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Title: Seasonal Distribution and Environment of Adult Pacific Herring (*Clupea harengus pallasi*) Near Auke Bay, Lynn Canal, Southeastern Alaska.

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The distribution of adult Pacific herring (*Clupea harengus pallasi*) near Auke Bay, Lynn Canal, southeastern Alaska, varied by depth and geographic area over 24 successive months during 1973-75. From June through September, schools concentrated at 5- to 37-m depths where zooplankton was abundant, and moderate currents were present in a stratified water column. The schools migrated from this area to wintering grounds in October when windstorms and sinking of cooling surface waters broke up stratification, day length shortened, and food abundance declined drastically. The schools remained near bottom in the deeper parts of the wintering grounds at 52- to 85-m depths into February or March when day length had increased, but temperatures and food abundance remained low. At this time, the herring left the wintering grounds and moved up Lynn Canal to areas near spawning beaches. Pacific herring remained in these areas until water temperatures increased and plankton blooms appeared in late April and May, at which time the fish moved into the shallows and spawned. By early summer, the schools gradually concentrated again on the main feeding grounds. An evaluation of the study design and potential for improvements in similar studies is included.

Seasonal Distribution and Environment of Adult Pacific Herring (*Clupea harengus pallasi*) Near Auke Bay, Lynn Canal, Southeastern Alaska

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX TABLES

Seasonal Distribution and Environment of Adult Pacific Herring, (*Clupea harengus pallasi*) Near Auke Bay, Lynn Canal, Southeastern Alaska

INTRODUCTION

General background and rationale

Herring, *Clupea harengus*, have supported vast fisheries in northern seas for centuries. Observations documenting their migrations, population dynamics, and biology are extensive, but almost none concern year-round distributions of a specific stock and its associated environmental variates. Off the Newfoundland coast, schools of Atlantic herring (*C. harengus harengus*) spend the summer feeding in the Gulf of St. Lawrence and migrate to fiords in late fall to overwinter (Winters 1976). Pacific herring (*C. harengus pallasi*) leave open coastal waters of British Columbia and move inshore in the fall to overwinter, schooled together above the bottom (Outram 1965).

Research on herring in Alaska has historically focused on stock separation and basic biology (Carlson 1980a). Stocks or populations of Pacific herring in southeastern Alaska have historically been defined by various means, including spatial-temporal distribution, behavioral, and biological characteristics. Five major stocks are presently identified by their concentration on certain wintering grounds: (1) Sitka, (2) Auke Bay, (3) Craig-Hydaburg, (4) Deer Island-Etolin Island (near Wrangell), and (5) Ketchikan stocks. Biomass estimates consistently exceeded 2.27 million kg (the minimum level for classification as a major stock) in each of these locales during the winters of 1971-79 (Dennis Blankenbeckler, Alaska Department of Fish and Game, Ketchikan, Alaska, personal communication).

In the early 1930's, the Pacific herring at Sitka, Craig, and Auke Bay were identified as separate major stocks by spawning and feeding locales, vertebral counts, growth rates, and tagging work (Rounsefell and Dahlgren 1935). Later tagging studies showed that the Sitka and Craig spawning stocks migrate and intermingle in summer feeding areas (Skud 1963) and that the Auke Bay and Ketchikan stocks do not intermingle with the others (Dahlgren 1936; Carlson 1977).

Although Rounsefell and Dahlgren (1935) described summer "feeding grounds" and spring "spawning grounds" of herring in the vicinity of Auke Bay, they apparently knew little about the winter distribution of the fish or the associated physical and biological factors at any season. In this paper, I describe the year-round distribution of adult Pacific herring in Auke Bay-Lynn Canal and environmental factors associated with month-to-month changes in vertical and horizontal distribution of the fish. The definition of the problem and the design of the study were based on known elements in the distribution of herring near Auke Bay and elsewhere in southeastern Alaska.

Major portions of this thesis were prepublished (Carlson 1980b) with the permission of the Graduate School, Oregon State University.

Statement of the problem

In the late 1960's, a new fishery on Pacific herring began in southeastern Alaska. The fishery targeted on ripe adult herring immediately prior to spawning and produced roe (eggs) for a specialty export market in Japan. Exploitation of the Auke Bay-Lynn Canal spawning stock in a roe fishery renewed an old controversy over the best use of the herring resource. Much public sentiment was in favor of having no commercial herring fishery and simply allowing the resource to be utilized as forage for salmon (*Oncorhynchus* spp.), halibut (*Hippoglossus stenolepis*), and other fishes.

Fishery managers, sport and commercial fishermen, the fishing industry, and citizens and politicians were involved in conflict due in part to lack of knowledge about the Auke Bay-Lynn Canal herring; the year-round distribution and seasonal movements of the fish were largely unknown. Also unknown was whether the Auke Bay-Lynn Canal herring represented a single stock or several stocks for management purposes. If more than one stock were involved, perhaps the herring could support more than one type of usage, or so the argument went. Because of the interest and controversy, I designed a research program that would resolve these questions.

The primary justification of the study was, of course, economic. Herring are important to commercial fisheries all over the northern hemisphere from the standpoint of food, bait, and forage for other fishes. Our lack of knowledge on the Auke Bay-Lynn Canal herring hindered their management and posed problems for harvest strategies. In addition, the study was expected to provide additional knowledge of the general biology of the herring and of the seasonal behavior of the species.

Design of the research

In developing a research plan, I first reviewed what was known about the Auke Bay-Lynn Canal herring: (1) Observations by sport and commercial fishermen identified several points of concentration where herring schools were often found during the warmer months. (2) Records of herring spawning activity in the area were well documented and complete for several decades (Skud 1959) up to 1983 (Joseph Muir, Alaska Department of Fish and Game, Juneau, Alaska, personal communication, March 1984). (3) Schools were known to migrate to near-surface waters during darkness and down again at dawn during warmer months. (4) Adult and immature herring formed separate schools and rarely intermingled.

I knew from firsthand experience during the reduction fishery of the early 1960's that there were herring concentrations during summer months in nearby Icy Strait, and a sizable contingent of herring that spawned in nearby Seymour Canal, but did not know if Auke Bay-Lynn Canal herring intermingled with the others. Tagging studies in the 1930's (Dahlgren 1936; Skud 1963) and early 1960's (Carlson 1977) provided evidence that the Auke Bay-Lynn Canal spawners did not migrate to join the Sitka and Craig spawners that were the mainstay of the summer reduction fishery at Cape Ommaney and lower Chatham Strait.

I believed that some of the herring overwintered in Auke Bay but did not know if all or most did, nor did I know how consistent their behavior and distribution were from year to year.

There was a widely held idea among the local residents that a "run" of herring suddenly materialized from the depths of the open ocean each spring to spawn and feed near Auke Bay through the summer, returning to this oceanic retreat every winter, thus totally disappearing from the Auke Bay-Lynn Canal vicinity during this time. The only argument I have heard in support of this idea was, "If we don't know where the herring are in winter, they must be out deep in the ocean somewhere." This idea has been perpetuated by subsequent referrals to it as an established "fact" in local news media, magazine articles, etc., despite a total lack of supporting evidence.

In determining the spatial and temporal distribution of the Auke Bay-Lynn Canal herring, I utilized several approaches for testing the integrity of this group of fish. One of the prime questions was whether or not the Auke Bay-Lynn Canal herring were a single stock. Central to this question was the basis for defining what constitutes a "stock", because a stock is whatever anyone wishes to define it as--the term has been so overused that it lacks a unique meaning in fishery science.

Because spawning groups of herring utilize more or less the same spawning ground on a more-or-less consistent basis from year to year, many "stocks" have been defined as spawning stocks (Rounsefell 1930), others as migratory stocks appearing along the same stretch of coastline at a particular time of year, e.g. the Buchan (North Sea) stock (Parrish and Craig 1963), and still others on a morphologicalbehavioral basis such as the White Sea herring stock (Anokhina 1963).

My definition of "stock" as applied to the Auke Bay-Lynn Canal herring is a group of herring that maintain their identity by utilizing certain spawning and wintering grounds within the same geographic area from year to year and have negligible exchange with other similarly defined stocks.

Hypotheses

For my purposes, I wished to test the hypothesis that the herring that spawned near Auke Bay constituted one stock that fed nearby in summer and overwintered in the area.

If true, the hypothesis of a single, year-round nonmigratory stock would have significant fishery management applications. They include: (1) No "outside" groups of fish would influence apparent abundance of the stock prior to or following the fishery. (2) The spring spawners would be the only group contributing progeny and influencing population dynamics. (3) Biomass estimates of the entire population could be made when schools were aggregated in a relatively confined wintering grounds, and movements were minimal.

A second hypothesis was that individual schools might be distinctive enough to be identified by a set of morphometric and/or meristic characters such as body size or age composition. If true, it could allow following specific aggregations through the course of seasons and defining more precisely the makeup of the stock by its individual components (the schools).

I further hypothesized that a behavioral model of herring schooling could be constructed and used to predict movement and activities of the herring and to relate these to environmental factors.

