biological measurements. Fish schools were sampled with a 6-foot by 6-foot opening, 30-foot long Isaacs-Kidd midwater trawl (IKMT), constructed by Research Nets, Inc. of Redmond, Washington. The IKMT was constructed with a plankton bucket cod end having a 1000 mesh sieve; the forward 15-foot portion of the net was l/Cinch Atlas mesh, and the cod end (15 feet) was l/S-inch Atlas mesh. A dorsal spreader bar and a V-shaped depressor, both attached to a towing bridle, held the net open during tows.

The net was lowered by winch to fishing depth as determined by the length of wire out and wire angle. The net was towed for 15 minutes at approximately 3 to 5 knots.

During each cruise, the calculated depth of fishing was verified with the hydroacoustic equipment.

3.1.3 Beach Seining

In addition to the IKMT trawl, shallow areas along the shorelines were sampled for forage fish using a beach seine. The seine (manufactured by Research Nets, Inc. of Redmond, Washington) was 130 feet long with a 50-foot long by 1 l-foot high center bag of l/S-inch mesh net, and with 40-foot wings of 1/4-inch mesh that tapered in height from 11 feet at the bag to 4 feet at the handles. The seine was deployed from a motorized skiff. One end of the seine was fixed by two persons at a point along the beach and then personnel in the skiff would extend the net in a large arc to a landing point further down the beach. The seine was then manually pursed and hauled ashore.

3.1.4 Temperature and Salinity

Vertical T/S profiles were collected at the end of each transect using an Applied Microsystems, Inc. conductivity-temperature-depth probe mounted with a transmisso-meter. Each vertical profile was downloaded onto a laptop computer on board the hydroacoustic vessel. This CTD equipment failed during two cruises, and a YSI Model 33 salinity-conductivity-temperature meter was used as a backup. YSI data were recorded manually at l-meter depth increments.

3.1.5 Biological Samples

All fish taken by trawl or seine were enumerated and identified using Hart (1973), Baxter (1991), or a draft key under preparation by the American Fisheries Society (1999, current draft) under preparation by K.A. and T.A. Mecklenburg, Auke Bay, Alaska as the principal reference keys. A preliminary identification of one snailfish species was made by Katherine Mecklenburg, Auke Bay, **and** several juvenile flatfish were identified by

Alisa Abookire, U.S. Geological Survey, Biological Resources Division (BRD), Anchorage. Several species identifications were confirmed by Martin Robards, U.S. Geological Survey, BRD, Anchorage.

Voucher specimens were collected and archived for species verification. Forage fish were measured to the nearest mm (fork length). In cases where large numbers of a particular species were captured, individuals from a subsample of 100-200 fish were measured. The wet weight of individuals randomly selected from each catch was determined to the nearest 0.1 g using an Ohaus triple beam balance. Fish were blotted dry of excess moisture prior to being weighed. Wet weights were taken from 25 fish per size group, where possible.

Subsamples of up to 25 forage fish species per size group were retained to determine gender and age. Gender was determined by visual inspection of the gonads. Saggital otoliths were excised and stored in labeled vials. They were examined later in the laboratory using the break and burn method for age determination. Where possible, reference age-O+ fish were used to index the appearance of the otolith centrum to older age groups.

Subsamples of forage fish were also retained to determine body composition (i.e., proximate analysis), diet, and Cytochrome P450 activity. The field methodologies involved in collecting and processing these fish are described below.

3.2 LABORATORY METHODS

Analysis for stomach content, proximate body composition, or Cytochrome P450 activity were conducted by independent laboratories. The protocols of each are detailed below. All samples were tracked with chain-of-custody procedures to ensure continual tracking of each sample from initial collection in the field until final laboratory extractions and assays were completed.

3.2.1 Proximate Body Composition

Proximate body composition, a measure of fish condition, reflects the physiological state of a fish in terms of the energy resources it has available for metabolism, with lipids being generally regarded as one of the most important components of these stored body resources. Proximate composition is the relative percentage of lipid, water, protein and ash (organic composition) to overall wet body weight in a fish specimen.

Proximate body composition was determined for subsamples of forage fish collected from each study area. Fish subjected to proximate composition analysis were prepared by dissecting out the digestive tract so that gut contents were not assayed for lipid, protein, or ash content. The stomachs taken from these fish were retained for diet analysis. Fish retained for proximate analysis were frozen aboard ship and later shipped to Dr. Don Schell of the University of Alaska Fairbanks who conducted the laboratory analysis.

Laboratory work for lipid analysis followed the procedure of Bligh and Dyer (1959). Fish were homogenized with a known quantity of added distilled water in a blender and 100-g subsamples of the homogenate were taken for water content, lipid and protein analysis. The sample for lipid analysis was extracted by blending with 200 ml of chloroform-methanol mix. The lipid fraction was removed by gentle filtration and placed in a porcelain-evaporating dish and the solvent removed by evaporation in a fume hood. The residual lipid was then weighed and the evaporation continued to constant weight. Following correction for the added water, the lipid content was calculated as a percent of wet weight.

Protein content was approximated by nitrogen analysis of a subsample. A sample of the whole fish homogenate was dried and ground to a powder and a subsample run on a LECO 600 CHN ANALYZER. Protein content was determined by multiplying the percent nitrogen by 6.25. Water content in the whole fish 'sample was determined by drying two subsamples to constant weight at 65°C. Correction was made for the water added to facilitate blending and the results listed as percent of wet weight. Ash content was determined by cornbusting two subsamples in a 550°C-muffle furnace to constant weight.

3.2.2 Cytochrome P450 Activity

One component of this study involved the assays of forage fish tissues to test for possible hydrocarbon contamination. The P450 Reporter Gene Assay (RGS) technique was employed. Activation of the aryl hydrocarbon receptor (AhR) and induction of the Cytochrome P450 system, specifically CYP1A1 in mammals and fish, is a well-studied mechanism of certain environmental contaminants. Coplanar polychlorinated biphenyls (PCBs) as well as high molecular weight polycyclic aromatic hydrocarbons (PAHs), assume a planar configuration similar to the prototype AhR-inducer, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), and share this mechanism of action (Wbitlock 1990). Although the link between CYP1 Al induction and specific toxicological effects is not fully known, the induction of CYP1 Al is widely used as a biochemical indicator of exposure to these contaminants in the aquatic environment (Stegeman and Hahn 1994; Collier et al. 1995, 1996).

The CYP1A1-induction potency of PCB congeners relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) has contributed to the toxicological information used in development of toxic equivalency factors (TEFs) for use in risk assessment (Safe 1990, 1994; USEPA 1996). Similarly, PAHs have been assigned TEFs based on toxicity studies using a wide array of endpoints, including carcinogenesis (USEPA 1993;

Delistraty 1997). Toxic equivalency factors determined from responses in vitro systems have indicated differences in potencies of these compounds in fish (Richter et al. 1997) and birds (Kennedy et al. 1996a) compared to mammals (Tillitt et al. 1991).

Based on the well-characterized biochemical response of CYP1 Al activation via the AhR, in vitro systems that utilize a reporter gene under transcriptional control of CYP1A1 have been developed and have the advantages of ease and specificity (Garrison et al. 1996). The RGS cell line (101L) is derived from the human hepatoma cell line, HepG2, into which a plasmid containing the human CYP1 Al promoter and 5-foot-flanking sequences, (which consist of three xenobiotic responsive elements (XREs)) fused to a reporter gene, Iuciferase, has been stably integrated (Postlind et al. 1993). The enzyme luciferase is produced in the presence of compounds that bind the XREs, and can be detected by a simple assay that measures relative light units with a luminometer. RGS has gained acceptance as a rapid and inexpensive approach to screening solvent extracts of environmental samples of soil, sediment, tissue, and water to detect compounds that activate the Ah-receptor (Anderson et al. In Press a).

Subsamples of forage fish to be analyzed for Cytochrome P450 activity were placed in sterilized glass containers and frozen aboard ship. Upon reaching port, the samples were shipped by overnight delivery to Dr. Jack Anderson of Columbia Analytical Services (CA'S) in Carlsbad, California. The detailed methodology used in the laboratory analysis has been described elsewhere (APHA 1996; ASTM 1997; Anderson et al. 1995). Tissues were first extracted in dichlomethane and then this solvent was replaced by a solvent mixture (DMSO/toluene/isopropyl alcohol; 2/1/1) better tolerated by the cells. A subsample of the tissue was measured for percent solids and a subsample of the dichloromethane was used to measure percent lipids.

Replicates of the tissue extracts were applied to approximately one million human liver cancer cells cultured in 6-well plates with 2 ml of medium. After a 16-hour incubation, the cells were washed with Hank's Balanced Salt Solution (Mediatech, Herndon, VA), and lysed with 200 µl of buffer containing 1% Triton, 25 mM glycylglycine, pH 7.8, 1.5 mM $MgSO_4$, 4 mM EDTA, and 1 mM dithiothreitol (DTT). Cell lysates were centrifuged at 6,000 rpm for 10 seconds, and 50 µl of the supematant was mixed with 100 µl of 0.1 M potassium phosphate buffer, pH 7.8, containing 5 mM ATP and 10 mM $MgCl_2$. Reactions were initiated by injection of 100 µl of luciferin, dissolved in 0.1 M potassium phosphate buffer, pH 7.8. Luminescence in relative light units (RLUs) was measured using a ML2250 Luminometer (Dynatech Laboratories, Chantilly, VA). Luciferase assay buffers were purchased from Analytical Luminescence Laboratory (Cockeysville, MD).

With each test run, a solvent blank (using a volume of the solvent mixture equal to the sample volume being tested) and a reference toxicant (TCDD at a concentration of 1 µg/ml) were also applied to three separate replicate wells. Mean fold induction of the solvent blank was set equal to 1, and the fold induction of each extract and TCDD was determined by dividing the mean relative light units (RLUs) produced by that solution by the mean RLUs produced by the solvent blank. Since 1 µg of benzo[a]pyrene (B[a]P) is known to produce a fold induction of 60, this factor and either the lipid or dry weight of the sample were used to convert fold induction values into B[a]P Equivalents (in µg/g) as shown in the formula below. The volume factor is the value required to express the total fold induction of the entire extract, as 20 if the response was measured for 10 µl out of a 200 µl extract. A similar approach was used to convert fold induction values to Toxic Equivalency values (TEQs). The second formula shows that the volume factor and weight are used in the conversion, but it has been demonstrated that TEQs produced by coplanar PCBs, dioxins and furans (in picograms/g) are equal to the fold induction observed. Since it is not possible to determine if PAHs or chlorinated hydrocarbons in the samples have produced the observed induction, the findings have been expressed in both ways. These should be considered either B[a]P/ or TEQ, but not both. TEQ estimates were divided by 1000 to convert the findings to ng/g. The standard deviation and coefficient of variation were recorded for each test solution.

$$B[a]PEq \text{ (in } \mu g/g) = \frac{\text{fold induction} * \text{volume factor}}{60 * \text{dry wt. (or lipid wt.)}}$$

$$TEQ \text{ (in ng/g)} = \frac{\text{fold induction} * \text{volume factor}}{1000 * \text{dry wt. (or lipid wt.)}}$$

3.2.3 Diet

Stomach content analyses were conducted on representative specimens of forage fish collected in each study area, and on a seasonal basis for the Cook Inlet site. For fish greater than 40-50 mm in length, stomachs were excised in the field as soon as possible after capture, pierced, and stored in 10% buffered formalin. Smaller fish were stored whole in 10% buffered formalin and their visceral cavities pierced when practical. Samples were later sent to Dr. Ted Cooney of the Institute of Marine Science, University of Alaska Fairbanks for analysis. The following description of laboratory methods was provided by Dr. Cooney.

In the laboratory, each specimen (whole fish or stomach) was rinsed for 2 minutes in running fresh water, then blotted dry. The total lengths of whole fish were then measured to the nearest mm. Stomachs (dissected from the whole fish or as supplied) were blotted, and weighed to the nearest mg. The state of fullness was estimated by inspection as empty, 25%, SO%, 75% or full, and then the stomachs were opened under a dissecting microscope.

Stomach contents were teased into a gridded petri dish, and the mass examined and sorted by species/taxa. In cases where there were judged to be many more than 100-300 individuals per taxonomic category, that taxon was subsampled. Subsampling consisted of homogeneously distributing the specimens over a grid of known dimensions. When between 100 and 150 individuals had been counted, the area associated with that count (number of gridded squares) was used to estimate a total count of the taxa from the subsample count. This process was replicated for all large counts, and the average of the two estimates entered as the number of that taxon per stomach. A taxon that did not contribute more than about 100-300 animals per stomach was counted in total and entered directly as the number per stomach.

Dry weights were determined for each category by one of two methods: (1) all specimens for a taxon were transferred to a pre-weighed aluminum pan, dried at 60°C for 24 hours and then weighed on a microbalance to the nearest microgram; or (2) in the case of subsampled taxa, 100 animals were transferred to a pre-weighed pan, dried and weighed. Total dry weight for a taxon was calculated by multiplying the dry weight per individual by the number of individuals, or directly from the measurements when all specimens in a taxon were weighed.

3.3 DATA ANALYSIS

3.3.1 Niche Overlap and Breadth

Schoener's (1970) index (*D*) was used as a measure of dietary overlap among any two fish species or groups. The equation is

$$D = 1 - 0.5 \sum |p_i - q_i|$$

where p_i is the proportion of total biomass of prey item *i in* one fish species and q_i is the proportion of total biomass of prey item *i* in a second fish species. The Schoener index is not sensitive to how resource states are divided (Krebs 1989). ***D*** ranges from 0 (no overlap) to 1 (complete overlap).

A second measure of dietary overlap, the Index of Relative Importance (IRI), was also calculated (Pinkas et al. 1971). The IRI is calculated for each prey field for any species of fish. The equation is

$$IRI_i = (N_i + W_i)F_i$$

where N_i is the percentage of the total number of prey that a specific prey i represents, W_i equals the percentage of total prey weight that a specific prey i represents, and F_i is the frequency of occurrence of prey i. The advantage of the IRI over the traditional Schoener Index is that while the former measures dietary overlap solely in terms of the proportion of prey mass consumed, the IRI takes into account the number of prey consumed and the frequency of occurrence.

The Shannon-Wiener formula (Shannon and Wiener 1963) was used as one measure of dietary breadth for a fish species or group. The formula is

$$H' = -\sum p_i \log_e p_i$$

where H' is the measure of niche breadth and p is the proportion of prey item i. Since the Shannon-Wiener measure can range from 0 to ∞, the evenness measure J' can be used to standardize to a scale of O-l. The equation is

$$J' = H'/\log_e n$$

where n is the total number of possible prey items. The total number of possible prey items was defined as all prey items identified from all fish collected within any seasonal survey.

Hurlbert (1978) argues that Levins' measure of niche breadth, which gives more weight to abundant resources, is more appropriate than the Shannon-Wiener index, which gives more weight to rare resources. We therefore calculated Levins' measure of niche breadth *(B)* as

$$B = 1/\sum p_i^2$$

where p is the proportion of prey item i.

3.3.2 Weight-Length Regression

A linear least squares regression model (Neter et al. 1989) applied to $\log_e$-transformed data was used to describe the weight-to-length relation for different forage fish species:

$$\log_e(W_i) = \log(a) + b\log_e(L_i) + e_i$$

where W_i is weight in g and L_i is length in mm, a and b are regression parameters, and e_i is the error term. Each data set was screened *a priori* for outlying observations based upon standard least-squares techniques described by Neter et al. (1989). Outlying x-observations in the regression analysis were identified by leverage values greater than $2p/n$, where p is the number of parameter estimates (in this case $p = 2$) and n is the number of observations (Neter et al. 1989). Outlying y-observations were identified by studentized deleted residuals ≥ 1.96 SD (a = 0.05) from the t-distribution.

4.0 RESULTS

4.1 SAMPLING EFFORT

The study consisted of four main sampling efforts: three at Chisik Island on 1 l-l 3 August 1997, 12- 15 May 1998, and 2-4 August 1998; and one in Shelikof Strait on 26-28 July 1998. There were a total of 105 hydroacoustic transects, 40 trawls, 19 seine hauls, and 105 CTD casts (Table 2).

The first survey at Chisik Island in August 1997 involved 28 hydroacoustic transects, 11 of which were run along the exposed eastern shore of the island itself (Figure 2). The remaining 17 transects were run in zigzag fashion along the entire length of Tuxedni Channel. Eleven trawls were conducted in conjunction with hydroacoustic contacts. There were three beach seines, two at site CA (near the abandoned Snug Harbor Cannery) on the southeastern shore of Chisik Island and one at site BB (a boulder outcrop adjacent to a gravel beach) on the island's northeastern shore. Ten T/S casts were made.

The same hydroacoustic transects were surveyed during the May and August 1998 studies with some minor modifications (Figure 3). Three additional offshore transects (transects 25, 26, and 27) were run and Transect 14 located near the northern end of Tuxedni Channel was eliminated because it was redundant with Transect 13 (see Figure 2). This yielded 30 hydroacoustic transects per survey. There were 13 trawls and 36 T/S casts during the May cruise and 11 trawls and 37 T/S casts in August. Three seine hauls were made in May, all at Fossil Point (Site FP). There were six seine hauls in August, two each at sites CA, BB, and FP.

Sampling in Shelikof Strait was conducted in Kukak Bay on 26 July, Hal10 Bay (Ninagiak Island) on 27 July and near the Shakun Islets on 28 July 1998 (Figure 4). A single hydroacoustic transect was run in Kukak Bay accompanied by 2 trawls and 3 T/S

Table 2. Summary of sampling effort for the Chisik Island/Shelikof Strait surveys.

Location	Survey Dates	Hydroacoustic Transects	Trawls	Seine Hauls	CTD Casts
Chisik Island	IO-13 August 97	28	11	3	10
Chisik Island	12-15 May 98	30	13	3	36
Shelikof Strait					
Kukak Bay	26 July 98	1	2	0	3
Hallo Bay	27 July 98	11	3	3	13
Shakun Islets	28 July 98	5	0	4	6
Chisik Island	2-4 August 98	30	11	6	37
	Total	105	40	19	105

casts. There were no seine hauls. Because of the absence of hydroacoustic contacts, the site was abandoned.

Sampling in Hal10 Bay on 27 July consisted of two hydroaconstic grids, one southeast of Ninagiak Island involving seven transects and the other off Cape Chiniak involving four transects (Figure 5). Three IKMT trawls were made, one each on transects 1, 2 and 9 and there were a total of 13 T/S casts. Two beach seine hauls were made at Site SP and another at Site NR.

Five hydroacoustic transects were surveyed near the Shakun Islets on 28 July 1998, but because of the absence of acoustic contacts (fish schools) no trawls were attempted (Figure 6). Six T/S casts were made. There were four beach seine hauls conducted just north of Cape Chiniak collectively designated as Site CB (Figure 6).

4.2 HYDROGRAPHY

4.2.1 Chisik Island August 1997

The Applied Microsystems, Inc. conductivity-temperature-depth probe failed during the August 1997 survey at Chisik Island and a YSI Model 33 salinity-temperature-density meter was used as a backup. Data were collected in l-meter increments to a depth of 12-13 meters (Figure 7).

Surface salinities around Chisik Island ranged from 13.7–19.4‰ within Tuxedni Channel and from 22.7–26.2‰ along the seaward transects (see Figure 2). Salinity at 12 meters was fairly consistent among all transects at 26.3–28.1‰. Water temperatures showed a similar spatial pattern, with surface temperatures ranging from 10.1-I 1. 1°C in Tuxedni Channel and from 12.4–12.7°C along the seaward transects. Temperatures at 12 meters were consistent among all sites at 12.2–12.9°C. The lower surface salinities and temperatures within Tuxedni Channel likely reflect the effect of cold, freshwater runoff from both mainland and Chisik Island streams.

The exception to the above was along transect 14 at the northern end of Chisik Island where surface salinity was 8.4‰ and temperature was 18.0°C. Both values changed to 12.0‰ and 26.3°C at two meters and remained fairly consistent with depth.

4.2.2 Chisik Island May 1998

There was little variability in water temperature and salinity in the vicinity of Chisik Island in May 1998 (Figure 7). Across all stations and depths, temperatures ranged from 5.2–6.7°C and salinities from 24.7–29.9‰. Vertical stratification was minimal and generally consisted of a surface lens of slightly warmer, less saline water in the top three meters of the water column. This lens was most prominent at sites in upper Tuxedni Channel.

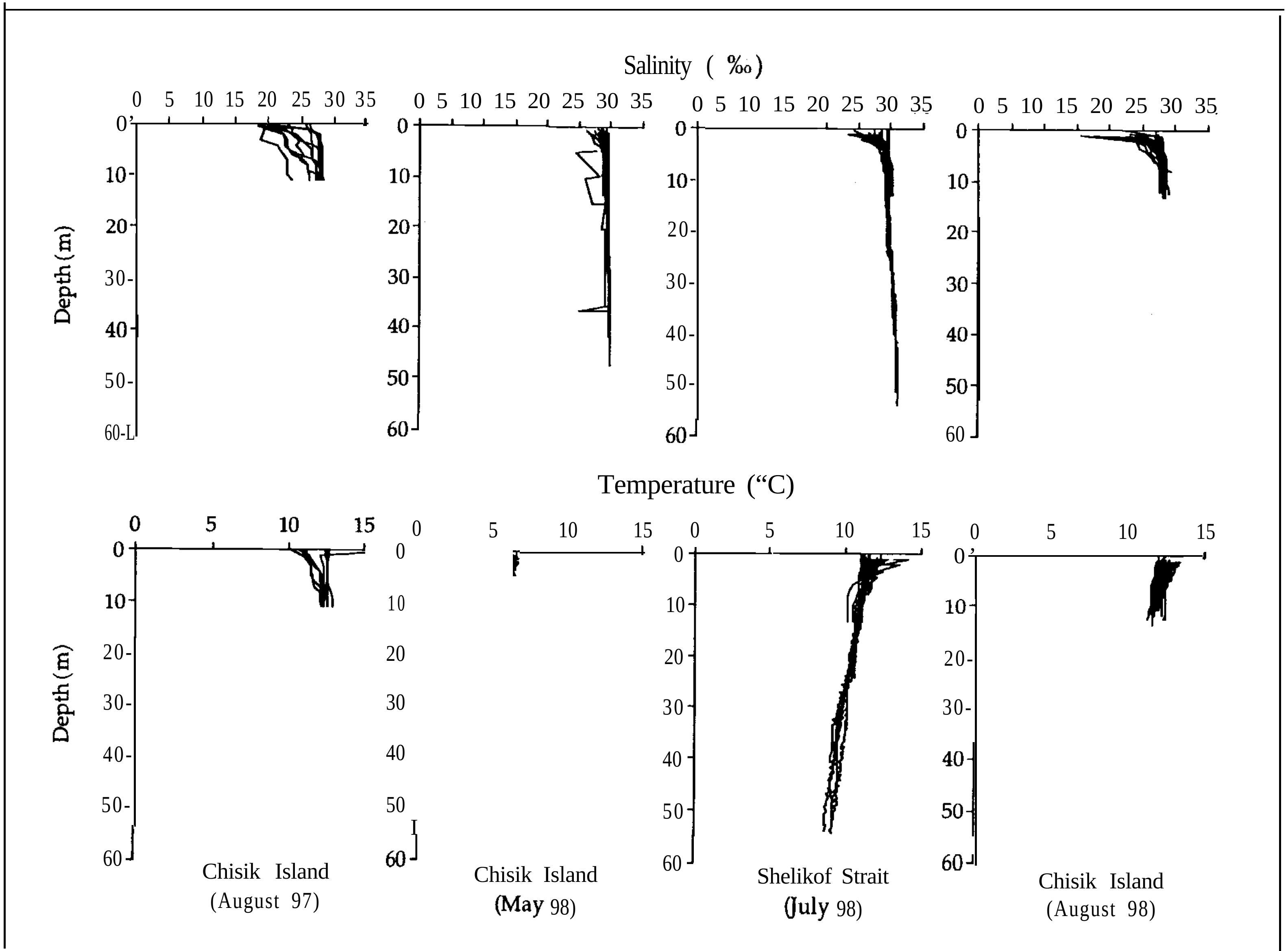


Figure 7. Composite vertical profiles of temperature and salinity for the four main sampling efforts.

4.2.3 Shelikof Strait July 1998

Waters at the three sampling locations in Shelikof Strait were all characterized by homogenous salinities (27.7-31.2‰) at depths below three' meters with only a slight tendency toward increasing salinity with depth. The upper three meters of the column varied between 23.5–30.1‰ depending on location and excluding several isolated anomalous surface measurements of <8.0‰ (not shown in Figure 7). At deep-water sites, temperature decreased in a linear fashion from about 11–12°C at 3 meters to 8–9°C at 55 meters.

4.2.4 Chisik Island August 1998

The Applied Microsystems, Inc. conductivity-temperature-depth probe failed during the August 1998 survey at Chisik Island and a YSI Model 33 salinity-temperature-density meter was used as a backup. Data were collected in l-meter increments. Because of strong currents at specific sites and their effect on wire angle, hydrographic data were taken down to a depth of 5.5 to 13 .0 meters, depending upon the transect.

Surface salinities within Tuxedni Channel ranged from 12.0–25.6‰ but there was no clear spatial gradient throughout the sampling grid. Surface salinities outside Tuxedni Channel seaward of Chisik Island ranged from 25.9–28.1‰. Bottom salinities (>5.0 m) ranged from 26.5–29.5‰ across all sites. Surface temperatures ranged from 11.9-13.6°C with the warmest waters occurring in Tuxedni Channel.

4.3 BIOLOGICAL

4.3.1 Species Composition

A total of 65,102 fish representing 26 species, 13 families, and 7 orders were collected during the 1997-1998 forage fish surveys (Tables 3 and 4). Ninety percent

Table 3. Fish species collected during the 1997- 1998 forage fish study.

Clupeiformes	Clupeidae	Pacific herring *Clupea pallasi*
Salmoniformes	Osmeridae	Eulachon *Thaleichthys pacificus*
		Longfin smelt *Spirinchus thaleichthys*
		Surf smelt *Hypomesus pretiosus*
	Salmonidae	Coho salmon *Oncorhynchus kisutch*
		Pink salmon *Oncorhynchus gorbuscha*
		Sockeye salmon *Onchorhynchus nerka*
		Dolly Varden *Salvelinus malma*
Gadiformes	Gadidae	Pacific cod *Gadus macrocephalus*
		Pacific tomcod *Microgadus proximus*
		Walleye pollock *Theragra chalcogramma*
Gasterosteiformes	Gasterosteidae	Threespine stickleback *Gasterosteus aculeatus*
Scorpaeniformes	Cottidae	Armorhead sculpin *Gymnocanthus galeatus*
		Pacific staghom sculpin *Leptocottus armatus*
		Unidentified sculpin
	Agonidae	Sturgeon poacher *Agonus acipenserinus*
		Tubenose poacher *Pallasina barbata*
		Unidentified poacher
	Cyclopteridae	Variegated snailfish *Liparis gibbus*
	Hexagrammidae	Masked greenling *Hexagrammos octogrammus*
Perciforrnes	Stichaeidae	Snake prickleback *Lumpenus sagitta*
		Daubed shanny *Lumpenus maculatus*
	Trichodontidae	Pacific sandfish *Trichodon trichodon*
	Ammodytidae	Pacific sand lance *Ammodytes hexapterus*
Pleuronectiformes	Pleuronectidae	Arrowtooth flounder *Atheresthes stomias*
		Starry flounder *Platichthys stellatus*
		Yellowfin *sole Pleuronectes asper*
		Butter *sole Pleuronectes isolepis*
		Unidentified sole

Table 4. Fish species collected by location

Chisik Island, IO-13 August 1997		Numbers Caught			Percent
Common Name	Scientific Name	Trawl	Seme	Total	Frequency
Pacific herrmg	*Clupea pallasi*	I,159	[illegible]	3,985	79 0
Snake prickleback	*Lumpenus sagitta*	791	3	794	15.7
Surf smelt	*Hypomesus pretiosus*	205	3	208	4.1
Longfin smelt	*Spirinchus thaleichthys*	18	-	18	0.4
Dolly Varden	*Salvelinus malma*		14	14	0.3
Pacific cod	*Gadus macrocephalus*	4	-	4	0.1
Threespine stickleback	*Gasterosteus aculeatus*	5	1	6	0.1
Yellowfin sole	*Pleuronectes asper*	6	-	6	0.1
Armorhead sculpin	*Gymnocanthus galeatus*	3	-	3	0.1
Sockeye salmon	*Onchorhynchus nerka*	2	-	2	<0.1
Pacific sand lance	*Ammodytes hexapterus*	2	-	2	<0.1
Sturgeon poacher	*Agonus acipenserinus*	1	-	1	<0.1
Pacific tomcod	*Microgadus proximus*	1	-	1	<0.1
Masked greenling	*Hexagrammos octogrammus*	1	-	1	<0.1
Daubed shanny	*Lumpenus maculatus*	1	-	1	<0.1
		2,199	2,847	5,046	

Chisik Island, 12-15 May 1998		Numbers Caught			Percent
Common Name	Scientific Name	Trawl	Seme	I otal	Frequency
Dolly Varden	*Salvelinus malma*		231	231	37.4
Eulachon	*Thaleichthys pacificus*	163	-	163	26.4
Pacific sand lance	*Ammodytes hexapterus*	12	97	109	17.6
Pacific herring	*Clupea pallasi*	41	13	54	8.7
Snake prickleback	*Lumpenus sagitta*	32	-	32	5.2
Walleye pollock	*Theragra chalcogramma*	11	-	11	1.8
Surf smelt	*Hypomesus pretiosus*		6	6	1.0
Starry flounder	*Platichthys stellatus*	3	-	3	0.5
Threespine stickleback	*Gasterosteus aculeatus*	1	2	3	0.5
Daubed shanny	*Lumpenus maculatus*	2	-	2	0.3
Longfin smelt	*Spirinchus thaleichthys*	1	-	1	0.2
Pacific sandfish	*Trichodon trichodon*	1	-	1	0.2
Pacific tomcod	*Microgadus proximus*	1	-	1	0.2
Unidentified sole	Pleuronectidae	1	-	1	0.2
		269	349	618	

continued

Table 4 continued

Shelikof Strait, 26-28 July 1998

Common Name	Scientific Name	Numbers Caught: Trawl	Seine	Total	Percent Frequency
Pacific herring	*Clupea pallasi*		58,571	58,571	99.4
Pacific stagbom sculpin	*Leptocottus armatus*		132	132	0.2
Dolly Varden	*Salvelinus malma*		93	93	0.2
Surf smelt	*Hypomesus pretiosus*		62	62	0.1
Unidentified sole	Pleuronectidae		24	24	<0.1
Starry flounder	*Platichthys stellatus*		11	11	<0.1
Pink salmon	*Oncorhynchus gorbuscha*		6	6	<0.1
Coho salmon	*Oncorhynchus kisutch*		2	2	<0.1
Unidentified fish		1	-	1	<0.1
Tubenose poacher	*Pallasina barbata*		1	1	<0.1
Pacific sandfish	*Trichodon trichodon*		1	1	<0.1
		1	58,903	58,904	

Chisik Island, 2-4 August 1998

Common Name	Scientific Name	Numbers Caught: Trawl	Seine	Total	Percent Frequency
Eulachon	*Thaleichthys pacificus*	239		239	44.x
Coho salmon	*Oncorhynchus kisutch*		93	93	17.4
Longfin smelt	*Spirinchus thaleichthys*	80	-	80	15.0
Starry flounder	*Platichthys stellatus*		38	38	7.1
Dolly Varden	*Salvelinus malma*		28	28	5.2
Unidentified sculpin	Cottidae		24	24	4.5
Unidentified sole	Pleuronectidae	12	-	12	2.2
Variegated snailfish	*Liparis gibbus*	4	-	4	0.7
Pacific sand lance	*Ammodytes hexapterus*	1	2	3	0.6
Snake prickleback	*Lumpenus sagitta*	3	-	3	0.6
Walleye pollock	*Theragra chalcogramma*	3	-	3	0.6
Threespine stickleback	*Gasterosteus aculeatus*		2	2	0.4
Unidentified poacher	Agonidae	2	-	2	0.4
Arrowtooth flounder	*Atheresthes stomias*	1	-	1	0.2
Butter sole	*Pleuronectes isolepis*	1	-	1	0.2
Pacific tomcod	*Microgadus proximus*	1	-	1	0.2
		347	187	534	
Grand Totals		2,816	62,286	65,102	

(N= 58,571) of the total catch was age-O+ Pacific herring collected in a single seine haul at Ninagiak Island on 27 July 1998 (Table 4). An additional 3,985 herring were collected during the 10-13 August 1997 survey at Chisik Island. There was also an anomalous catch of 790 snake prickleback *Lumpenus sagitta* taken at Chisik Island on 11 August 1997 when the trawl inadvertently sampled the seafloor during one trawl haul in Tuxedni Channel.

The remainder of this report will deal primarily with the following forage fish species: Pacific herring, Pacific sand lance, walleye pollock, eulachon, surf smelt, and longfin smelt.

4.3.2 **Species Accounts**

4.3.2.1 ***Pacific Herring***

A total of 62,610 herring were collected during the study of which 94% (*N* = 58,571) were age-O+ fish collected in a single seine haul at Ninagiak Island on 27 July 1998 (see Table 4). The remaining herring were collected at Chisik Island during 10-13 August 1997 (*N* = 3,985) and 12-15 May 1998 (N= 54). No herring were collected at Chisik Island during the 2-4 August 1998 survey.

Two principal size cohorts of herring were collected at Chisik Island in August 1997: 25-46 mm and 64-91 mm FL (Figure 8). Sub samples of aged fish indicated that the two groups were age-O+ and age-l+ fish, respectively. Age-O+ fish collected by seine actually consisted of two distinct modes and probably represents the presence of different spawning cohorts. Virtually all of the herring collected at Chisik Island the following spring by either seine or trawl were age-l+ fish ranging in length from 49 to 96 mm. An additional age-2 herring at 135 mm was also collected (not shown in Figure 8). Young-of-the-year ranging in length from 29 to 48 mm were collected the following summer of

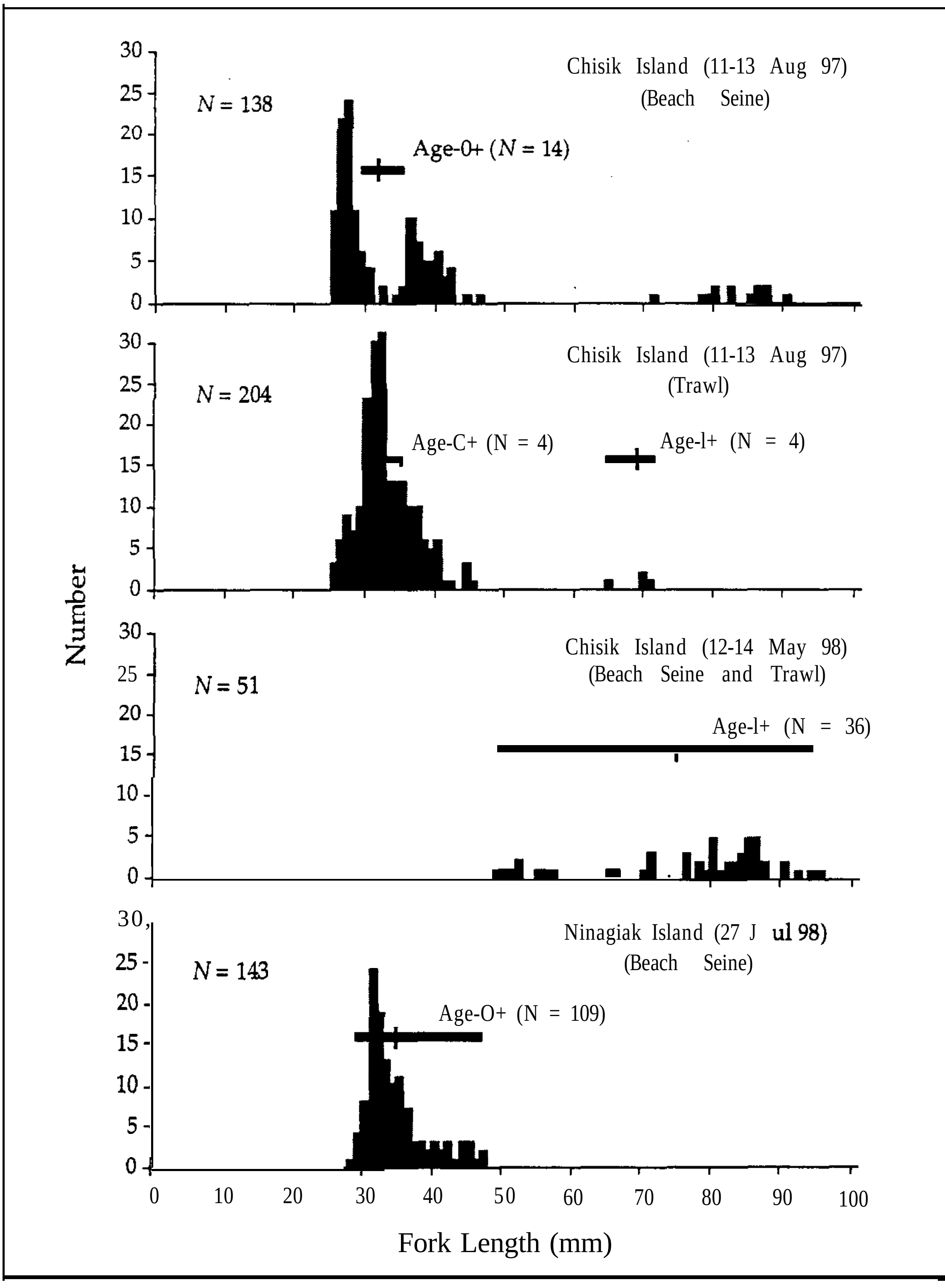


Figure 8. Length frequency of Pacific herring collected at Chisik Island and Ninagiak Island. No herring were collected either by trawl or seine at Chisik Island during the 2-4 August 1998 survey. Hash mark and horizontal bar within each panel indicates the mean length and range of aged fish.

1998 at Ninagiak Island. A single age-l+ fish at 127 mm was also recorded (not shown in Figure 8).

Length-frequency data for herring collected during 2-6 August 1996 as part of ADF&G surveys conducted at four primary sampling sites in Prince William Sound (PWS) (Figure 9) are shown in Figure 10. Although no fish were aged during the August ADF&G study, sub samples of fish collected six weeks earlier at the same sites were aged via scale analysis. Based upon the composite distributions from both surveys, we assumed that the smaller size cohorts of herring collected by ADF&G at Zaikof, Simpson, and Whale bays from 2-6 August 1996 were age-O+ fish. Figure 11 contains length-frequency data for herring collected at the Barren Islands/Kachemak Bay (B/K) during July 1998 as part of a U.S. Geological Survey (USGS) study. Based on the distribution relative to the time of year, we assumed that the small size cohort ($\leq$ 60 mm) represented age-O+ fish.

The above data were compared to length data for age-O+ herring collected in this study at Chisik Island in summer 1997 and Ninagiak Island in summer 1998 (Figure 12). Not only was there was a significant difference (P < 1.0 E-9) in fish length by site (ANOVA), but post hoc analysis (Tukey HSD test, Lentner and Bishop 1986) yielded significant differences (P < 0.001) in length among all sites, the exception being between Zaikof Bay and B/K (P = 0.11). Such differences are to be expected given the spatial segregation of herring stocks. In general, however, the lengths of age-O+ herring collected in July 1998 at the B/K were more similar to those observed in PWS in early August 1996 than to fish collected during mid-summer at either Chisik Island or Ninagiak Island.