In addition, I expected our efforts to identify patterns in environmental change and expected that these patterns would be correlated to herring behavior--general activity and movements from month to month if not day to day, and through darkness and daylight. In summary, objectives of the study were (1) To determine whether the herring that spawned near Auke Bay were a single stock that fed nearby in summer and overwintered in the area, (2) To determine whether the herring schools were distinctive and could be identified by their age structure or by morphometric or meristic characters, (3) To construct a behavioral model for prediction of movements of herring and relation of movement to environmental factors, and (4) To document seasonal changes in the environment of adult herring and identify correlations between environmental changes and herring behavior.

METHODS

Each month from July 1973 to December 1973, we located schools of adult Pacific herring by extensive searches over a broad area in order to ascertain the general distribution of the species in Lynn Canal. When this was learned, a standard search pattern was devised to cover the area of expected occurrence (Figure 1). This pattern, which covered about 97 km^2 (60 mi^2) of Lynn Canal, was designed (1) to prevent biasing the study toward areas where schools were known to be at a given time and (2) to afford an opportunity to obtain comparative environmental data from areas with and without herring. The search pattern was used from January 1974 to June 1975. From July 1975 to June 1978, we located Pacific herring schools seasonally in summer, fall, winter, and spring. Schools of herring were located with echo sounders and vector-scanning sonar, by observations of surface disturbance ("flipping" behavior of herring schools) and bird and sea-mammal activity. Most observations were made between 0800 and 1600 hours; some were made at all hours of the day and night during all seasons. Fieldwork was carried out from the FRV MURRE II, a 25.9-m power barge, the FRV JOHN N. COBB a 29-m purse seiner, the FRV SEARCHER, a 10-m gillnetter, and the FUBAR, an 8.5-m skiff.

To verify acoustic targets and determine age structure of the schools, on 113 days between 1973 and 1978, we collected Pacific herring with multiple-hook jigs, bottom trawls, midwater trawls, and beach seines (Appendix Table A). Sample size ranged from 1 to 600; usually 30-60 fish were collected from each school. Samples were frozen until processed in the laboratory, where ages of individual

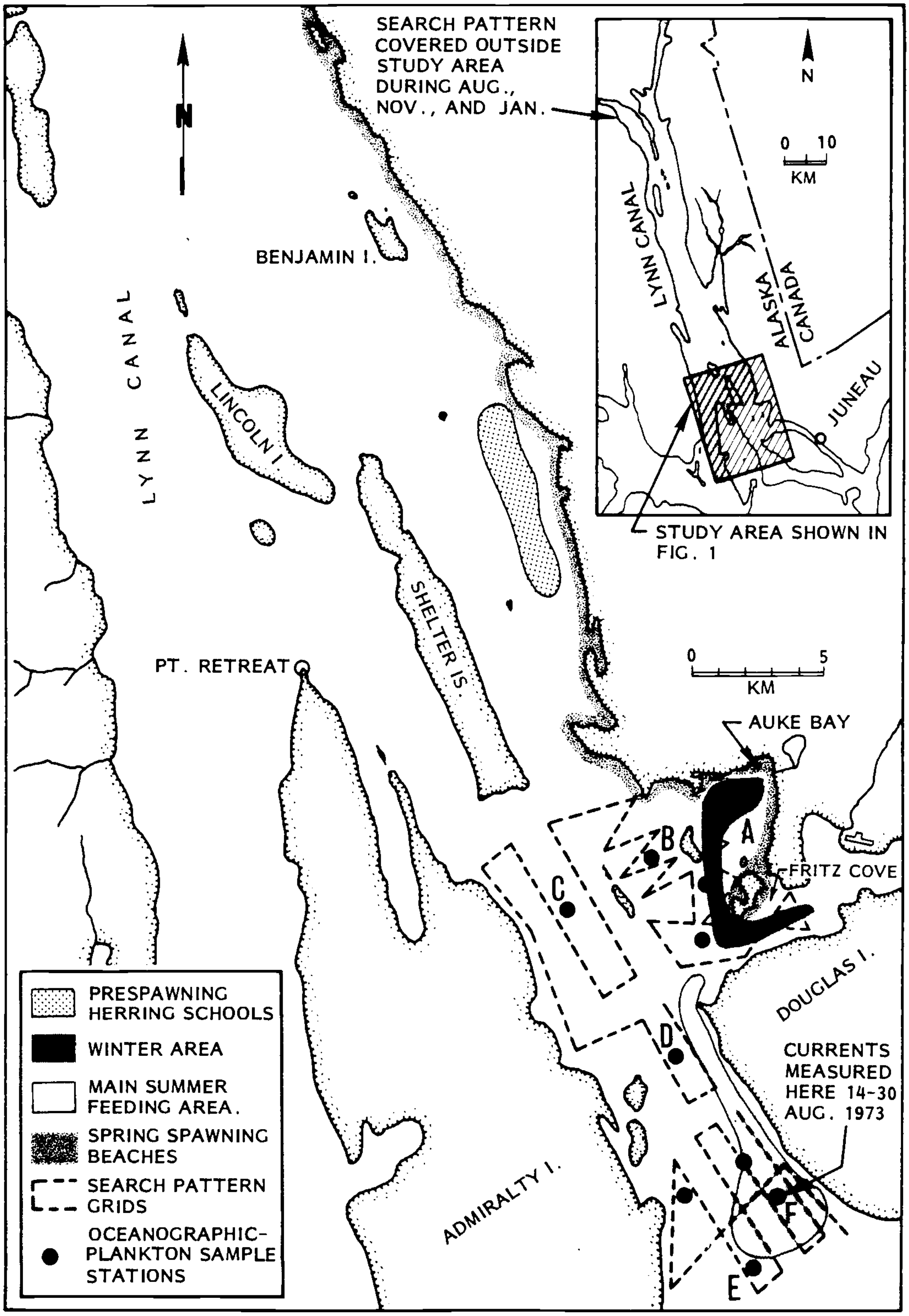

Figure 1.--Seasonal distribution of herring schools in the vicinity of Auke Bay, Lynn Canal, Alaska, showing main concentrations, standard monthly search patterns, waters surveyed up the length of Lynn Canal, oceanographic and plankton sample stations, and the station where currents were measured.

fish were determined from scale readings.

Sampling was designed to measure conditions in a wide range of space and time, not merely conditions where and when herring were found. Temperature and salinity were measured from surface to bottom with a Plessy[1] graphic salinity-temperature-depth profiling system at least once per month during 1973-77 at 3-10 stations (Figure 1). Several other sites were sampled once, including sites off beaches where spawning had recently occurred. At comparable depths and times, temperature and salinity were similar at all stations, so only a few profiles were taken on any day. Currents were measured off western Douglas Island during 14-30 August 1973 at selected depths with Braincon type-381 histogram current meters. Equipment loss negated attempts to measure currents at two other stations. Zooplankton was sampled once each month during 41 days from July 1973 to June 1975 with 60-cm diameter bongo tow nets of 0.333-mm and 0.505-mm mesh (Appendix Table B). Typically, surface, midwater, and near-bottom tows were made for 10 min each at 3-6 stations and were monitored using a bathykymograph and three flowmeters. A mean of 338 m^3 of water was strained (at depth) during each tow. Severe weather routinely reduced the winter tows to three locations. Samples were immediately preserved in 10% formalin, and total volume of zooplankton was later determined by water displacement. The relative

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[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, United States Department of Commerce.

abundance of major groups of zooplankton (copepods, euphausiids, etc.) was determined and predominant genera and species identified.

Day lengths and monthly air temperatures and wind velocities for the Auke Bay vicinity were obtained from the National Weather Service in Juneau, Alaska.

I calculated curvilinear polynomial regressions and plotted and examined them for year-to-year differences in the pattern of Pacific herring school distribution as it related to changing environmental factors. I then subjectively chose the model with the best balance between high correlation coefficient and high number of degrees of freedom. The pattern was similar each year; therefore, observations from all years were combined to give an account of "typical" behavior of schools.

The strategy behind early methodology was uncomplicated: observe, search for, verify the presence, areal extent, and vertical distribution of herring schools by every possible means. We spent most of the available working days in summer and fall in a small boat with an echo sounder and surveyed a broad area (Figure 1) for herring schools, sampling them with jigs. We looked in areas of known concentration of schools and in adjacent areas and repeatedly searched day after day until we had identified the main areas of consistent concentration of schools in what turned out to be the summer feeding grounds off Douglas Island (Figure 1).

We explored the possibility that sizable segments of the stock occurred outside the main study area. During 1974-76, we searched the entire length of Lynn Canal (Figure 1) for herring schools in

August, November, and January, using means comparable to those previously described.

From 1973 to 1978, a total of 153 days of fieldwork was devoted to following the distribution of herring schools and sampling herring and zooplankton, and a total of at least 48 additional days was devoted to oceanographic observations.

To test for differences in environmental conditions in areas where herring were, and were not, found, I used two-tailed paired t-tests and looked at temperature, salinity, and zooplankton abundance at near-surface, midwater, and near-bottom depths over all seasons and most months between October 1973 and June 1975. I compared conditions between the summer feeding area, the wintering area, and other areas where the herring were not found during the study.

I used scatter diagrams to compare the age-length composition of separate samples of herring.

RESULTS AND DISCUSSION

The study revealed the patterns of seasonal distribution of herring schools, from summer feeding areas to overwintering grounds to areas near spawning beaches and to spring spawning sites before return to summer haunts. Vertical distribution was from midwater to near surface in summer, near bottom in winter and tidal shallows during spring spawning. A diurnal movement to near-surface waters during twilight or darkness and descent before, or around, daylight was noted during all seasons.

The results of paired t-tests (Table 1) showed few differences in temperatures, no difference in salinity, and only one difference in zooplankton abundance between areas. Surface temperatures tested higher at the wintering area than the summer feeding area and other area (P = 0.02, 0.01). Temperatures at 50-m depth tested higher at the summer feeding area than the wintering area (P = 0.03). Zooplankton abundance tested higher at the other area (where herring were not found) than at the wintering area (P = 0.01).

In general, sea temperature, salinity, and zooplankton abundance levels were similar where herring were found during summer and winter and where they were never found. Although some tests showed significant difference, these probably lack biological significance because sea surface temperatures were typically variable, the mean difference in temperature at 50 m was small (0.162°C) even where significant, and zooplankters were markedly patchy in distribution throughout the study area.

Table 1.--Results of two-tailed paired t-tests to compare sea temperatures, salinity, and zooplankton abundance at surface, 20-m, and 50-m depths in the vicinity of Auke Bay, Lynn Canal, southeastern Alaska, October 1973 to June 1975. Compared are locales frequented by herring in winter and summer and other locales where herring were not found during the study.

Variable	Depth	Locations compared	t-test value	d.f.	Significance level	H: mean difference = 0
Sea temperature	surface	Winter area vs summer area	2.4763	18	0.02	Reject
	20 m	Winter area vs summer area	0.6186	18	0.54	Accept
	50 m	Winter area vs summer area	-2.3717	18	0.03	Reject
Sea temperature	surface	Winter area vs other area	2.8603	14	0.01	Reject
	20 m	Winter area vs other area	-0.8273	14	0.42	Accept
	50 m	Winter area vs other area	-1.8653	14	0.08	Accept
Sea temperature	surface	Summer area vs other area	-0.9196	14	0.37	Accept
	20 m	Summer area vs other area	-1.4930	14	0.16	Accept
	50 m	Summer area vs other area	-0.3591	14	0.72	Accept
Zooplankton abundance	surface	Winter area vs summer area	0.5308	11	0.61	Accept
	20 m	Winter area vs summer area	1.4149	8	0.19	Accept
	50 m	Winter area vs summer area	-0.5803	15	0.57	Accept
Zooplankton abundance	surface	Winter area vs other area	0.7654	11	0.46	Accept
	20 m	Winter area vs other area	-0.3021	12	0.77	Accept
	50 m	Winter area vs other area	-3.2782	11	0.01	Reject
Zooplankton abundance	surface	Summer area vs other area	0.1207	13	0.90	Accept
	20 m	Summer area vs other area	-0.8229	6	0.44	Accept
	50 m	Summer area vs other area	-1.9163	12	0.08	Accept
Salinity	surface	Winter area vs summer area	-0.8768	16	0.31	Accept
	20 m	Winter area vs summer area	-1.4175	17	0.17	Accept
	50 m	Winter area vs summer area	-0.4186	16	0.68	Accept

Movements of the schools

Hundreds of echogram and sonar observations of Pacific herring schools on the summer feeding grounds near Auke Bay (Figure 1) showed that although horizontal movements were not always extensive, the schools rarely stopped moving during this period, and their vertical distribution changed daily, even hourly, and probably changed constantly. Years of monitoring the distribution of herring sought by the reduction fishery in southeastern Alaska led Kolloen and Smith (1953) to conclude that "during the summer months, the [Pacific] herring schools are constantly moving in search of food."

Overwintering schools were concentrated but nonetheless moved horizontally and vertically within the confines of the wintering area each day.

Woodhead (1966) reviewed the evidence that herring schools appear to follow an isolume in their vertical migrations, and he concluded that light is the primary factor in initiating vertical movement of herring but that there is no single "optimum level," and the relationship of light intensity to depth distribution of herring is not clear cut.

Dragesund (1980) reported that a drastic decline in abundance of the Norwegian spring spawning herring stocks was accompanied by changes in behavior of the remaining fish. After spawning, the herring no longer made long feeding migrations out in the Norwegian Sea and off Iceland but instead remained in coastal waters to feed through the summer. Rather than overwintering in the southwestern part of the Norwegian Sea as before, when stocks were abundant, they moved into the fiords to overwinter and remained there from October to February.

Although the magnitude of the Norwegian spring-spawner stock far surpasses the Auke Bay-Lynn Canal stock (the former estimated in millions of tons, the latter in millions of pounds), I believe that behavior dependent upon abundance characterizes both groups. The distribution and migrations of herring anywhere probably differ considerably when stocks are at low- versus high-abundance levels. Restricted movements and isolated occurrence appear to typify stocks low in abundance, and substantial migrations and intermingling with other adjacent stocks appear to typify stocks when at high abundance levels.

During the period 1973-77, biomass estimates for the Auke Bay-Lynn Canal herring ranged from 2.7 to 6.8 million kg and averaged 4.9 million kgs for the entire period (Joseph Muir, Alaska Department of Fish and Game, Juneau, Alaska, personal communication). So, the stock was at or near the high range in abundance throughout the study.

Summer distribution of schools

During the warmer months, late May through September, scattered schools of adult Pacific herring were found over much of the nearshore waters of southern Lynn Canal and northern Stephens Passage, but herring consistently concentrated along the western shore of Douglas Island (Figure 1). I frequently saw the schools feeding on plankton, and the herring readily struck at jigs designed

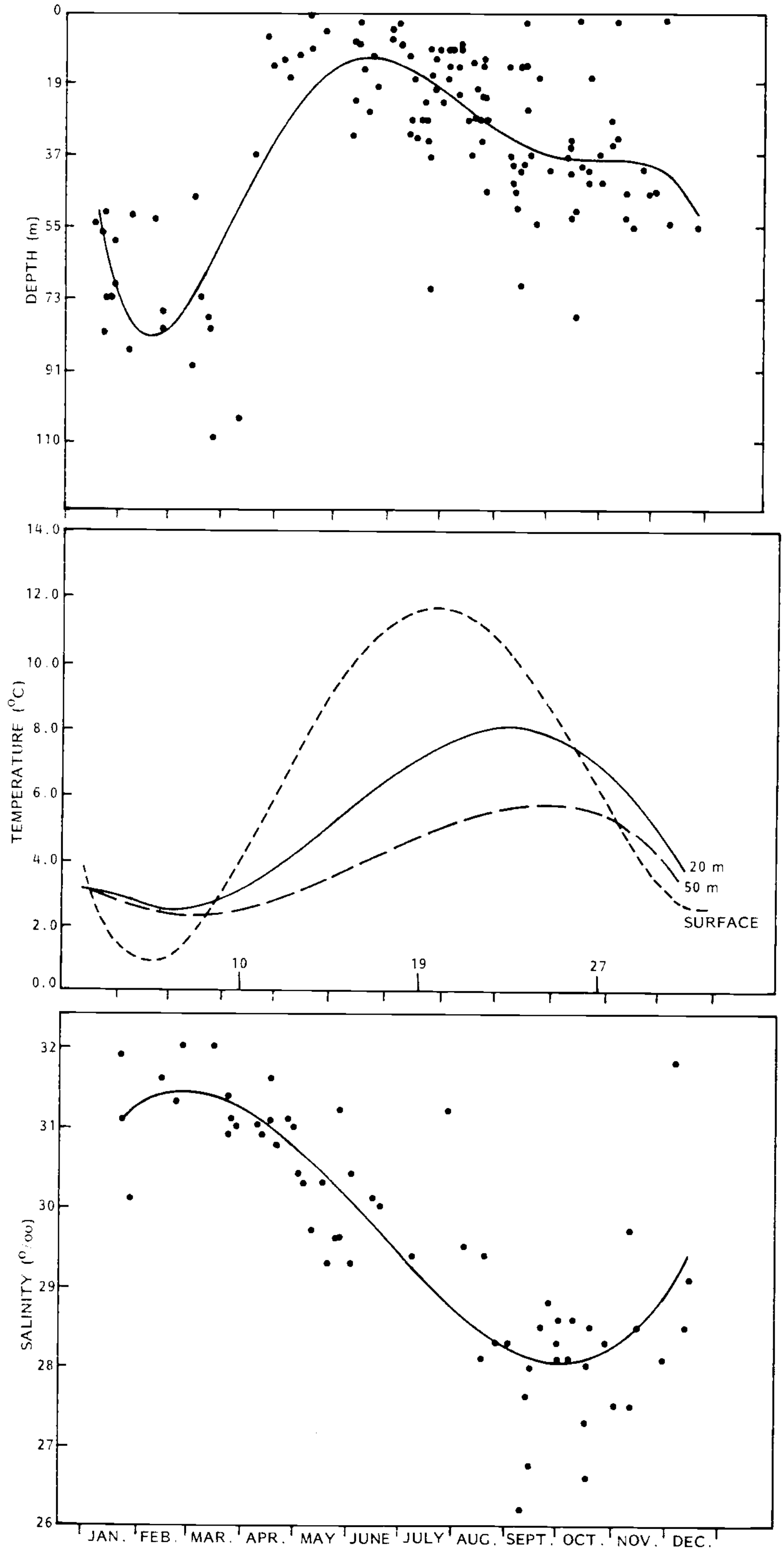

Figure 2.--Midpoint daytime depth of herring near Auke Bay, Lynn Canal, Alaska (1973-76), and temperatures (1973-76) and salinity (1974-76) near Auke Bay, Lynn Canal. Sea temperatures were measured at the surface and at 20- and 50-m depths. Salinity was measured at 10-20-m depths.

to simulate euphausiids. The schools ranged from surface to near bottom during daytime, but most were between 5 and 37 m (Figure 2). During summer months, mean air temperature (10-15°C), sea-surface temperatures (10-15°C), and daylight (14-18 hours), were maximal for the year; mean monthly wind velocities (11-15 km/hour) and salinities at 10-20 m depths (28-30°/₀₀) were minimal for the year (Figure 2). In general, salinity had little or no relation to the distribution of Pacific herring during any season. Atlantic herring can tolerate salinity as low as 5°/₀₀ for weeks at a time (Brawn 1960a).