A similar comparison was made between age-l+ herring collected at Chisik Island in May 1998 and those collected at the four primary PWS sites in May and June of 1996

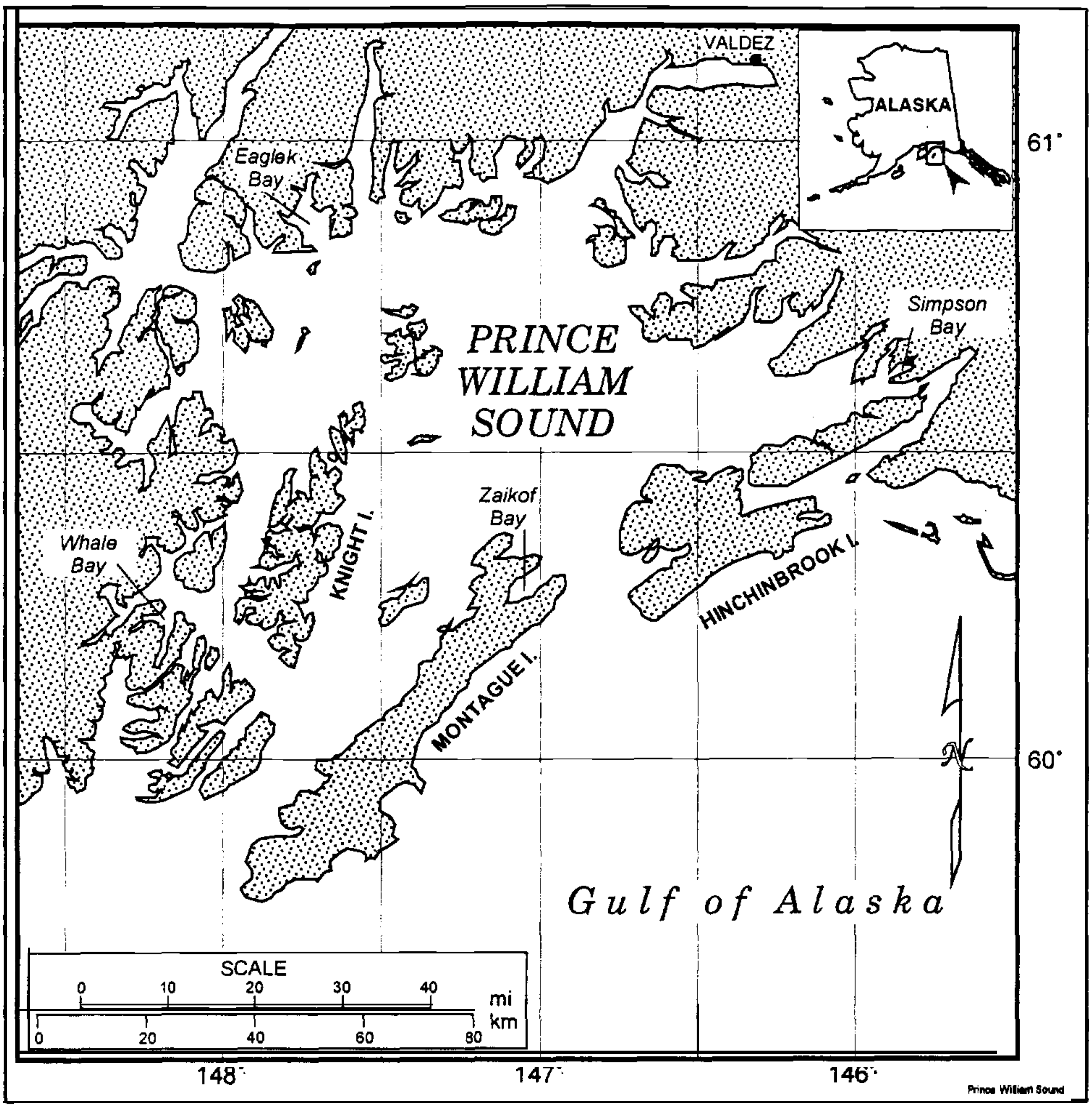


Figure 9. Map of the Prince William Sound region.

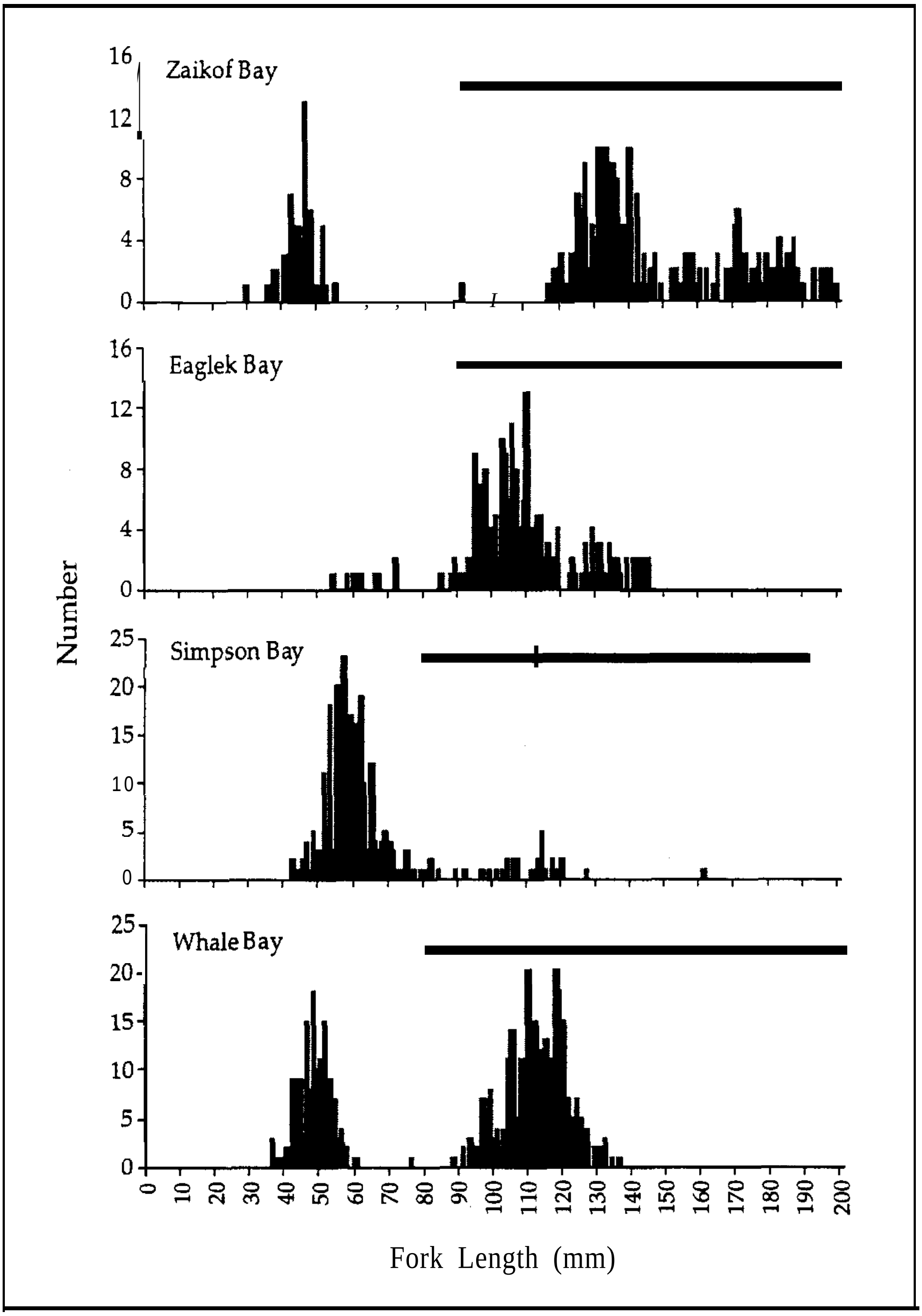


Figure 10. Length-frequency distributions for unaged herring collected from four locations in PWS, August 1996. No aging data are available for the surveys. Hash mark and horizontal line within each panel indicates the mean length and range of age 1+ herring identified (scales) from June 1996 surveys at each site. Based upon the comparative distributions, we assummed that the smallest size cohorts at Zaikof, Simpson, and Whale bays represent age-0+ herring. Data courtesy of Evelyn Brown, Alaska Department of Fish and Game.

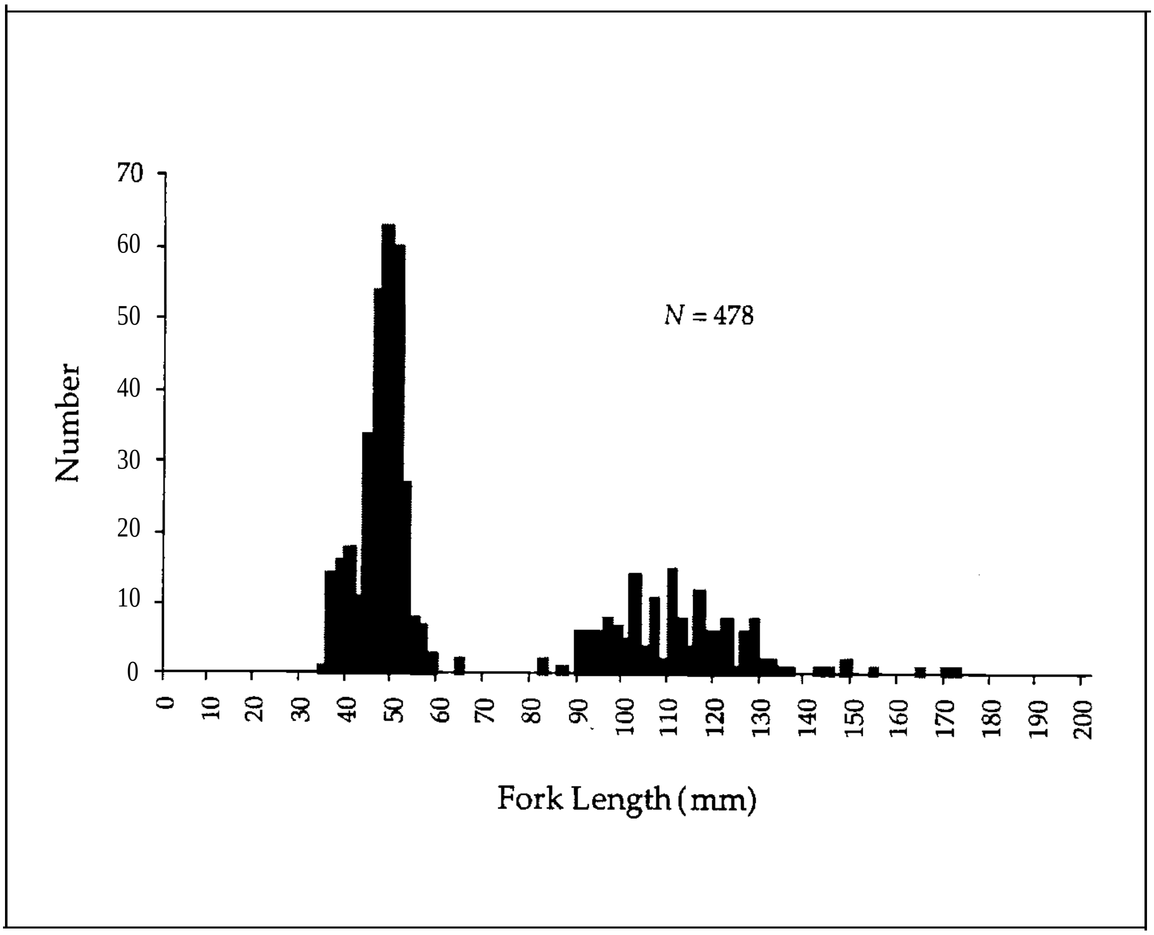


Figure 11. Length-frequency distribution for Pacific herring collected at Barren Island and Kachemak Bay in July 1998. We assumed that the smaller size cohort (≤60 mm) consisted of age-0 fish. Data courtesy of John Piatt, Biological Resource Division, U.S. Geological Survey.

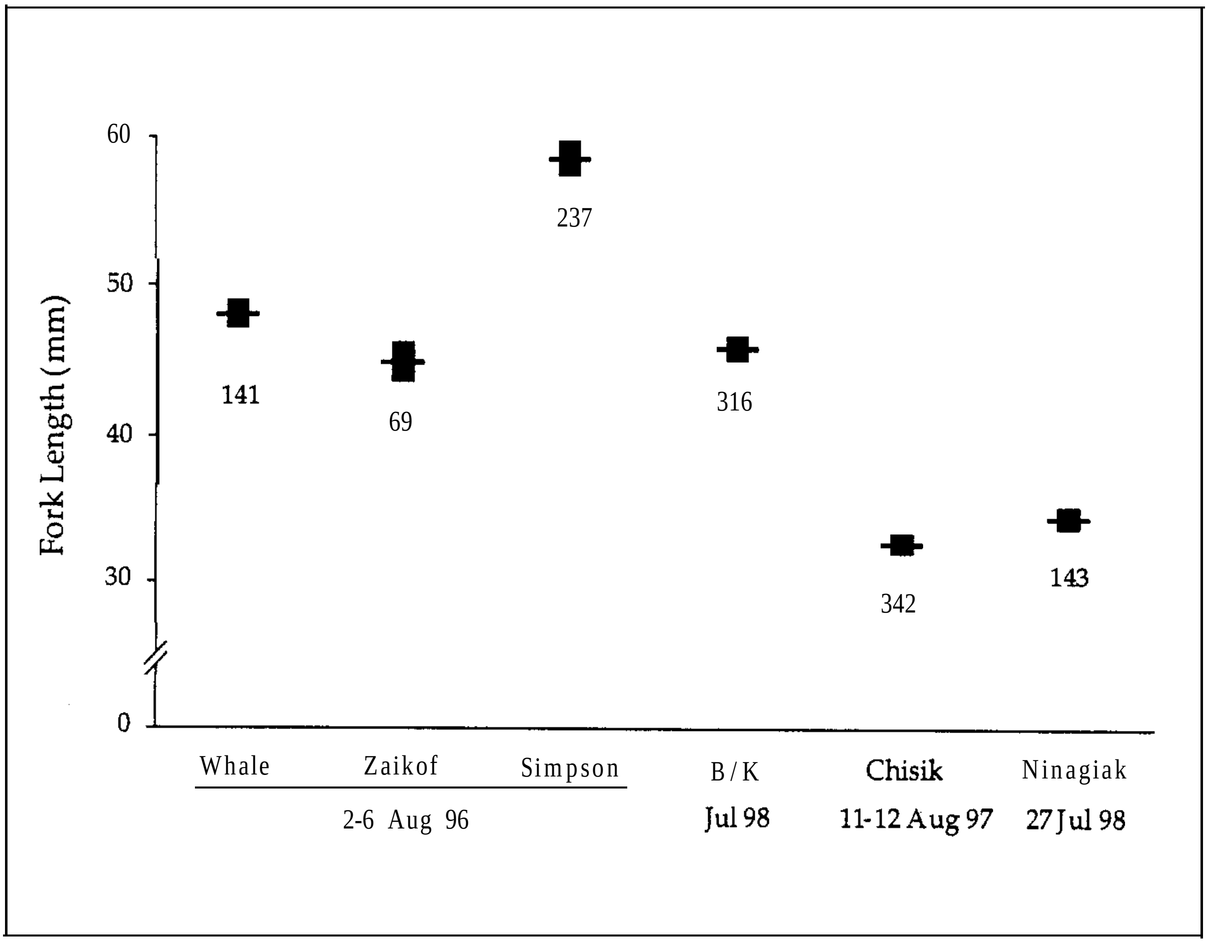


Figure 12. Mean (±2 SE) fork lengths of age-O+ Pacific herring collected during summer from three locations in Prince William Sound (Whale Bay, Zaikof Bay, Simpson Bay), Barren Island and Kachemack Bay (B/K), Chisik Island and Ninagiak Island. Numbers denote sample size. PWS data courtesy of Evelyn Brown, Alaska Department of Fish and Game. Barren Island/Kachemak Bay data courtesy of John Piatt, Biological Resource Division, US. Geological Survey.

(Figure 13). Significant differences ($P < 0.001$) among sample sites/surveys again indicated substantial spatial and temporal variability in length within the age cohort; however, the herring collected at Chisik Island were again markedly smaller than those collected in PWS.

The length differences noted above for age-O+ and age-l+ herring could be partially due to a year effect associated with some level of enhanced growth or productivity in 1996 (i.e., PWS) as opposed to a regional difference between PWS and Cook Inlet. On the other hand, the generally warmer and less saline conditions that prevail around Chisik Island could reflect lower productivity relative to colder, more marine upwelling areas in PWS and the B/K region. Piatt et al. (1997) indeed reported that during the summer 1996, shelf waters in the B/K region were colder and more saline than waters at Chisik Island. The significantly smaller age-O+ herring taken at Ninagiak Island in July 1998 relative to fish being collected that same month in the B/K region precludes a year effect and more strongly suggest a regional difference in growth patterns for young herring.

Analysis of Covariance (ANCOVA) performed on loge-transformed weight and length data was used to compare the condition or weight-to-length relationship among herring from Cook Inlet, PWS, and the B/K at similar times in the season (Table 5). Because of the narrow length range of herring collected at Chisik and Ninagiak islands, comparisons were limited to fish from a size range common to both this study and the studies conducted in PWS and B/K. For May comparisons, fish ranged from 71-89 mm (no B/K data) and for mid-summer comparisons they ranged from 30-50 mm (see Table 5).

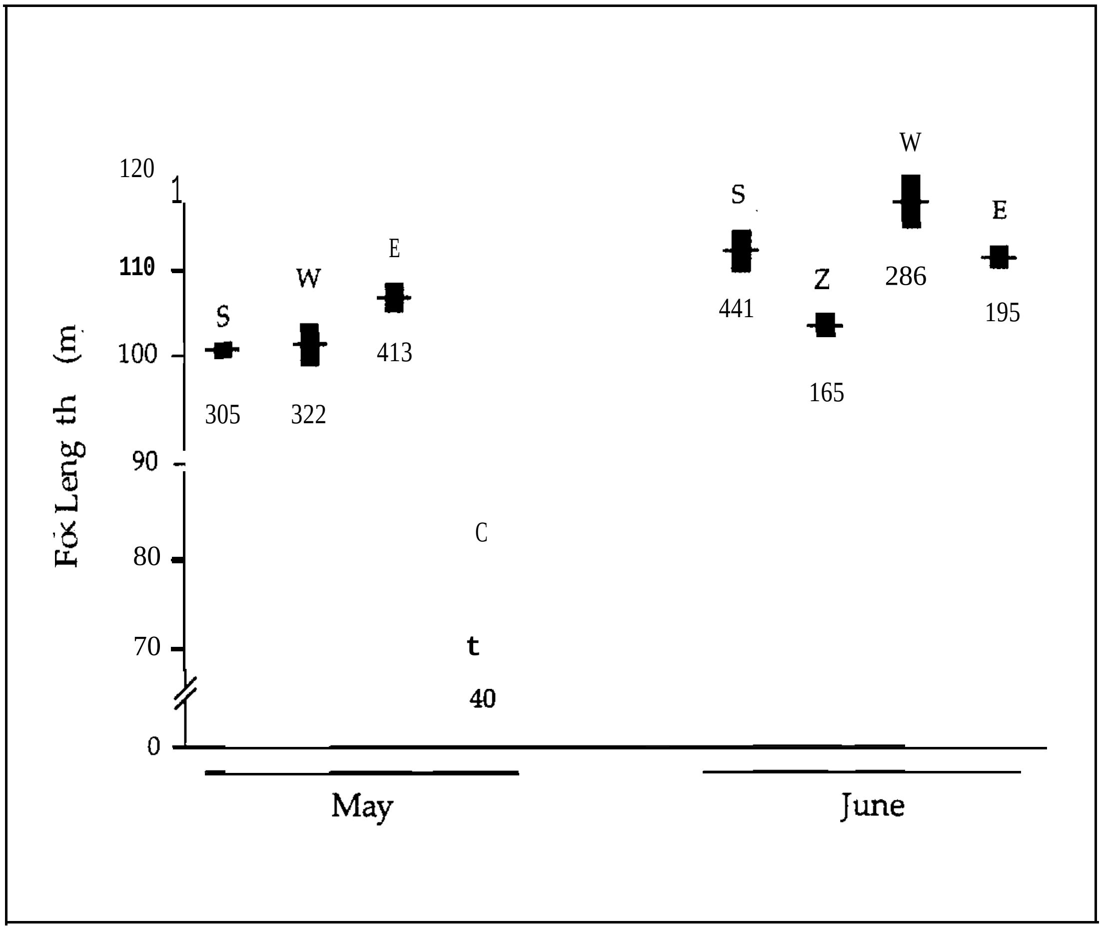


Figure 13. Mean (±2 SE) fork lengths of age-l+ Pacific herring collected from four locations in Prince William Sound (E = Eaglek Bay, Z = Zaikof Bay, S = Simpson Bay, W = Whale Bay) during May and June 1996. Also shown is the mean (±2 SE) fork length of age-l+ herring collected near Chisik Island (C) in May 1998 (black bar). Numbers denote sample size. PWS data courtesy of Evelyn Brown, Alaska Department of Fish and Game.

Table 5. Pacific herring used in weight-to-length ANCOVA.

Length Range	Location	Date	N
71-89 mm	Chisik Island (this study)	12-May-97	35
	Eaglek Bay	1 O-May-96	45
	Whale Bay	12-May-96	34
30-50 mm	Ninagiak Island (this study)	27-Jul-98	41
	Barren Islands/Kachemak Bay	Jul-98	270
	Whale Bay	2-Aug-96	84
	Zaikof Bay	4-Aug-96	56

For herring collected in May, there was no significant (*P* = 0.57) interaction effect and when the ANCOVA was re-run without the interaction term there was no significant (*P* = 0.10) site effect. Over the length range of fish examined, there was no difference in the condition of herring from Chisik Island in 1997, Whale Bay in 1996, and Eaglek Bay in 1996. Comparison of fish collected during summer yielded a significant (*P* < 0.01) interaction (i.e., unequal slopes). Subsequent inspection of the dam indicated that age-O+ herring from Ninagiak Island weighed less than fish from the other sites (Figure 14). Results are probably not biologically meaningful because they translate into weight differences of fractions of grams, well within the realm of normal spatial, feeding, and statistical variability.

4.3.2.2 Eulachon

Eulachon were collected at Chisik Island only on 13-15 May 1998 (N = 163) and 2-4 August 1998 (N = 239). Fish collected in May consisted of two distinct size groups: 50-130 mm and 182-243 mm FL (Figure 15). The smaller group included age-O+ (52-65 mm) and age-l+ (70-I 15 mm) fish while the larger group consisted primarily of age-4

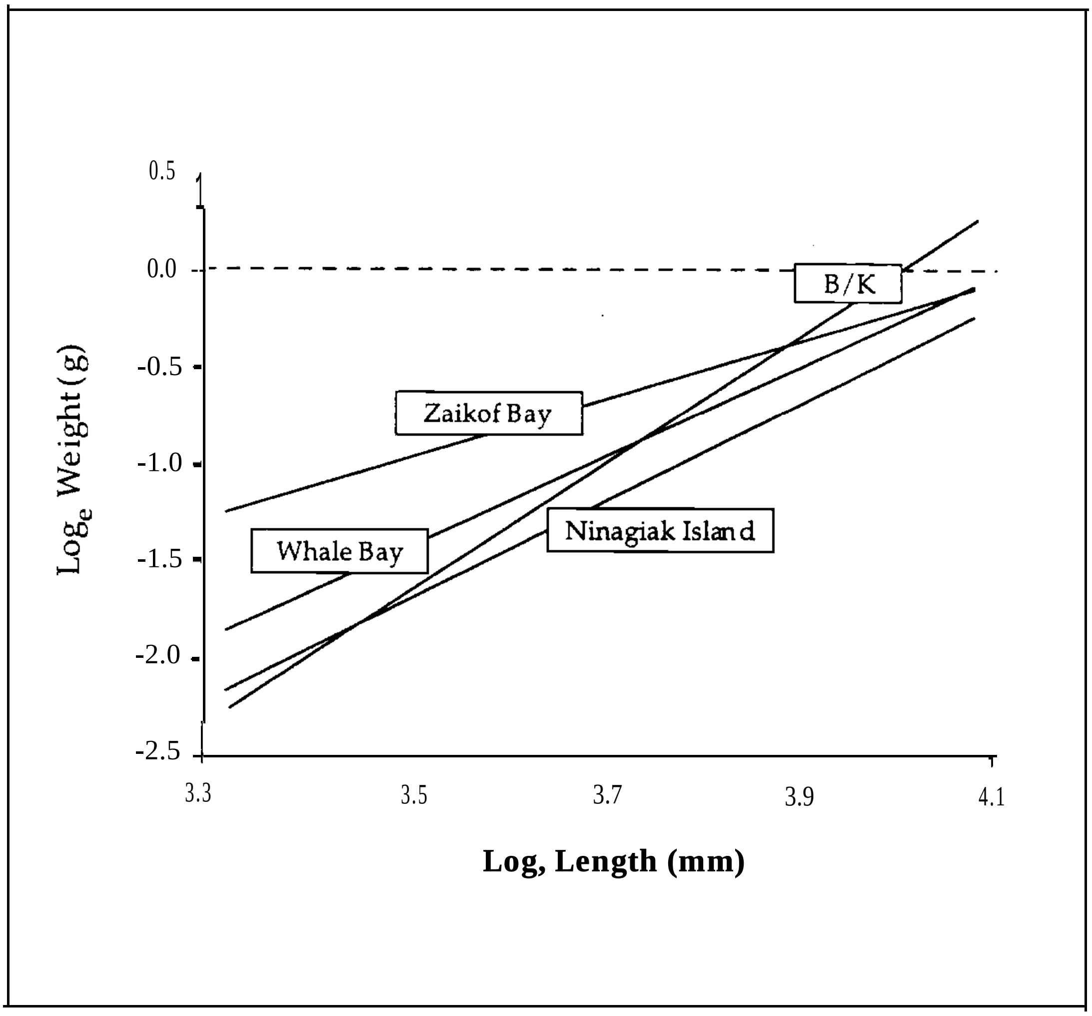


Figure 14. Weight-length regressions for Pacific herring (30-50 mm) collected at Ninagiak Island on 27 July 1998, at Barren Island/Kachemak Bay (B/K) in July 1998, in Whale Bay on 2 August 1996, and in Zaikof Bay on 4 August 1996.

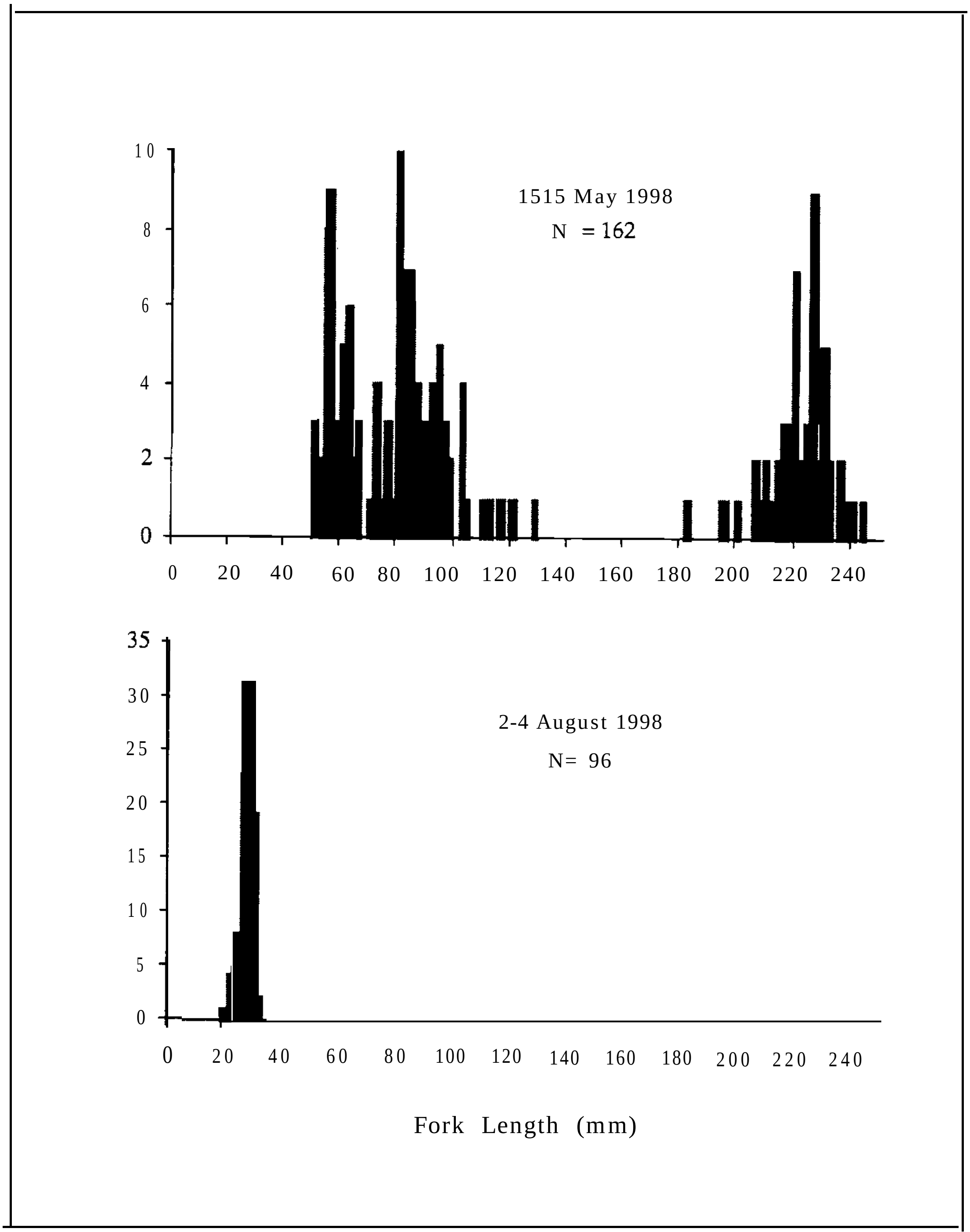


Figure 15. Length-frequency distribution for eulachon collected at Chisisk Island in spring and summer, 1998.

fish (200-235 mm, N = 18) with a few 3- and 5-year-olds. Most of the larger fish were in spawning condition and were taken by trawl on Transects 1, 4 and 5 near the mouth of Tuxedni Channel (see Figure 3). Eulachon spawn on sandy substrate (Hart 1973) and shallow sand bars were prevalent along the mainland shore of lower Tuxedni Channel. Spawning was probably imminent. Eulachon taken in August were young-of-the-year (19-32 mm) probably from the spawning observed the previous May (Figure 15).

Among spawners (9 males, 12 females examined) there were no significant gender-related differences (f-test) in either length ($P > 0.85$) or weight ($P > 0.61$). Females averaged 222.5 mm and 78.4 g while males average 223.5 mm and 80.6 g. Least-squares linear regression on loge-transformed length and weight data yielded a significant ($P < 0.001$) relationship, $y = -12.965 + 3.209x$ (Figure 16).

4.3.2.3 *Pacific Sand Lance*

A total of 114 sand lance were collected during the study of which 109 were taken by seine at Fossil Point site FP (Chisik Island, see Figure 3) on 14 May 1998. The bottom at this location was very sandy which could have accounted for increased abundance. Sand lance ranged in length from 59 to 135 mm FL and their size distribution was generally bimodal (Figure 17). Fish less than 80 mm were age-l+ while aged fish greater than 100 mm consisted of 2-to 4-year-olds. Of 42 randomly selected fish, there were 20 females and 22 males. Least-squares linear regression on loge-transformed length and weight data yielded a significant ($P < 0.001$) relationship, $y = -12.420 + 2.888x$ (Figure 18).

4.3.2.4 *Walleye Pollock*

Only 14 walleye pollock were collected during the entire study, all at Chisik Island: 11 (101-142 mm FL) on 14 May 1998 and three on 4 August 1998. The latter

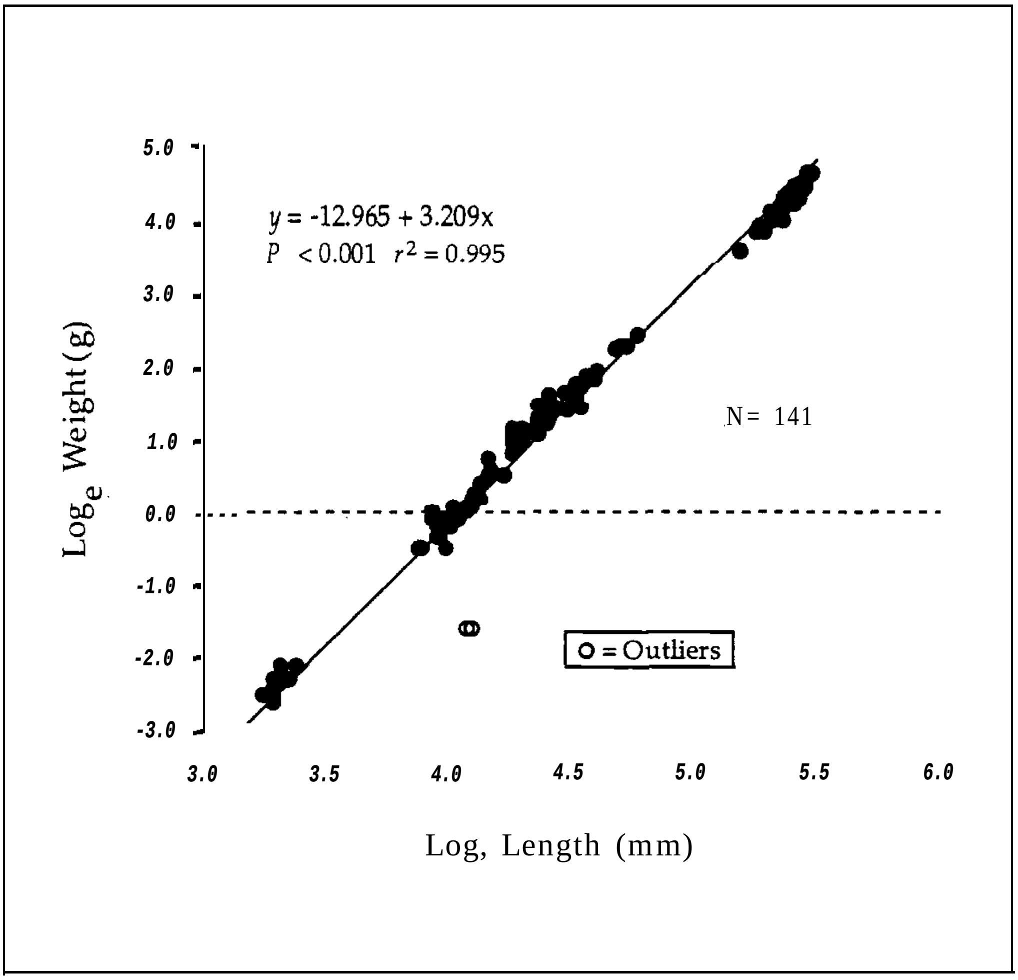


Figure 16. Weight-length regression for eulachon collected at Chisik Island from 13-15 May 1998 and 2-4 August 1998.

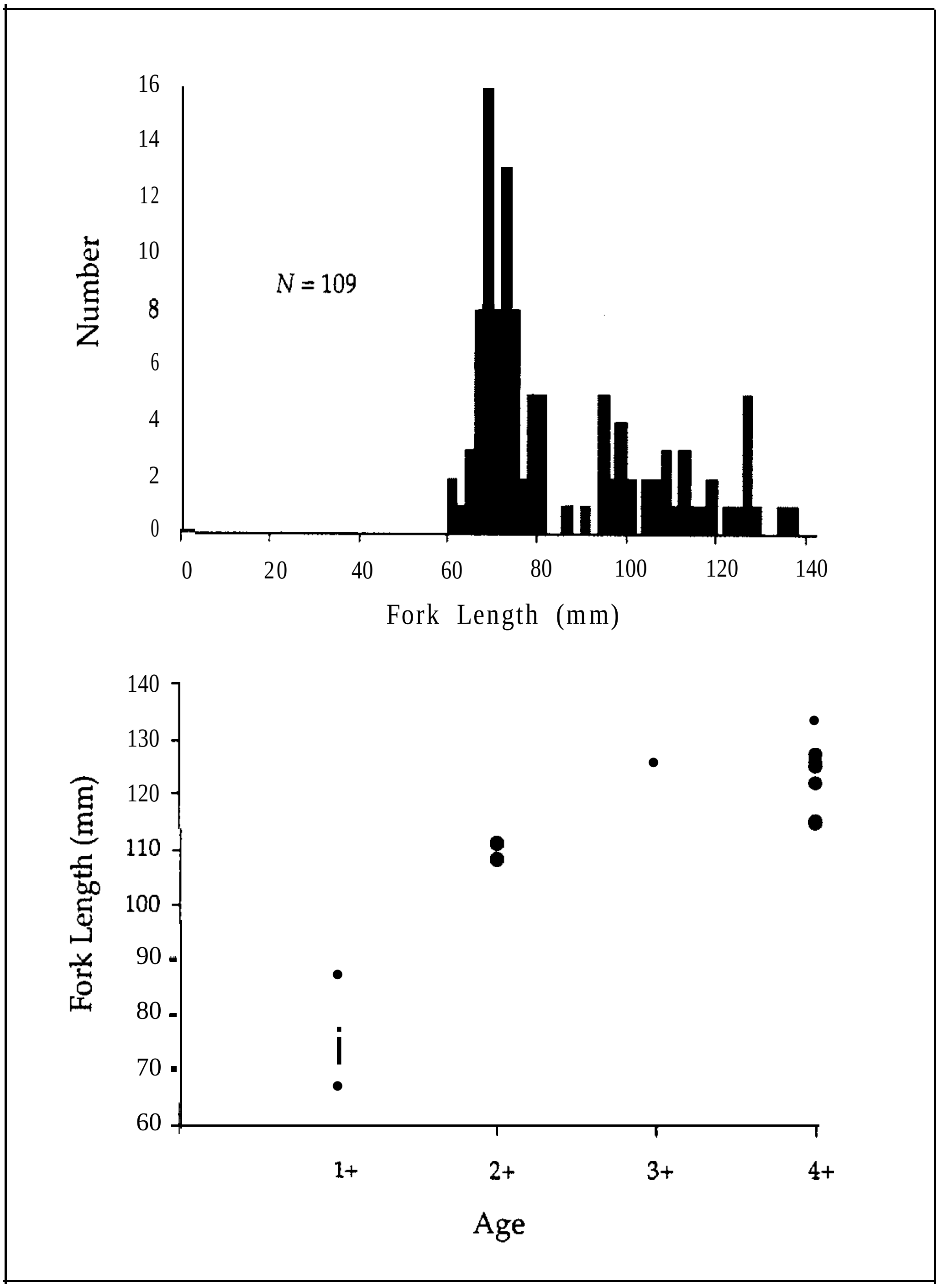


Figure 17. Length frequency (top panel) and length at age (bottom panel) of sand lance collected at Fossil Point, Chisik Island, on 14 May 1998.