After surface temperatures peaked in mid-July, median depth of Auke Bay-Lynn Canal herring schools increased through September. From mid-July to September, the schools concentrated at 10- to 37-m depths, where temperatures of 6.0-9.0°C and 4.0-7.0°C prevailed over the entire period at 20 m and 50 m, respectively, so that the 20- to 50-m depths provided a relatively smooth gradient of cooler water beneath a thermocline that was present at 10-15 m.

Food abundance and composition

Zooplankton in mid-depth to near-bottom (16-49 m) waters was most abundant but patchy during May-September. Copepods became abundant in surface waters after June (Figure 3). Copepods and euphausiids together accounted for over 95% of total zooplankton volume. Copepods were predominant during early summer; by August, euphausiids became equally predominant (Figure 3). Other organisms frequently encountered included amphipods, chaetognaths, pteropods, larvaceans, and barnacle larvae. Quast (manuscript in preparation)

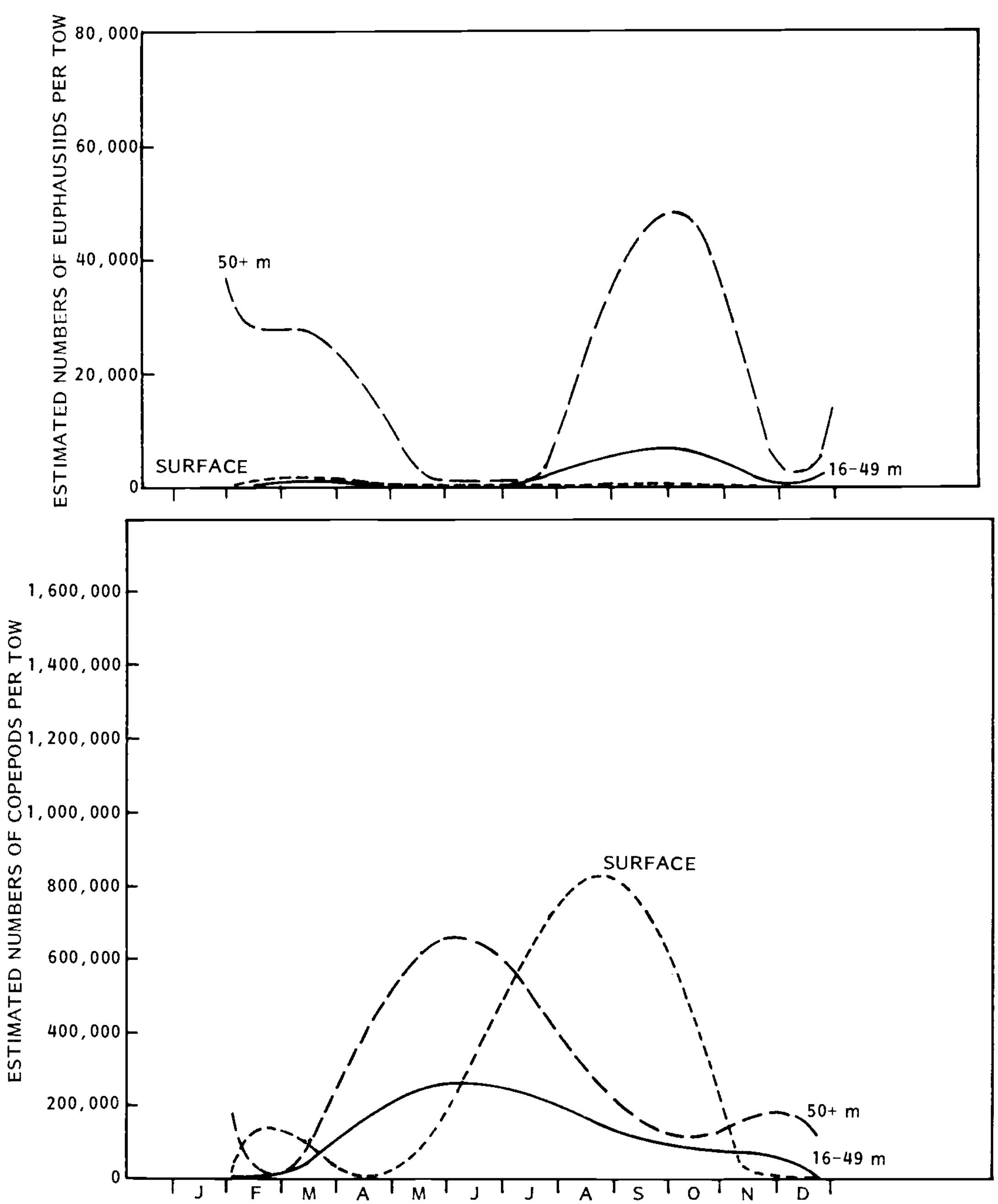

Figure 3.--Monthly abundance of euphausiids and copepods in surface, 16-49-m, and 50+-m depths in the vicinity of Auke Bay, Lynn Canal, Alaska.

found that feeding of the Auke Bay-Lynn Canal herring after spawning was optimally timed with peak zooplankton abundance and long days of illumination in early summer and that visceral fat accumulation reached a peak roughly a month later. He found also that fat accumulation declined from that point on, mostly because much food energy went into gonadal buildup.

Haight (1973) found that copepods were the primary food of Auke Bay-Lynn Canal Pacific herring during summer. The most abundant copepod in my zooplankton samples was *Pseudocalanus*, but the herring stomachs that Haight examined contained mostly the larger copepods *Metridia*, *Calanus*, and *Euchaeta*, which concentrate near bottom. Copepod density at 0- to 16-m depths in and near the summer feeding grounds was typically on the order of thousands of individuals per m^3. North Sea Atlantic herring aggregate to a patch of *Calanus* when the copepods had a population density of 30-40 per m^3 (Cushing 1955). In addition to copepods, euphausiids and sometimes hyperid amphipods are important foods of Pacific herring off Hokkaido, the Kuril Islands, and Kamchatka (Motoda and Sakai 1946; Kun 1949), but they were apparently not often utilized by Auke Bay-Lynn Canal herring. The main concentrations of euphausiids were deeper than 50 m during daytime, below the depths of most herring schools and probably unavailable in daylight. The dominant euphausiid by numbers and frequency of occurrence was *Thysanoessa raschii*, which migrates to surface waters at dusk (Mauchline and Fisher 1969), as do Pacific herring, so this euphausiid could become available nightly if movements of both coincided with sufficient light for herring feeding. Apparently, they did not when and where we sampled. Woodhead (1966) concluded that clupeids in general (including Atlantic herring and Pacific herring) "do not feed much in darkness," and cites many findings in support of his conclusion.

Currents

Current velocity in the summer feeding area off western Douglas Island at depths of 2, 18, and 37 m (bracketing the vertical distribution of the herring schools) was generally <26 cm/second during 14-30 August 1973, far less than the maximum swimming speed of adult Atlantic herring--83-146 cm/second (Brawn 1960b). Slightly greater currents occurred on the surface where the maximum velocity for the entire period was 94 cm/second. Oscillating flows paralleled the shoreline with net easterly flow at mid-depth (18 m) and near-bottom (37 m) and net westerly flow at the surface. Schools appeared to move back and forth with succeeding tides along the shoreline of the main summer feeding area. Bolster (1958) found that the "longest axes of herring school traces (on an echogram) lay in line with the direction of the tidal stream."

The moderate currents that prevailed over the summer feeding grounds probably oriented the herring and carried in planktonic foods but generally lacked sufficient velocity to displace schools or affect their chosen direction of movement, which was normally upcurrent.

Current velocity in Auke Bay at 1- and 20-m depths averaged 16 cm/sec and 5 cm/sec, respectively, from August 18 to September 9, 1972 (Kirk 1972). Near-bottom currents in Auke Bay between July 1982 and September 1983 ranged from 2.9 to 15.0 cm/sec at 27-m depths and were generally <10 cm/sec during any month of the year (J. F. Karinen and B. L. Wing, unpublished data on file National Marine Fisheries Service, Northwest and Alaska Fisheries Center Auke Bay Laboratory, P.O. Box 210155, Auke Bay, AK 99821).

So, it appears that currents in the wintering area are relatively low, both in winter when the herring are in the bay and in summer when they are elsewhere. The protected nature of the wintering area with sheltered waters and minimal currents is probably characteristic of herring wintering areas in general.

Fall migration of schools

In early fall, the herring schools gradually moved deeper (Figure 2) as air temperature decreased; sea-surface waters cooled, became more dense, and sank; mean wind velocities increased; and day length declined. During October, fall storms created surface turbulence, upwelling and mixing (Bruce et al. 1977), and nearly uniform temperatures at all depths. Copepod abundance declined at all depths and approached a yearly minimum. The breakup of the thermocline at this time was accompanied each year by movement of the herring schools from open passages into the sheltered wintering area in Auke Bay and Fritz Cove, frequently followed by humpback whales (*Megaptera novaeangliae*), Steller sea lions (*Eumetopias jubata*), and hordes of sea birds. Pacific herring in the Bering Sea similarly appeared on the wintering grounds in October and November (Shaboneev

1965; Wespestad and Barton 1981).

Winter distribution of schools

During November and December as sea temperatures gradually fell and day length reached the yearly minimum of 6 hours, the herring schools remained deep and close to the bottom during daylight hours; at night, they rose in the water column and dispersed. By January or February, the schools concentrated at 52-85 m, close to yearly maximum depths, and distribution centered in Fritz Cove (Figure 1). Feeding essentially ceased once the Pacific herring moved into the wintering grounds. Although copepods were scarce through January and February, some foods were present, mainly euphausiids at depths >50 m (Figure 3); however, little or no food was present in herring collected in winter (Haight 1973). Similarly, only 6 of 11,102 Pacific herring in British Columbia contained food during November and January (Wailes 1936). In midwinter during daylight, schools of adult herring typically formed dense concentrations near bottom. Occasionally, the schools were found "flattened out" on the bottom of Auke Bay on midwinter days, not distinguishable on an echo sounder but vulnerable to capture by a bottom trawl. This behavior was not observed in adjacent Fritz Cove where waters are deeper. Dr. A. S. Hourston (Pacific Biological Station, Nanaimo, British Columbia, personal communication) has observed overwintering Pacific herring schools similarly flatten out on the bottom in British Columbia. He believes the schools generally avoid light levels sufficient for visual detection by predators, and when the schools are over bottom too shallow to provide cover at a preferred light level, they descend as deep as possible, where the bottom itself may provide cover and protection.

Pacific herring schools near St. Matthew Island in the Bering Sea during January (1979) were clumped near bottom over 275-m depths during daylight and moved back and forth 40-80 m upslope during the course of a day (Ralph DiCaprio, Commercial Fisherman, 6749 First Avenue N.W., Seattle, WA 98117, personal communication).

Migration to spawning grounds

During February or early March, when day length was about 10 hours and increasing rapidly but sea temperatures and zooplankton abundance remained at midwinter levels, the herring moved out of Fritz Cove and Auke Bay and concentrated near bottom in 73-110 m off traditional spawning beaches in Lynn Canal to the north. They remained there until late April to early May when sea-surface temperatures increased to 5-6°C, and daylight increased to 15-16 hours a day. Plankton blooms then obscured surface visibility, and the herring moved into tidal shallows and commenced spawning. Cook Inlet herring were seen actively feeding soon after spawning, but stomachs examined during spawning and earlier were empty (Rounsefell 1930). Most of the herring stomachs examined in spring by Barton (1978) from Bristol Bay to Norton Sound were empty or had only traces of food. Spawning in the Auke Bay vicinity typically took place over a 2-3 week period between late April and early May during 1973-78 and even extended to late May (in 1974). After spawning, the herring gradually returned to summer haunts as sea temperatures increased, salinities decreased, copepod abundance increased, and the water column again became stratified.

Hourston (1982) concluded that British Columbia herring could be divided into valid spawning stocks and managed as such because of the high degree of homing of adult fish to the same spawning grounds in consecutive years.

Integrity of the stock

We searched for Pacific herring schools north of the Auke Bay-Lynn Canal study area in August 1974, November 1975, and January 1976 to determine whether we were working with a single, discrete group of herring that spawn in Lynn Canal (inset, Figure 1). The cruises were for 5-7 days and thoroughly covered the entire length of Lynn Canal. We found only a few small, scattered traces of mostly juvenile herring. Within the study area, over 24 consecutive months, disappearance of schools from one locale always coincided with their appearance in another. From November to May, we found no sign of schools over summer feeding grounds, and from June to October, we found few signs of herring in the wintering area. Herring that winter in Auke Bay and Fritz Cove apparently constitute most of the stock of fish that spawn in the Auke Bay-Lynn Canal area and are exploited in a spring roe fishery in lower Lynn Canal.

I could not distinguish separate schools on the basis of age-length structure. Age structure of each school was similar to the composite of samples (Table 2) taken throughout the study area,

Table 2.--Age composition of Pacific herring (annual percentages) collected in the vicinity of Auke Bay, Lynn Canal, southeastern Alaska, 1973-77. T = trace amounts (<0.5%).

Year	Total herring collected	Age										
		0	I	II	III	IV	V	VI	VII	VIII	IX	X+
1973	1,503	-	3	13	4	7	22	25	11	7	5	3
1974	1,363	-	T	1	29	11	8	21	11	8	5	4
1975	786	-	1	5	18	33	10	8	16	6	2	2
1976	3,873	-	T	T	2	12	21	13	16	21	8	5
1977	1,403	4	1	40	7	4	7	13	7	9	5	2

and the same year classes predominated in successive years. If this were not the case, a valid argument could be advanced that we followed more than one group of fish in the study.

CONCLUSIONS

Explaining fish behavior (e.g., distribution) by interrelated environmental factors (e.g., sea temperatures, day length, and food abundance) is difficult. One correlation stood out in my study: breakup of the thermocline in October (for five consecutive years) was correlated with the move of herring from feeding grounds to the wintering area. The loss of stratification in the water column occurred over a few days and more likely acted as a cue to the move than did more gradual changes in the environment. If true, this cue could be used to predict movement of other herring stocks and deserves further study.

The yearly distribution pattern of the Auke Bay-Lynn Canal stock of Pacific herring differs from that of the Sitka and Craig stocks, major stocks in southeastern Alaska, and major stocks in British Columbia that make extensive summer feeding migrations (Skud 1963; Outram and Humphreys 1974). Like the Auke Bay-Lynn Canal herring, Ketchikan herring apparently do not migrate to intermingle with Sitka and Craig herring on common feeding grounds (Carlson 1977); therefore, the yearly distribution of the Ketchikan stock may fit the pattern of the Auke Bay-Lynn Canal stock. Such a pattern--large stocks that do not make long migrations-- may describe other stocks of Pacific herring when their year-round distribution is learned.

An assessment of how well objectives of the study were met is as follows:

Objective (1) was met. I determined that the herring that spawned near Auke Bay were a single stock that fed nearby in summer and overwintered in the area.

Objective (2) was met. I determined that individual herring schools were not distinctive in their age structure or morphometric or meristic characters and could not be identified by this means.

Objective (3) was not met. I was not able to construct a meaningful behavioral model for prediction of movement of herring and the relation of movement to environmental factors.

Objective (4) was met. I documented seasonal changes in the environment of adult herring and identified the correlations that existed between environmental change and herring behavior.

Analysis of the study

This study tested three hypotheses and answered certain ancillary questions. The hypothesis that the Auke Bay-Lynn Canal herring were a single stock that remained in the same area year-round was, I believe, confirmed. No widely separated groups of herring were found on different wintering grounds, and spawning activities and summer feeding schools displayed a consistent pattern of distribution from year to year. So, the hypothesis of consistent, predictable behavior of the herring was also confirmed.

The hypothesis that a deterministic model can relate seasonal movements of the herring and environmental factors for predictive purposes may be valid, but I could not clearly distinguish causative factors versus associated factors in the environment. A major hindrance to constructing such a model was the multiple factors in the herring's environment, which interact and change frequently, so that one is dealing with a flux of conditions. The conceptual model (Figure 4) was an attempt to visually depict the seasonal cycles in herring school distribution. The arrangement and position of schools and surrounding factors are only approximate and meant to emphasize the interrelationship of prime factors in the environment and how these change through the year.

Among the questions the study did not answer was the stock structure in terms of individual schools: Did a school more or less maintain its members over an extended time, or is there a frequent breakup of large schools and coalescense of small schools or some other routine recombination, without a lasting clearcut identity to any particular school? Given the great mobility, vast numbers, and high mortality rates for adult herring, the latter possibility seems more likely.

Redirected emphasis

Future studies of herring seasonal distribution and environment should differ in design from this study in several ways:

Summer distribution and food abundance

It is now possible to obtain, easily and rapidly, biomass estimates on zooplankton, and to assess the abundance of herring foods, such as euphausiids and copepods (Sameoto 1979), because

Figure 4.--Conceptual model of major components in the seasonal distribution of Pacific herring and their environment in the vicinity of Auke Bay, Lynn Canal, southeastern Alaska.

technology in hydroacoustics has progressed considerably in the last decade.