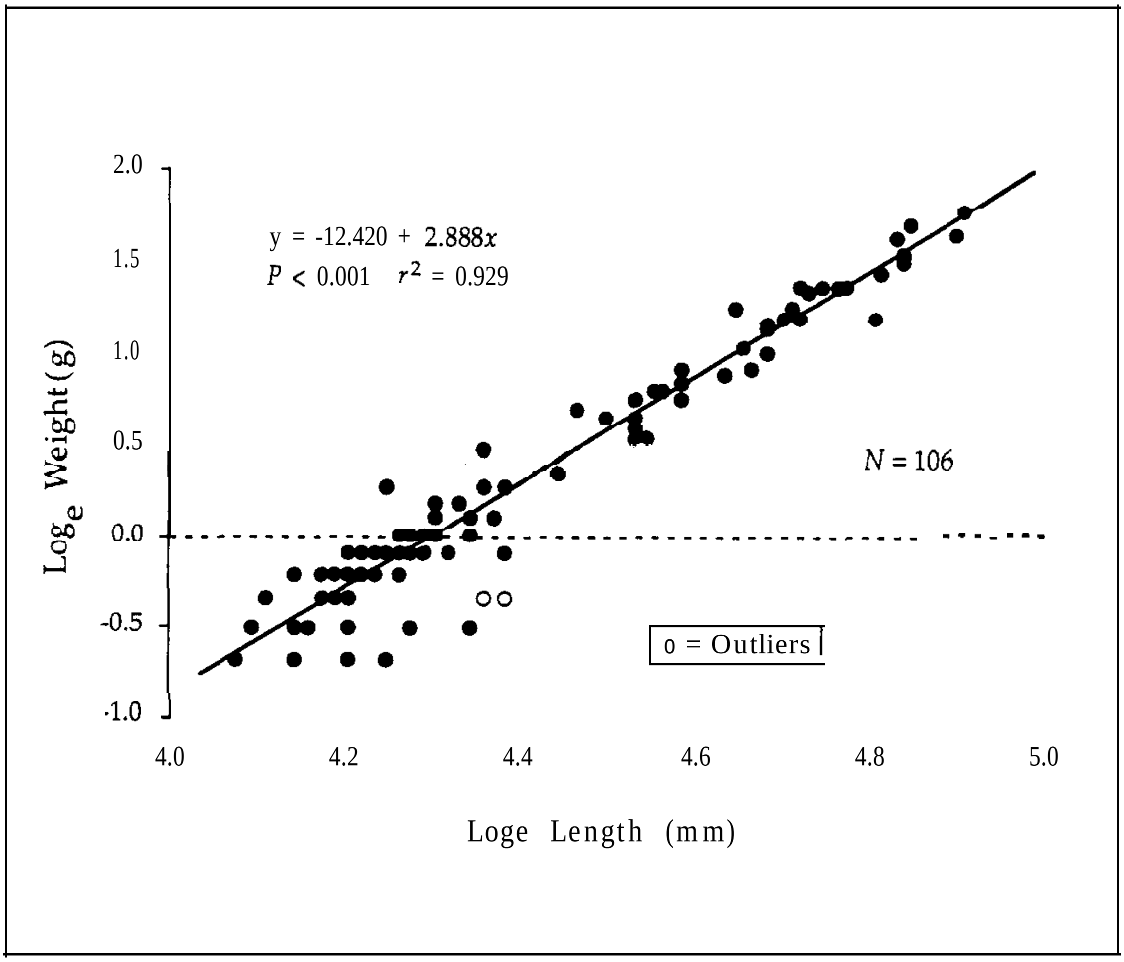


Figure 18. Weight-length regression for Pacific sand lance collected at Chisik Island on 14 May 1998.

three fish were aged as age-O+ (48 mm), age-l+ (67 mm), and age-3 (163 mm). Least-squares linear regression on loge-transformed length and weight data for all fish yielded a significant ($P < 0.001$) relationship, $y = -12.420 + 2.888x$ (Figure 19).

4.3.2.5 Surf Smelt

A total of 171 surf smelt were collected at Chisik and Ninagiak islands (Figure 20). Length-frequency distributions indicate the presence of age-O+ (25-45 mm) and age-l+ (75-85 mm FL) fish at Chisik Island in summer 1997. Only age-l+ fish were observed at Ninagiak Island in summer 1998. The six fish caught at Chisik Island were age-2+ fish. (It is likely that the age-O+ fish at 73 mm at Chisik Island in August 1997 and the single age-l+ fish at 109 mm in May 1998 were misidentifications). Least-squares linear regression on loge-transformed length and weight data for all fish yielded a significant ($P < 0.001$) relationship, $y = -12.076 + 3.152x$ (Figure 21).

4.3.2.6 Longfin Smelt

Ninety-nine longfin smelt were collected at Chisik Island: 18 in August 1997, one in May 1998, and 80 in August 1998. Fish from the 1997 summer survey ranged in length from 71-96 mm FL and consisted of 1- and 2-year-olds (Figure 22). Smelt from August 1998 ranged in length from 54-127 mm and consisted of 1- to 3-year-olds. There was considerable size overlap in age cohorts but this may partially be due to difficulties in otolith aging. Ages of surf smelt cannot be determined with certainty (Hart 1973). Least-squares linear regression on loge-transformed length and weight data for fish collected in August 1998 yielded a significant ($P < 0.001$) relationship, $y = -13.158 + 3.275$~ (Figure 23).

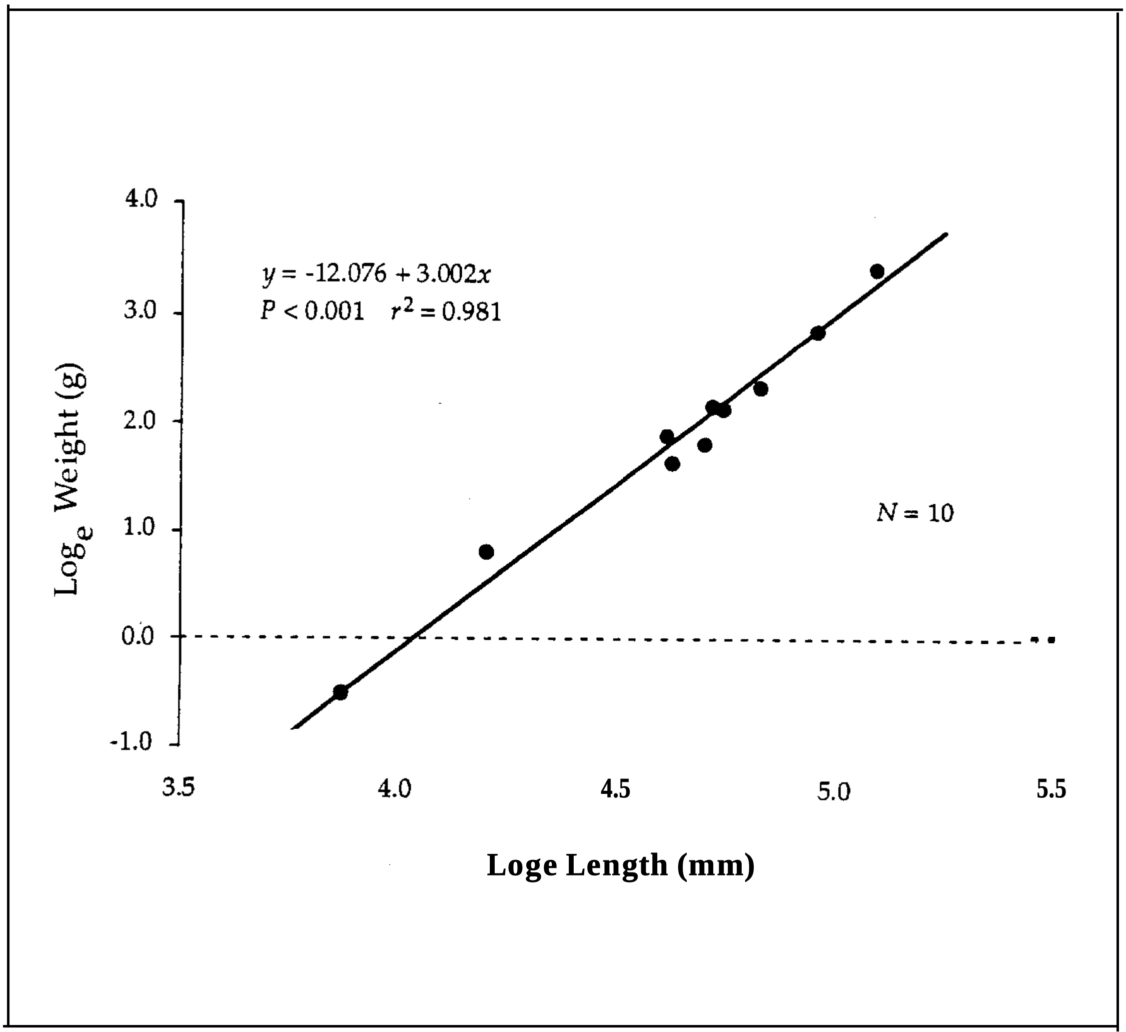


Figure 19. Weight-length regression for walleye pollock collected at Chisik Island from 13-15 May 1998 and 2-4 Aug 1998.

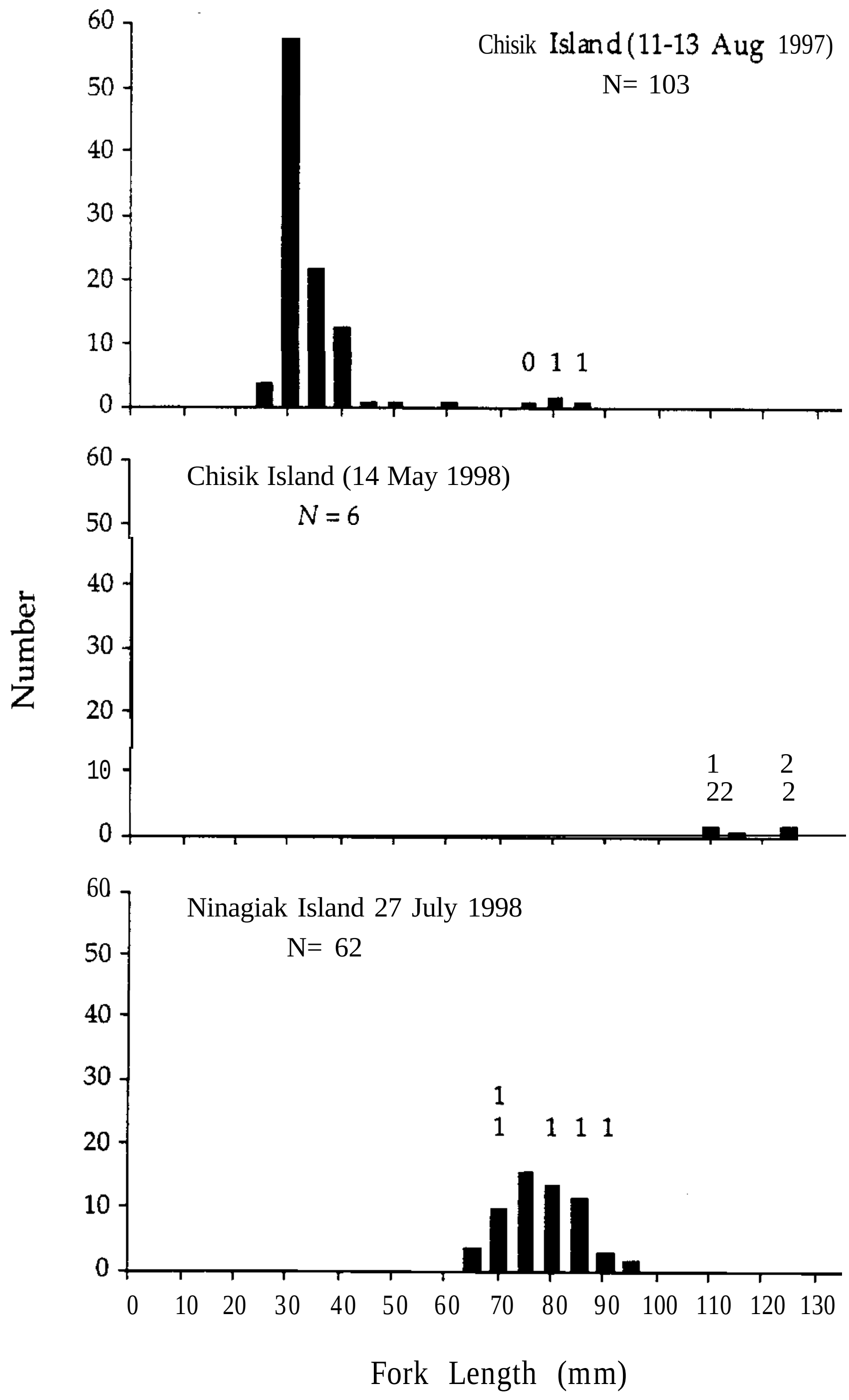


Figure 20. Length frequency of surf smelt collected at Chisik and Ninagiak islands. Numerals indicate ages (+) of individual fish relative to their length. Based upon the collective data, it is assumed that fish in the 2540 mm range collected from Chisik Island in August 1997 were young-of-the-year.

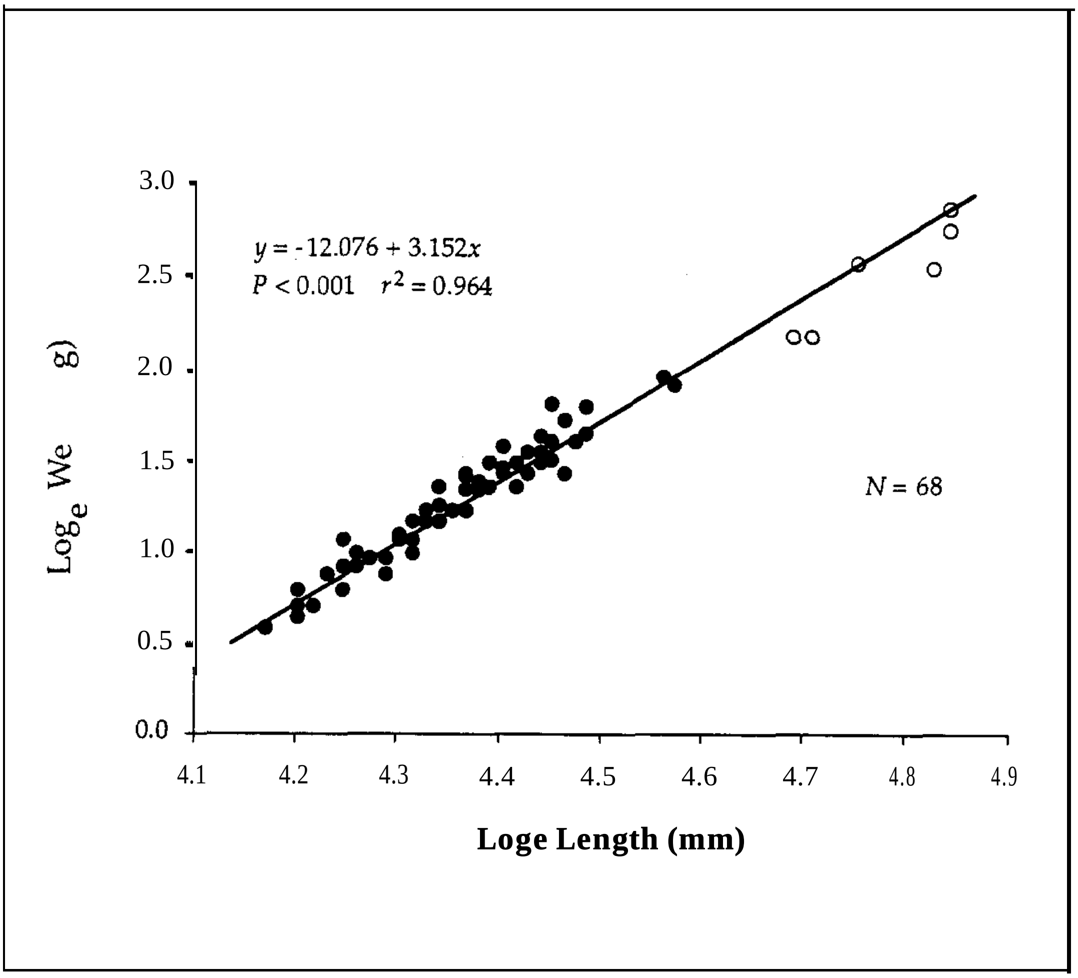


Figure 21. Weight-length regression for surf smelt collected at Chisik Island from 14 May 1998 (open symbols) and Ninagiak Island on 27 July 1998 (closed symbols).

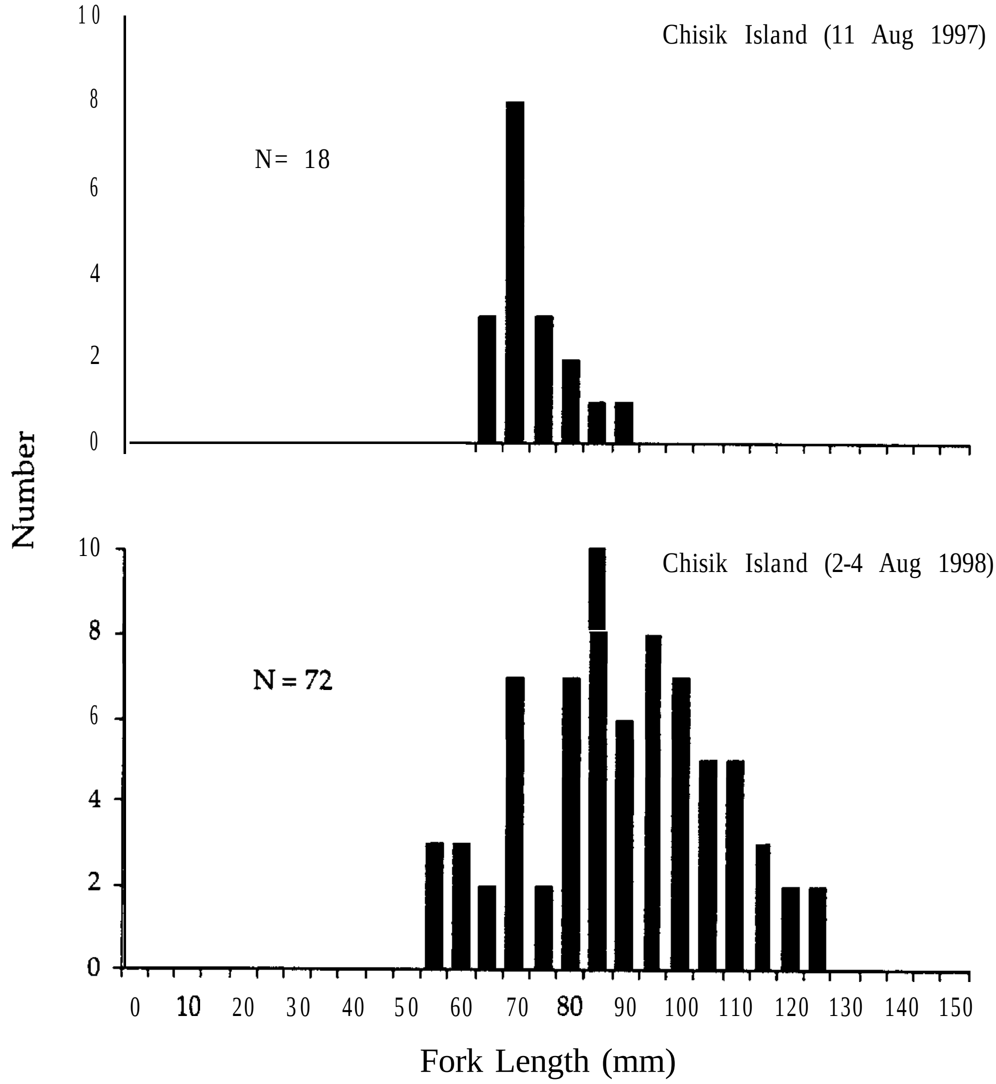


Figure 22. Length frequency of longfin smelt collected at Chisik Island during the summers of 1997 and 1998.

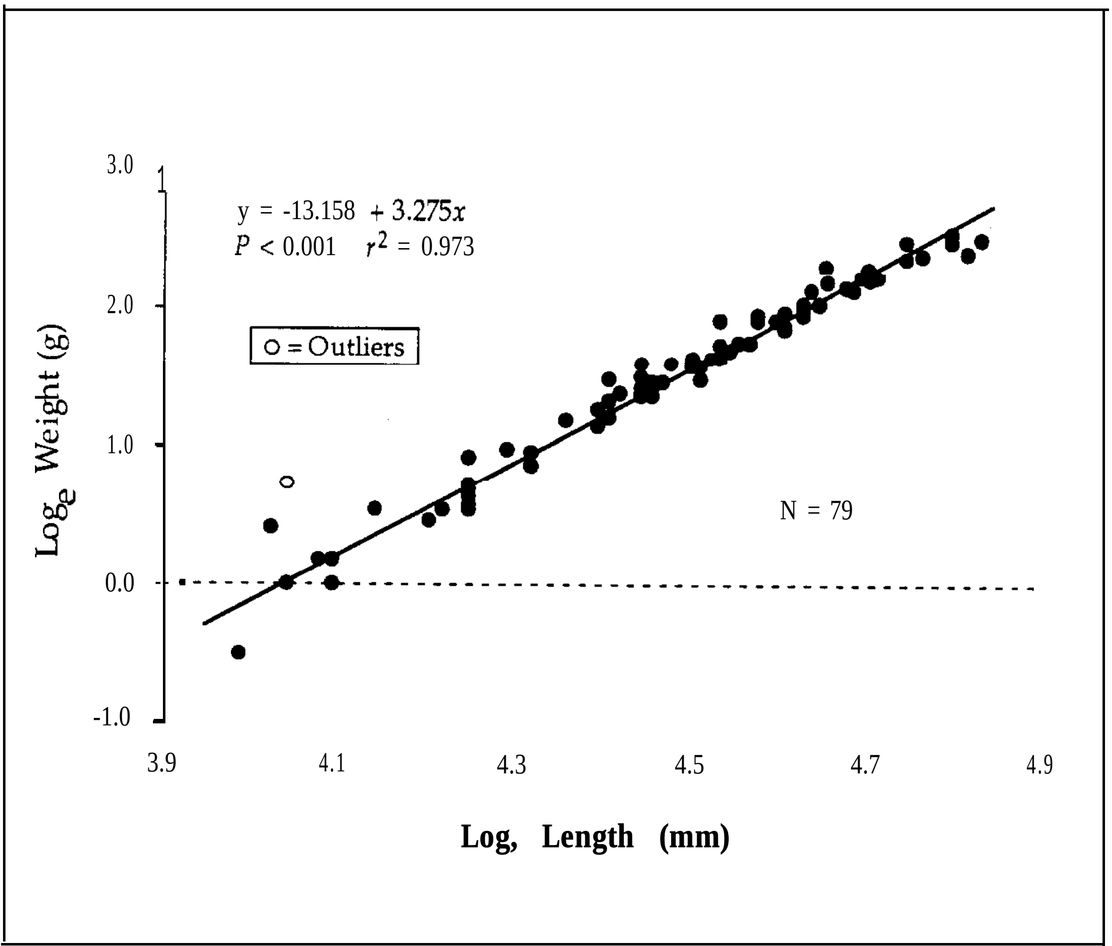


Figure 23. Weight-length regression for longfin smelt collected at Chisik Island from 2-4 August 1998.

4.3.3 Diet

4.3.3.1 Stomach Fullness

Stomach fullness data for the 351 fish collected for dietary analysis are presented in Table 6. There was a fairly even distribution in percent stomach fullness during the Chisik Island surveys of August 1997 and May 1998. Only 22% (N = 58) of **268** fish had empty stomachs, and this included 20 eulachon (205-243 mm) taken by trawl at the mouth of Tuxedni Channel on 14 May 1998 (Tl-H6). All of the eulachon were in spawning condition and cessation of feeding in conjunction with their spawning run may have accounted for their empty stomachs. The proportion of empty stomachs was much higher (5 1%) during the 1998 summer surveys at Ninagiak and Chisik islands; of 83 fish collected, only 14 (16%) had stomachs greater than 50% full.

4.3.3.2 Stomach Contents

The diets of herring and surf smelt in August 1997 at Chisik Island were quite similar and very selective (Table 7). Several copepodite stages of *Eurytemora* sp. dominated the diets of both species with barnacle larvae (a composite of cyprid and nauplius stages) comprising an additional 10% of total dry mass. An unidentified parasitic invertebrate (perhaps as an internal parasite; Ted Cooney, UAF, pers. comm. 1998), unidentified decapod larvae, and harpacticoid copepods were minor dietary components. A small number of unidentified very small eggs were in many stomachs, possibly from *Eurytemora* sp. The similarity in diet yielded a Schoener index value of 0.967 (Table 8), the highest observed in the study, and the specialized diet of both species yielded some of the lowest measures of dietary breadth across the entire study (Table 9). IRI values also indicated that *Eurytemora* sp. and to a lesser extent barnacle cyprids were the most important food items for both fish species (Table 10).

Table 6. Fish stomach fullness expressed as percent of full stomach by transect/haul and species. Fish with trace amounts of prey in their stomachs are listed as 0 percent.

Location	Transect/ Haul	Date	Species	Length Range (mm)	Percent Fullness 100	75	50	25	0
Chisik Island	T3-H1	12-Aug-97	Surf smelt	28-43				3	19
	T6-H3	12-Aug-97	Herring	30-39	2	9	7	2	1
	T7-H5	13-Aug-97	Herring	70-72			1	1	
	CA-BS-1	14-Aug-97	Herring	27-45	25	15	1	4	7
	CA-BS-2	14-Aug-97	Surf smelt		2			1	
			Total		29	24	9	11	27
Chisik Island	T17-H3	13-May-98	Longfin smelt	54					1
	T17-H3	13-May-98	Sand lance	70-72			1		1
	T18-H2	13-May-98	Herring	80-91	5		2	3	
	T18-H2	13-May-98	Sand lance	63	1				
	T22-H4	13-May-98	Sand lance	67-80		1			2
	T22-H4	13-May-98	Eulachon	48-93			1	8	1
	T22-H4	13-May-98	Pollock	110					0
	T22-H5	13-May-98	Eulachon	54					1
	FP-BS-1	14-May-98	Sand lance	67-92	12	1			
	FP-BS-1	14-May-98	Surf smelt	109-125		1	2		
	FP-BS-2	14-May-98	Surf smelt	75-127		1	2		
	FP-BS-2	14-May-98	Surf smelt	127		1			
	FP-BS-3	14-May-98	Sand lance	65-135	15	5	3	1	
	FP-BS-3	14-May-98	Surf smelt	116-127	2				
	T1-H6	14-May-98	Eulachon	205-243				1	20
	T1-H6	14-May-98	Pollock	108-123				25	
	T1-H6	14-May-98	Herring	65	1				
	T5-H7	14-May-98	Eulachon	60-61	1				1
	T5-H7	14-May-98	Herring	51			1		
	T5A-H8	14-May-98	Herring	71-85	3	2	3	4	
	T5A-H8	14-May-98	Eulachon	50-58				4	1
	T7-H9	14-May-98	Herring	85	1				
	T7-H9	14-May-98	Pollock	102-112	2				
	T7-H9	14-May-98	Eulachon	80-115		1	7	10	3
	T9-H10	14-May-98	Pollock	101-125	2			1	
			Total		45	13	22	57	31

Continued

Table 6 continued

Location	Transect/ Haul	Date	Species	Length Range (mm)	Percent Fullness 100	75	50	25	0
Ninagiak Island	NR-1-BS	27-Jul-98	Herring	31-42			5	4	12
	NR-I-BS	27-Jul-98	Surf smelt	67			1		
	SP-I-BS	27-Jul-98	Surf smelt	67-89	2	4	3	1	
	SP-2-BS	27-Jul-98	Herring	127		1			
			Total		2	5	9	5	12
Chisik Island	T3-H1	2-Aug-98	Longfin smelt	70-105		3	1	2	4
	T3-H1	2-Aug-98	Tomcod	62		1			
	T3-H2	2-Aug-98	Longfin smelt	57-115			3	3	3
	T3-H2	2-Aug-98	Sand lance	67					1
	T8-H4	2-Aug-98	Longfin smelt	60-75		1			4
	T8-H4	2-Aug-98	Eulachon	28-30					5
	T9-H5	2-Aug-98	Eulachon	26-30					5
	T9-H6	2-Aug-98	Eulachon	27-30					5
	T3-H7	3-Aug-98	Longfin smelt	78-125				4	2
	T4-H11	4-Aug-98	Pollock	48-67		1			1
	T5-H9	4-Aug-98	Pollock	163		1			
			Total		0	7	4	9	30
			Grand Total		76	49	44	82	100
			Overall Sample Size						351

Table 7. Prey items identified from fish collected at Chisik Island and Ninagiak Island. Values are percent of total stomach dry weight biomass. Prey items that constitute > 5% of total biomass are highlighted in **bold.**

	Chisik Island										Ninagiak Is.	
	2-4 Aug 97				13-14 May 98					2-3 Aug 98**	27 Jul 98	
	Herring	Surf Smelt	Herring (Trawl)	Herring (Seine)	Herring	Sand Lance	Eulachon*	Pollock	Surf Smelt	Longfin Smelt	Herring	Surf Smelt
Taxon *N* =	67	6	22	45	28	43	42	9	6	30	21	11
No. Sets =	3	2	1	1	6	5	5	4	3	4	2	2
FL (mm) =	27-45	30-45	30-39	27-45	65-91	63-135	48-115	101-133	109-127	57-125	31-42	67-89
Barnacle nauplii					0.63	0.20	0.13	0.00	0.02			
Crangonidae zoea					0.10	0.19	0.52	0.10	0.06			
Phyllodocidae (Polychaete)					<0.01	0.11		0.71	0.10			
Polychaete												0.01
Isopod						<0.01	0.04		0.46			
Harpacticoid copepod	0.01		0.32	0.06	co.01	0.22		co.01	0.13	<0.0I	0.71	0.93
Barnacle cyprid	0.07	0.11	0.11		0.2 1	0.07	co.01	<0.01	0.02			0.04
Cumacea						0.03	0.16	co.01	0.00	0.03		
Fish												
Fish egg					co.01	0.04			0.13			
Decapod zoea					0.03	0.08	0.03	0.04	0.01			
Decapcd megalopa										0.08		
Amphipoda					0.00	0.01	0.08	0.01	0.06	0.01		0.01
Eurytemora sp.	0.92	0.89	0.55	0.94	0.01	0.04	0.02	0.00	<0.01	10.0 I	0.10	<0.01
Sagitta sp.								0.08				
Byblis sp.								0.05				
Pseudocalanus sp.					co.01	<0.01	<0.01	0.01	<0.01	co.01	0.03	
Parathemisto sp.										0.34		
Unident. small copepod					0.01	<0.01	<0.01		co.01			
Ostracod						<0.01			co.01			
Unident. invertebrate eggs (sm)					<0.01	<0.01			co.01			

* Excludes a trawl haul of spawning adults, most of which had empty stomachs.

** Excludes one tomcod, three sand lance, three pollock, and 15 eulachon (with empty stomachs).

Continued

Table 7 continued

	Chisik Island										Ninagiak Is.	
	2-4 Aug 97				13-14 May98					2-3 Aug 98**	27 Jul 98	
	Herring	Surf Smell	Herrmg (Trawl)	Herrmg (Seine)	Herring	Sand Lance	Eulachon*	Pollock	Surf Smelt	Longfin Smelt	Herring	Surf Smelt
Taxon N =	67	6	22	45	28	43	42	9	6	30	21	11
No. Sets =	3	2	1	1	6	5	5	4	3	4	2	2
FL (mm) =	27-45	30-45	30-39	27-45	65-9 I	63-135	48-1 15	101-133	109-127	57- I25	31-42	67-89
Arcartia sp.							<0.01					
Arcartia longiremis											0.03	
Unidentified decapod larva	<0.01		0.02									
Mysis sp. juvenile					co.01			<0.01		0.49		
Calanus marshallae						<0.01		<0.01				
Centropages sp.					co.01	<0.01			<0.01			
Pasiphaea sp.										0.01		
Neocalanus sp.					co.01							
Metridia pacifica						<0.01						
Unident. polychaete larvae						<0.01	<0.01		co.01			
Conchoecia sp.								<0.01				
Monstrilla sp. (copepod)						<0.01			<0.01			
Brachyrhyncha sp. zoea						<0.01	<0.01					
Gastropod larvae						<0.01						
Chaetognatha										0.03		
Chironomid									<0.01			co.01
Aetideidae (copepod)						co.01						
Copepod (small)											0.13	
Euphausid calyptopis						<0.01						

* Excludes a trawl haul of spawning adults, most of which had empty stomachs.

** Excludes one tomcod, three sand lance, three pollock, and 15 eulachon (with empty stomachs).

Table 8. Schoener similarity index values.

	Chisik Island						Ninagiak Is.
	2-4 Aug 97	13-14 May 98					27-Jul-98
	Surf Smelt	Eulachon	Pollock	Sand Lance	Herring	Surf Smelt	Surf Smelt
Eulachon			0.087	0.423	0.259	0.177	
Pollock				0.167	0.030	0.149	
Sand Lance					0.398	0.392	
Herring	0.967					0.110	0.714

Table 9. Shannon-Wiener and Levin index measures of dietary breadth.

		Shannon- Weiner		Levin
Sampling Location	Species	H'	J	B
Chisik Island 2-4 August 1997	Herring	0.304	0.088	1.173
	Surf smelt	0.345	0.100	1.244
Chisik Island 13-14 May 1998	Eulachon	1.490	0.434	3.060
	Walleye pollock	0.988	0.288	1.970
	Sand lance	2.125	0.619	6.696
	Herring	1.061	0.309	2.139
	Surf smelt	1.628	0.474	3.535
Ninagiak Island 27 July 1998	Herring	0.949	0.303	1.875
	Surf smelt	0.310	0.099	1.147
Chisik Island 2-3 August 1998	Longfin smelt	1.248	0.398	2.743

Table 10. Index of Relative Importance (IRI) values.

	Chisik Island								Ninagiak Is.	
	2-4 Aug 97		13-14 May98					2-3 Aug 97	27 Jul 98	
	Herring	Surf Smelt	Hemng	Sand Lance	Eulachon	Pollock	Surf Smelt	Longfin Smelt	Herring	Surf Smelt
Barnacle nauplii	0	0	9,222	5,218	4,086	35	905	'0	0	0
Crangonidae zoea	0	0	711	1,863	4,976	I.139	445	0	0	0
Phyllodocidae (Polychaete)	0	0	0	420	0	2,147	669	0	0	0
Polychaete	0	0	0	0	0	0	0	0	0	7
Isopod	0	0	0	I	14	0	3,343	0	0	0
Harpacticoid copepod	21	0	3	4,227	0	19	7,406	5	Il.727	9.606
Barnacle cyprid	2,405	163	2.41 1	990	6	5	380	0	0	255
Cumacea	0	0	0	22	217	II	I	135	0	0
Fish	0	0	0	0	0	0	0	0	0	0
Fish egg	0	0	I	242	0	0	1,110	0	0	0
Decapod zoea	0	0	117	336	13	620	18	0	0	0
Decapod megalopa	0	0	0	0	0	0	0	164	0	0
Amphipcda	0	0	0	14	41	35	501	II	0	9
Eurytemora sp.	9,757	4,31I	69	a79	359	516	133	114	0	I
Sagitta sp.	0	0	0	0	0	80	0	0	0	0
Byblis sp.	0	0	0	0	0	57	0	0	0	0
Pseudocalanus sp.	0	0	8	100	40	213	23	146	0	0
Parathemisto sp.	0	0	0	0	0	0	0	4,123	0	0
Unident. small copepod	0	0	56	13	I	0	I	0	0	0
Ostracod	0	0	0	76	0	0	29	0	0	0
Unident. invertebrate eggs (sm)	0	0	432	35	0	0	0	0	0	0
Arcartia sp.	0	0	0	0	2	0	0	0	0	0
Arcartia longiremis	0	0	0	0	0	0	0	0	0	0
Unidentified decapod larva	4	0	0	0	0	0	0	0	0	0
Mysis sp. juvenile	0	0	0	0	0	17	0	1,540	0	0
Calanus *m* *shallae*	0	0	0	1	0	4	0	0	0	0
Centropages sp.	0	0	1	4	0	0	1	0	0	0
Pasiphaea	0	0	0	0	0	0	0	8	0	0
Neocalanus sp.	0	0	1	0	0	0	0	0	0	0
Metridia pacifica	0	0	0	I	0	0	0	0	0	0
Unident. polychaete larvae	0	0	0	0	2	0	0	0	0	0
Conchoecia sp.	0	0	0	0	0	5	0	0	0	0
Monstrilla sp. (copepod)	0	0	0	0	0	0	I	0	0	0
Brachyrhyncha zoea	0	0	0	I	0	0	0	0	0	0
Gastropod larvae	0	0	0	0	0	0	0	0	0	0
Chaetognatha	0	0	0	0	0	0	0	47	0	0
Chironomid	0	0	0	0	0	0	3	0	0	0
Aetideidae (copepod)	0	0	0	0	0	0	0	5	0	0
Copepod (small)	0	0	0	0	0	0	0	0	0	0
Euphausid calyptopis	0	0	0	0	0	0	0	0	0	0

Although *Eurytemora* sp. was the dominant food source for herring in all samples, fish collected by trawl in Tuxedni Channel had higher proportions of barnacle cyprids and harpacticoid copepods. Individual *Eurytemora* sp. taken from the stomachs of herring collected by trawl in the channel were, on average, 7.6 times the mass of individual *Eurytemora* sp. taken from beach seined fish (Figure 24). All of the seined fish came from a single haul (CA-BS-1; see Figure 2) on 14 August 1997. There was apparently some degree of habitat partitioning among different size classes of the copepod. Assuming that the smaller *Eurytemora* sp. are from a more recent bloom, herring may have encountered and fed extensively on a high-density, nearshore swarm of copepods which could account for the majority of stomachs being 75% to 100% full. Speculation that the unidentified small eggs may be *Eurytemora* sp. (Ted Cooney, UAF, pers. comm. 1998) also suggests a bloom at site CA since 24 of the 26 herring that had consumed eggs were collected there. Herring in mid channel encountered older, more depleted cohorts requiring them to switch to the other food sources. Few full stomachs were encountered. High *Eurytemora* sp. density at site CA is also suggested in the smelt diet. Only six of twenty-five smelt collected in the August survey had food in their stomachs of which three were taken at site CA in a haul one hour after CA-BS-I (i.e., CA-BS-2). Two of the smelt were 100% full and the other *25%* full of *Ewytemora* sp.

There was also some evidence of prey partitioning among size classes of herring at site CA. Herring from beach seine haul CA-BS-1 ranged in size from 28-45 mm FL. Of the 13 fish <32 mm, none had consumed unidentified eggs and only one had eaten barnacle cyprids. Of the 32 fish 232 mm, 23 had consumed eggs and 29 had consumed barnacle cyprids. This difference could be due to morphological differences among different fish size classes.