Hydroacoustic estimates of food density in areas frequented both regularly and rarely by herring during the summer could provide evidence for testing correlation of the two. Recent studies by Wing and Krieger (1982) in nearby (to my study) waters of Icy Strait and Frederick Sound have identified areas consistently rich and other areas consistently poor in zooplankton abundance through the summer months. I believe herring distribution in summer could be explained on the basis of their concentration in demonstrably rich feeding areas and infrequent presence in areas where zooplankton foods were scarce.

The next logical step in a study so designed (to use food abundance as a key explanation in herring distribution in summer) would be to relate the richness of an area to oceanographic conditions. At once, primary and secondary productivity and water transport come to mind as key elements in attempting to establish correlations.

Methodology involved in setting up hydroacoustic surveys of zooplankters would probably call for (a) establishing geographic limits to the areas to be compared, (b) laying out surface grids for survey transects that cover horizontal distribution of the zooplankton swarms, (c) establishing a base abundance level for subsequent comparison, and (d) sampling zooplankton to identify echo sounder targets.

Tagging experiments

Whereas my study inferred movements and identity (as a stock) of the herring schools by their presence or absence, and the consistency and seasonality of the foregoing, a mark-and-recapture effort could improve future studies of seasonal distribution and basic biology of herring.

The marking of adult herring with highly visible external tags in batches or lots from separate aggregations or schools over a relatively short time frame such as several weeks, and subsequent recoveries of marked fish could test a number of ideas:

(1) Recovery of individuals from the same lots exclusively at the same time, could be regarded as evidence for a continued identity of schools, and the duration of this identity could be tested at least within and between seasons.

(2) Near-simultaneous recovery of individuals from two or several lots in the same locale could be regarded as evidence for intermingling and interchange among schools and lack of a lasting identity as such.

Coded-wire microtags developed for use on young salmon are suitable for tagging adult herring (Krieger 1982). These could be useful in longer-term studies of distribution between seasons and years, on the same or different spawning grounds and feeding areas.

Spawning times and phytoplankton blooms

An ancillary study of the timing of herring spawning and incidence of phytoplankton blooms might show some correlation between spawning activity and density of surface cover acting as a screen to aerial predators. A study of this sort could also merely reveal association--a complex of other factors acting concurrently with phytoplankton blooms and neither promoting or restraining spawning activity. However, it could be worthwhile to examine the timing of these phenomena more closely in attempting to explain herring distribution on spawning grounds.

Juvenile herring school distribution

The seasonal distribution of juvenile or prerecruit herring and their environment could be viewed as an entirely separate, distinct study in its own right. However, the relation of juvenile to adult distribution could generate testable concepts for understanding both.

Juvenile herring tend to concentrate closer to shore than adults, often in intertidal shallows during spring and summer, sometimes above adult schools on wintering grounds, but definitely separate from adults.

A mark-and-recovery project that aimed at marking juveniles in the year prior to expected recruitment and focused recovery effort in the following 2 years (when all or most of the marked fish would be adults) would be unique--it has not been done. Such a study could reveal patterns of juvenile distribution that tied into adult distribution. Several hypotheses come to mind: (1) schools of young fish may concentrate near the adult summer feeding areas and overwintering areas, but utilizing shallower depths, (2) schools of young may overwinter progressively closer to adults, recruiting to adult schools on the wintering grounds prior to spawning or recruiting as newly matured fish on the spawning grounds, (3) schools of young fish may utilize one or more areas consistently in the seasons before recruitment, with a definable pattern of schools of young fish concentrating in the same "staging grounds" during one or more seasons in the year prior to recruitment, (4) conversely, random distribution of schools of young fish over all seasons without any pattern or definable consistency might reflect broad tolerance and lack of clearly preferred level for most factors in their environment.

Methodology for a study of juvenile herring distribution regardless of whether or not mark and recovery is done, would probably involve searching shorelines, following generally shallow depth contours. This would serve to establish a standard survey route based on frequency of occurrence of schools of young after intensive surveys of a broad area, encompassing a range of depths to bracket their distribution vertically and horizontally. Samples of young fish could be aged to examine age-size and distribution from ages 0+ to III. Sampling gear could include midwater trawls, gillnets, seines, and jigs.

Overview - potential improvements

In general, future studies of herring distribution and environment could be improved by utilizing numerical abundance estimates to a larger extent than I did, for all elements involved.

Hydroacoustic estimates of herring and zooplankton abundance would be most useful in this regard.

A longer term, more comprehensive study should examine distribution of a herring stock at widely differing levels of abundance. When a stock is depressed, the herring display a different pattern of seasonal distribution than when they are abundant. There may really be no such thing as a "typical" distribution pattern for herring or surrounding biological variates but an abundance-dependent pattern for both.

BIBLIOGRAPHY

Anokhina, L. E. 1963. Some aspects of the fecundity of the herring in the White Sea. Pages 123-127 *in* B. B. Parrish, editor. Contributions to herring symposium 1961. Volume 154, Rapports et Procès-Verbaux des Réunions, Conseil International pour l'Exploration de la Mer.

Barton, L. H. 1978. Finfish resource surveys in Norton Sound and Kotzebue Sound. Outer Continental Shelf Environmental Assessment Program Final Report. Alaska Department Fish and Game, Anchorage, Alaska, USA.

Bolster, G. C. 1958. On the shape of herring schools. Journal du Conseil, Conseil International pour l'Exploration de la Mer 23:228-234.

Brawn, V. M. 1960a. Survival of herring (*Clupea harengus* L.) in water of low salinity. Journal of the Fisheries Research Board of Canada 17:727-726.

Brawn, V. M. 1960b. Underwater television observations of the swimming speed and behavior of captive herring. Journal of the Fisheries Research Board of Canada 17:689-698.

Bruce, H. E., D. R. McLain, and B. L. Wing. 1977. Annual physical and chemical oceanographic cycles of Auke Bay, southeastern Alaska. United States National Oceanic and Atmospheric Administration Technical Report, National Marine Fisheries Service, Special Scientific Report Fisheries 712.

Carlson, H. R. 1977. Results of a tagging study of Pacific herring in southeastern Alaska in 1960-62 using radioactive body-cavity tags. Northwest and Alaska Fisheries Center Processed Report, Auke Bay Laboratory, Auke Bay, Alaska, USA.

Carlson, H. R. 1980a. Herring research in the gulf of Alaska--A historic overview. Pages 63-68 *in* B. R. Melteff and V. G. Wespestad, editors. Proceedings of the Alaska herring symposium. Alaska Sea Grant Report 80-4.

Carlson, H. R. 1980b. Seasonal distribution and environment of Pacific herring near Auke Bay, Lynn Canal, southeastern Alaska. Transactions of the American Fisheries Society 109:71-78.

Cushing, D. H. 1955. Production and a pelagic fishery. Fishery Investigations, Ministry of Agriculture Fisheries and Food (Great Britain), series II, Salmon and Freshwater Fisheries, volume 18, number 7. Her Majesty's Stationery Office, London, England.

Dahlgren, E. H. 1936. Further developments in the tagging of the Pacific herring, *Clupea pallasii*. Journal du Conseil, Conseil International pour l'Exploration de la Mer 1:229-247.

Dragesund, O. 1980. A review of management practices and research activities on Norwegian spring spawning herring. Pages 207-238 *in* B. R. Melteff and V. G. Wespestad, editors. Proceedings of the Alaska herring symposium. Alaska Sea Grant Report 80-4.

Haight, R. E. 1973. Food and feeding habits of Pacific herring in the vicinity of Auke Bay, southeastern Alaska. Unpublished data, Northwest and Alaska Fisheries Center Auke Bay Laboratory, Auke Bay, Alaska, USA.

Hourston, A. S. 1982. Homing by Canada's West Coast herring to management units and divisions as indicated by tag recoveries. Canadian Journal of Aquatic Sciences 39:1414-1422.

Kirk, D. K. 1972. Physical hydrography and nutrient nitrogen budget of Auke Bay, Alaska. Master's thesis, Oregon State University, Corvallis, Oregon, USA.

Kolloen, L. N., and K. A. Smith. 1953. Southeastern Alaska exploratory herring fishing operations, winter 1952/53. Commercial Fisheries Review 15(11):1-24.

Krieger, K. J. 1982. Tagging herring with coded-wire microtags. Marine Fisheries Review 44:18-21.

Kun, M. S. 1949. Pitanie tikhookeanstoi sel'di v severinoi chasti Tatarskogo proliva [Feeding of the Pacific herring in the northern part of the Tartary strait]. Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO)-Izvestiya, volume 29. Manuscript not seen; cited by Piskunov (1955).

Mauchline, J., and L. R. Fisher. 1969. The biology of euphausiids. *In* F. S. Russell and M. Yonge, editors. Advances in marine biology, volume 7. Academic Press, New York, New York.

Motoda, S., and Y. Hirano. 1963. Review of Japanese herring investigations. Pages 249-261 *in* B. B. Parrish, editor. Contribution to herring symposium, 1961. Volume 154, Rapports et Procès-Verbaux des Réunions, Conseil International pour l'Exploration de la Mer 154:249-261.

Motoda, S., and T. Sakai. 1946. Feed of the spring herring. Hokkaido Suisan Shikenjo Geppo 3:155-165. Manuscript not seen; cited by Motoda and Hirano (1963).

Outram, D. N. 1965. Canada's Pacific herring. Department of Fisheries of Canada, Ottawa, Canada.

Outram, D. N., and R. D. Humphreys. 1974. The Pacific herring in British Columbia waters. Circular 100, Fisheries and Marine Service. Pacific Biological Station, Nanaimo, British Columbia, Canada.

Parrish, B. B., and R. E. Craig. 1963. The herring of the North-Western North Sea--post-war changes in the stock fished by Scottish drifters. Pages 139-158 *in* B. B. Parrish, editor. Contributions to herring symposium 1961. Volume 154, Rapports et Procès-Verbaux des Réunions, Conseil International pour l'Exploration de la Mer.

Piskunov, I. A. 1955. Biology of herring inhabiting the waters of southwestern Kamchatka and northern Kuril Islands. Voprosy Ikhtiologii 4:63-70.

Quast, J. C. (Manuscript in preparation). Growth, anabolic partitioning, and seasonal fat and reproduction cycles in Pacific herring, *Clupea harengus*, from the Auke Bay vicinity, southeastern Alaska. Manuscript on file, Northwest and Alaska Fisheries Center Auke Bay Laboratory, Auke Bay, Alaska.

Rounsefell, G. A. 1930. Contribution to the biology of the Pacific herring, *Clupea pallasii*, and the condition of the fishery in Alaska. United States Bureau of Fisheries Bulletin 45:227-330.

Rounsefell, G. A., and E. H. Dahlgren. 1935. Races of herring, *Clupea pallasii*, in southeastern Alaska. United States Bureau of Fisheries Bulletin 48:119-141.

Sameoto, D. D. 1979. Quantitative measurements of euphausiids using a 120 kHz sounder and their in situ orientation. Canadian Journal of Fisheries and Aquatic Sciences 37:693-702.

Shaboneev, I. E. 1965. Biology and fishing of the herring in the eastern part of the Bering Sea. Pages 130-146 *in* Soviet fisheries investigation in the Northeast Pacific, part IV. Israel Program for Scientific Translations, Jerusalem, Israel.

Skud, B. E. 1959. Herring spawning surveys in southeastern Alaska. United States Fish and Wildlife Service Special Scientific Report No. 321.

Skud, B. E. 1963. Herring tagging experiments in southeastern Alaska. United States Bureau of Commercial Fisheries Fishery Bulletin 63:19-32.

Wailes, G. H. 1936. Food of *Clupea pallasii* in southern British Columbia waters. Journal of the Biological Board of Canada 1:477-486.

Wespestad, V. G., and L. H. Barton. 1981. Distribution, migration, and status of Pacific herring. Pages 509-525 *in* D. W. Hood and J. A. Calder, editors. The Eastern Bering Sea shelf, oceanography and resources, volume I. University of Washington Press, Seattle, Washington, USA.

Wing, B. L. and K. J. Krieger. Unpublished manuscript. Humpback whale prey studies in southeastern Alaska, summer 1982. Manuscript on file, National Marine Fisheries Service Auke Bay Laboratory, Auke Bay, Alaska, USA.

Winters, G. H. 1976. Recruitment mechanisms of southern Gulf of St. Lawrence Atlantic herring (*Clupea harengus harengus*). Journal of the Fisheries Research Board of Canada 33:1751-1763.

Woodhead, P. M. J. 1966. The behaviour of fish in relation to light in the sea. Pages 337-403 *in* H. Barnes, editor. Oceanography and marine biology, an annual review, volume 4. George Allen and Unwin, London, England.

APPENDIX

Appendix Table A.--Dates and locations of herring collections for target verification and biological information in the Auke Bay-Lynn Canal vicinity and adjacent parts of northern southeastern Alaska, 1973-78.

Date	Vessel	Gear	Place	n
1973				
April 23	Fubar	Beach Seine	Tee Harbor	300
July 18	Fubar	Jig	Middle Pt.	175
July 19	Fubar	Jig	Middle Pt.	37
July 25	Fubar	Jig	Middle Pt.	12
Aug 8	Fubar	Jig	N. Pt. Louisa	28
Aug 8	Fubar	Jig	Tee Harbor Entrance	37
Aug 10	Fubar	Jig	Pt. Stephens	75
Aug 13	Fubar	Jig	N. end Shelter Island	7
Aug 14	Fubar	Jig	Pt. Stephens	16
Aug 20	Fubar	Jig	S. Middle Pt.	13
Aug 20	Fubar	Jig	Inner Pt.	13
Aug 21	Murre II	Jig	Middle-Inner Pt.	50
Aug 23	Fubar	Jig	Middle-Inner Pt.	17
Aug 27	Fubar	Jig	Georges Rock	23
Aug 27	Fubar	Jig	S.E. Portland Island	16
Aug 28	Fubar	Jig	N.W. Coughlan Island	18
Aug 29	Fubar	Jig	S.E. Coughlan Island	1
Aug 29	Fubar	Jig	Gibby Rock	2
Aug 29	Fubar	Jig	S.E. Georges Rock	5
Aug 30	Fubar	Jig	S. Outer Pt.	1
Aug 30	Fubar	Jig	W. Outer Pt.	4
Aug 30	Fubar	Jig	N.W. Spuhn Island	18
Sept 6	Fubar	Jig	S.E. Coughlan Island	4
Sept 11	Fubar	Jig	N. Pt. Louisa	2
Sept 12	Fubar	Jig	Tee Harbor Entrance	1
Sept 13	Fubar	Jig	Middle Pt.	85
Sept 13	Fubar	Jig	N. Inner Pt.	21
Sept 17	Fubar	Jig	Favorite Reef	2
Sept 18	Fubar	Jig	N.W. Middle Pt.	6
Sept 18	Fubar	Jig	N.W. Inner Pt.	11
Sept 19	Fubar	Jig	S. Pt. Lena	19
Sept 20	Fubar	Jig	S. Pt. Lena	4
Sept 20	Fubar	Jig	N. Coughlan Island	3
Sept 21	Fubar	Jig	Brown Bluff N. Douglas Is.	5
Sept 26	Fubar	Jig	W. Middle Pt.	2
Oct 4	Fubar	Jig	Middle-Inner Pt.	27
Oct 16	Murre II	Jig	Brown Bluff N. Douglas Is.	1
Oct 17	Murre II	Jig	N. Scull Island	3
Oct 19	Murre II	Jig	N. Coughlan Island	102
Oct 23	Murre II	Jig	Auke Bay-Fy. term to Indian Pt.	40
Oct 24	Murre II	Jig	Auke Bay-Fy. term to Wadleigh Creek	238
Oct 25	Murre II	Jig	Auke Bay-Fy. term to Indian Pt.	51
Oct 25	Murre II	Jig	Auke Bay-Lab to Wadleigh Creek	97

Appendix Table A.--continued.

Date	Vessel	Gear	Place	n
1973				
Nov 2	Fubar	Jig	Auke Bay Baltzo Pt.-N. Coughlan Island	7
Nov 16	Fubar	Jig	Auke Bay-Auke Creek-Indian Point	5
Nov 30	Murre II	Jig	Auke Bay-Flower Island	2
Dec 3	Murre II	Jig	Auke Bay - Center	10
Dec 27	Fubar	Jig	Auke Bay - Center	66
1974				
Jan 18	Murre II	40' Trawl	Auke Bay - Center	11
Jan 25	Murre II	40' Trawl	Auke Bay - Center	62
Feb 7	Murre II	40' Trawl	Auke Bay - Center	9
Feb 14	Murre II	Jig	Portland-Coughlan Island	1
Feb 22	Murre II	40' Trawl	Auke Bay - Center	79
Mar 14	Murre II	40' Trawl	Fritz Cove	67
Apr 19	Cape Falcon	Seine	Pt. Terese	Unknown
Apr 25	Skiff	Jig	Tee Harbor	22
Apr 26	Fubar	Jig	Indian Cove	30
Apr 29	Fubar	Jig	Auke Bay	22
May 9	Fubar	Jig	Auke Bay-Fy. term.	35
May 15	Fubar	Jig	Auke Bay-Lab	40
May 31	--	Fish stranded in pool - Auke Nu Cove		360
May 31	Fubar	Jig	Auke Cape	33
June 19	Fubar	Jig	Auke Nu Cove-Coughlan Island	2
June 21	Fubar	Jig	Off Outer Pt.	4
June 27	Fubar	Jig	Off Auke Cape	1
June 27	Fubar	Jig	N. Middle Pt.	21
July 19	Murre II	Jig	Off Middle-Inner-Outer Pt.	27
July 29	Murre II	Jig	Off N. Douglas Island	4
July 29	Murre II	Jig	Off Outer-Middle Pt.	12
Aug 7	Murre II	Jig	Off Inner-Outer Pt.	142
Aug 28	Murre II	Jig	Off Middle-Inner Pt.	70
Aug 29	Murre II	Jig	Off Middle-Inner Pt.	5
Sept 23	Murre II	Jig	N. Middle Pt.	7
Sept 30	Murre II	Jig	N. Middle Pt.	48
Oct 11	Fubar	Jig	Auke Bay - Center	24
Oct 16	Murre II	Jig	Off Auke Cape	36
Nov 8	Murre II	Jig	Auke Bay - near Lab	27
Dec 12	Murre II	40' trawl	Auke Bay Center to Lab	580
1975				
Jan 29	Murre II	40' trawl	Fritz Cove	16
Jan 29	Murre II	40' trawl	Auke Bay	255
Mar 16	Skiff	hand	Auke Bay	17
Mar 20	Murre II	40' trawl	Fritz Cove	226
Mar 20	Murre II	40' trawl	Auke Bay	73
Mar 27	Murre II	40' trawl	Berners Bay	2
Apr 22	Murre II	40' trawl	S. Eagle River Flat	1

Appendix Table A.--continued.