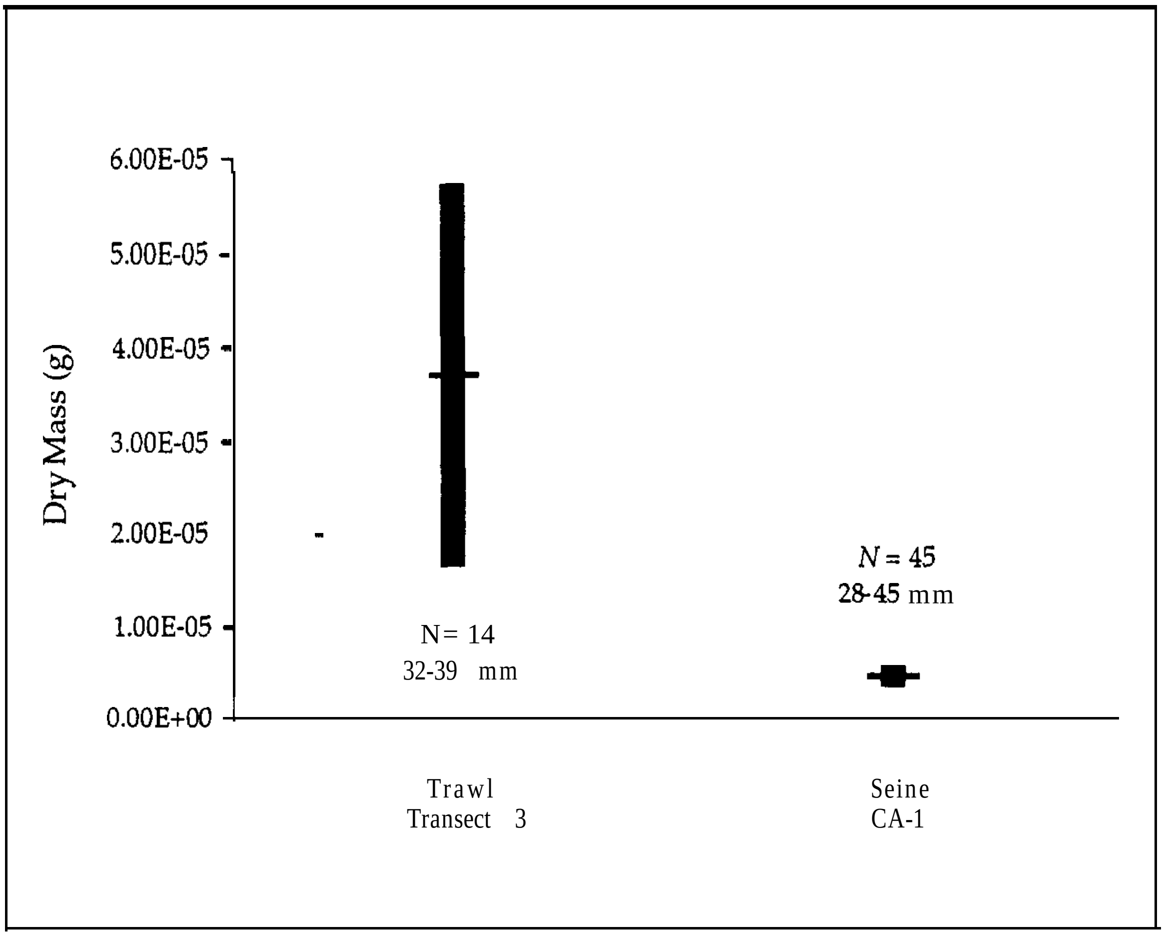


Figure 24. Mean (± 95% CI) dry mass (g) of individual *Eurytemora* sp. eaten by age-O+ Pacific herring from a mid-channel trawl and a beach seine at Chisik island, August 1977. Individual mass was estimated by dividing the total dry mass by the number of individuals for each dissected fish stomach. Fish that did not consume *Eurytemora* sp. are not included in the count. There was no significant difference (f-test, P = 0.56) in fish length between sites.

Thirty-one prey taxa were identified in the stomachs of five fish species (eulachon, herring, pollock, surf smelt, and sand lance) that were collected for dietary analysis at Chisik Island in May 1998 (Table 7). There was weak to moderate dietary overlap among species (Table 8). Pollock diet was unique, consisting primarily of Phyllodocidae polychaetes (71%), which suggests demersal feeding. Secondary components were Crangonidae zoea (10%), the amphipod *Byblis* sp. (8%) and the copepod ***Pseudocalanus*** sp. (5%). The dominance of these four prey yielded the lowest measures of dietary breadth (*SI* = 0.087) of the five species (Table 9). Phyllodocidae was a minor dietary component in, and *Byblis* sp. and Pseudocalanus sp. completely absent from, the diets of the other four species and accounts for the low level of dietary overlap observed between these species and pollock (Table 8). Comparative IRI values for Phyllodocidae and zoea indicate that while the former accounts for a much greater prey mass, Crangonidae can be considered an important prey item based upon the higher number of organisms consumed and higher frequency of occurrence (Table 10).

Smelt diet was different from that of eulachon and herring largely due to the presence of isopods (46%), harpacticoid copepods (13%), fish eggs (13%), and Phyllodocidae polychaetes (10%) in the former. Moderate levels of dietary overlap were found between sand lance and eulachon (*SI* = 0.423) due to the co-occurrence of barnacle nauplii and Crangonidae zoea; sand lance and herring (*SI* = 0.398) due to the co-occurrence of barnacle nauplii, Crangonidae zoea, and barnacle cyprids; and sand lance and smelt (*SI* = 0.392) due to the co-occurrence of Crangonidae zoea, Phyllodocidae polychaetes, and harpacticoid copepods.

Sand lance diet exhibited the highest measure of dietary breadth (Table 10); sand lance consumed 26 prey fields, six of which accounted for more than 5% of dry stomach mass (Table 7). IRI values also suggest that a larger number of prey fields were important in the sand lance diet. The broader trophic spectrum is partially attributable to dissimilarity within the sand lance diet. Two groups collected by seine at Fossil Point (see Figure 3) within an hour of each other yielded two size classes of fish and a ***D*** = 0.329 (Table 11). While harpacticoid copepods (71%) and barnacle nauplii (12%) were the dominant components in the diets of smaller sand lance, larger fish fed more evenly (J' = 0.59; B = 6.58) among a much larger assortment of about 10 prey categories.

Three species of forage fish were collected for dietary analysis in summer 1998: herring and surf smelt at Ninagiak Island in Shelikof Strait and longfin smelt at Chisik Island. Longfin smelt diet was dominated by mysids and parathemisto amphipods (Tables 7 and 10). Surf smelt fed almost exclusively on harpacticoid copepods resulting in the lowest measures of dietary breadth for any species in the entire study (Table 9). Herring similarly feed most heavily on harpacticoid copepods and the dietary overlap between herring and surf smelt was high at ***D*** = 0.714 (Table 8).

4.3.3.3 Diet Discussion

The dietary overlap between herring and sand lance at Chisik Island in May (***D*** = 0.398) was well below index values of >0.50 that have been reported for fish of similar size in PWS during summer (Willette et al. 1995; Sturdevant 1996; Sturdevant et al. 1998). Dietary overlap indices values for herring and pollock (***D*** = 0.030) and pollock and sand lance (P = 0.167) were also well below PWS summer values which ranged from 0.28–0.53 (Willette et al. 1995; Sturdevant 1996), and a November value of 0.35 for herring/pollock (Sturdevant 1996). Much of this dissimilarity in feeding habits may be attributable to the dietary absence of calanoid copepods. Calanoids are a major component in the diets of these three species in Prince William Sound and the Cook Inlet area (Willette et al. 1995, 1997; Sturdevant 1996; Blackburn and Anderson 1997; Sturdevant et al. 1998), and both pollock and herring exhibit a specific preference for ***Pseudocalanus*** sp. (Cooney et al. 1980; Grover 1990, 1991; Willette et al. 1995). The dietary absence of calanoids suggests low abundances of these organisms in the Chisik

Table 11. Prey items identified from two seine samples of sand lance collected within an hour of each other on 14 May 1998 at Fossil Point near Chisik Island. Prey items that constitute > 5% of total dry biomass are highlighted in bold. PSI = 0.329.

Taxon	Percent Dry Biomass 1810 h	Percent Dry Biomass 1910 h	IRI 1810 h	IRI 1910 h
Harpacticoid copepod	0.71	0.05	14,749	56
Barnacle nauplii	0.12	0.23	2,472	71
Crangonidae zoea	0.08	0.22	449	71
Phyllodocidae (Polychaete)	0.01	0.15	29	35
Barnacle cyprid	0.03	0.09	393	68
Decapod zoea	0.00	0.10	1	35
Eurytemora sp.	0.02	0.03	488	68
Fish egg	0.00	0.06	0	59
Cumacea	0.00	0.04	0	9
Ostracod	0.01	0.00	171	38
Amphipoda	0.00	0.01	1	18
Pseudocalanus sp.	0.01	0.00	107	50
Metridia pacifica	0.00	0.00	5	6
Isopod		0.00	0	3
Unident. small copepod	0.00	0.00	13	9
Centropages sp.	0.00	0.00	14	15
Calanus marshallae	0.00	0.00	1	6
Gastropod larvae	0.00	0.00	0	9
Euphausid calyptopis	0.00		1	0
Brachyrhyncha sp. zoea		0.00	0	21
Unident. polychaete larvae	0.00		1	6
Monstrilla sp. (copepod)		0.00	0	3
Conchoecia sp.			0	0
Mysis sp. juvenile			0	0
Unident. invertebrate eggs (sm)			0	0
Sagitta sp.			0	0
Arcartia sp.			0	0
Byblis sp.			0	0
Aetideidae (copepod)			0	0
Neocalanus sp.			0	0
Chironomid			0	0
N	13	24		
Mean length (mm)	72.1	109.0		
2 SE	4.0	8.7		
A =	1.09	2.01		
J' =	0.32	0.59		
B =	1.92	6.58		

Island area, at least within the short time frame in which sampling for this study was conducted. Fish were collected from several different locations (i.e., lower and upper reaches of Tuxedni Channel and on the Cook Inlet side of Chisik Island) so there was adequate spatial scope to the dietary collections. Whether the absence of calanoids merely represented a brief fluctuation in abundance or a longer-term seasonal absence of this prey field for the Chisik Island area is unknown.

Pollock appear to have relied more on demersal feeding with polychaetes and *Byblis* sp. amphipoda comprising 76% of their diet. While the preponderance of barnacle nauplii (63%), barnacle cyprids (21%), and Crangonidae zoea (10%) in the diets of herring suggests a pelagic feeding regime. The difference in the feeding habits of these two species resulted in an almost complete absence of dietary overlap (SI = 0.03). Large sand lance (mean length = 109 mm) were the most diverse feeders (H' = 2.01, J' = 0.59, B = 6.58) while small sand lance fed heavily on harpacticoid copepods and barnacle nauplii. The difference in sand lance diet could reflect both size-related differences in foraging and variable schooling encounters with prey assemblages in a patchy trophic environment.

The preponderance of *Eurytemora* sp. in the diets of herring and smelt in August 1997 may have been a somewhat localized event. All of the fish which fed almost exclusively on the smaller *Eurytemora* sp. came from the same seine site within the same hour and appear to have been exploiting a copepod bloom in the nearshore shallows. Herring feeding in Tuxedni Channel preyed on larger *Eurytemora* sp. and relied more on barnacle cyprids, suggesting that they were not exposed to the most recent copepod bloom. The dominance of harpacticoid copepods in the diets of herring and smelt at Ninagiak Island in 1998 may also have been a localized phenomenon, since most fish from both species were collected at the same location on the same day. The more diverse herring diets reported for the May 1998 survey and for surveys in PWS (Willette et al.

1995; Sturdevant 1996; Sturdevant et al. 1998) involve greater numbers of sampling sets, sampling sites, and fish. Overall, the low breath of the herring diet-a few prey categories contributing most of the biomass-was consistent with studies conducted in PWS (Willette et al. 1995; Sturdevant 1996; Sturdevant et al. 1998).

It must be noted that the results of the diet study must be viewed in the broadest of terms. Sample sizes were small and the number of samples limited. Given the opportunistic feeding nature of some fish, coupled with the temporal and spatial variability in prey abundance, suggests that a longer time series of diet data are required to more firmly characterize forage fish diet preference in these study areas. Sand lance, for example, can change their feeding patterns quite rapidly. Sand lance in Prince William Sound shifted from a morning diet of larvaceans (46%) and decapod larvae (33%) to a mid-day diet of small calanoid copepods (45%), barnacle larvae (31%), and harpacticoid copepods (16%), to a late afternoon diet that consisted primarily of small calanoid copepods (Sturdevant et al. 1998).

4.3.4 Proximate Body Composition Analysis

Results of the proximate body composition analyses are presented in Table 12. All values discussed in the following are in terms of percent of dry body mass.

Not unexpectedly, lipid content of adult and moderately sized eulachon (> 40%) collected in May 1998 was the highest of any species (Table 12). Eulachon are renowned for their high oil content which is unique among fish oils in that it is solid at ordinary temperatures (Hart 1973). Lipid content as high as 50% has been reported for eulachon from PWS and lower Cook Inlet (Anthony et al. 1998). Lipid content for a group of age-l+ fish 53-97 mm in length taken in the May 1998 survey was substantially lower than for larger fish. While the reason for this cohort disparity is unknown, lipid levels of

Table 12. Summary data for forage fish proximate body composition analyses expressed as percent dry mass content (mean ± 2SE). Analyses were based upon pooled samples of fish ranging from 2 to 50 individuals, depending on size. Means were therefore calculated based upon pooled samples of fish and not single fish.

						Percentage of Dry Mass		
Location	Date	Species	Size (mm)	N	Age	Lipid	Protein	Ash
Chisik Island	10-13 Aug 1997	Herring	25-40	120	o+	10.1 ± 0.4	77.4 ± 0.9	12.5 ± 0.6
			70-72	3	1+	25.8	64.4	9.8
		Longfin smelt		1		31.2	58.5	10.3
		Surf smelt		1		10.7	79.5	9.9
Chisik Island	12-15 May 1998	Eulachon	53-97	36		25.3 ± 3.7	63.5 ± 1.2	11.1 • 1.2
			90-127	6		40.6 ± 8.5	51.0 ± 7.3	8.4 ± 1.2
			217-243	10	1	41.8 ± 1.5	52.9 ± 1.2	5.2 ± 0.4
		Herring	71-95	13	1+	9.5 ± 1.3	74.5 ± 0.8	16.0 ± 1.4
			135	1	2+	9.7	76.2	14.0
		Tomcod	127	1		2.8	74.1	23.1
		Sand lance	59-98	44		9.0 ± 1.8	74.0 ± 1.8	17.0 ± 1.5
		Pollock	102-142	3		5.5 ± 3.4	74.5 ± 13.0	20.1 • 9.5
Ninagiak Island	27 July 1998	Herring	127	1		29.4	60.9	9.7
			30-38	600+	o+	8.8 ± 0.6	79.4 ± 0.6	11.8 ± 0.4
Chisik Island	2-4 Aug 1998	Longfin smelt	57-110	42		23.8 ± 5.5	66.5 ± 0.6	9.7 ± 0.8
		Pollock	163	1		2.1	81.7	16.2

16.8–21.4% have been reported for eulachon from the Bering Sea and Gulf of Alaska (Payne et al. 1997).

While very few tomcod and pollock were available for analysis from the study (Table 12), results do support PWS findings that gadids have some of the lowest lipid content among forage fishes (Roby et al. 1996; Anthony et al. 1998). Lipid content for a single tomcod collected at Chisik Island in May was 2.8% and for three pollock was 5.5% (average). A single pollock taken at Chisik Island in the summer 1998 had a lipid content of 2.1%.

Lipid data for three age classes of Pacific herring collected during the summers of 1997 (Chisik Island) and 1998 (Hallo Bay) are compared to data reported for a 1995 PWS study by Roby (1996). Although only single age-l+ and age-2+ fish and pooled estimates of age-O+ fish lipid content are available for the 1997-1998 Cook Inlet Forage Fish study, inspection suggests no major differences in the summer lipid content between fish collected in Cook Inlet versus those taken in PWS (Figure 25). In both locations, lipid content had a positive correlation with age. This same relationship was reported for the extended PWS study (Anthony et al. 1998). The lipid content for age-l+ and age-2+ herring in May of 1998 was clearly lower than any of the summer values for the same age cohorts.

The lipid content for sand lance collected at Chisik Island in May 1998 was much lower than had been reported for PWS during summer (Figure 26). Mean lipid content in PWS was >25% in July and August. Mean lipid content at Chisik Island in May 1998 was 9.0%. Longfin smelt collected at Chisik Island in August 1998 had a mean lipid content of 23.8%. Excluding eulachon and lanternfish, this places longfin smelt among those PWS species exhibiting the highest levels of lipid reserves (Roby et al. 1996; Anthony et al. 1998).

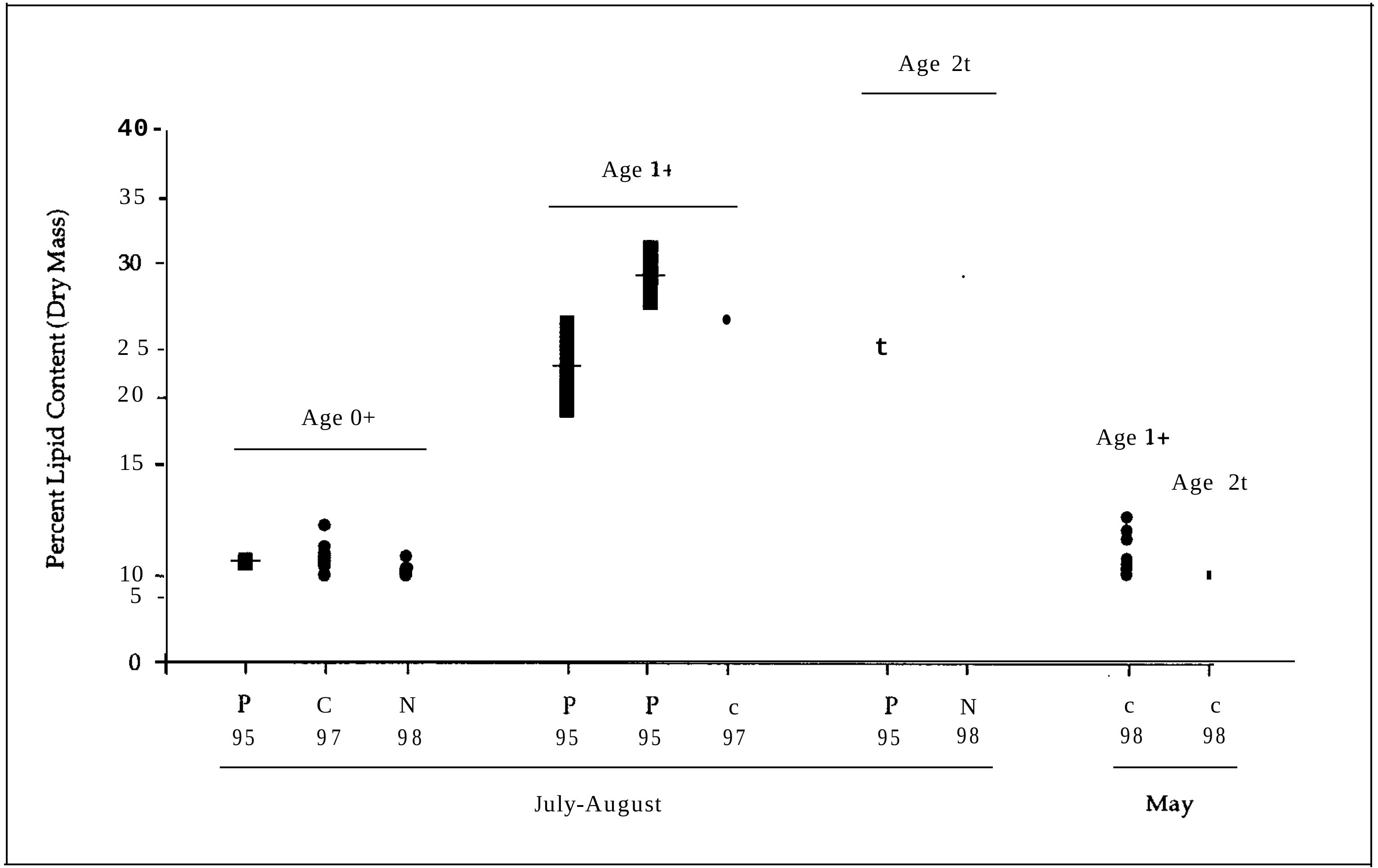


Figure 25. Percent lipid content (dry mass) for Pacific herring by age class from Prince William Sound (P), Chisik Island (C), and Ninagiak Island (N). The year in which sampling occured is denoted beneath each site location. Data for PWS from Roby et al. (1996) and (Anthony and Roby 1997) and are espressed as mean ±2 SE. Each data point for Chisik or Ninagiak islands is a value determined from a pooled sample of 2025 fish and there are no estimates of variance.

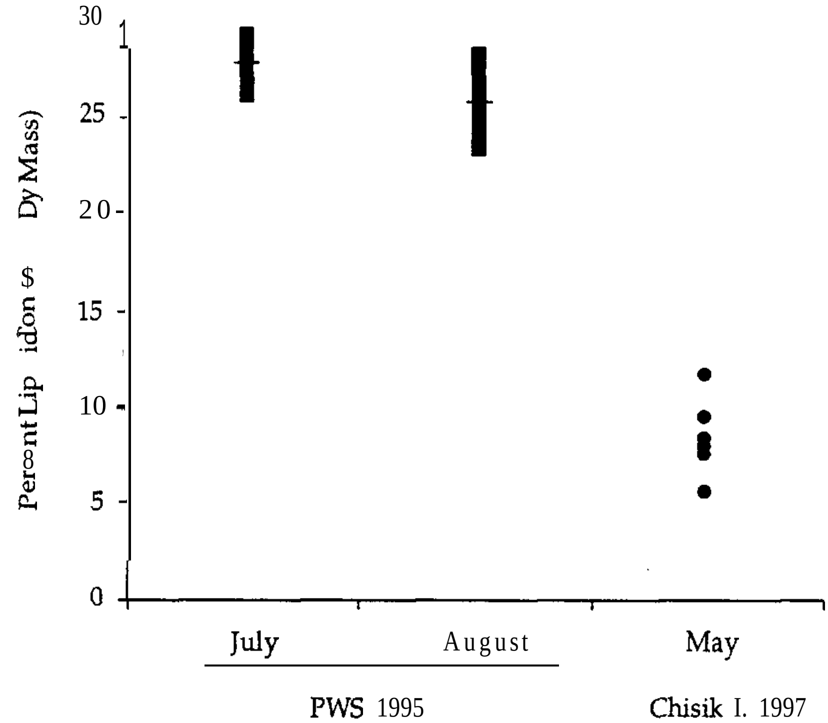


Figure 26. Percent lipid content for age 1+ Pacific sand lance from Prince William Sound (PWS) and Chisik Island. Data for PWS from Roby et al. (1996) and is expressed as mean ±2 SE. Each data point for the Chisik Island data is a value determined from a pooled sample of 6-8 fish and there are no estimates of variance.

It is not clear if the low lipid content of herring and sand lance at Chisik Island represents a normal seasonal trend or is unique to the lower Cook Inlet area. Fish typically exhibit seasonal cycles in which energy stores accumulated during the feeding season are used for metabolism in winter and early spring when foraging is minimal (MacKinnon 1972; Newsome and Leduc 1975; Foltz and Norden 1977; Dawson and Grimm 1980; Pierce et al. 1980; Dutil 1986; Boivin and Power 1990; Fechhelm et al. 1995). The low lipid levels observed in May might be the consequence of fish not having yet replenished energy reserves depleted during the previous winter. For sand lance and herring, lipid content is the primary determinant of energy density (Anthony et al. 1998). The time required for these species to re-establish energy reserves likely would be a critical factor in determining their nutritional value as forage fish.

4.3.5 Cytochrome P450 Activity

Results of the Cytochrome P450 analyses are presented in Table 13. The assay results are reported as Benzo [a] Pyrene Equivalents (B[a]PEq) per gram of fish tissue. Six species of forage fish were sampled, including only a single group of longfm smelt (0.26 μg B[a]PEq/g) and pollock (1.06 μg B[a]PEq/g), and thus there was no replication for these two species. Of the four remaining species, contaminant levels for herring were consistently low at less than 1 .OO μg B[a]PEq/g at both Chisik Island and Shelikof Strait. Only two groups of sand lance were sampled, but they were two of the samples that showed the highest P450 activity in this study (2.46 and 3.57 μg B[a]PEq/g). They came from consecutive beach seine hauls at Fossil Point, Chisik Island, during May 1998. Sand lance are the most demersally-oriented of the species tested and increased contact with benthic substrates could increase exposure to potential contaminants.

Eulachon were collected during two midwater trawl hauls at Chisik Island on 14 May 1998 and there was a dichotomy in the P450 analyses among the two groups.

Table 13. Summary of Cytochrome P450 activity levels in forage fish.

Area	Date	Location	No. Fish	Fork Length (mm)	Species	B(a)PEq (µg/g dry wt)
Chisik Island	11-13 Aug97	BS1CA	25	25-30	Herring	<.29
		BS1CA	10	35-40	Herring	<.44
		BS1CA	35	25-30	Herring	<.12
		BS1CA	35	25-30	Herring	<.14
		BS2CA	25	25-30	Herring	<.07
		BS2CA	30	25-30	Herring	<.07
		BS2CA	3	73-87	Surf smelt	<.22
		T14H10	10	25-31	Herring	<1.0
		T3H1	20	36-45	Herring	0.35
		T5H2	3	67-80	Longfin smelt	0.26
		T5H2	20	28-48	Surf smelt	0.84
		T6H3	20	25-39	Herring	<.21
		T6H3	30	25-39	Herring	<.32
		T9H7	20	29-34	Herring	<.28
Chisik Island	14-May-98	T1H6	1	219	Eulachon	<.3
		T1H6	1	227	Eulachon	0.36
		T1H6	1	215	Eulachon	0.37
		T1H6	1	230	Eulachon	<.3
		T1H6	1	229	Eulachon	0.38
		T1H6	1	210	Eulachon	<.3
		T1H6	1	205	Eulachon	0.31
		T1H6	1	225	Eulachon	<.3
		T1H6	1	224	Eulachon	<.3
		T1H6	1	206	Eulachon	<.3
		T7H9	5	90-101	Eulachon	2.91
		T7H9	5	88-115	Eulachon	0.45
		T7H9	5	80-98	Eulachon	1.11
		T7H9	5	80-93	Eulachon	0.49
		T7H9	4	72-93	Eulachon	1.28
		T7H9	6	65-78	Eulachon	0.91
		T7H9	2	112-120	Eulachon	1.04
		BS1FP	6	93-123	Sand lance	2.46
		BS2FP	5	93-108	Sand lance	3.57
		BS1FP	1	125	Surf smelt	<2.4
		BS1FP	1	111	Surf smelt	1.41
		BS1FP	1	109	Surf smelt	2.44
		BS2FP	1	125	Surf smelt	0.82
		BS3FP	1	116	Surf smelt	1.56
		BS3FP	1	127	Surf smelt	1.22
		T9H10	3	101-125	Pollock	1.06

continued

Table 13 continued

Area	Date	Location	No. Fish	Fork Length (mm)	Species	B(a)PEq (µg/g dry wt)
Ninagiak Island	27-Jul-98	BSINR	50+	31-39	Herring	0.3 1
		BSINR	50+	31-39	Herring	0.63
		BSINR	50+	31-39	Herring	0.26
		BSINR	50+	31-39	Herring	0.33
		BS INR	50+	31-39	Herring	0.28
		BSlNR	50+	31-39	Herring	0.29
		BSINR	50+	31-39	Herring	0.21
		BSlNR	50+	31-39	Herring	0.26
		BSINR	50+	31-39	Herring	0.24
		BSlNR	50+	31-39	Herring	0.34
		BSZSP	4	84-96	Surf smelt	0.21
		BS2SP	5	70-82	Surf smelt	0.35
		BSZSP	5	69-89	Surf smelt	0.37
		BSZSP	4	74-85	Surf smelt	0.47
		BS2SP	4	79-86	Surf smelt	0.39
		BS2SP	4	75-97	Surf smelt	0.30
		BSZSP	5	74-85	Surf smelt	0.33
		BSZSP	5	67-80	Surf smelt	0.72
		BSZSP	5	67-80	Surf smelt	0.42
		BSZSP	6	70-76	Surf smelt	0.95

Ten spawning eulachon taken in trawl T1H6 all had P450 activity levels ≤ 0.38 µg B[a]PEq/g, while juveniles from seven groups had activity levels that ranged from 0.45-2.91 µg B[a]PEq/g. The reasons for this difference are unknown but may relate to potential contaminant levels in the habitats recently occupied by adults versus juveniles.

There were also slight differences in P450 activity levels within surf smelt samples. Juveniles (≤ 96 mm FL) collected in summer for Chisik Island and Ninagiak Island had activity levels ≤ 0.95 µg B[a]PEq/g, while fish ranging in length from 109-127 mm FL collected at Chisik Island in May had activity levels ranging from 0.82-2.44 µg B[a]PEq/g. Whether the higher levels at Chisik Island represented localized exposure to potential contaminants or merely the immigration of fish from other areas of exposure is uncertain.

The following text was contributed by Dr. Jack Anderson who conducted the laboratory Cytochrome P450 analyses.

The majority of samples that produced P450 RGS responses above the 99% upper confidence interval for the collection region were either sand lance or surf smelt. It appears these may be excellent choices for monitoring the possible uptake of contaminants including PAHs, coplanar PCBs, dioxins and furans. These are the classes of compounds detected by the RGS assay, but we do not know which class or specific compounds produced the observed induction of the CYP1A1 gene in the test system. Fish collected from sites in Cook Inlet appear to contain higher amounts of inducing compounds than those collected from the Shelikof Strait. Additional collections of sand lance and surf smelt as part of a longer-term monitoring program could possibly detect any possible increases in pollutants.

Even though the values for sand lance and surf smelt from Cook Inlet are higher than those from Shelikof Strait, this level of P450 RGS response is not alarming. Baseline for liver and ovary tissues from relatively clean areas appears to be between about 0.3-0.5 µg B[a]PEq/g. Samples of liver and ovary from fish inhabiting a site in California contaminated with PCBs and PAHs produced RGS responses of 3.0–4.5 µg/g (Anderson et al. In Press b). As efficient accumulators of chemicals, marine mussels have been deployed in two different studies at sites in San Diego Bay (Anderson et al. In Press b). Mussels collected or deployed at clean sites produced RGS responses of 6.0-7.0 µg/g. Mussels held at contaminated sites produced RGS responses of about 40, 70 and even 295 µg B[a]PEq/g.

The two most contaminated samples in this investigation of forage fish from Cook Inlet produced values of 2.9 and 3.6 μg/g, so these fish are approaching levels of inducing compounds that indicate potential hydrocarbon environmental contamination.

4.4 HYDROACOUSTIC ASSESSMENT OF FORAGE FISH SCHOOLS

The following summarizes results of the acoustic sampling for each survey period. Figures that accompany this test illustrate organism schools or layers detected by hydroacoustics.

4.4.1 August 1997 – Chisik Island

During the August 1997 survey, echograms showed mainly scattered layers of varying density rather than discrete, dense schools. Throughout Tuxedni Channel there was often a shallow mid-water layer (<15m) and a deep (>25 m) bottom-associated layer (Figure 27a-c). A few small, dense schools were detected at the north end of the channel on the western half of transects 9-13. In that area, schools between 10– to 40-meter depths often appeared tall and narrow in shape, while shallower schools were more round in shape. Few schools occurred outside of Chisik Island, although an extensive layer of organisms extended from a depth of 10 to 20 meters to the bottom in most parts of that area.

Ten aggregation layers of organisms that were observed on echograms were also sampled by trawl in August 1997 (Figure 28a-j). Hauls were made both inside and outside of Chisik Island. Sampled layers ranged from 298 to 2,047 meters in length, from 4 to 29 meters in thickness, from 209 to 1,433 meters in width (estimated from closest cross-transect), and from 0.6 to 30 million m^3 in volume (Table 14). Depth at mid-point

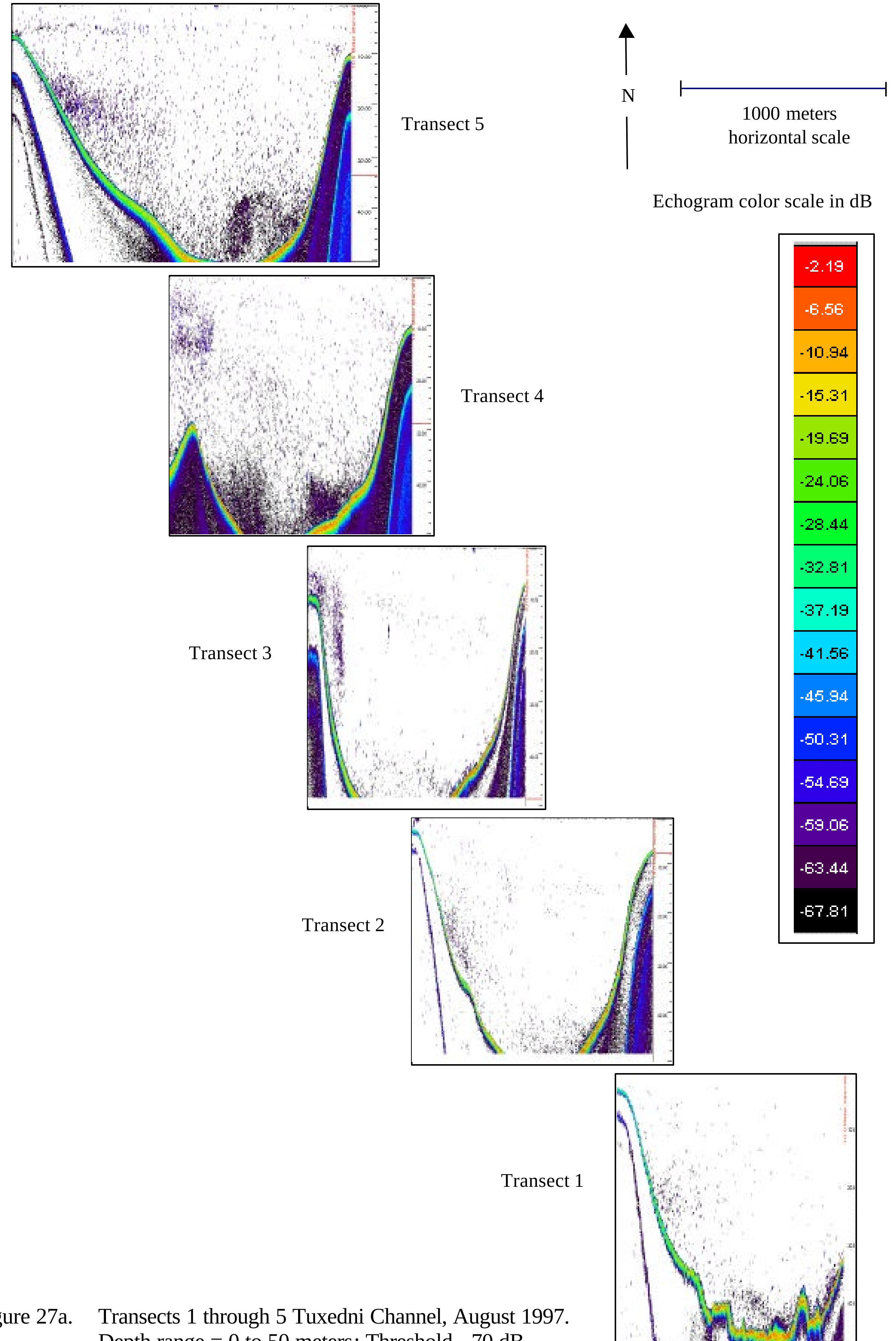


Figure 27a. Transects 1 through 5 Tuxedni Channel, August 1997.
Depth range = 0 to 50 meters; Threshold - 70 dB.

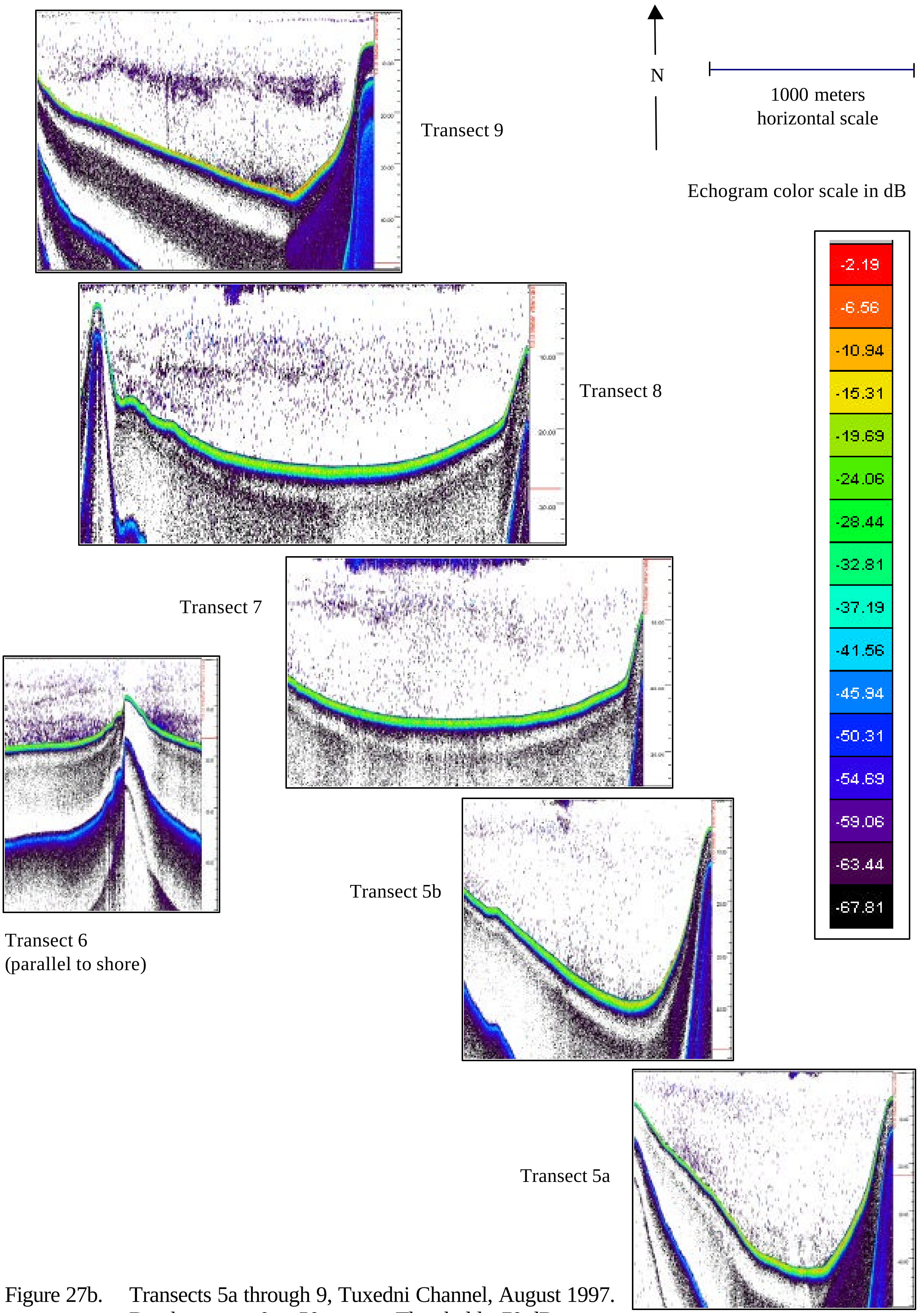


Figure 27b. Transects 5a through 9, Tuxedni Channel, August 1997. Depth range = 0 to 50 meters; Threshold - 70 dB.

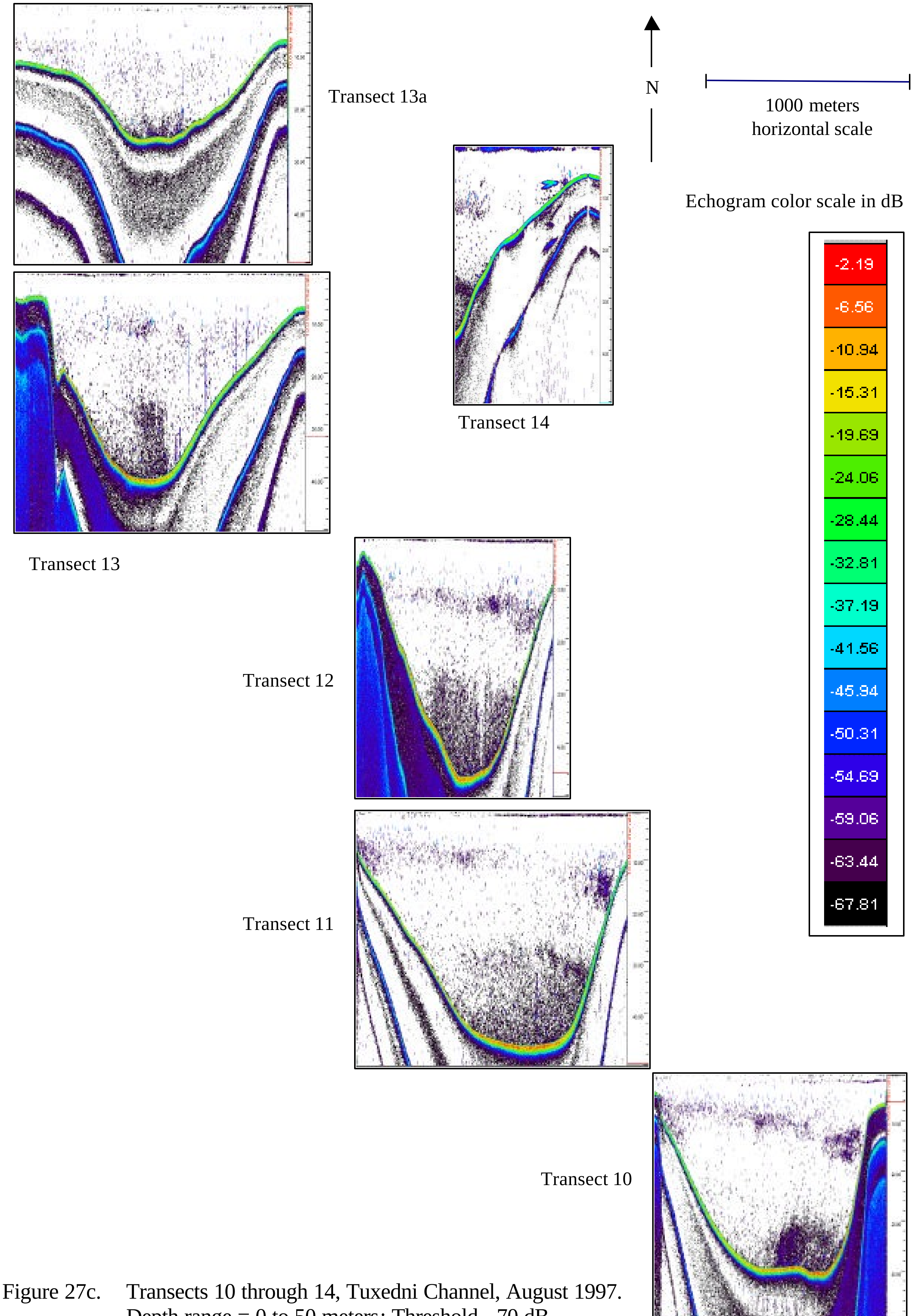


Figure 27c. Transects 10 through 14, Tuxedni Channel, August 1997.
Depth range = 0 to 50 meters; Threshold - 70 dB.

Figure 28. Echograms of organism schools or layers sampled by trawl at Chisik Island, August 1997. Summary data for enclosed areas are provided in Tables 14 and 15.

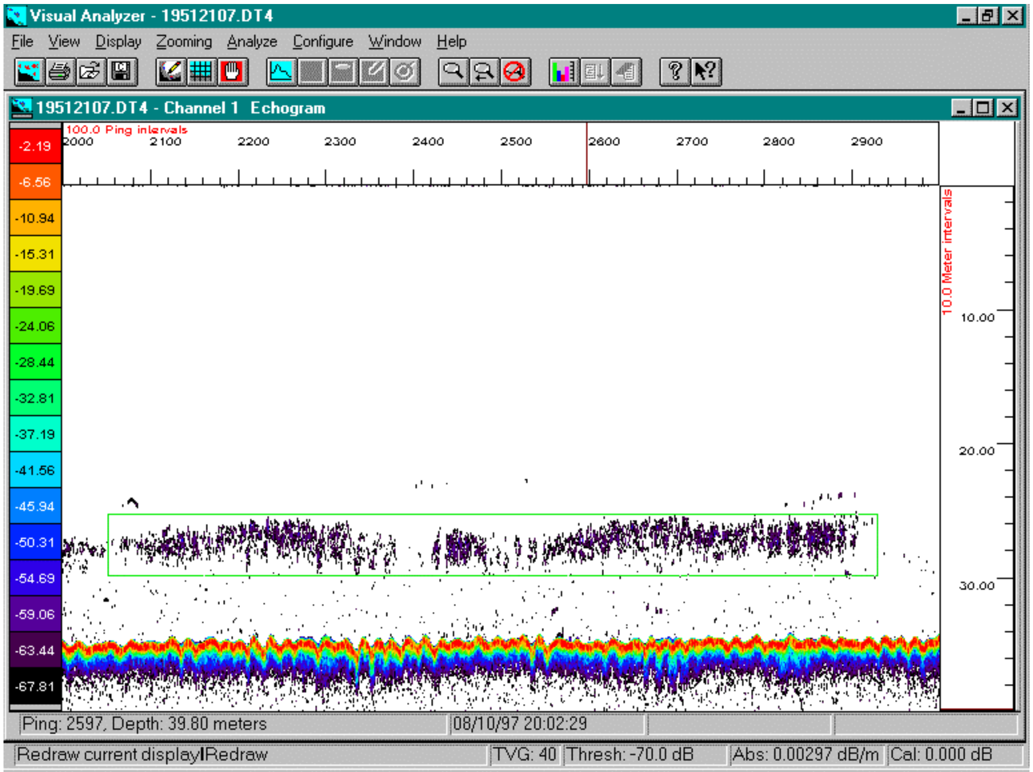


Figure 28a. Transect 0 haul 0, August 10, 1997.

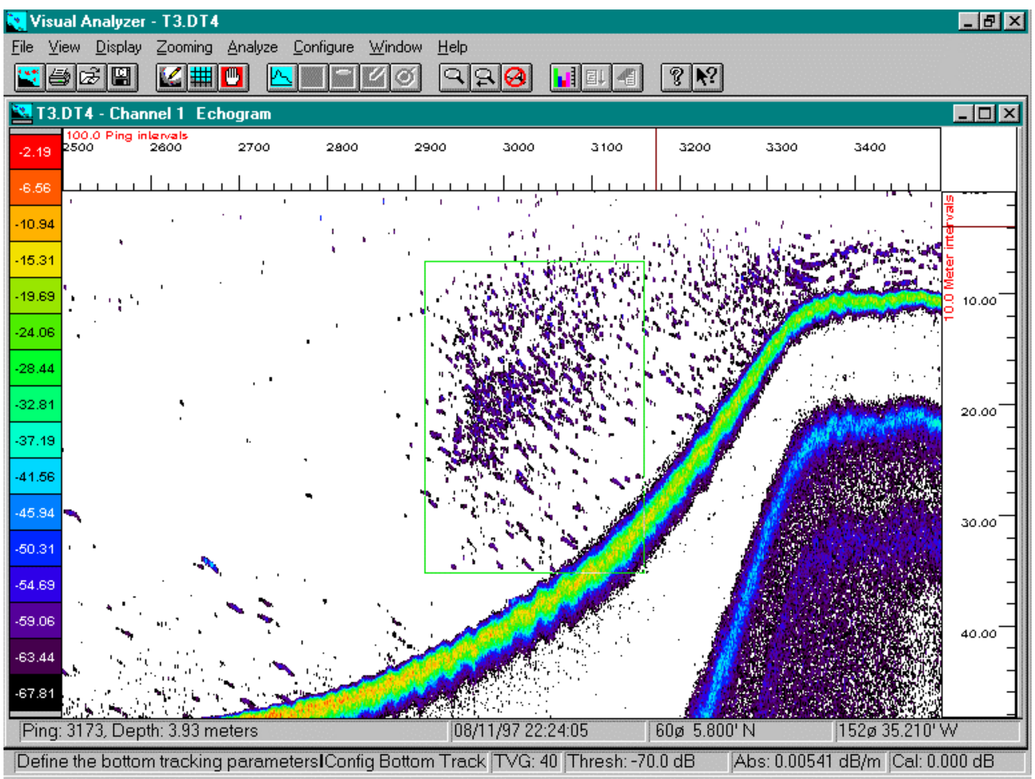


Figure 28b. Transect 3 haul 1, August 11, 1997.

Figure 28 continued

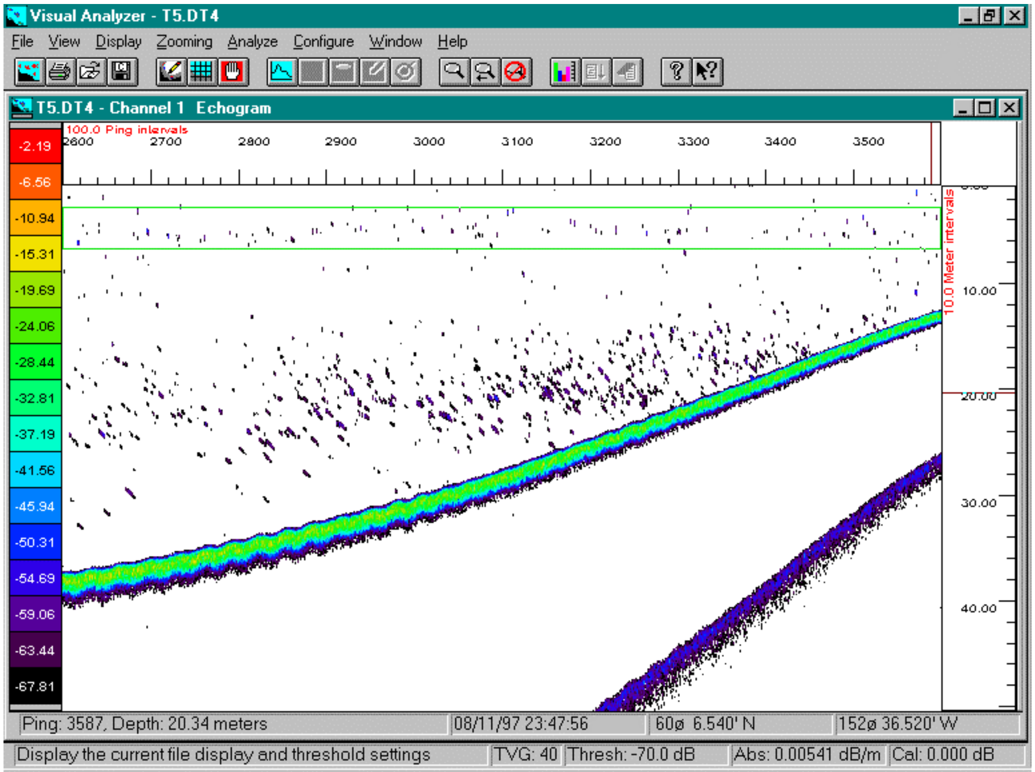


Figure 28c. Transect 5 haul 2, August 11, 1997.

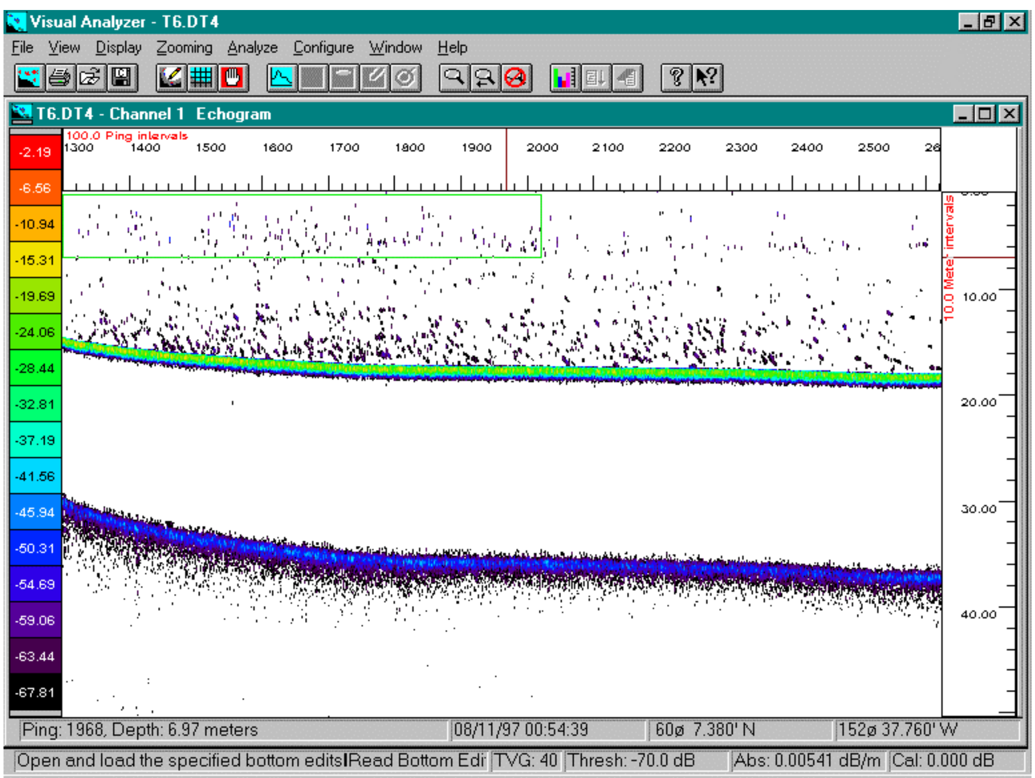


Figure 28d. Transect 6 haul 3, August 11, 1997.

Figure 28 continued

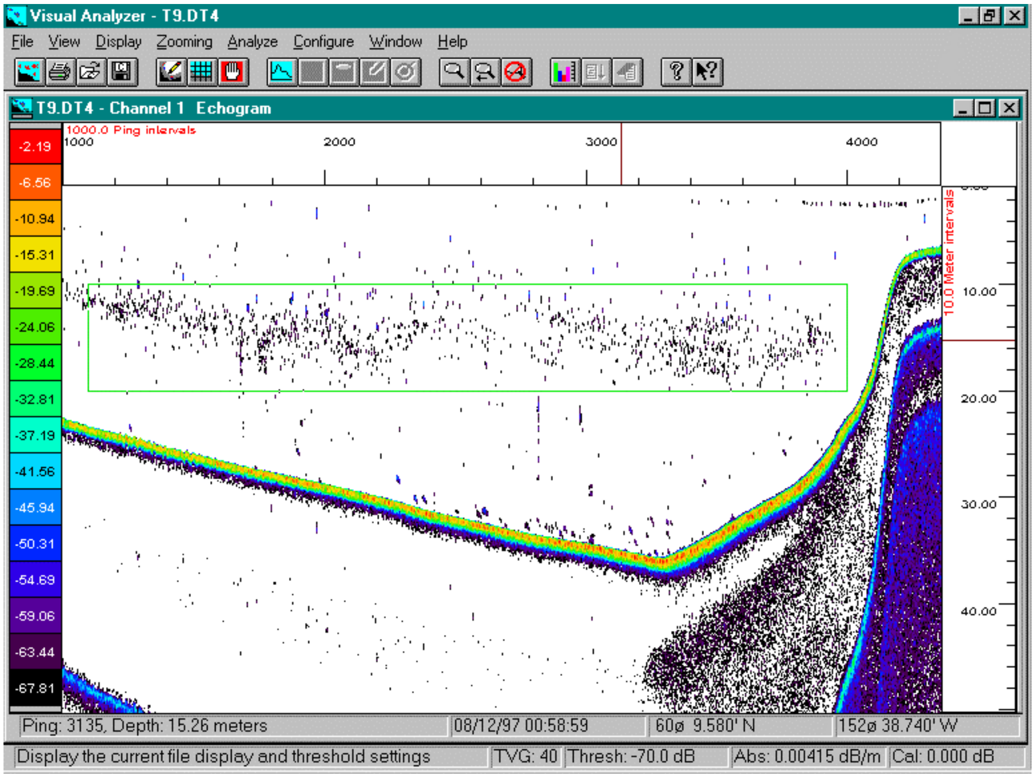


Figure 28e. Transect 9 haul 7, August 12, 1997.

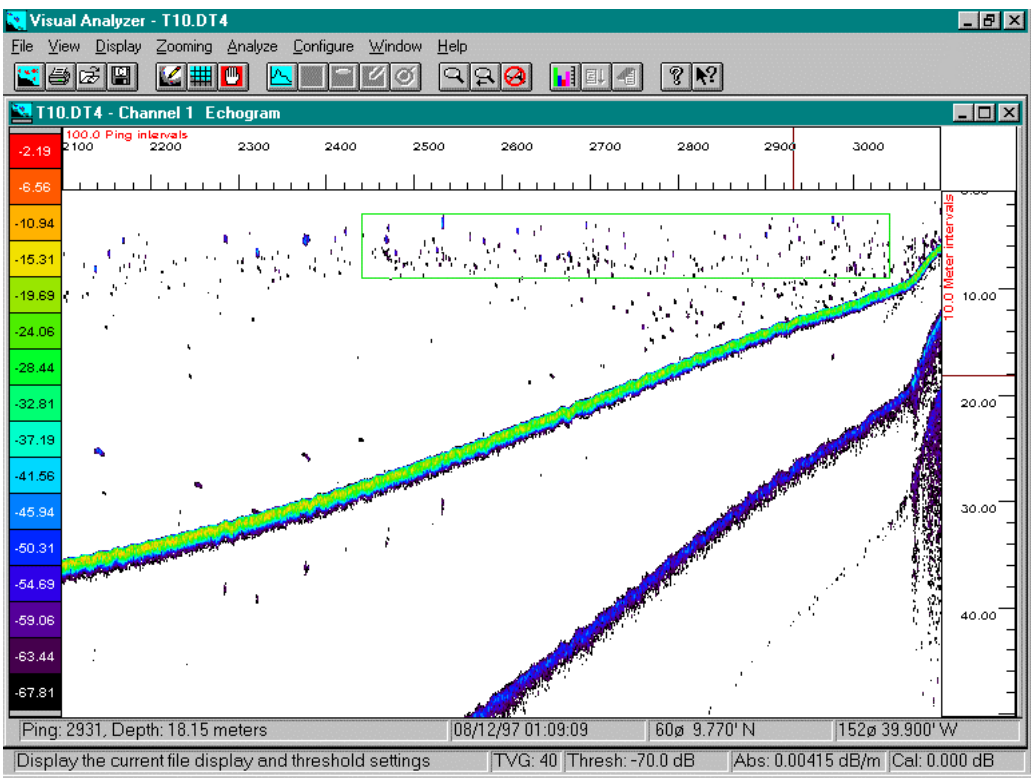


Figure 28f. Transect 10 haul 8, August 12, 1997.

Figure 28 continued

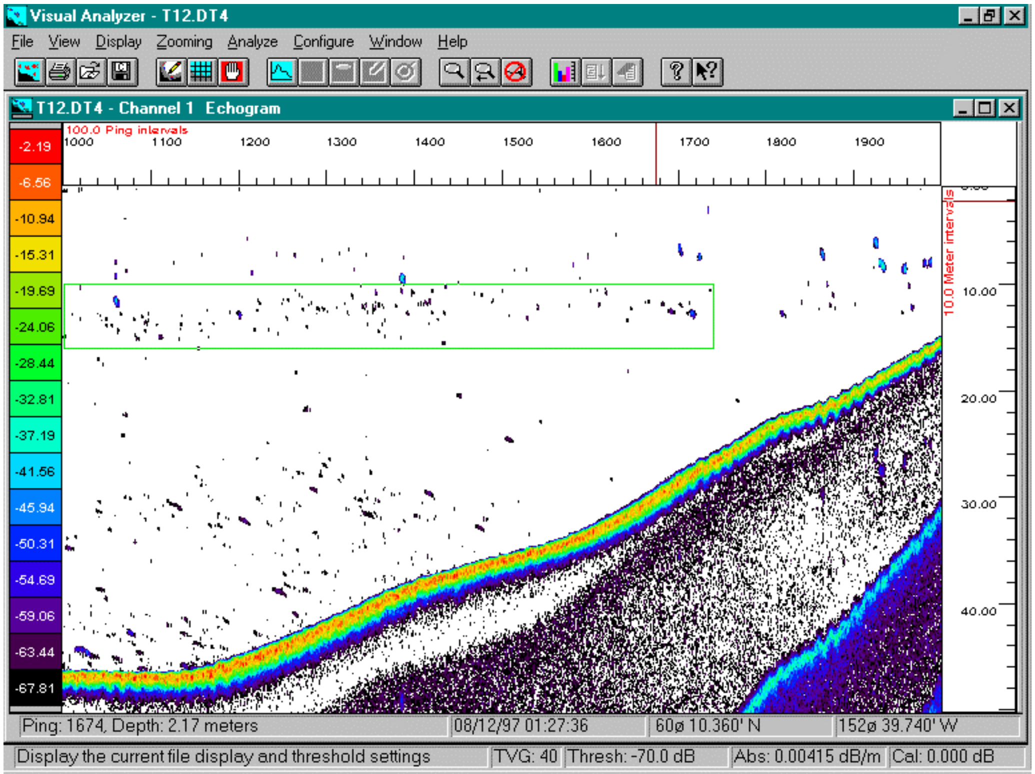


Figure 28g. Transect 12 haul 9, August 12, 1997.

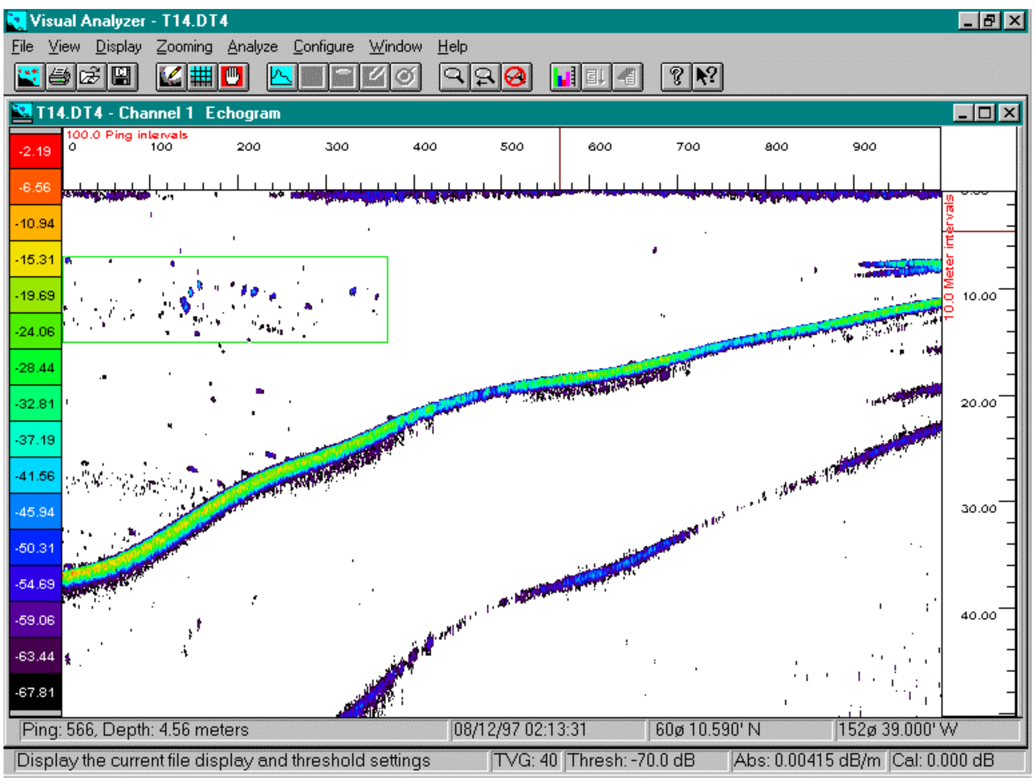


Figure 28h. Transect 14 haul 10, August 12, 1997.

Figure 28 continued

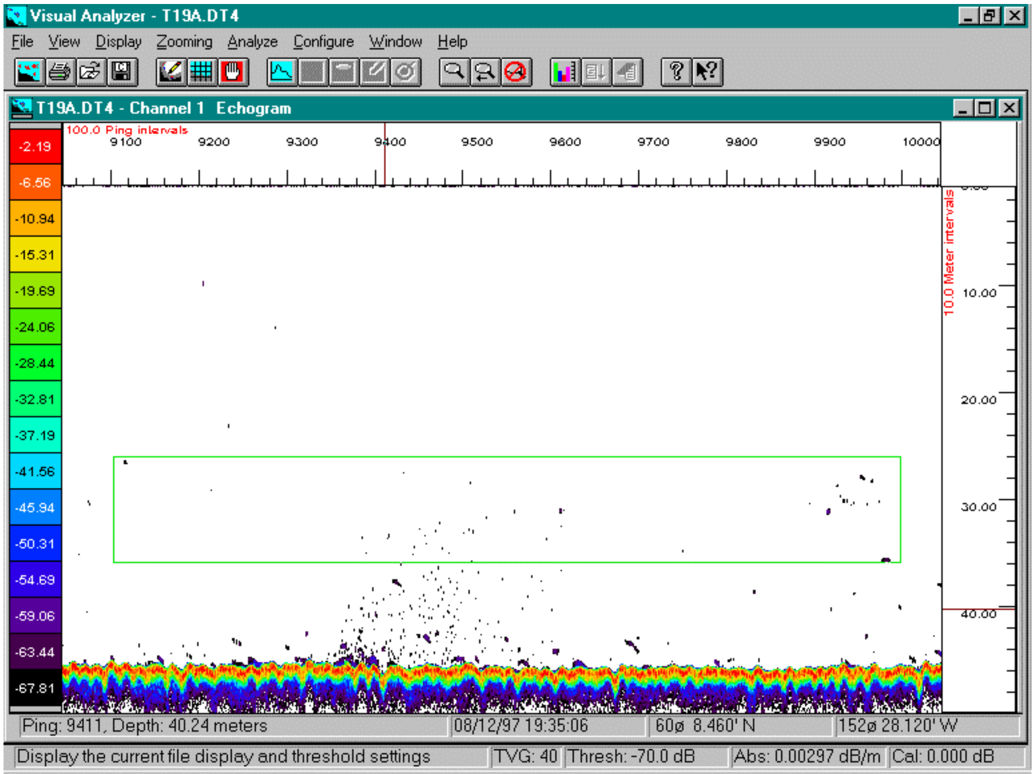


Figure 28i. Transect 19 haul 4, August 12, 1997.

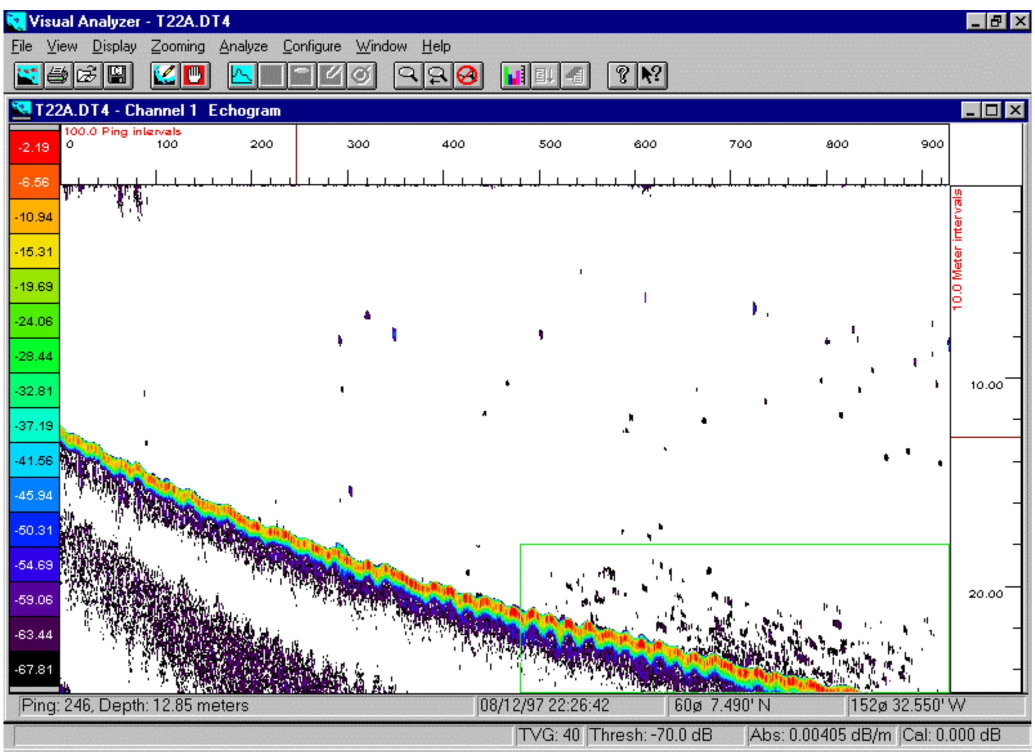


Figure 28j. Transect 22 haul 5, August 12, 1997.

Table 14. Acoustic measurements of organism schools and layers that were also sampled by trawl in 1997 and 1998. All data were collected in **the vicinity of Chisik Island.**

Survey	Date	Transect grp	Trans.	Trawl Haul	Trawl Depth (m)	Group type	Mid depth (m)	School or Layer size: length (m)	thick. (m)	width (m)	vol. (m^3)	Mean Sigma	Mean vol bss* over all	Mean vol bss* samples > threshold**	Mean number per m^3 over all	Mean number per m^3 > threshold	Total organisms in group	Mean g per org +	Biomass (kg) Total	Biomass (kg) Forage fish	Forage fish density (g/m3)
Aug-97	10	outside offshore	0	0	25	layer	27.5	1,717	4	1,202	8.67E+06	9.56E-07	7.59E-08	3.54E 07	0 079	0.37	6.88E+05				
Aug-97	11	inside zig-zags	3	1	30	layer	22.0	298	29	209	1.80E+06	9 38E-07	2 53E-07	1.65E 06	0.270	1.76	4.87E+05	3239	I 58E+04	1 58E+04	8.75E-01
Aug-97	11	inside zig-zags	5	2	6	layer	5.0	1,602	4	1,121	7.36E+06	5 74E-07	3.08E-07	7.42E-06	0.533	12.94	3.96E+06	4220	1.67E+05	1.67E+05	2.27E-02
Aug-97	11	inside zig-zags	6	3	2	layer	4 2	3%	6	277	6.04E+05	6.33E-07	4 99E-07	8.19E 06	0.788	1293	4.75E+05	2734	1.30E+04	1.29E+04	2.14E+00
Aug-97	12	inside zig-zags	9	7	15	layer	15 1	2,047	10	1.433	2.96E+07	5 24E-07	9.78E-08	4.98E-07	0.187	0.95	5.53E+06	2.98	1.65E+04	1.16E+04	3.90E-04
Aug-97	12	inside zig-zags	10	8	6	layer	5.6	970	6	679	4.08E+06	5.36E-07	8.20E-07	8.47E-06	1.529	,580	6.25E+06	11.00	6.87E+04	6.87E+04	1.68E+00
Aug-97	12	inside zig-zags	12	9	12	layer	13.1	1,158	6	811	5.73E+06	4.55E-07	1.41E-07	1.46E-06	0.310	3.22	1.78E+06	3.04	5.40E+03	1.54E+03	2.68E-04
Aug-97	12	inside zig-zags	14	10	10	layer	11.0	450	8	315	1.14E+06	9.30E-07	6.25E-07	5 17E-06	0.673	5.56	7.64E+05	863	6.60E+03	5 65E+03	4.97E 0i
Aug-97	12	outside offshore	19	4	30	layer	33.6	1,717	9	1,202	1.86E+07	2.20E-07	1.44E-09	5.39E-08	0.007	024	1.22E+05				
Aug-97	12	outside zig-zags	22	5	22	layer	20.6	413	9	289	1.08E+06	6.01E-07	2.79E-08	1.15E-07	0.046	0 19	5.00E+04	3.57	1 78E+02	1.78E+02	1 66E-02
May-98	12	outside offshore	0	1	10	layer	7.0	5,025	6	2,312	6.97E+07	4.95E-07	7.48E-09	2.52E-06	0 015	5.08	1.05E+06	2.89	3.04E+03	7.17E+02	1.0.X.03
May-98	14	inside zig-zags	1	6	8	school	8.0	120	4	28	1.32E+04	5.76E-07	8.24E-06	1.91E-05	14.32,	3323	1.89E+05	8 14	1.54E+03	1.23E+03	9.33E+00
May-98	15	inside zig-zags	4	13	10	layer	5.8	373	8	172	5.37E+05	5.48E-07	2.15E-05	1.41E-04	39.34,	257 31	2 11E+07	3.86	8.15E+04	2.28E+04	4.25E+00
May-98	14	inside zig-zags	5	7	5	school	5.5	213	7	49	7.20E+04	5.77E-07	3.77E-05	7.82E-05	65.402	135.63	4.71E+06	14.13	6.65E+04	6.65E+04	9.24E+01
May-98	14	inside zig-zags	5a	8	7	school	7.1	620	8	143	6.98E+05	5 40E-07	2.07E 05	1.08E-04	38.326	199.88	2.68E+07	4.20	1.13E+05	9.44E+04	1.35E+01
May-98	14	inside zig-zags	7	9	12	layer	9.9	810	6	373	1.84E+06	5.76E-07	2.31E-06	1 WE.05	4.003	27 79	7.38E+06	3 4 0	2 50E+04	4.23E+03	2 29E-01
May-98	15	inside zig-zags	7	11	7	layer	8.5	233	7	107	1.75E+05	5.x.507	1.00E-06	3.42E 06	1.703	5.80	2.99E+05	3 3 0	9.86E+02	1 30E+02	7.41E 02
May-98	15	inside zig-zags	7	12	6	school	5.7	743	6	171	8.00E+05	5.07E-07	7.12E-06	1.29E-04	,404,	255 13	1.12E+07	2.66	3.22E+04	5.60E+00	7.01E-04
May-98	14	inside zig-zags	9	10	11	layer	9.5	932	7	429	2.76E+06	6.01E-07	1.27E-06	6.31E-06	2.106	10 49	5.80E+06	2.87	1.66E+04	4.24E+01	1 54E-03
May-98	13	outside zig-zags	17	3	5	layer	3.5	142	5	65	4.62E+04	449E.07	2.62E 06	3.31E-05	5.823	73.7,	2.69E+05	1.27	3 42E+02	3 42E+02	7.41E-01
May-98	13	outside zig-zags	18	2	5	layer	6.4	218	9	100	1.92E+05	5.53E-07	3.31E-07	6.03E-06	0.599	10.90	1 15E+05	502	5.78E+02	5.06E+02	2.63E-01
May-98	13	outside zig-zags	22	4	32	layer	30.7	659	17	303	3.47E+06	8.07E-07	1.15E-07	2.47E-07	0.143	0.31	4.95E+05	2.80	1.39E+03	4.59E+02	1.32E-02
May-98	13	outside zig-zags	22	5	32	layer	28.1	474	20	218	2.08E+06	7.52E 07	8.04E-08	2 54E-07	0.107	034	2 23E+05	1.87	4.16E+02	5 89E+01	2.83E-03
Aug-98	4	inside zig-zags	2	10	20	layer	20.0	1,443	12	1.515	2.62E+07	4.79E-07	1.27E-08	3.83E-06	0.026	7.99	6.94E+05	0.25	1.73E+02	0.00E+00	0.00E+00
Aug-98	2	inside zig-zags	3	1	35	layer	'lo.6	1,002	2,	1,052	2.25E+07	1 01E-06	6.94E-08	2.47E-07	0.069	025	1.55E+06	0.58	8.92E+02	3.64E+02	1.62E-03
Aug-98	2	inside zig-zags	3	2	42	layer	436	142	15	149	3.17E+05	1.06E-06	3.68E-08	1.32E.07	0 035	0.12	1.10E+04	2.02	2.22E+01	4.30E+00	1.36E 03
Aug-98	2	inside zig-zags	3	3	20	layer	225	215	5	225	2.42E+05	5 90E-07	1.28E-09	2.40E 07	0.002	041	5.26E+02	134	7.02E-01	5 52E 01	2.28E-04
Aug-98	3	inside zig-zags	3	7	40	layer	40.6	960	21	1,008	2.05E+07	9.12E-07	8.55E-08	1.75E 07	0.094	019	1.92E+06	232	4.46E+03	1.98E+03	9.67E-03
Aug-98	4	inside zig-zags	4	11	50	layer	45.6	1,174	11	1,232	1.62E+07	1.15E-06	2.02E-08	1.71E 07	0.018	015	2.86E+05	4.20	1.20E+03	8.24E+02	5.09E-03
Aug-98	4	inside zig-zags	5	8	40	layer	40.0	1,379	20	1.446	3.99E+07	1.02E-06	4.67E-08	4.21E-07	0.046	041	1.83E+06	1.2,	2.22E+03	1.38E+03	3.46E-03
Aug-98	4	inside zig-zags	5	9	45	layer	40.0	1,379	20	1,446	3.99E+07	1.02E-06	4.67E-08	421E.07	0.046	04,	1.83E+06	273	5 01E+03	2.98E+03	7.47E-03
Aug-98	2	inside zig-zags	8	4	20	layer	195	2,102	7	2,207	3.34E+07	5.64E-07	2.76E 08	7.23E.07	0.049	1.28	1.64E+06	5.56	9.09E+03	8.68E+03	2.60E-02
Aug-98	2	inside zig-zags	9	5	20	layer	22.1	437	14	459	2.79E+06	6.30E 07	9.12E-08	8 13E-07	0.145	1.29	4.04E+05	16.41	6.63E+03	6.60E+03	2 37E 01
Aug-98	2	inside zig zags	9	6	22	layer	210	53,	8	558	2.37E+06	5.87E 07	1.64E-08	3 78E-07	0.028	0.64	6.63E+04	7.52	4.99E+02	4.84E+02	2 04E-02

* Mean volume backscattering strength in arithmetic rm.
** Mean value calculated for the portion of the water umn in which organisms were detected.
+ All species captured in net.

ranged from 4 to 30 meters, covering much of the water column. Corresponding trawl samples contained mainly small herring and smelt, as well as various invertebrates including shrimp and mysids (Table 15). There was no particular pattern in catch composition related to depth, type of aggregation targeted, or location of sample in nearshore areas. Offshore hauls captured only invertebrates and no forage fish. In nearshore layers, hydroacoustic estimates of total forage fish per layer and forage fish density varied from 33-1070 kg and from 0.0000001-0.037 g/m^3, respectively, with highest densities in the upper 10 meters of the water column (Table 14).

A total of 52 aggregation layers and 26 schools were detected and measured hydroacoustically on all transects sampled in August 1997. Extensive layers of organisms averaging over 6 km long occurred outside Chisik Island in the offshore zone (Table 16). Layers were shorter (2.1 km) inside Chisik island, and shortest (1.2 km) in the nearshore zone outside the island (length of nearshore layers was limited partly by transect length). Layer thickness ranged from 7.5-14.9 m. Schools (mean length 22 m) were much smaller than layers. School size was similar in nearshore areas inside and outside Chisik Island; however, schools were deeper in the water column and over deeper water inside the island (Table 16).

4.4.2 May 1998 -- Chisik Island

During the May 1998 survey, small, dense schools of organisms were abundant throughout nearshore areas, particularly in Tuxedni Channel adjacent to Chisik Island, and mainly in the upper 15 m of the water column (Figure 29a-c). School shapes were variable but included tall and narrow as well as round forms. Schools were not observed in offshore sampling outside Chisik Island. Layers were also commonly observed in this survey, both in offshore and nearshore areas.

Table 15. Predominant forage fish and invertebrate species and percent of numbers and biomass, by survey, transect, and haul. Forage species included Longfin smelt, surf smelt, eulachon, Pacific sand lance, Pacific herring, and juvenile walleye pollock.