Date	Vessel	Gear	Place	n
1975				
May 1	Skiff	Beach seine	Auke Bay	1
May 7	Fubar	Jig	Tee Harbor	63
May 7	Fubar	Jig	Auke Bay	1
May 7	none	Hook & line	Yankee Cove	10
June 13	Fubar	Jig	S.E. Portland Island	2
June 17	Murre II	Jig	Outer-Middle Pt.	5
June 18	Murre II	Jig	S. of Outer Pt.	25
July 7	Murre II	Jig	Hoonah dock, Port Frederick	51
July 8	Skiff	Gillnet	Tee Harbor	11
July 9	Murre II	Jig	Hawk Inlet-cannery dock	6
July 10	Skiff	Jig	Hawk Inlet-entrance lt.	51
Sept 16	Murre II	Jig	Scull Island-Middle Pt.	2
Sept 17	Murre II	40' Trawl	Off Horse Shoal	85
Oct 16	Fubar	Jig	Auke Bay-Wadleigh Cr.	6
Oct 17	Fubar	Jig	Auke Bay-center	1
Oct 28	Fubar	Jig	Auke Bay-Auke Nu Cr.	2
Nov 19	Murre II	40' Trawl	Auke Bay	2
Nov 26	Searcher	Jig	Auke Bay	23
1976				
Jan 22	J. N. Cobb	30' MW Trawl	Fritz Cove	399
Jan 22	J. N. Cobb	Eastern Otter Trawl	Auke Bay	300
Jan 24	J. N. Cobb	Eastern Otter Trawl	Portland-Coughlan Island	1
Jan 29	J. N. Cobb	Eastern Otter Trawl	Lutak Inlet	4
Jan 29	J. N. Cobb	30' MW Trawl	N. Taiya Inlet	9
Feb 26	Murre II	40' Trawl	Fritz Cove	91
Mar 23	Murre II	40' Trawl	Fritz Cove	54
Mar 25	Murre II	40' Trawl	N. of Cohen Island	300
Apr 12	Murre II	40' Trawl	N. of Cohen Island	228
Apr 26	Seiner	Purse Seine	N. of Cohen Island	895
Apr 29	Gillnetter	Gillnet	Amalga Harbor	436
May 21	Skiff	Seine	Auke Nu Cove	510
July 6	Searcher	Jig	S. Shelter Island	15
July 30	Searcher	Jig	Yasha Island, Chatham Str.	38
July 31	Searcher	Jig	Yasha Island, Chatham Str.	17
Aug 1	Murre II	Jig	Chaik Bay, Chatham Str.	27
Aug 1	Searcher	Jig	Village Pt., Hood Bay Entr.	15
Aug 1	Murre II	Jig	S. Hood Bay Entr.	19
Aug 1	Murre II	Jig	Killisnoo Island to Hood Bay Entr.	30
Aug 2	Searcher	Jig	W. of Danger Pt., Admiralty Island	22
Aug 2	Murre II	Jig	NW Parker Pt., Admiralty Island	73
Oct 19	Murre II	40' Trawl	S. Horse Shoal	350

Appendix Table A.--continued.

Date	Vessel	Gear	Place	n
1977				
Jan 17	J. N. Cobb	30' MW Trawl	Fritz Cove	528
Jan 19	J. N. Cobb	30' MW Trawl	Head of Port Frederick	600
Jan 21	J. N. Cobb	30' MW Trawl	S. Arm Hood Bay	520
Jan 23	J. N. Cobb	30' MW Trawl	Long Bay Tenakee Inlet	~100
Jan 27	J. N. Cobb	30' MW Trawl	Fritz Cove	300
Feb 24	None	Gillnet	Head of Auke Bay	15
Mar 8	Searcher	Jig	off Pt. Terese	2
Mar 27	Murre II	40' Trawl	N. of Cohen Island	3
Nov 15	J. N. Cobb	Trawl	Auke Bay	139
1978				
Mar 23	Murre II	Trawl	Auke Bay	1
Apr 12	Murre II	40' Trawl	Fritz Cove	1

Appendix Table B.--Dates, locations, and depth intervals of zooplankton collections in the Auke Bay-Lynn Canal, southeastern Alaska, vicinity, 1973-75.

Date	Vessel	Gear	Places-Stations	Depth	n
1973					
July 24	Fubar	60 cm Bongo nets	off Middle Pt.	0-16 m	2
Aug 20	Murre II	60 cm Bongo nets	off Middle Pt.	Surface	1
Aug 21	Murre II	60 cm Bongo nets	Middle Pt.	18, 37, 64 m	3
Sept 13	Fubar	20 cm Bongo nets	off Middle Pt.	18, 51 m	2
Sept 14	Fubar	20 cm Bongo nets	off Middle Pt.	18, 33, 51 m	4
Sept 17	Fubar	20 cm Bongo nets	W. Pt. Louisa	6, 20 m	2
Sept 18	Fubar	20 cm Bongo nets	Inner-Middle Pt.	21, 43, 51 m	3
Sept 20	Fubar	20 cm Bongo nets	S. Pt. Lena	9 m	1
Oct 17	Murre II	60 cm Bongo nets	off Middle Pt.	9, 37, 51 m	3
Oct 19	Murre II	60 cm Bongo nets	S. Portland-S. Coughlan Island	9, 37, 74 m	3
Oct 23	Murre II	60 cm Bongo nets	Auke Bay-off Indian Pt.	9, 46 m	4
Dec 5	Murre II	60 cm Bongo nets	Portland-Coughlan Island	9, 27, 55 m	3
Dec 5	Murre II	60 cm Bongo nets	Auke Bay-Center	9, 27, 46 m	3
Dec 7	Murre II	60 cm Bongo nets	Stations E, F, D	9, 27-37, 55-64 m	9
1974					
Jan 23	Murre II	60 cm Bongo nets	Stations F, E, D	9-55m	9
Jan 24	Murre II	60 cm Bongo nets	Stations C, B, A	9-72 m	9
Jan 25	Murre II	6' I-K Trawl	Station A	55 m	1
Feb 19	Murre II	60 cm Bongo nets	Stations F, E, D	9-55 m	8
Feb 20	Murre II	60 cm Bongo nets	Stations C, B, A	9-72 m	10
Feb 25	Murre II	60 cm Bongo nets	Fritz Cove	90 m	1
Mar 18	Murre II	60 cm Bongo nets	Station A	9-55 m	3
Mar 19	Murre II	60 cm Bongo nets	Stations F, E, D	9-55 m	9
Mar 20	Murre II	60 cm Bongo nets	Stations C, B	9-72 m	6
Apr 22	Murre II	60 cm Bongo nets	Stations F, E	9-36 m	4
Apr 23	Murre II	60 cm Bongo nets	Stations D, B, A	9-72 m	9
May 29	Murre II	60 cm Bongo nets	Stations F, E, D	9-55 m	8

Appendix Table B.--continued.

Date	Vessel	Gear	Places-Stations	Depth	n
1974					
May 30	Murre II	60 cm Bongo nets	Stations C, B, A	9-72 m	9
July 9	Murre II	60 cm Bongo nets	Stations F, E, D	9-55 m	8
July 10	Murre II	60 cm Bongo nets	Stations C, B, A	9-72 m	9
Aug 20	Murre II	60 cm Bongo nets	Stations F, E, D	9-55 m	8
Aug 21	Murre II	60 cm Bongo nets	Stations C, B, A	9-72 m	9
Sept 26	Murre II	60 cm Bongo nets	Stations F, E, D	9-55 m	8
Sept 27	Murre II	60 cm Bongo nets	Stations C, B, A	9-72 m	9
Oct 23	Murre II	60 cm Bongo nets	Stations F, B, A	9-72 m	9
Nov 29	Murre II	60 cm Bongo nets	Stations F, B, A	9-72 m	9
Dec 17	Murre II	60 cm Bongo nets	Stations F, B, A	9-72 m	8
1975					
Jan 28	Murre II	60 cm Bongo nets	Stations F, B	9-72 m	5
Jan 29	Murre II	60 cm Bongo nets	Station A	9-37 m	2
Mar 21	Murre II	60 cm Bongo nets	Stations F, B, A	9-72 m	9
Apr 30	Murre II	60 cm Bongo nets	Stations F, B, A	9-72 m	8
May 23	Murre II	60 cm Bongo nets	Stations F, B, A	9-72 m	8
June 13	Murre II	60 cm Bongo nets	Stations F, B, A	9-72 m	8