Date	Trans.	Haul	Predominant fish & per haul (by) Fish # 1	Fish # 2	Invert. # 1	Number captured per: Forage fish	Other fish*	Mysids euphaus. &	Other** inverts.	Grand total	% of number per: Forage fish	Mysids euphaus. &	Combine	Biomass (g) per: Forage fish	Mysids euphaus. &	Combined	Forage fi
10-Aug-97	0	0			ctenophores	0	0	0	20	20	0%	0%	0%	0	0	0	0.0
11 Aug.97	3	1	herring	surf		467	0	0	0	467	100%	0%	100%	15.125	0	15,125	100.0
11 Aug-97	5	2	surf	herring		90	0	0	0	90	100%	0%	100%	3,798	0	3,798	100.0
11 Aug-97	6	3	herring	longfin smelt		62	1	5	23	91	68%	5%	74%	2,474	14	2.488	99.4
12-Aug-97	9	7	herring		mysids	64	0	1,300	1	1,365	5%	95%	100%	2,856	1,211	4,067	70.2
12-Aug-97	10	8	herring			11	0	0	0	11	100%	0%	100%	121	0	121	100.0
12-Aug-97	12	9	herring	surf	shrimp	15	0	120	0	135	11%	89%	100%	117	294	411	28.5
12-Aug-97	14	10	herring	surf	shrimp	33	0	25	0	58	57%	43%	100%	429	72	501	85.7
12-Aug-97	19	4			ctenophores	0	0	0	11	11	0%	0%	0%	0	0	0	0.0
12-Aug-97	22	5	surf	herring		7	0	0	0	7	100%	0%	100%	25	0	25	100.0
12-May-98	0	1	herring		shrimp	9	0	109	1	119	8%	92%	99%	81	262	343	23.6
14-May-98	1	6	eulachon	pollock	shrimp	29	0	62	0	91	32%	68%	100%	593	148	741	80.1
15 May-98	4	13	eulachon		shrimp	37	0	1,100	0	1,137	3%	97%	100%	1,229	3,157	4,386	28.0
14-May-98	5	7	eulachon	herring		16	0	0	0	16	100%	0%	100%	226	0	226	100.0
14 May-96	5A	8	herring	eulachon	shrimp	18	0	12	0	30	60%	40%	100%	180	34	214	83.9
14-May-98	7	9	eulachon	pollock	shrimp	38	1	2,000	0	2.031	2%	98%	100%	1,166	5,740	6,906	16.9
15-May-98	7	11	eulachon	tomcod	shrimp	33	1	2,500	0	2,534	1%	99%	100%	1,089	7.175	8,264	13.2
15-May-98	7	12	herring		shrimp	1	0	2,000	0	2,00[illegible]	0%	100%	100%	1	5,740	5,741	0.0
14-May-98	9	10	pollock		shrimp	5	0	1,500	0	1,505	0%	100%	100%	11	4,305	4,316	0.3
13-May 98	17	3	herrmg	sandlance		6	0	0	0	6	100%	0%	100%	14	0	14	100.0
13-May 98	18	2	herring	sandlance	shrimp	11	0	5	0	16	69%	31%	100%	101	14	115	87.6
13-May-98	22	4	eulachon	sandlance	shrimp	18	0	215	0	235	8%	92%	100%	206	415	621	33.1
13-May-98	22	5	sandlance	eulachon	shrimp	7	0	122	0	129	5%	95%	100%	37	224	261	14.2
2-Aug-98	2	10	eulachon		mysids	8	0	20	0	28	29%	71%	100%	0	7	7	0.0
2-Aug-98	3	1	longtin smelt		mysids	11	1	500	2	514	2%	97%	99%	121	175	296	40.9
2-Aug-98	3	2	longfin smelt	sole	shrimp	13	0	220	0	233	6%	94%	100%	91	379	470	19.3
2-Aug-98	3	3	eulachon	sole	mysids	8	0	50	3	61	13%	82%	95%	64	18	82	78.5
3-Aug-98	3	7	eulachon	longfin smelt	shrimp	18	0	110	0	128	14%	86%	100%	132	165	297	44.5
4-Aug-98	4	11	longfin smelt	sole	shrimp	15	0	45	0	60	25%	75%	100%	173	79	252	68.7
4-Aug-98	5	8	longfin smelt	eulachon	mysids	22	0	323	0	345	6%	94%	100%	260	158	418	62.1
4-Aug-98	5	9	longfin smelt	eulachon	mysids	31	0	306	1	338	9%	91%	100%	549	374	923	59.5
2-Aug-98	8	4	eulachon	longfin smelt	mysids	49	0	130	0	179	27%	73%	100%	949	46	995	95.4
2-Aug-98	9	5	eulachon		mysids	85	0	18	1	104	82%	17%	99%	1,700	6	1,706	99.6
2-Aug-98	9	6	eulachon		mysids	58	0	100	1	159	36%	63%	99%	1,160	35	1,195	97.1

* Other fish were a minor fraction of the catch.

** Other invertebrates constituted a minor fraction of the catch.

Table 16. Characteristics of organism schools and layers observed with acoustics in 1997 and 1998, summarized by survey, sampling location, and transect group.

Survey	Aggregation Type	Location	Transect Group	Mean length (m)	Mean thick. (m)	Mean width* (m)	Mean volume (m³)	Mean depth (m)	Mean bottom depth** (m)	Schools/Layers Sampled for length	Schools/Layers Sampled for width	Schools/Layers Sampled by trawl	Standard Deviation length	Standard Deviation thickness	Standard Deviation width	Standard Deviation depth	Standard Deviation bottom depth
Aug-97	layer	Chisik	inside zig-zags	2,097	14.9	1,465	4 6E+07	21 4	32.2	24	4	7	1.366	8	701	12	10
"	"	"	outside offshore	6,246	1 4 6	4,366	4.0E+08	2 6 2	35.7	14	0	1	4.274	7	~	7	a
"	"	"	outside zig-zags	1,215	7.5	849	7.7E+06	152	24 9	14	0	1	976	4		6	8
"	school	Chisik	inside zig-zags	22	4.9	15	1.6E+03	16.6	31.4	21	0	0	19	4		8	8
"	"	"	outside offshore		2.4			29.1	37 9		0	0		1		4	1
"	"	"	outside zig-zags	22	2 6	16	9.2E+02	8.6	13.4	5	0	0	20	1		4	4
May-98	layer	Chisik	inside zig-zags	1,065	13.1	931	2 4E+07	19.7	29.5	45	7	4	1,196	10	781	11	10
"	"	"	outside offshore	3,072	18.7	1,613	8 3E+07	20.0	31 9	14	0	1	2,741	11		10	10
"	"	"	outside zig-zags	2.212	22.4	1,039	5 1E+07	23.3	24	9	0	4	1,883	11		9	8
"	school	Chisik	inside zig-zags	118	1.9	27	6 1E+03	7 0	222	116	23	4	422	1	20	3	13
"	"	"	outside offshore	18	1.7	4	1 2E+02	5.7	9.7	5	0	0	10	0		4	3
"	"	"	outside zig-zags	299	2.0	68	4 0E+04	4.4	146	26	0	0	646	1		2	14
Jul-98	layer	Hallo Bay	outside zig-zags	3.145	15.3	•		36.2	47.4	a	0	0	1,790	9		10	5
		Kukak Bay			12.3	•		21.0	4 3 4		0	0		8	•	12	8
	school	Cape Chiniak	"	19	2.1			7.9	9.2	22	0	0	19	1		3	3
		Hallo Bay		123	7 0			3 3 6	44	89	0	0	327	8		12	I I
	.	Kukak Bay			5 4			24.3	41.3		0	0		4		13	12
Aug-98	layer	Chisik	inside zig-zags	1.868	13.0	1.987	4.8E+07	26.4	3 5 6	15	6	11	1,007	7	2,444	10	11
			outside offshore	6.016	16.0	6,334	6.1E+08	33.0	35 0	2	0	0	5,179	0		1	1
			outside zig-zags	2.214	11.2	2,331	5.80E+07	29.9	31 0	9	0	0	2.053	9		11	11
	school	Chisik	inside zig-zags	17	2.6	19	8.7E+02	18.0	23.4	68	15	0	14	2	11	9	8
			outside offshore	14	2.2	18	5.0E+02	21 8	31 1	8	0	0	6	1		9	6
			outside zig-zags	15	2.3	16	5.4E+02	17.7	23 2	7	0	0	7	2		10	9

'Mean width estimated using length/width ratio from nearest transect group where width measurements were made.
"Beneath layer or school.

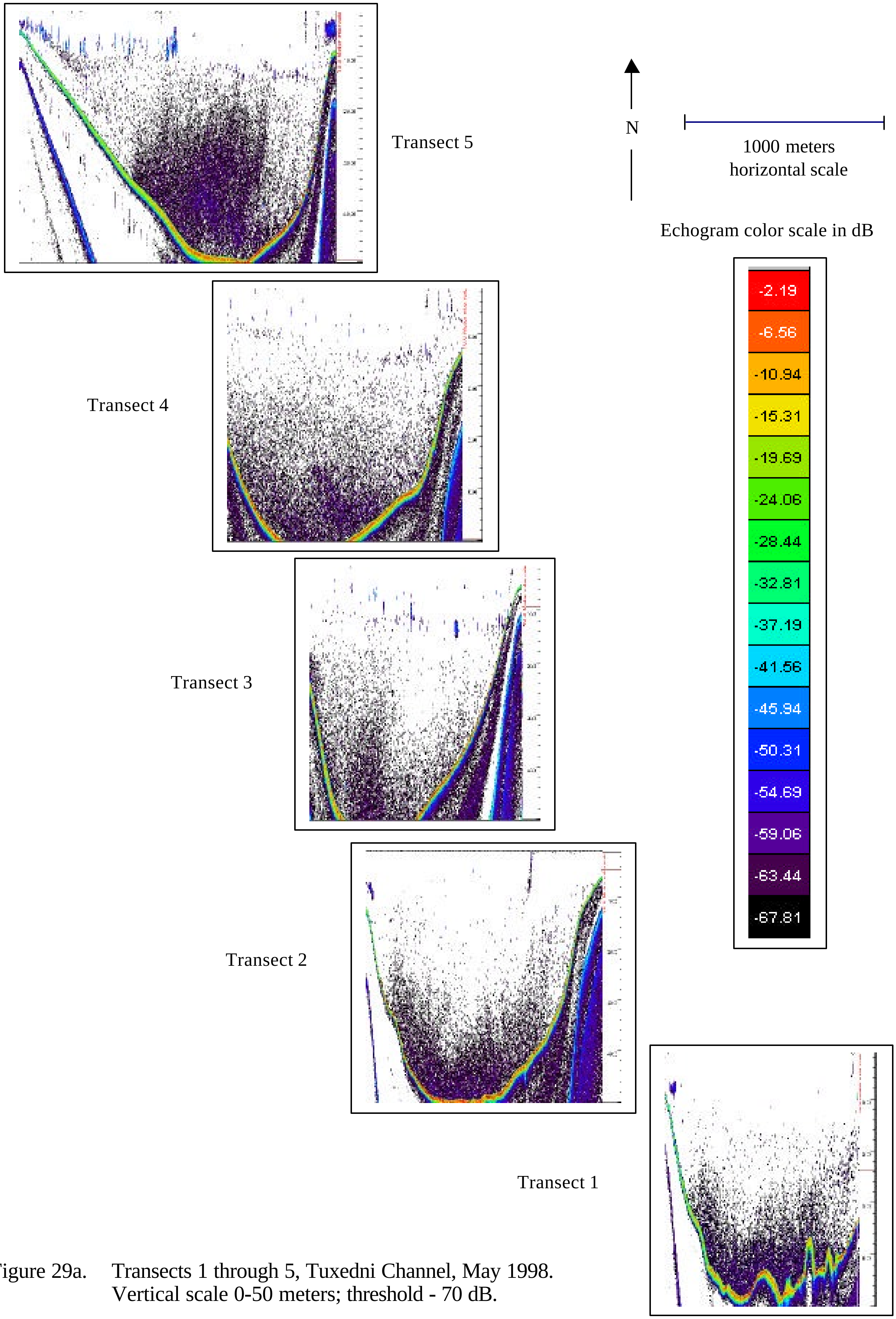


Figure 29a. Transects 1 through 5, Tuxedni Channel, May 1998.
Vertical scale 0-50 meters; threshold - 70 dB.

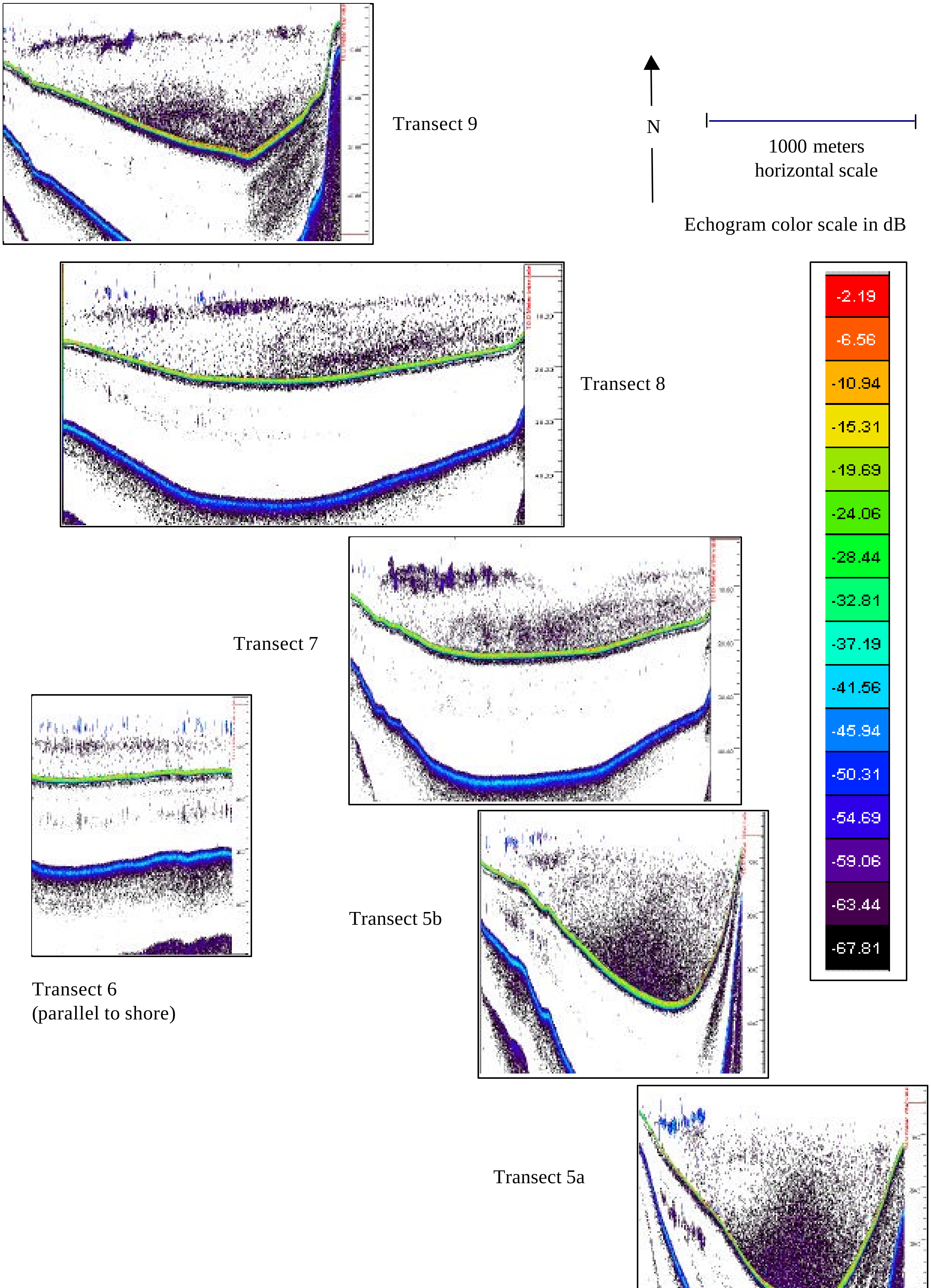
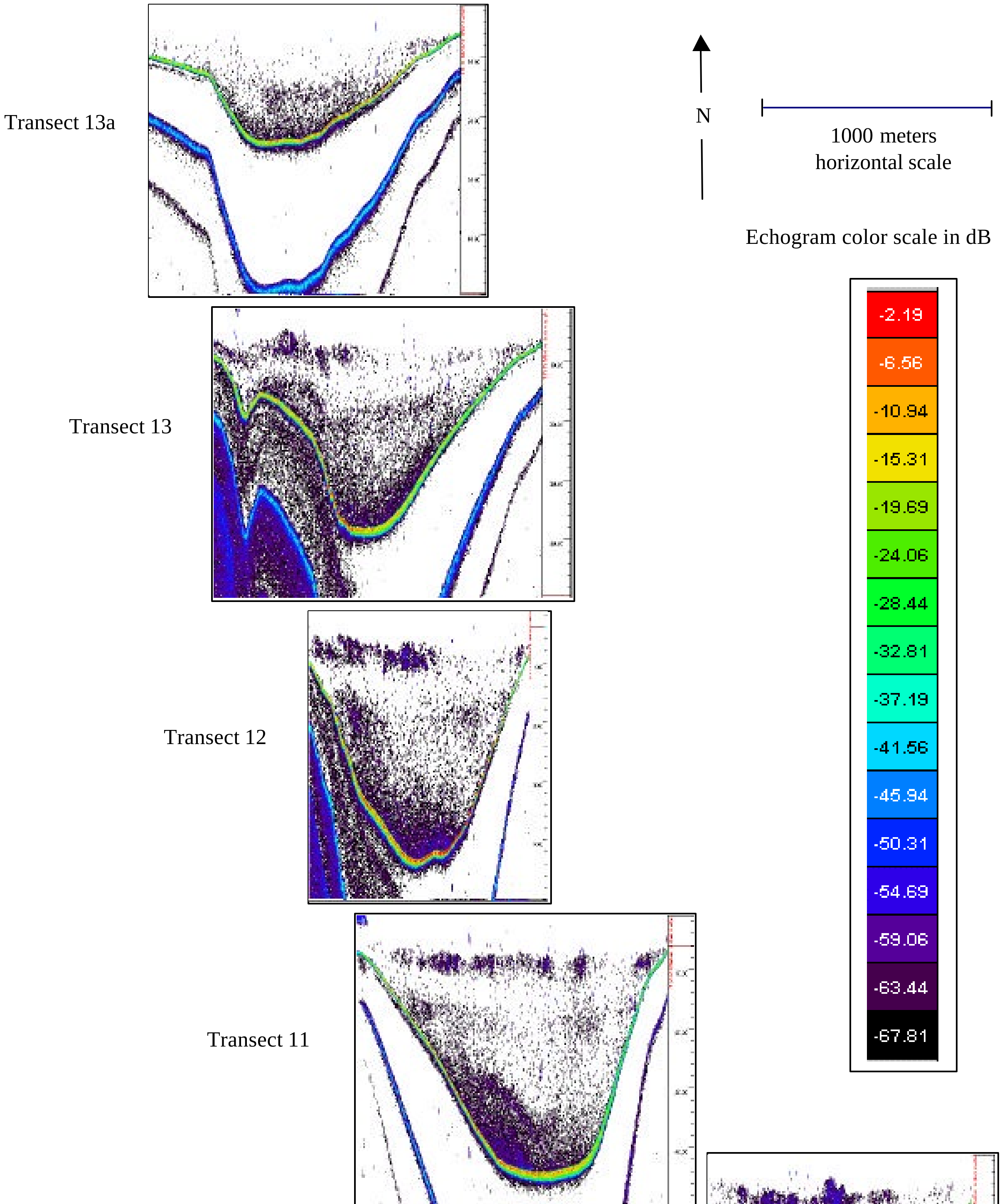


Figure 29b. Transects 5a through 9, Tuxedni Channel, May 1998. Vertical scale 0-50 meters; threshold - 70 dB.



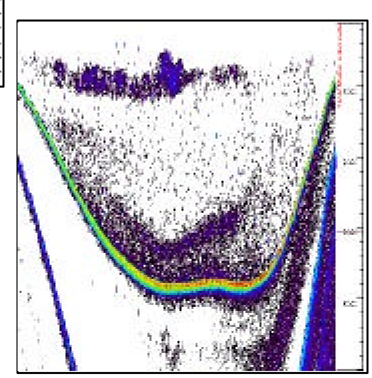


Figure 29c. Transects 10 through 13a, Tuxedni Channel, May 1998.
Vertical scale 0-50 meters; threshold - 70 dB.

Nine layers and four schools that were observed on echograms were also sampled by trawl in May 1998 (Figure 30a-m). Hauls were made both inside and outside of Chisik Island. Sampled layers ranged from 142–5,025 m in length, from 5-20 m in thickness, from 65-2,312 m in width (estimated from closest cross-transect), and from 0.046–69 million m^3 in volume (Table 14). Depth at mid-point ranged from 7-30 m, covering much of the water column. Sampled schools ranged from 120-743 m in length, from 4-8 m in thickness, from 28-171 m in width (estimated from closest cross-transect), and from 0.013-0.8 million m^3 in volume (Table 14). Depth at mid-point ranged from 5.5-8 m. Corresponding trawl samples contained mainly herring, several species of smelt, and shrimp (Table 15). There was no particular pattern in catch composition related to depth, type of aggregation targeted, or location of sample, although offshore hauls captured few forage fish. In nearshore samples hydroacoustic estimates of total forage fish per aggregation and forage fish density varied from 7-248,000 kg and from 0.000005-345 g/m^3, respectively, with highest densities in the upper 10 m of the water column (Table 14).

A total of 68 layers and 147 schools of organisms were detected and measured hydroacoustically on all transects sampled in May 1998. Offshore layers averaged 3 km in length (Table 16). Aggregation layers in nearshore areas inside and outside Chisik Island were about 2 km long, which was partly restricted by transect length. Layer thickness ranged from 13-22 m. Schools were much smaller than layers. Length of schools in nearshore areas averaged 118 m and 299 m inside (Tuxedni Channel) and outside of Chisik Island, respectively. Mean depth of schools was less than 8 m in all areas (Table 16).

Figure 30. Echograms of organism schools or layers sampled by trawl at Chisik Island, May 1998. Summary data for enclosed areas are provided in Tables 14 and 15.

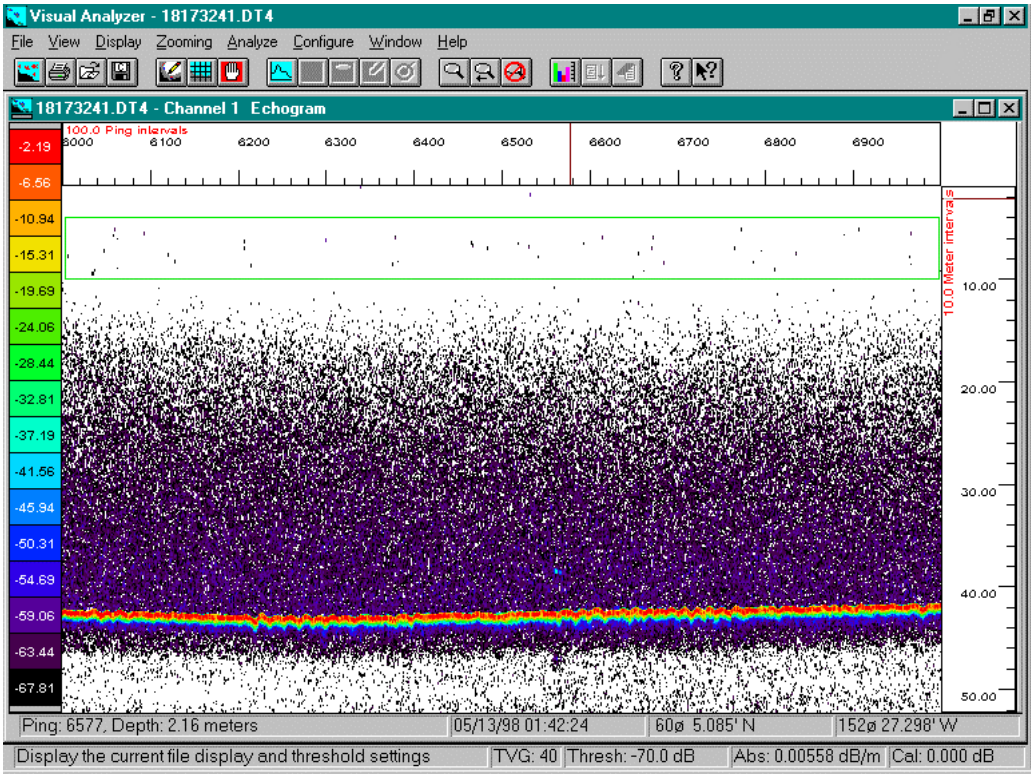


Figure 30a. Transect 0 haul 1, May 12, 1998.

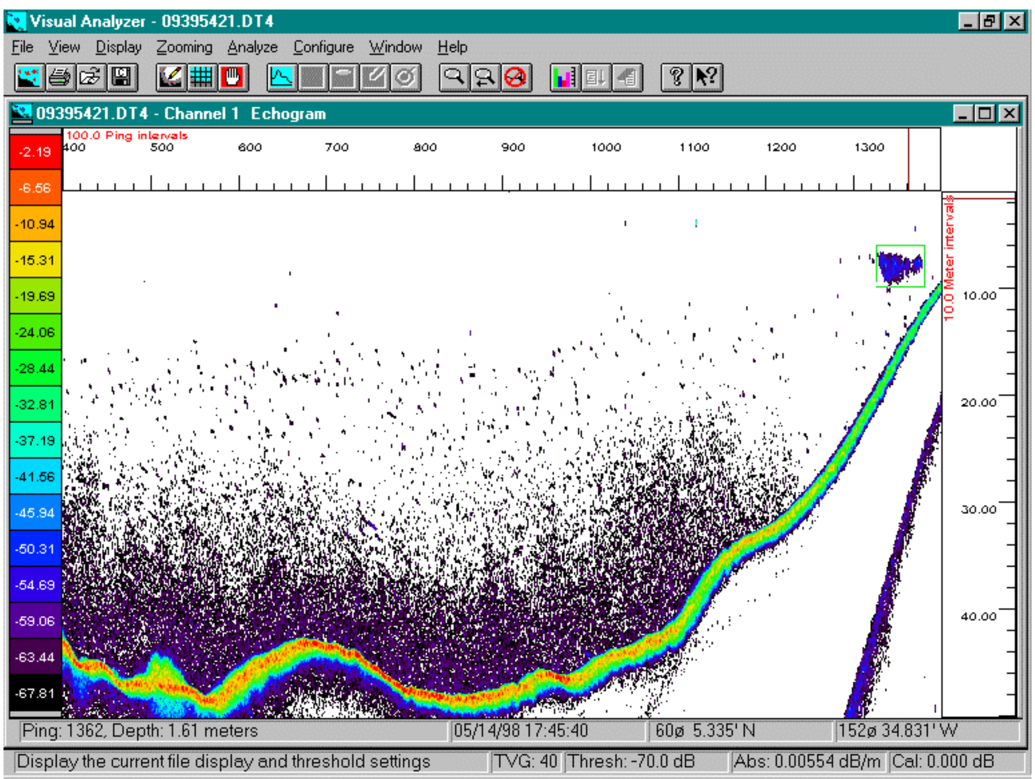


Figure 30b. Transect 1 haul 6, May 14, 1998.

Figure 30 continued

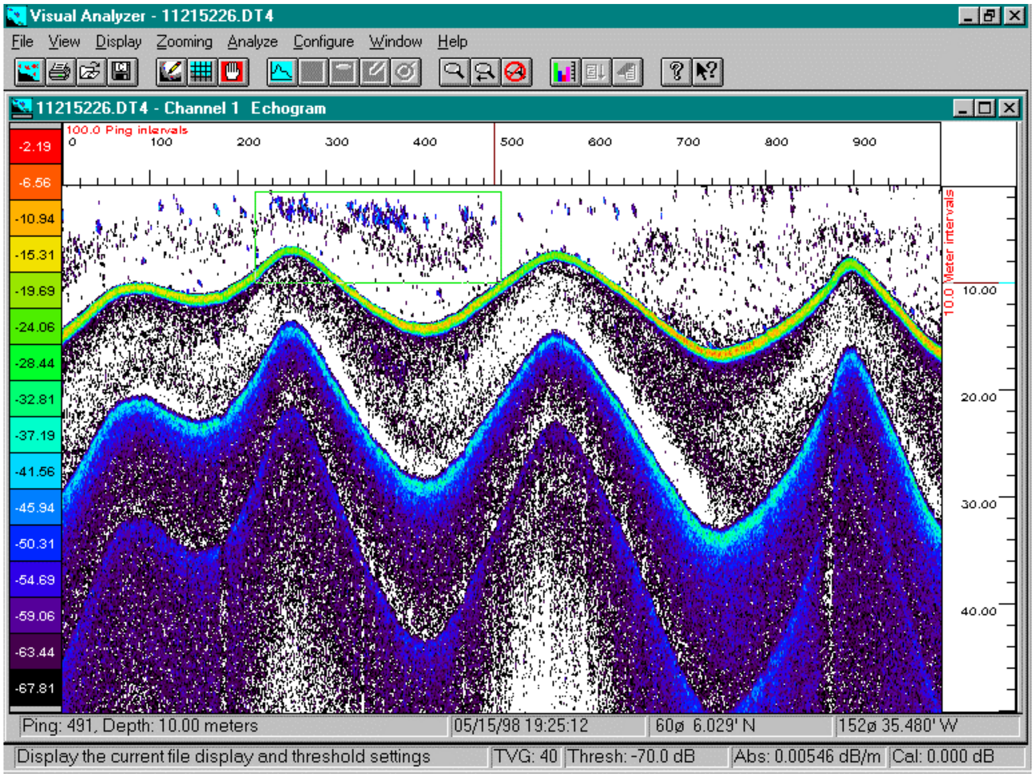


Figure 30c. Transect 4 haul 13, May 15, 1998.

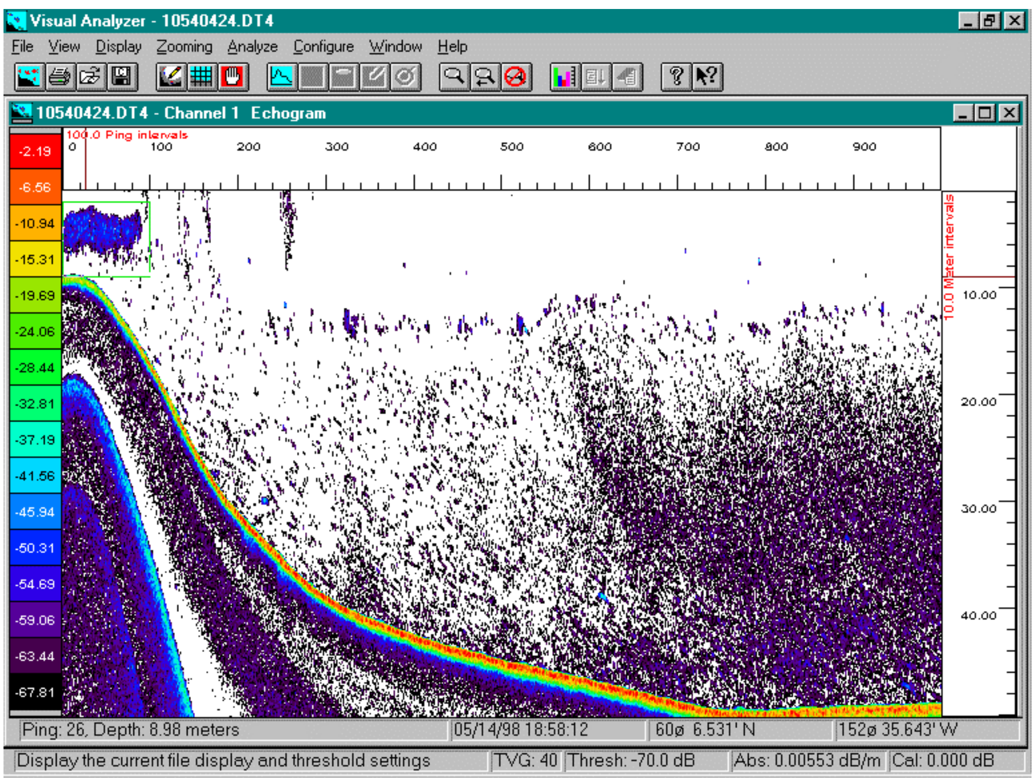


Figure 30d. Transect 5 haul 7, May 14, 1998.

Figure 30 continued

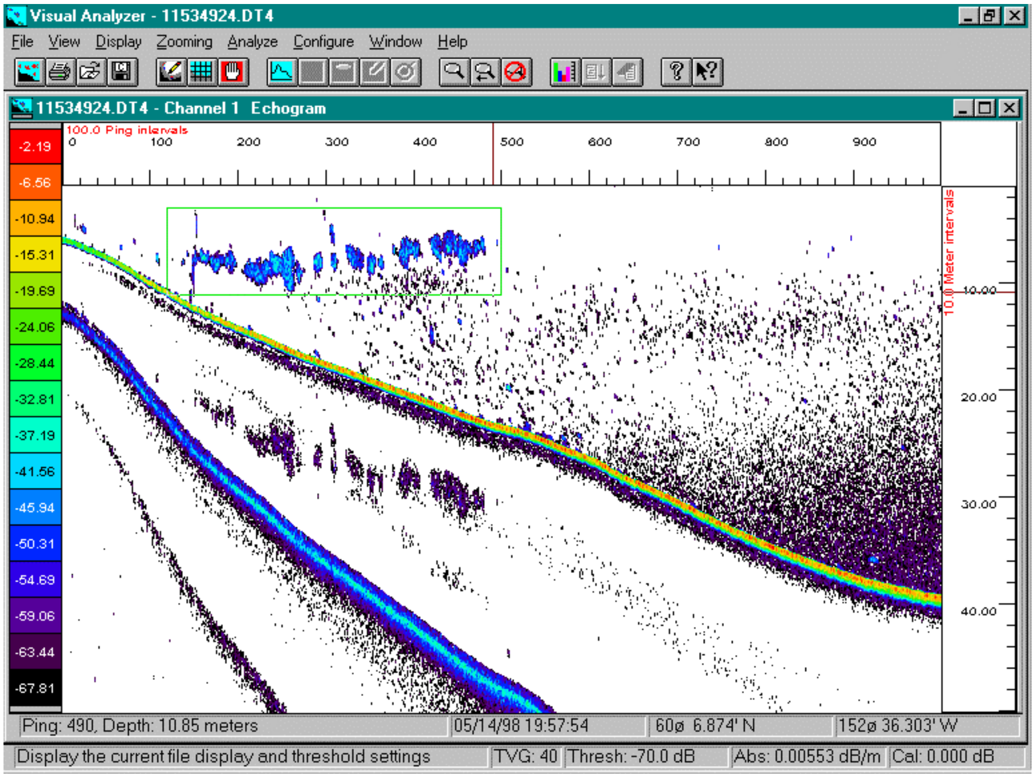


Figure 30e. Transect 5a haul 8, May 14, 1998.

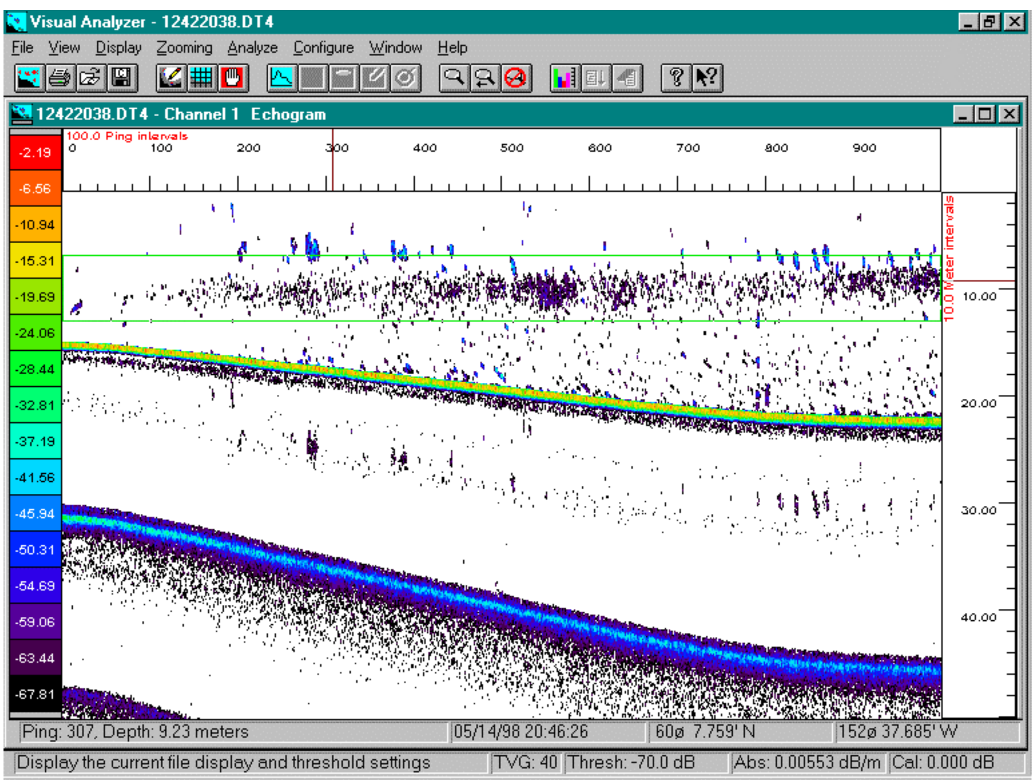


Figure 30f. Transect 7 haul 9, May 14, 1998.

Figure 30 continued

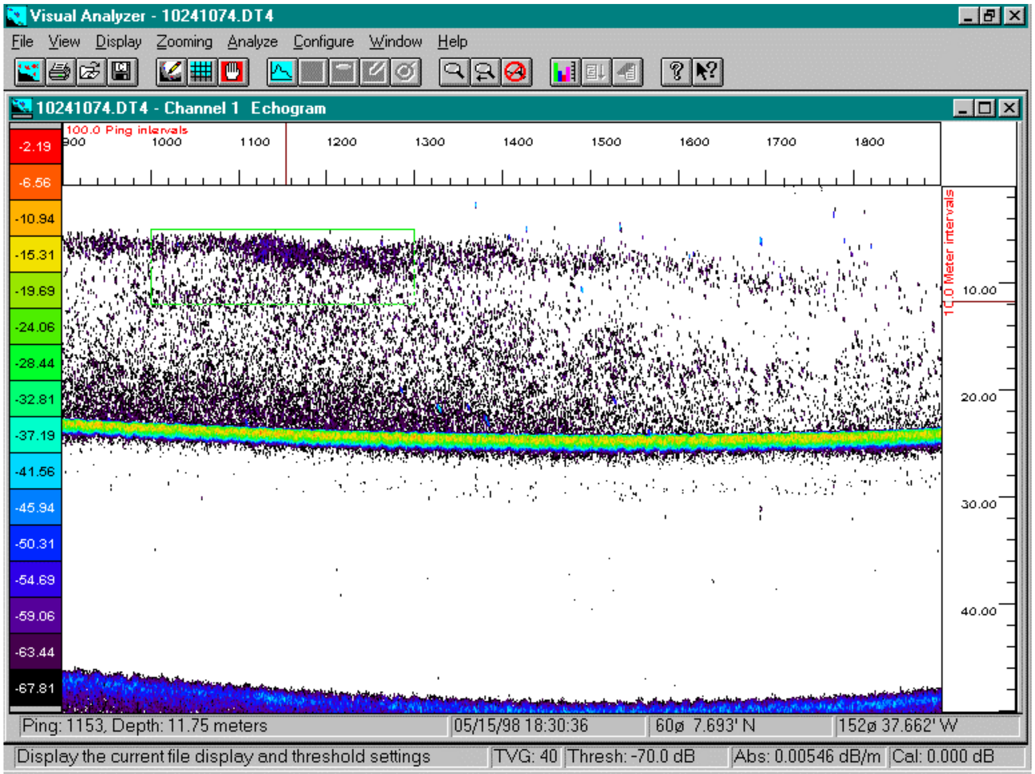


Figure 30g. Transect 7 haul 11, May 15, 1998.

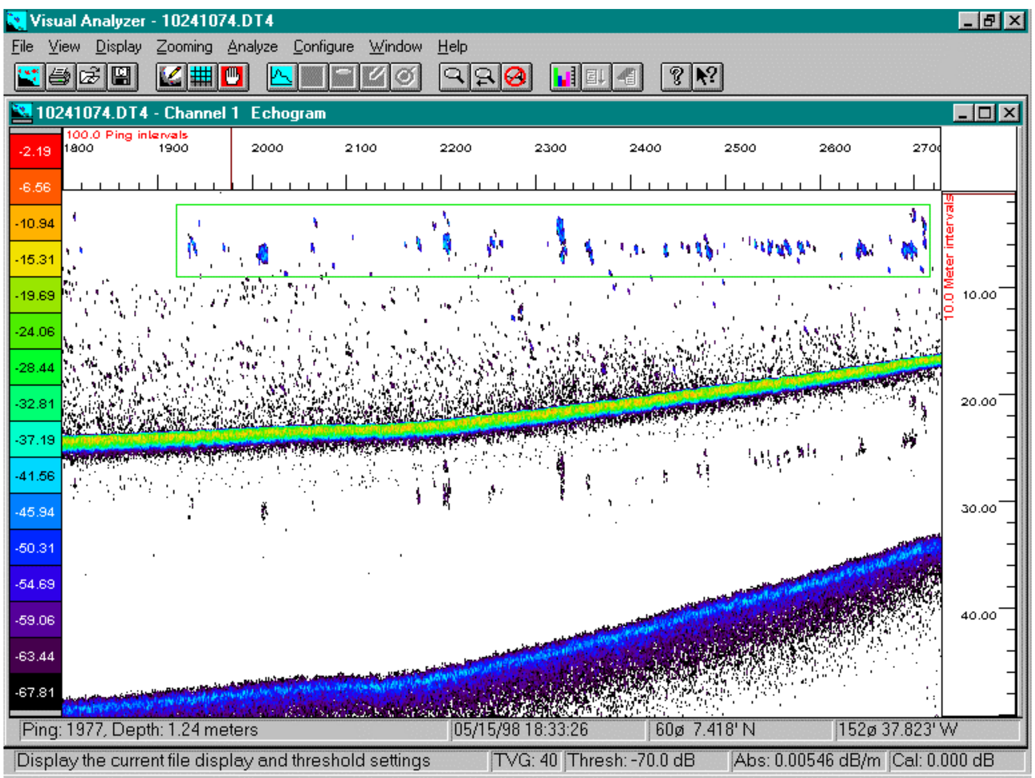


Figure 30h. Transect 7 haul 12, May 15, 1998.

Figure 30 continued

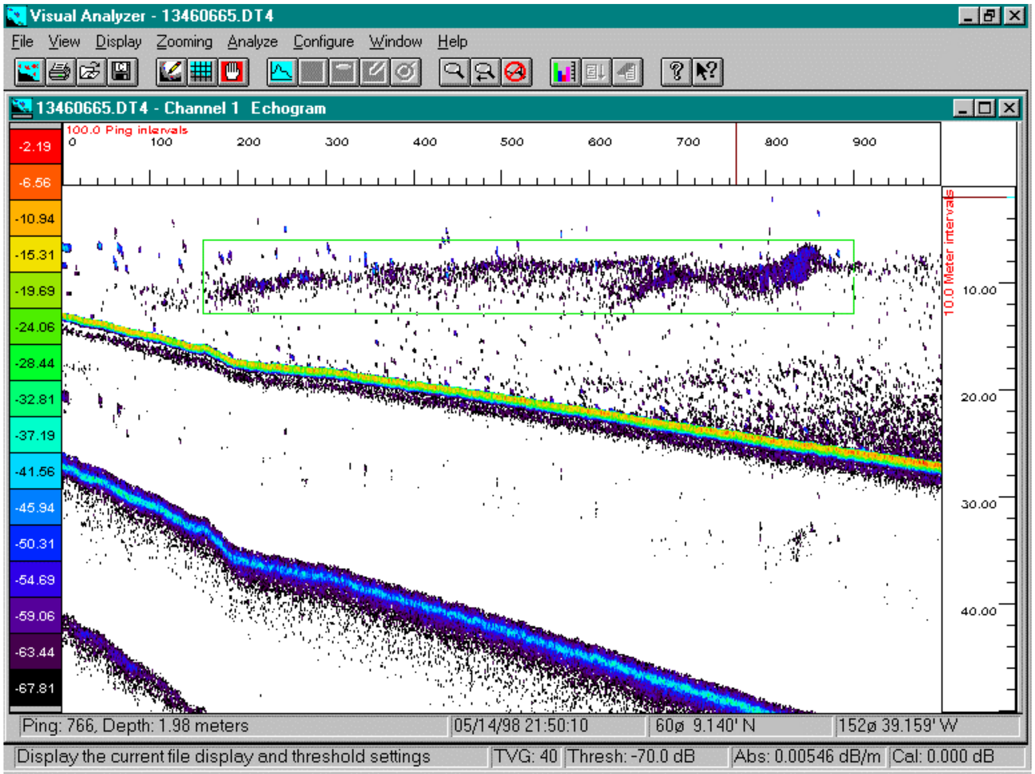


Figure 30i. Transect 9 haul 10, May 14, 1998.

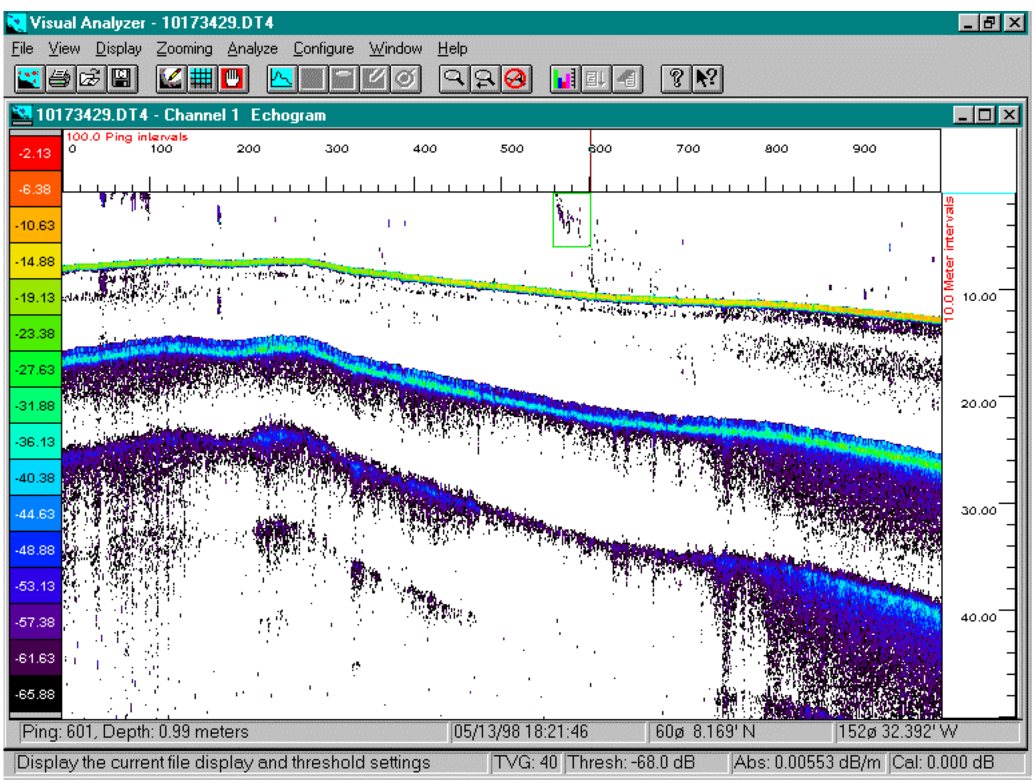


Figure 30j. Transect 17 haul 3, May 13, 1998.

Figure 30 continued

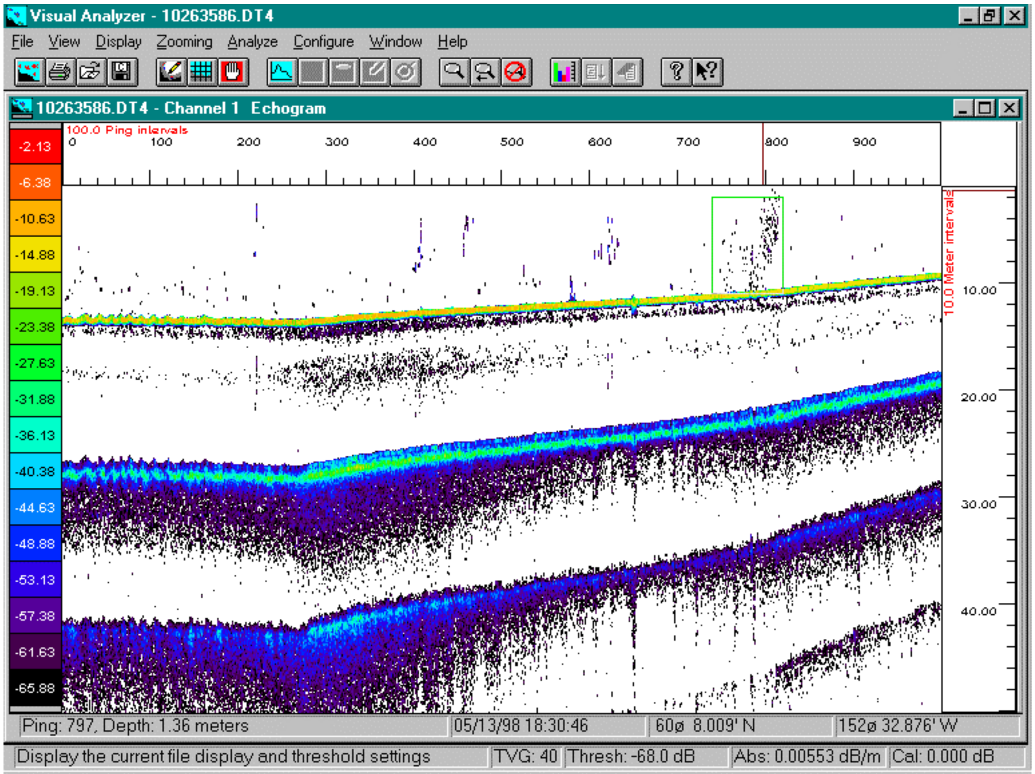


Figure 30k. Transect 18 haul 2, May 13, 1998.

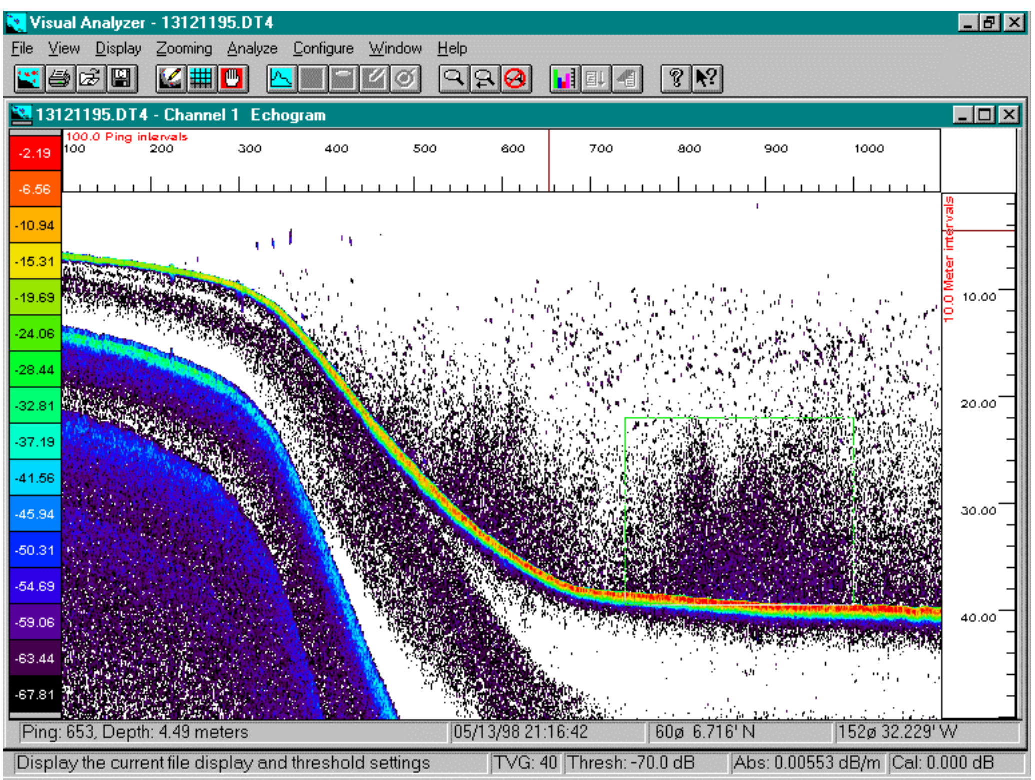


Figure 30l. Transect 22 haul 4, May 13, 1998.

Figure 30 continued

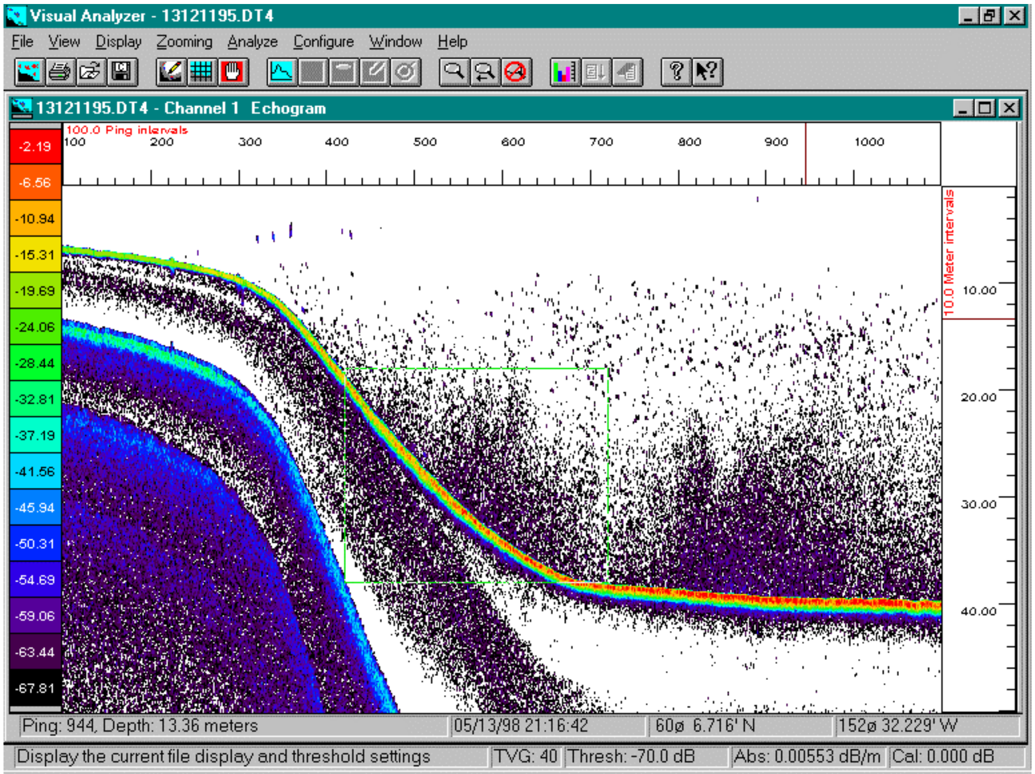


Figure 30m. Transect 22 haul 5, May 13, 1998.

4.4.3 July 1998 -- Shelikof Strait

Field operations were restricted by poor weather and rough seas during the July 1998 survey of study areas along Shelikof Strait. Limited acoustic data were 'obtained at Hal10 Bay, Kukak Bay, and Cape Chiniak, but no usable data were obtained at Shakun Reef. Trawling was also hampered by weather and no forage fish were captured in any of the hauls in Shelikof Strait. A considerable number of small schools of organisms (mean length 19-123 m) were observed in the upper 10 m of Cape Chiniak and Hallo Bay transects (Table 16), but species identification was not possible from available trawl data and biomass estimates were not attempted.

4.4.4 August 1998 – Chisik Island

During the August 1998 survey, echograms showed layers of varying density as well as some discrete, dense schools of organisms. A deep layer (> 25 m) was seen in the southern portion of Tuxedni Channel (transects 1-5) and a dense midwater layer (15-30 m) occurred in its northern part (Figure 3 la-c). Several small, dense schools were also seen throughout the water column in the north end of the channel (transects 9-13a). These schools mostly appeared tall and narrow in shape. Outside offshore transects were run with difficulty due to rough weather, and transect 19 was not sampled. Few appreciable schools or layers were seen on other transects outside Chisik Island, either nearshore or offshore.

Eleven layers of organisms observed on echograms were also sampled by trawl in August 1998 (Figure 32a-j). No dense, discrete schools were sampled and hauls were made only inside of Chisik Island due to rough seas and lack of appreciable fish aggregations elsewhere. Sampled layers ranged from 142-2,102 m in length, from 5-2 1 m in thickness, from 209–1,433 m in width (estimated from closest cross-transect), and from 0.3-40 million m^3 in volume (Table 14). Depth at mid-point ranged from

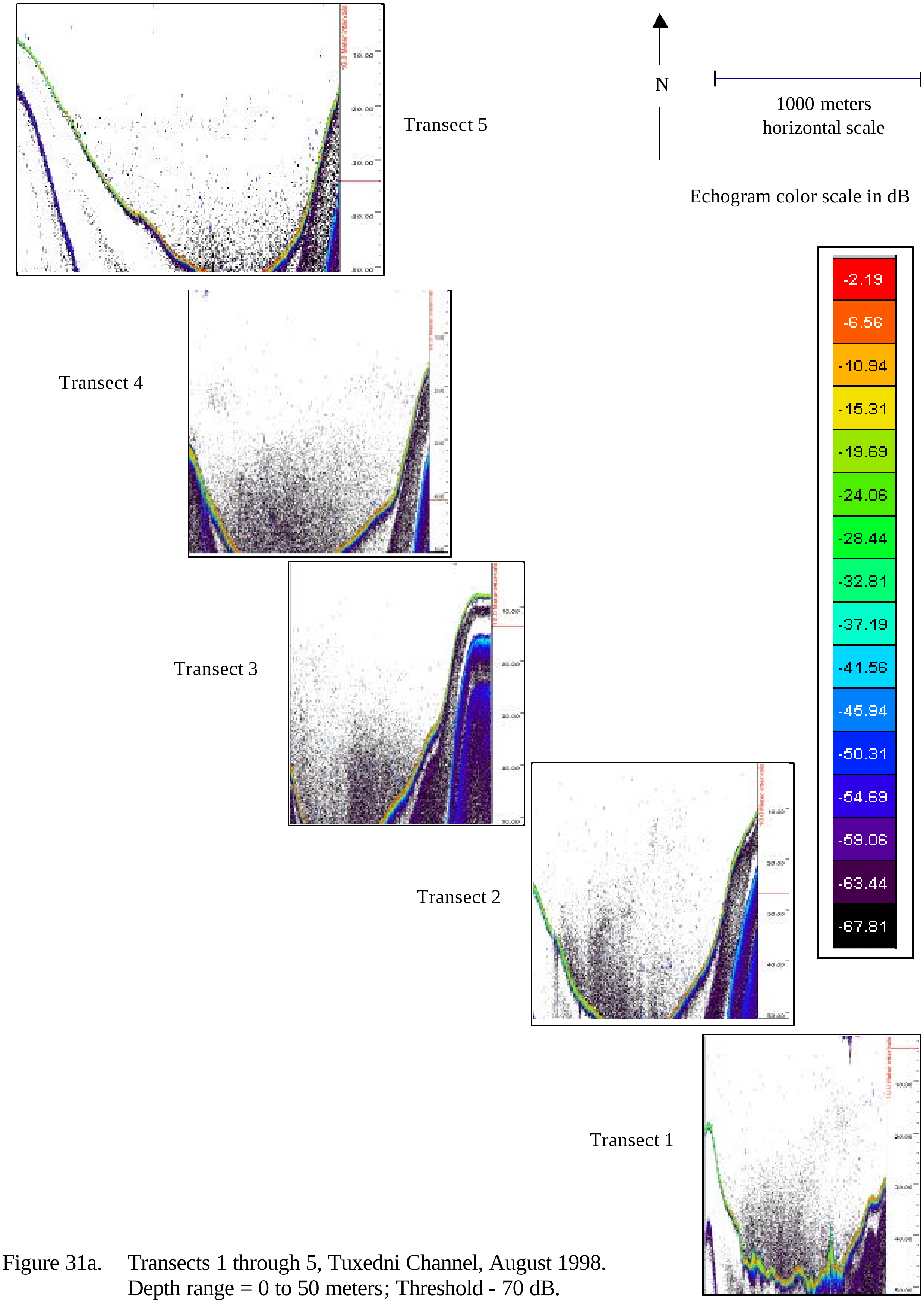


Figure 31a. Transects 1 through 5, Tuxedni Channel, August 1998.
Depth range = 0 to 50 meters; Threshold - 70 dB.

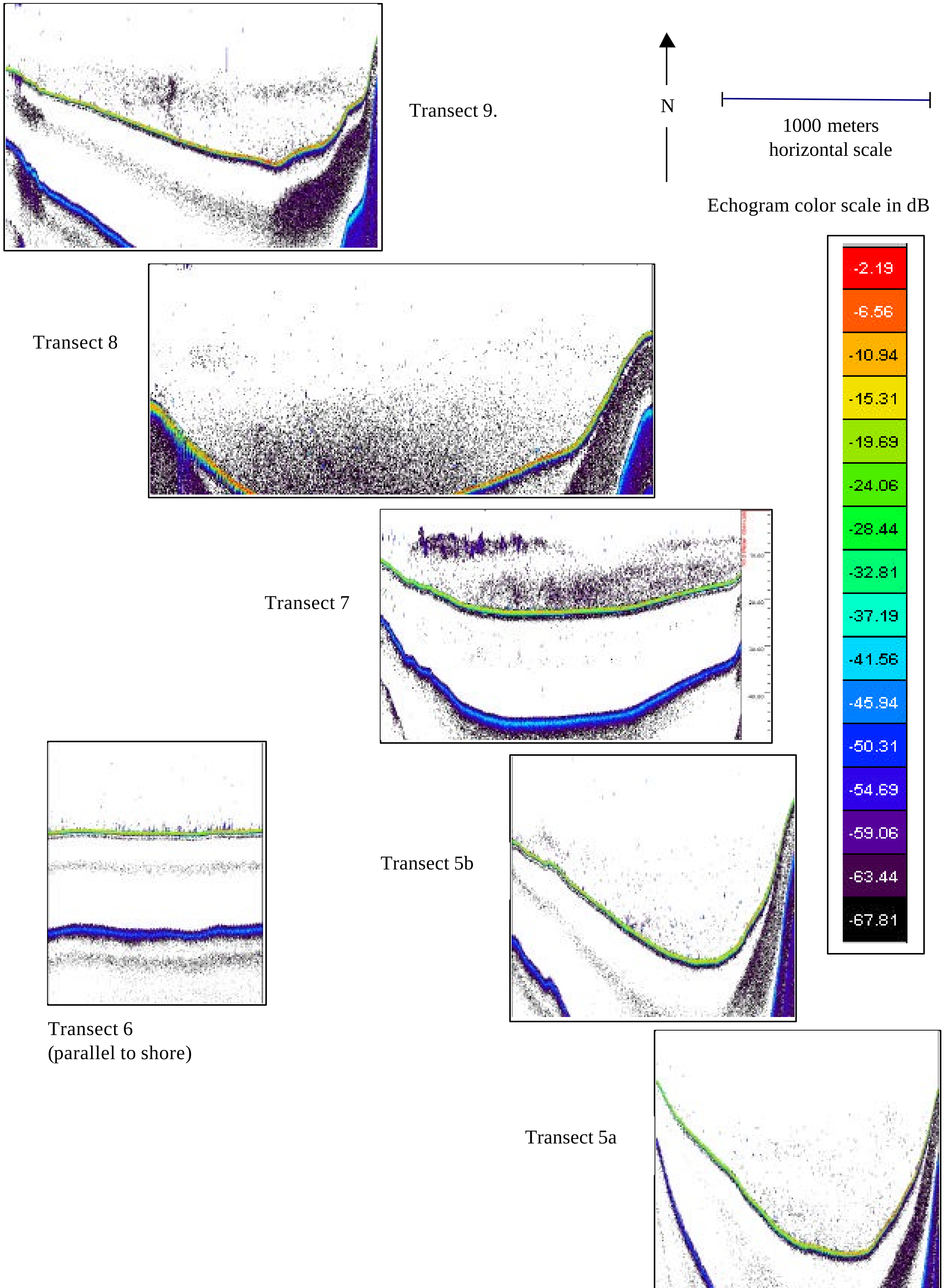


Figure 31b. Transects 5a through 9, Tuxedni Channel, August 1998. Depth range = 0 to 50 meters; Threshold - 70 dB.

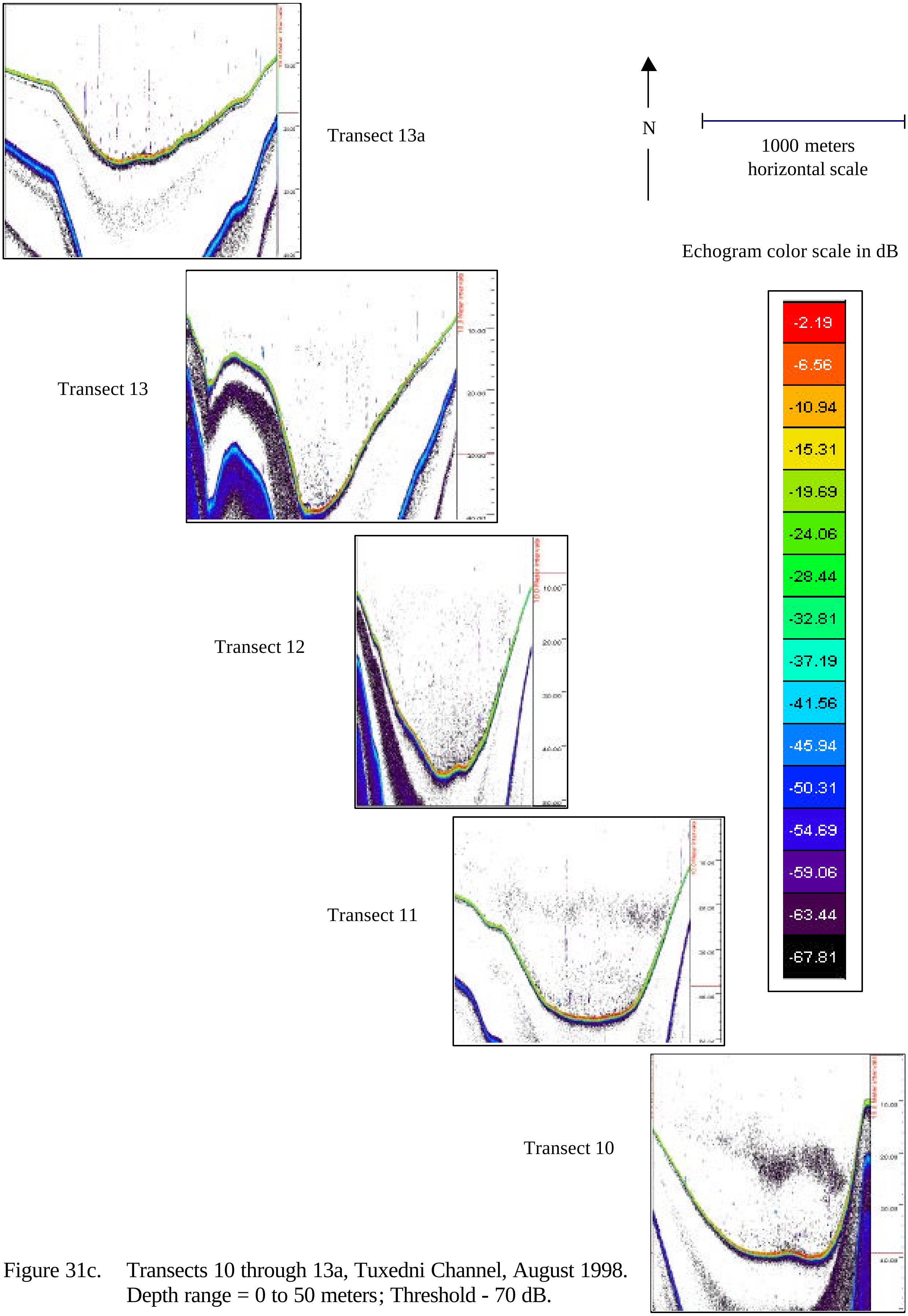


Figure 31c. Transects 10 through 13a, Tuxedni Channel, August 1998. Depth range = 0 to 50 meters; Threshold - 70 dB.

Figure 32. Echograms of organism schools or layers sampled by trawl at Chisik Island, August 1998. Summary data for enclosed areas are provided in Tables 14 and 15.

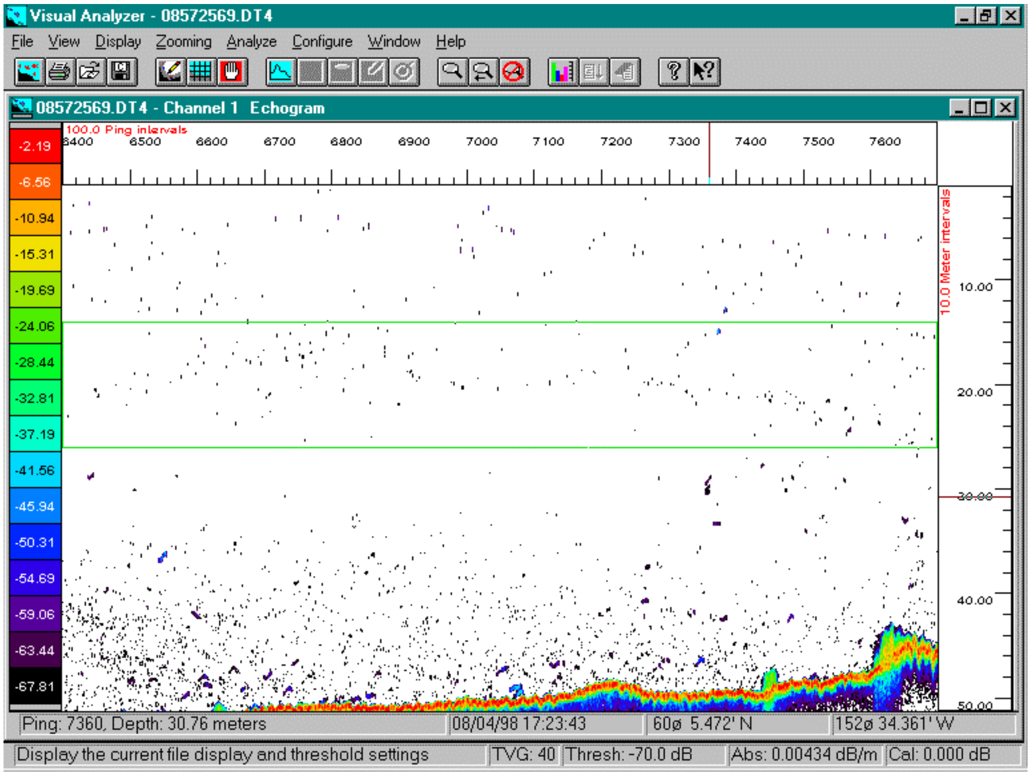


Figure 32a. Transect 2 haul 10, August 4, 1998.

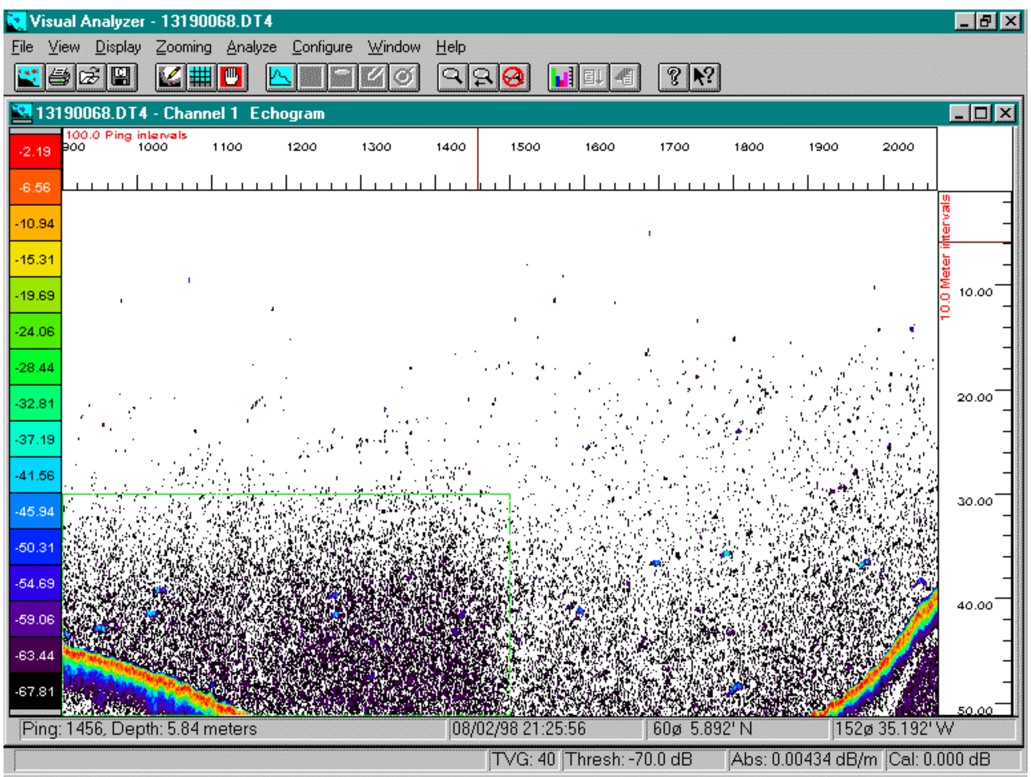


Figure 32b. Transect 3 haul 1, August 2, 1998.

Figure 32 continued

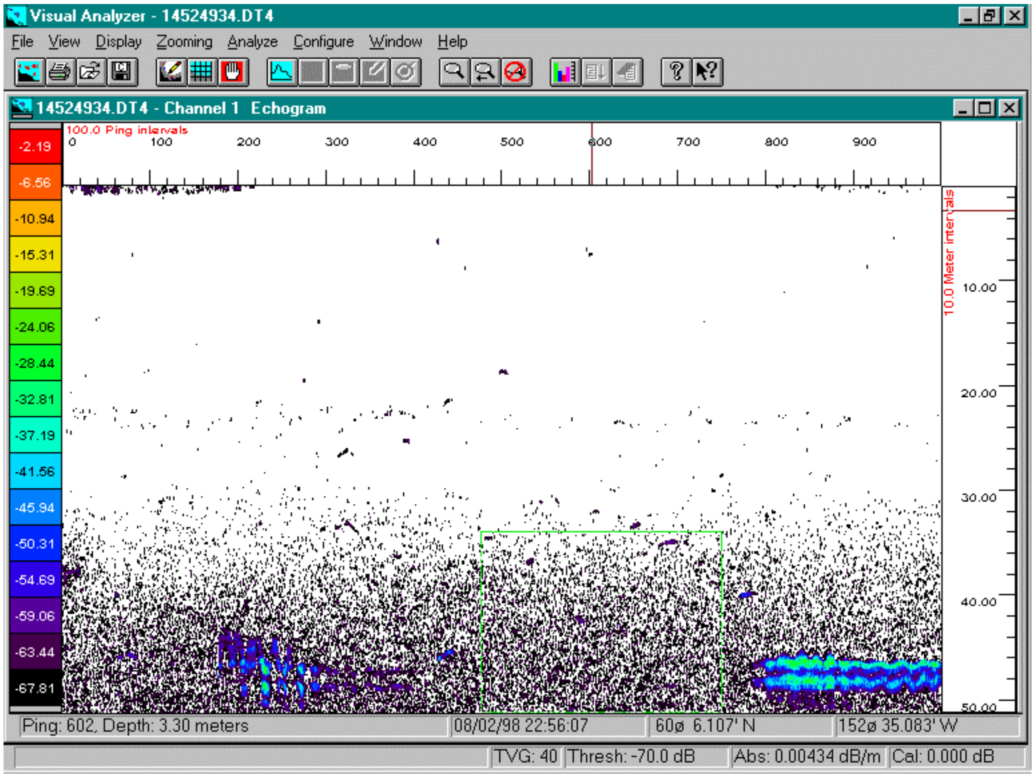


Figure 32c. Transect 3 haul 2, August 2, 1998.

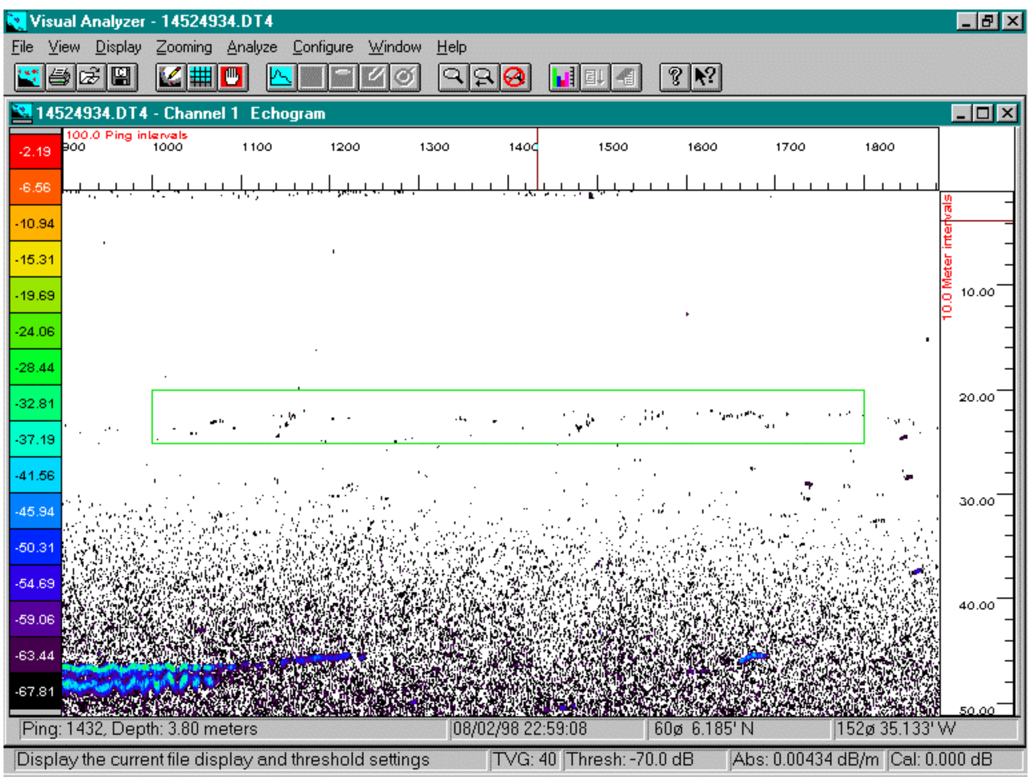


Figure 32d. Transect 3 haul 3, August 2, 1998.

Figure 32 continued

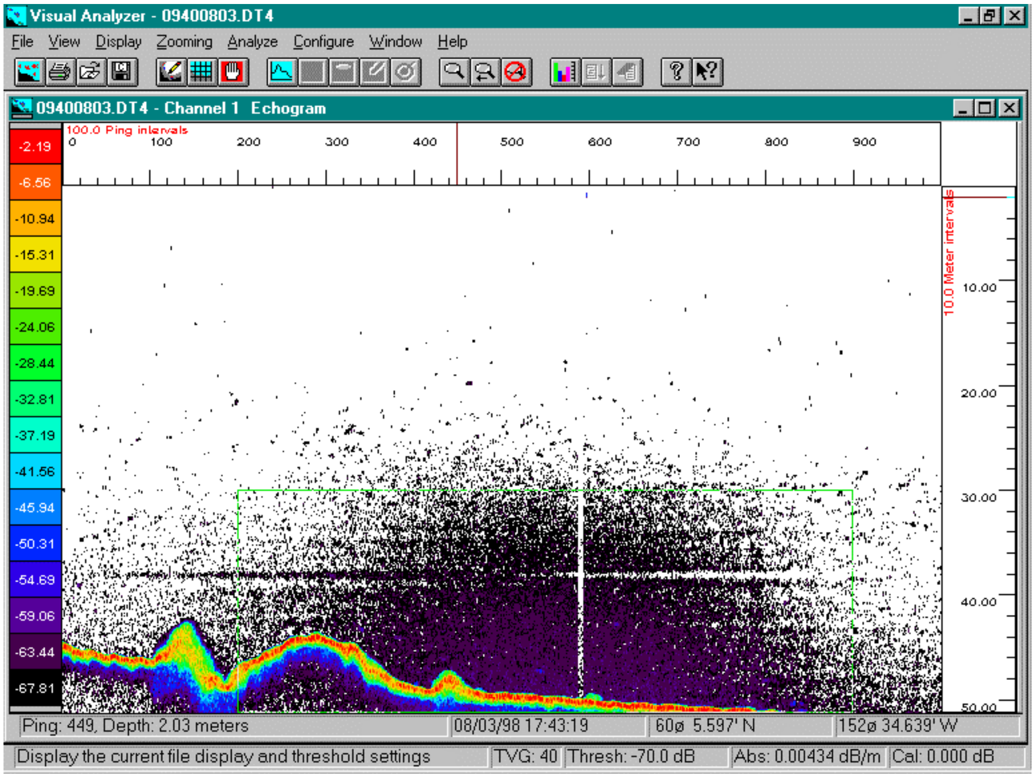


Figure 32e. Transect 3 haul 7, August 3, 1998.

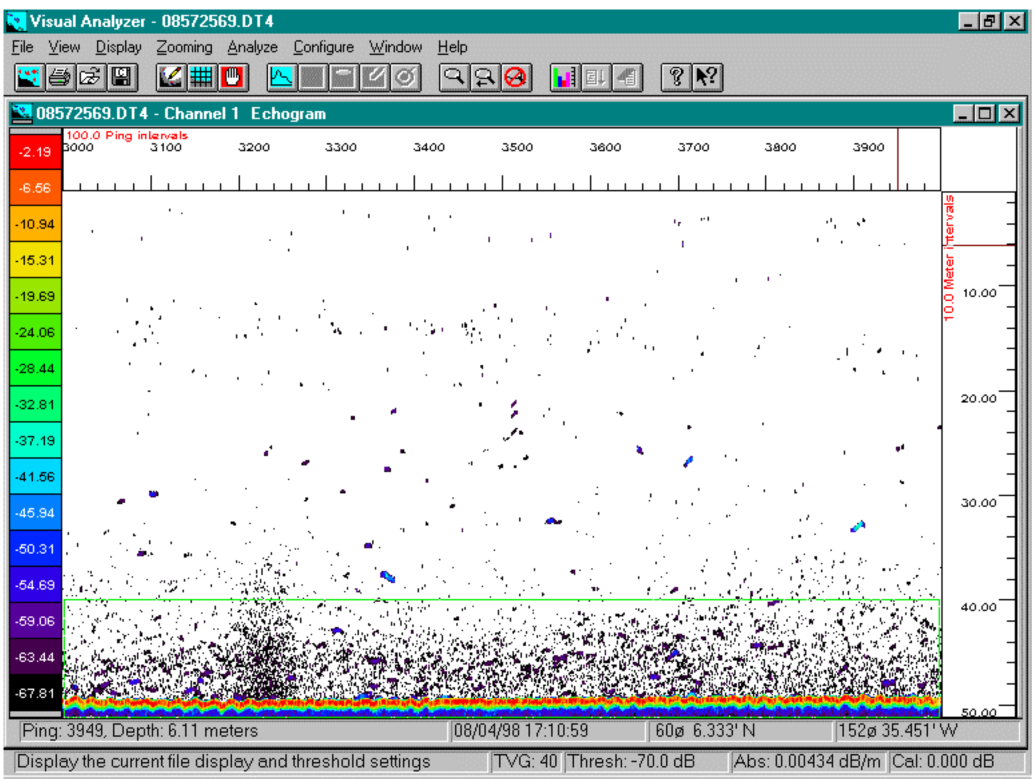


Figure 32f. Transect 4 haul 11, August 4, 1998.

Figure 32 continued

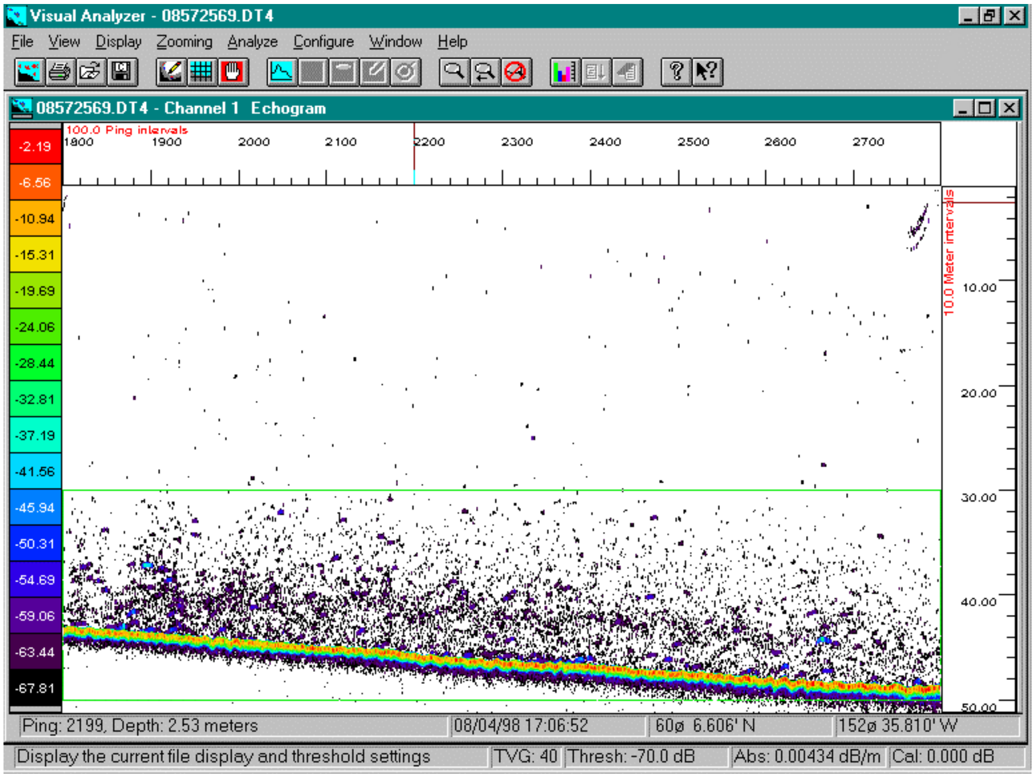


Figure 32g. Transect 5 hauls 8 & 9 (both on same layer), August 4, 1998.

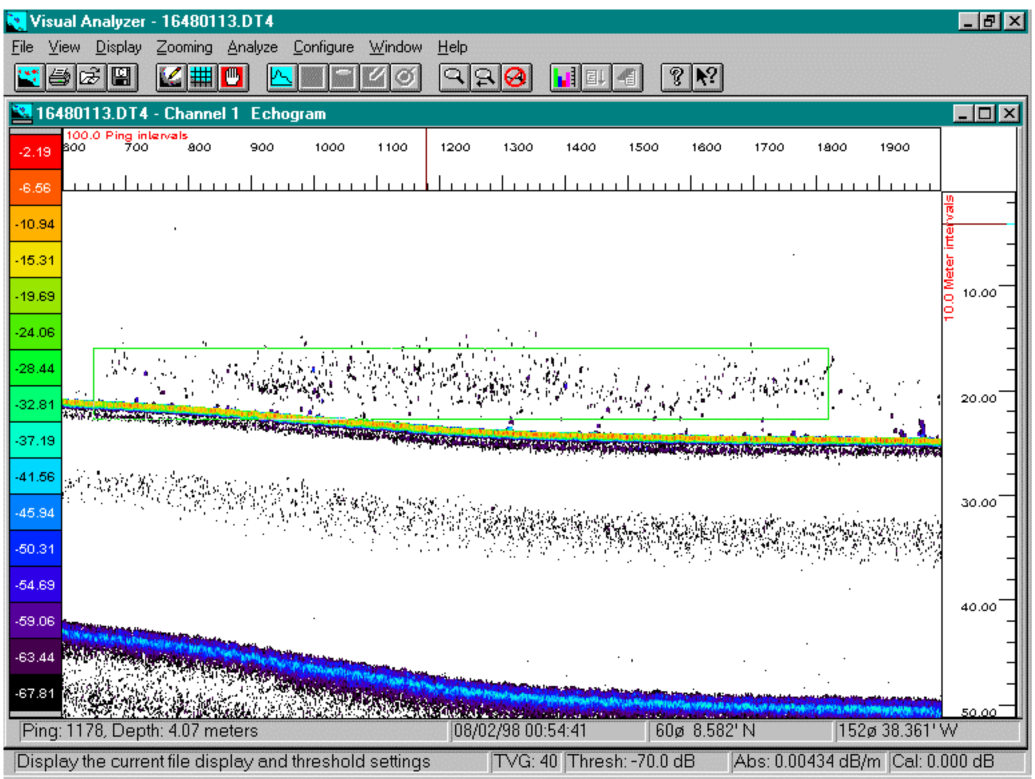


Figure 32h. Transect 8 haul 4, August 2, 1998.

Figure 32 continued

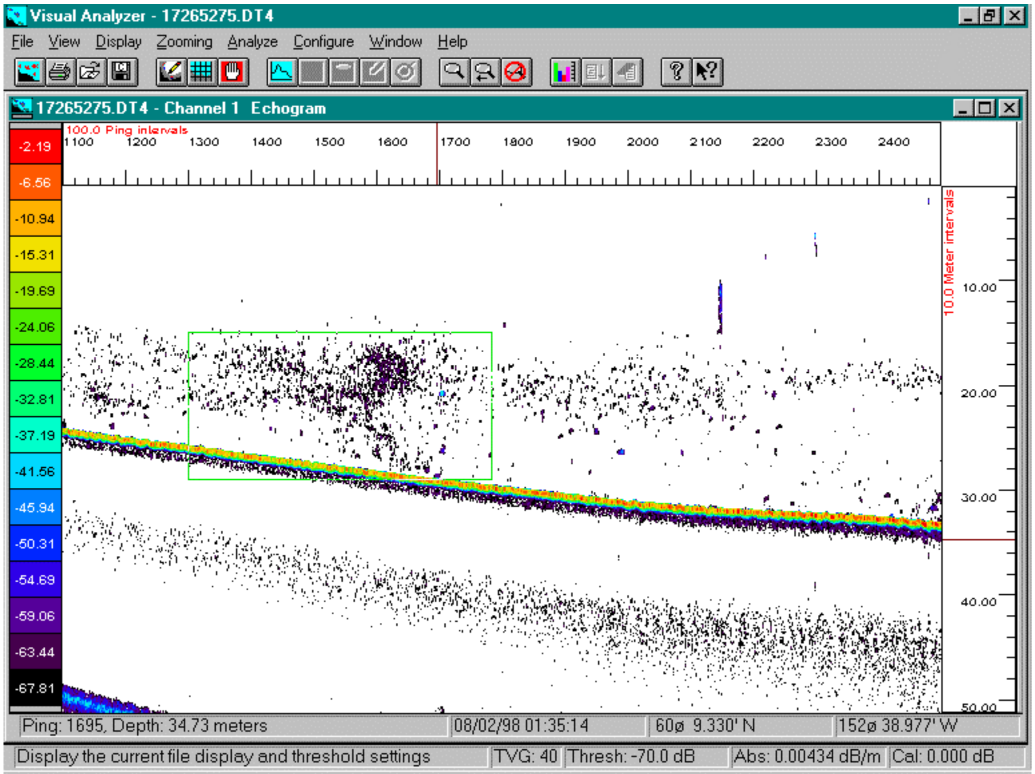


Figure 32i. Transect 9 haul 5, August 2, 1998.

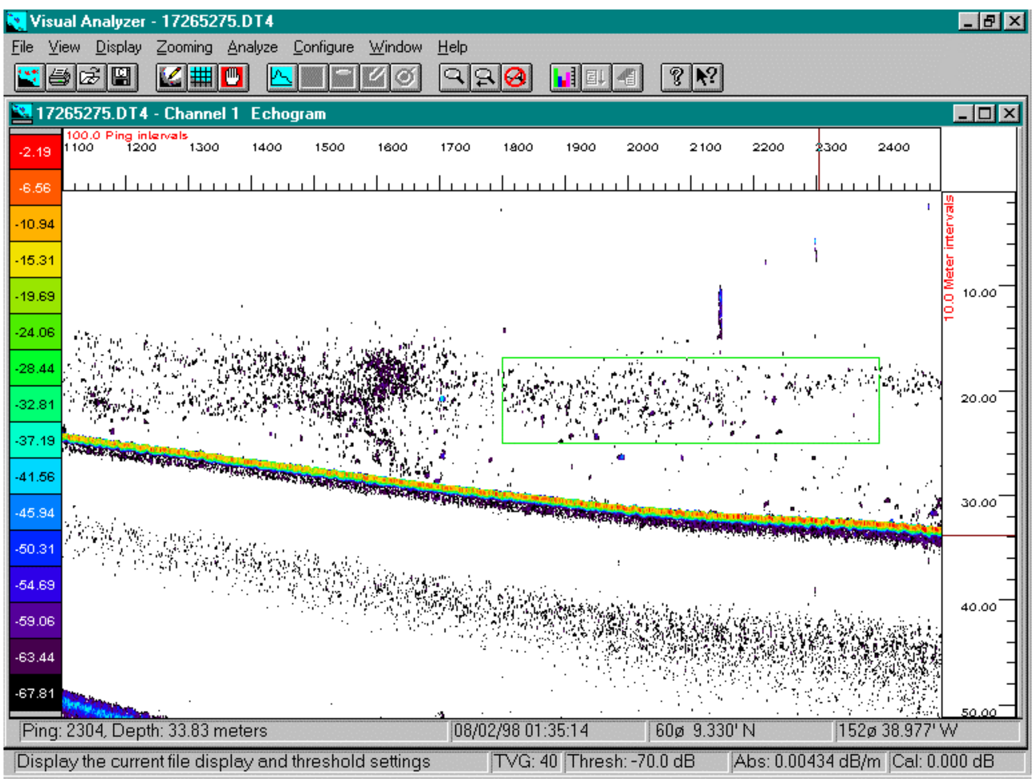


Figure 32j. Transect 9 haul 6, August 2, 1998.

19.5-45.6 m. Corresponding trawl hauls consistently captured a variety of smelt and shrimp (Table 15). All net hauls were between 20 and 50 m, and there were no obvious trends in species composition over this depth range. In nearshore layers, hydroacoustic estimates of total forage fish per layer and forage fish density varied from 0–675 kg and from 0.0-0.0026 g/m^3, respectively (Table 14).

A total of 26 layers and 83 schools of organisms were detected and measured hydroacoustically in August 1998. The two layers detected offshore from Chisik Island averaged over 6 km long (Table 16). In nearshore areas inside and outside Chisik Island, layers were shorter, averaging about 2 km long (length of nearshore layers was limited partly by transect length). Layer thickness ranged from 11-16 m. Schools (mean length 14-17 m, mean thickness 2.2-2.6 m) were much smaller than layers. School size, mid-point depth (18-23 m), and depth of water where schools occurred (23-3 1 m) were similar inside and outside of Chisik Island (Table 16).

4.4.5 Discussion

Of the three surveys conducted near Chisik Island in 1997 and 1998, forage fish abundance was by far the highest during the May 1998 survey. At that time dense schools were most numerous, acoustically measured forage fish densities in schools were highest, and trawl catches of forage species were largest on average. Acoustic measurements also indicated that schools were shallower (mean depth < 10 m) and larger (mean length up to 299 m) in May 1998 than in either August survey (mean depth typically > 15 m; mean length < 25 m). Many of the hydroacoustic patterns and associated catches in May 1998 can be attributed to the presence of eulachon and shrimp (Table 15). Among eulachon, adult spawners dominated catch along transects 1 and 5, juveniles along transects 7 (hauls 9 and 11) and 22, and both spawners and juveniles along Transect 4. Overall, shrimp accounted for about 85% of the total biomass. Shrimp constituted more than 90% of total catch in 8 of 13 hauls. Thus, only a small part of the hydroacoustic and trawl surveys of May 1998 were associated with herring, pollock, and sand lance.

Comparing the two August surveys, forage fish densities were higher and layers were more extensive in 1997 than in 1998.

In all surveys of the Chisik Island region, schools were more common nearshore than offshore, and were most numerous in Tuxedni Channel. Although individual species composition varied among surveys and hauls, forage fish and crustaceans predominated in trawl catches throughout surveys near Chisik Island. The most common forage fish species, by survey, were herring in August 1997, herring and eulachon in May 1998, and eulachon and other smelt in August 1998.

Some useful information was obtained in the July 1998 survey of Shelikof Strait despite severe restriction of sampling by poor weather. Few layers were seen in this area, but an appreciable number of small, dense schools were observed. Difficulty trawling in rough seas prevented determination of their species composition, however.

Several potential sources of error were encountered in the course of field work and data analysis. During analysis, individual layers and schools were often difficult to define and to measure accurately. Layers were frequently complex in shape and interconnected, making it difficult to determine on the echograms where one ended and ‘the next began. Also, the schools frequently extended out of the study area, so their spatial extent was only roughly described. Dense schools were more clearly defined on echograms and easier to measure than layers. Lengths of schools were easily obtained from measurements on regular transects, but measuring widths of observed schools proved difficult in practice. Many schools were small and probably highly mobile, so, when returning to a marked location to run a cross-transect, the chance of relocating a specific school was small. Because of this difficulty and sampling time constraints, few width measurements were obtained. The effectiveness of targeting the trawl on specific schools, as well as the trawl's efficiency in general, were also undoubtedly reduced by the small size and high mobility of schools. Recent surveys of forage fish in Prince William Sound (Haldorson et al. 1996) describe larger and more easily delineated fish schools than were observed near Chisik Island. Haldorson et al. (1996) were also better able to sample and identify school species makeup through use of an underwater video camera and a larger net than was available for this present study.

Acoustic measurement of density and abundance of fish in schools can be problematic because it is often difficult to obtain accurate species composition and target strength information for species apportionment and scaling of echo integration. This is especially true of highly mobile mixed species assemblages observed during daylight hours (N. Lemberg, Washington Department of Fish and Wildlife, pers. comm. 1999). Although the 2x2 m midwater trawl net used in this study captured fish over 20 cm in length, it was likely too small to avoid size selectivity, so we used *in situ* target strength measurements rather than target strength estimated from fish lengths to scale echo integration. *In situ* measurements usually provide accurate target strength estimates; however, their accuracy may be reduced with dense schools due to bias against small targets, inability to resolve usable single targets within dense schools and a resulting over-representation of unrepresentative targets outside schools, and extinction of energy through shading (MacLennan and Simmonds 1992; MacLennan and Menz 1996; Misund and Beltstad 1996). In mixed size and species aggregations, a wide variation in target strength among organisms in relation to their contribution to school biomass can lead to error in biomass estimates. Avoidance of the survey boat by shallow schools has also been observed in some instances (Misund and Beltstad 1996). Since we often encountered dense mixed species layers and schools, as was evident from trawl catches and echogram characteristics, all of these factors were likely at play to some extent. Still, the large changes in school size, density, and biomass observed between areas and seasons are undoubtedly valid indicators of major trends in the abundance and distribution of forage fish schools in lower Cook Inlet.

5.0 MONITORING CONSIDERATIONS

5.1 INTRODUCTION

One objective of this study was to recommend elements of an approach toward future monitoring forage fish populations in the Cook Inlet and Shelikof Strait region. The purpose and objectives of a monitoring program should be clearly defined, since sampling techniques and selection of specific parameter measurements may differ depending on objectives of the monitoring program.

Basic ecological understanding of the lower Cook Inlet and northern Shelikof Strait coastal marine environments should involve annual and seasonal sampling of habitat and forage fish populations. Sampling should be conducted during each season of the year to assess forage fish species composition and biological characteristics during periods of spawning, early life history, migration, and overwintering. To be most useful, monitoring should extend over multiple years (three or more) so that a time series of data is established from which interannual trends can be identified. Multi-year dynamics in forage fish species composition and biological characteristics of species is important in understanding the population dynamics of species of fish, birds, and marine mammals that may feed on forage fishes.

Monitoring should include sampling for forage fish species distribution and abundance in each of the major habitat types present in the region. These habitat types include bays and estuaries, river deltas, rocky shorelines, tidal flats, island groups, and sand and gravel beaches.

5.2 SAMPLING AREAS

Two regions in lower Cook Inlet/Shelikof Strait were sampled during this study: Chisik Island and northwestern Shelikof Strait. Future monitoring in this region is recommended in these two areas using small vessels to conduct systematic hydroacoustic surveys for forage fish schools followed by targeted midwater trawling of fish schools located with the hydroacoustics equipment. Nearshore zigzag sampling patterns are recommended for hydroacoustic searching and trawl sampling. Additional beach seining in these areas may be necessary to supplement the numbers of fish collected during the trawling efforts to ensure sufficient numbers for tissue analyses or meristic measurements.

During this study, multiple sampling efforts were conducted near Chisik Island, and as a consequence more experience in this area was obtained. Continued monitoring in these areas will likely be most successful in Tuxedni Channel and near the shore of Chisik Island from Duck Island south to the Tuxedni Channel entrance. The nearshore waters in these areas were most productive of forage fish, and offshore areas extending into Cook Inlet were not. Monitoring should focus on the protected waters of Tuxedni Channel from the entrance northward to the end of Chisik Island and the Fossil Point area. Shallow water will preclude sampling from small vessels in Tuxedni Bay, although some sampling can be conducted in the gut of the bay to the northwest of the end of Chisik Island.

A single sampling effort was conducted in Shelikof Strait, and a few embayments were surveyed for forage fish schools-Kukak Bay, Hallo Bay and Swikshak Bay. Of these areas, Hallo Bay and Swikshak Bay were most productive of forage fish, and future monitoring is recommended in both of these locations. Additional sampling in the Shelikof Strait region is recommended. The nearshore areas will likely be most productive of forage fish, as offshore surveys, although limited, were not productive. Future monitoring is recommended in the coastal bight north of Kiukpalik Island, the coastal areas west and north of Douglas Reef, around the islets and submerged reefs of Douglas Reef, and the small embayments south and north of Cape Douglas.

Sampling in Shelikof Strait will be more difficult given its greater distance from coastal ports and the limited number of refuge areas for small vessels. Poor weather in the area also will be a factor in determining the success of future sampling in Shelikof Strait.

5.3 TIME SERIES OF BIOLOGICAL DATA

A time series of seasonal and geographic data on forage fish populations should consider the following parameters:

- length and weight
- species composition
- age and growth
- condition (proximate body composition and length/weight relationships)
- movements patterns
- hydrography (temperature and salinity, by depth)

Length and weight data are the basic measurements that are fundamental to understanding fish population structure. These measurements provide the basis for determining patterns in growth, production, and population health. Length (fork) and wet weight data should be collected from a minimum of 25-50 fish per species group. Where multiple size classes are present, 25-50 fish per size group will provide statistically robust data sets.

53.1 Species Composition

Composition of fish inhabiting a sampling area may vary with season. Each species collected should be verified with a key and/or by confirmation through consultations with known expert taxonomists or scientists familiar with the fauna in the study region. Voucher specimens should be retained for later species identification and for examination by others; adult and juvenile stages should be retained.

5.3.2 Age

Age should be determined for each species group from 25-50 individuals. Where multiple age (size) classes are present, 25-50 fish per size group will provide statistically valid sample sets for age analysis and comparison among age classes and among species groups. Age analysis employing microscopic examination of otoliths is recommended. The break and burn technique for highlighting growth rings is recommended (see the Methods section of this report). Otoliths from a known age group of fish (e.g., young-of-the-year) may be required for confirmation of the otolith centrum and the pattern of calcification in subsequent years.

53.3 Growth

Fish growth may be determined from length or weight data. Generally, 25-50 fish per size group should be measured for length (fork length is the common parameter) and wet weight. Techniques for measuring length and weight are discussed in the Methods section of this report.

53.4 Condition

Length/weight relationships provide a measure of fish condition. Proximate body composition data also provide insights into fish condition. This regression can be calculated from the length and weight data described above and in the Methods section of this report. See Section 5.5 below.

5.3.5 Movement Patterns

Mark/recapture studies, radio tracking, and visual observation can assess fish movement patterns. Although not monitored during this study, future monitoring in the Cook Inlet/Shelikof Strait region might consider studies of the seasonal movement patterns of forage fish schools to determine the habitats used by these species, and the degree of overlap among species using the general study area. However, these studies can be time consuming, logistically difficult, and expensive to conduct. Given the large numbers of forage fish likely present in the study area, marking a sufficient number of fish to document movement patterns may not be feasible. The appropriate number of marks placed in the population will require experimentation. It is likely that mass marking using thermal marks of juveniles or other mass marking techniques could be successful.

5.3.6 Hydrography

Temperature and salinity characteristics of the waters of this region are important hydrographic monitoring parameters. T/S vertical profiles should be monitored at multiple geographic locations (e.g., start and end of transects) during each sampling effort in each study area sampled. Continuous vertical profiles of T/S can be gathered using a Seabird, Hydrolab, or comparable oceanographic sampling instrument. Data can be downloaded into computer tiles in the field and therefore are readily available for analysis in the office.

The time series of data described above should extend for a minimum of three years to capture interannual variability and to permit statistical assessment of trends in these parameters.

Annual syntheses of these data should focus on understanding ecological processes in the Cook Inlet and Shelikof Strait regions, including predator-prey dynamics between forage fish populations and adjacent populations of seabirds, marine mammals, salmon, and groundfish.

5.4 CONTAMINANT EXPOSURE USING THE P450 RGS ASSAY

The analyses of tissue samples from several species of fish from both Cook Inlet and Shelikof Strait indicated that two of the species, surf smelt and sand lance (from the Chisik Island/Tuxedni Channel area), contained higher amounts of the chemicals detected by this assay (high molecular weight PAHs, coplanar PCBs, dioxins/furans). This would indicate that fish containing these higher levels of inducing compounds would also have higher levels of P450 in their livers. From the RGS results, the types of contaminants inducing the assay response cannot be determined. Even if the chemicals producing the RGS responses are PAHs, the source of these compounds could be natural seeps, vessel leakage or small spills, as well as oil and gas operations.

To identify the types of inducing compounds found to be somewhat higher in the tissues of surf smelt and sand lance, a tiered approach should be used. The extracts of those samples that indicate higher levels of contamination can be further analyzed by GC/MS to determine if PAHs or coplanar PCBs are present. If both of these types of compounds are absent, then dioxins and furans would be suspected, and would require a separate sub-sample for confiiation. Once the type of chemical contamination is identified, the sources and pathways, and potential effects, can be investigated.

Since only two species were found to exhibit potential elevated tissue levels of PAH or related contaminants, further monitoring of these species may be warranted. Other sites in the lower Cook Inlet region could be sampled, and additional samples could be obtained from the Fossil Point area in Tuxedni Channel to confirm the P450 assay results obtained in this study. If found again at this site, further investigation of the characteristics of this location may be warranted, including potential sources of contaminants from adjacent beach or upland areas. A minimum of 10 fish per species should be collected from each site monitored for further tissue contaminants testing.

Zooplankton sampling also should be conducted seasonally in these same areas to assess the food base upon which forage fish are feeding. Data which describe the relative abundance and species composition of zooplankton in these habitats would enable assessment of whether the diet of forage fish is due to prey availability or targeted prey selection.

5.5 PROXIMATE ANALYSIS

Analysis of lipid, water, protein, and ash content-proximate body composition— of forage fish species is useful in determining fish condition. Seasonal and interannual comparisons over multiple sequential years should be considered, as condition in a single season or year is not sufficient for understanding the dynamics of fish condition in a region. With seasonal and interannual data over time, lipid/water ratios can help provide understanding of environmental conditions that contribute to overall fish health (prey availability, predation pressures, etc.). Lipid reserves are important indicators of a fish's ability to overwinter, and may give clues to overwintering success. Proximate body composition data also may be useful to other researchers working on the population dynamics and body condition of forage fish predatory species (marine mammals, sea birds, other fishes).

5.6 DIET COMPOSITION

Diet studies of forage fish species can identify principal dietary components, degree of stomach fullness, and the diversity of prey used by fish in a given season or study area. This work is usually time consuming (sorting and identifying stomach contents) and potentially costly.

Diet information is useful in interpreting proximate body composition data. For example, changes in lipid levels or fluctuations in growth rates and length/weight relationships may be better explained with diet composition data.

Stomach content analyses should be conducted on specimens of forage fish collected in each study area, and on a seasonal basis. Fish from which stomachs are taken can be used for other tests such as for proximate analysis. Twenty-five fish per size group from each species should be sampled.

5.7 SAMPLING METHODOLOGIES

The techniques used in this study to locate and capture forage fish included hydroacoustics to locate and measure forage fish schools, accompanied by midwater trawling to identify species and biological characteristics of fish inhabiting these schools. In the Cook Inlet and Shelikof Strait study areas, this study determined that forage fish schools primarily were located in nearshore and inshore areas; none were offshore (l-5 km offshore). Use of the paired hydroacoustics and midwater trawling technique may be limited by size of towing vessel and size of the midwater trawl. Consideration should be given to net avoidance by larger fish species.

A larger trawl will require more vessel horsepower to fish the net at a recommended 3-5 knot towing speed. A modified herring trawl fitted with the size of net mesh used in this study may require a 50-70 ft towing vessel, but this combination of large net and vessel would reduce net avoidance and increase the number of specimens collected from fish schools. Cost constraints may preclude such large vessels, however. In such a case, the smaller vessel towing a 6-ft IICMT, as used in this study, may still successfully sample forage fish schools, The trawl towing vessel should, at a minimum, be equipped with a line winch for towing the trawl, line meter, and a wire angle indicator to accurately fish the net at a predetermined depth. GPS and associated navigation software are required for accurate trawl positioning.

In addition to sampling with trawls, beach seine sampling can be used successfully to acquire fish for meristic measurements or laboratory tests. Although not necessarily targeted on schools of fish, beach seining may be more successful in collecting the numbers of fish needed for measurements or other tests. Fish schools may seasonally concentrate along the shoreline where capture with beach seines is fairly easy.

5.8 STATISTICAL CONCERNS

The question of statistical sensitivity and protocol with regard to the monitoring forage fish populations in lower Cook Inlet and Shelikof Strait contains an inherently high degree of potential variability. One factor that cannot be specifically determined by *a priori* is the catch rates of the important species and cohorts that will be encountered during the monitoring surveys. Technically, adequate sample size cannot be quantitatively estimated until the experimenter first defines the level of difference that is considered to be "biologically meaningful." As an example, Krebs (1989) considers sampling the size of fish taken from two different lakes. If detecting a difference of 8 mm or more in mean length is the criterion for a meaningful disparity, then one merely assumes a parametric distribution, a type I error significance level of a = 0.05, a type II error significance level of β = 0.05, and then looks up the sample size in a table compiled by Davies (1956) based upon the standard deviation of the variable being measured based upon previous studies. If the meaningful differential is only 6 mm, then the required sample size will increase. In general, detecting a significant difference of 0.5 standard deviations of the underlying population at the above $\propto$ and β levels requires a sample size of n = 54; a difference of 1 standard deviation is n = 16 (Davies 1956). In terms of practical field effort, sample sizes of 25-50 should be the adequate sample sizes for statistical comparisons at the 95% CI. If, however, budgetary constraints limit the number of total samples, the decision must then be made as to the most effective subdivision of that sampling allotment.

Before any definitive statistical protocol can be established, the scope and budgetary issues must first be resolved. Second, a hierarchy must also be determined within those budgetary guidelines that will prioritize the issues, species, and cohorts of major importance.

6.0 SUMMARY AND CONCLUSIONS

The 1997- 1998 Forage Fish Study was conducted as a series of synoptic surveys of limited field duration. The objectives of the study were to develop 'a database describing the seasonal abundance, biological characteristics, contaminant exposure, and ecological importance of forage fish and to recommend parameters and methodologies for future fisheries monitoring in this region. The following are some of the more pertinent findings of the 1997-1998 Cook Inlet/Shelikof Strait Forage Fish Study.

- A total of 65,102 fish representing 26 species, 13 families, and 7 orders were collected during the 1997-1998 survey. Forage fish species consisted of Pacific herring (N= 62,610), Pacific sand lance (N= 114), walleye pollock (N= 14), eulachon (N = 402), surf smelt (N = 171), and longfin smelt (N = 99). Ninety percent of the total catch was age-O+ Pacific herring collected in a single seine haul at Ninagiak Island on 27 July 1998.

- Age-l+ Pacific herring collected at Chisik Island in May 1998 were, on average, 25-30 mm smaller than age-O+ herring collected from several sites in Prince William Sound (PWS) in May 1996. Age-O+ herring collected at Chisik Island in summer 1997 and at Ninagiak Island in summer 1998 were significantly smaller than herring collected at several sites in PWS in summer 1996 and in the Barren Islands/Kachemak Bay area in summer 1998. While a year-effect (i.e., higher productivity in 1996) is a distinct possibility, the smaller sizes of juvenile herring (based upon measurements made at comparable times of the year) at Chisik Island could reflect lower productivity associated with the generally warmer and less saline conditions that prevail around Chisik Island relative to colder, more marine upwelling areas in PWS and the Barren Islands/Kachemak Bay region.

- Over equivalent length ranges (71-89 mm) for herring collected in the month of May, there was no difference in the condition of fish from Chisik Island in 1997, Whale Bay (PWS) in 1996 and Eaglek Bay (PWS) in 1996. The PWS herring are subsets of the age-l+ fish discussed above that were, as age groups, larger than Chisik Island herring. If the subset comparisons were in any way indicative of the PWS age cohorts, it would suggest that while herring at Chisik Island in the month of May were significantly smaller than May fish in PWS, they were not in poorer condition.

- Spawning eulachon (200-235 mm) were collected at Chisik Island in May 1998. Likely, young-of-the-year (19-32 mm) of that spawning group were collected three months later in August 1998.

- There was a high degree of dietary overlap ***(D = 0.967)*** between herring and surf smelt collected during August 1997 at Chisik Island. Their diets consisted primarily of the copepodite ***stage*** of ***Eurytemora*** sp. harpacticoid copepods and barnacle larvae. There were indications of prey partitioning among herring: ***Eurytemora*** sp. eaten by fish collected in mid channel were substantially larger than in fish collected in nearshore seines. Smaller prey taken from herring nearshore probably reflects encounters with recent copepod blooms.

- The diet of walleye pollock collected during the May 1998 survey at Chisik Island was quite different ***(D*** < 0.167) from that of herring, sand lance, eulachon, and surf smelt. Pollock appear to feed demersally, with polychaetes and *Byblis* sp. amphipoda comprising 76% of their diet. The highest degree of dietary overlap was between sand lance and eulachon ***(D***= 0.423), largely due to the co-occurrence of barnacle nauplii and Crangonidae zoea. The remaining dietary overlaps among' herring, sand lance, eulachon, and surf smelt were weak to moderate with *D* values ranging from 0.117 to 0.398. Dominant prey items were barnacle nauplii, Crangonidae zoea, Phyllodocidae polychaetes, harpacticoid copepods, and barnacle cyprids.

- Different feeding regimes (*D* = 0.329) were observed between different size classes of sand lance collected in consecutive seine hauls at Fossil Point near Chisik Island during May 1998. Larger fish (mean length = 109 mm) consumed a more diverse spectrum of prey with 6 taxa contributing > 6% to overall diet and harpacticoid copepods representing 5%. In contrast, smaller fish (mean length = 72 mm) relied primarily on harpacticoid copepods (72%), barnacle nauplii (12%), and Crangonidae zoea (8%).

- Much of the dissimilarity in feeding habits of herring, pollock, and sand lance at Chisik Island in May 1998 may be attributable to the dietary absence of calanoid copepods. Calanoids are a major component in the diets of these three species in Prince William Sound and other areas in Cook Inlet, and both pollock and herring exhibit a specific preference for ***Pseudocalanus*** sp. The dietary absence of calanoids suggests low abundances of these organisms in the Chisik Island area, at least within the short time frame in which sampling was conducted during this study. Calanoid copepods were also absent in the diets of herring collected at Chisik Island in August 1997 and Ninagiak Island in July 1998. It is unknown whether the absence of calanoids merely represents brief fluctuations in abundance or a longer term regional trend in low absence of this prey group for the Chisik Island and western Shelikof Strait areas. If the latter is true, then Chisik Island may be an inherently poor feeding area for forage fish.

- Proximate analysis indicated that lipid content for eulachon, tomcod, and pollock are generally consistent with results obtained in PWS and other areas in lower

Cook Inlet. Eulachon tend to have the highest lipid content of any of the forage fishes, while the gadids tomcod and pollock tend to have the lowest. Lipid content of Pacific herring increased with age in a fashion consistent with trends reported for herring collected in PWS during summer. Percent lipid content within each age class was also consistent with PWS data.

- The percent lipid content for age-l + and age-2+ herring collected at Chisik Island in May 1998 was substantially lower than that reported for similar aged fish collected during summer at Chisik Island, Ninagiak Island, and PWS. The percent lipid content for age-l+ sand lance collected at Chisik Island in May 1998 was substantially lower than that reported for age-l+ sand lance collected during summer in PWS. In both cases, the lower lipid content in May compared to summer most likely reflects the depletion of lipid reserves during the preceding winter as opposed to a regional trend indicative of poor forage fish health.

- Results of the limited Cytochrome P450 analyses indicated that activity levels were low (< 0.95 μg B[a]PEq/g) for all fish collected at Chisik Island in August 1997 and Ninagiak Island in July 1998. The highest P450 RGS responses were associated with sand lance (2.46 and 3.57 μg B[a]PEq/g) and surf smelt (0.82-2.44 μg B[a]PEq/g) collected at Chisik Island in May 1998. Even these highest values are not alarming but do suggest that these two taxa may represent good indicator species for potential hydrocarbon contamination. Whether the higher concentrations at Chisik Island in May 1998 represented localized exposure to contamination or merely the immigration of fish from other areas of exposure is uncertain.

- Forage fish schools were present near Chisik Island during all surveys, but few distinct schools were observed in Shelikof Strait. Midwater trawl confirmation of schools detected by hydroacoustics was conducted in all study areas, but forage fish schools were only located at Chisik Island. Schools near Chisik Island were most abundant in Tuxedni Channel or near the island's western shore; only one forage fish school was located offshore.

- Forage fish schools were most abundant at Chisik Island in spring (May) versus summer (August). During spring, forage fish school density was greater, schools were shallower and larger, and school composition was primarily crustacean (Crangonid and Pandalid Shrimp), with eulachon and herring the most prevalent forage fish species present.

- During the summer period at Chisik Island, forage fish schools were deeper and smaller, density was lower, and composition was primarily herring in 1997 and eulachon and longfin smelt in 1998.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places: and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS). collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the Offshore Minerals Management Program administers the OC competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS Royalty Management Program meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.