Paired Open Beach Seines to Study Estuarine Migrations of Juvenile Salmon

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ABSTRACT—A paired seine technique was developed to study the timing and direction juvenile Pacific salmon were moving nearshore along straight, long unobstructed beaches in southeastern Alaska. The seines were anchored in place and fished simultaneously in an L-shaped configuration: One seine open in one direction; the other open in the opposite direction. Fishing the paired seines required four people and a small (5.1 m) boat powered by an outboard motor (15 hp minimum).

In 261 paired sets between late March and mid-June of 1981 and 1982, the directional seines were particularly effective in sampling pink salmon, Oncorhynchus gorbuscha *and chum salmon,* O. keta, *fry; coho salmon,* O. kisutch, *smolts; and Dolly Varden,* Salvelinus malma, *smolts and adults. Thirty-eight other species of fish were also captured. Preliminary results showed that pink salmon fry migrating nearshore were most abundant from mid-May to early June and were predominantly migrating north along the west side of upper Chatham Strait.*

Introduction

Marine mortality of pink salmon, *Oncorhynchus gorbuscha*, which is usually very high during their initial coastal migration (Parker, 1968), can be affected by the route and timing of migration to the open sea. Migrations of pink salmon fry toward the sea have been tracked along single inland passages by repeatedly sampling the fish with towed surface trawls or purse seines (Barraclough and Phillips, 1978; Healey, 1980). These fishing methods, however, are not appropriate for southeastern Alaska (Fig. 1) where a myriad of inland passages exists, and the fry can migrate in several directions to the open sea. Thus, we conceived a technique for fishing seines anchored

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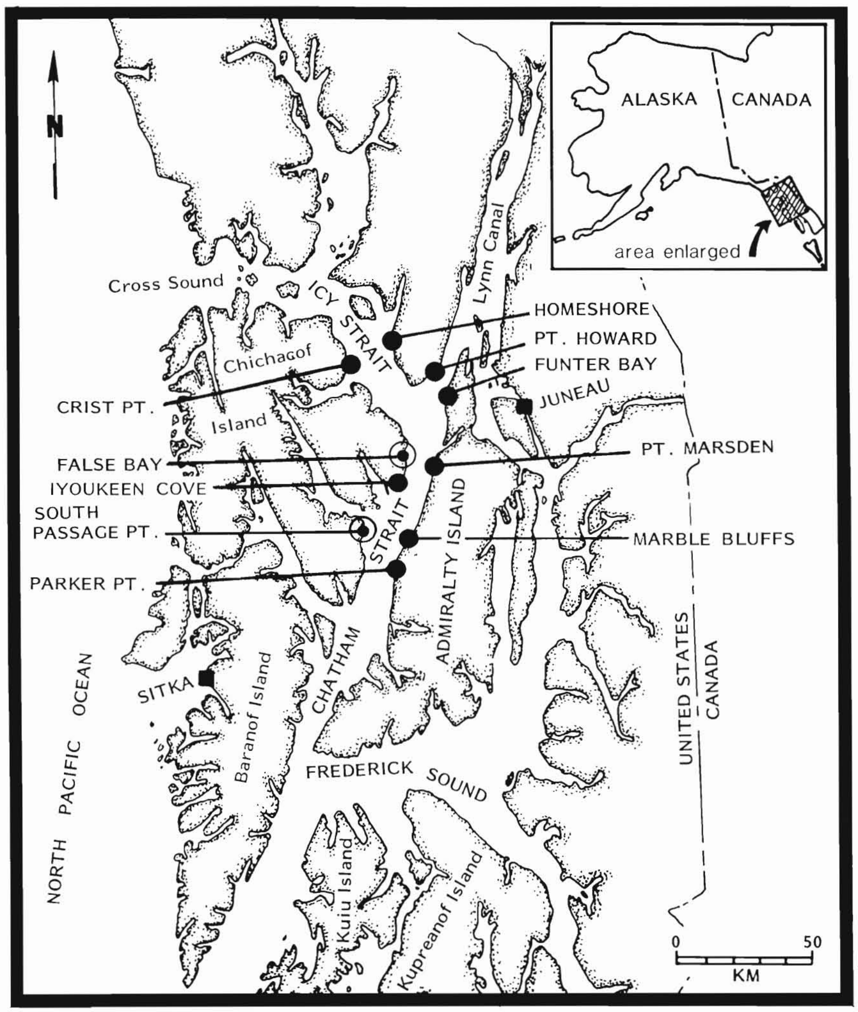

Figure 1.—Location of beach seining sites in the northern part of southeastern Alaska, 1981 and 1982.

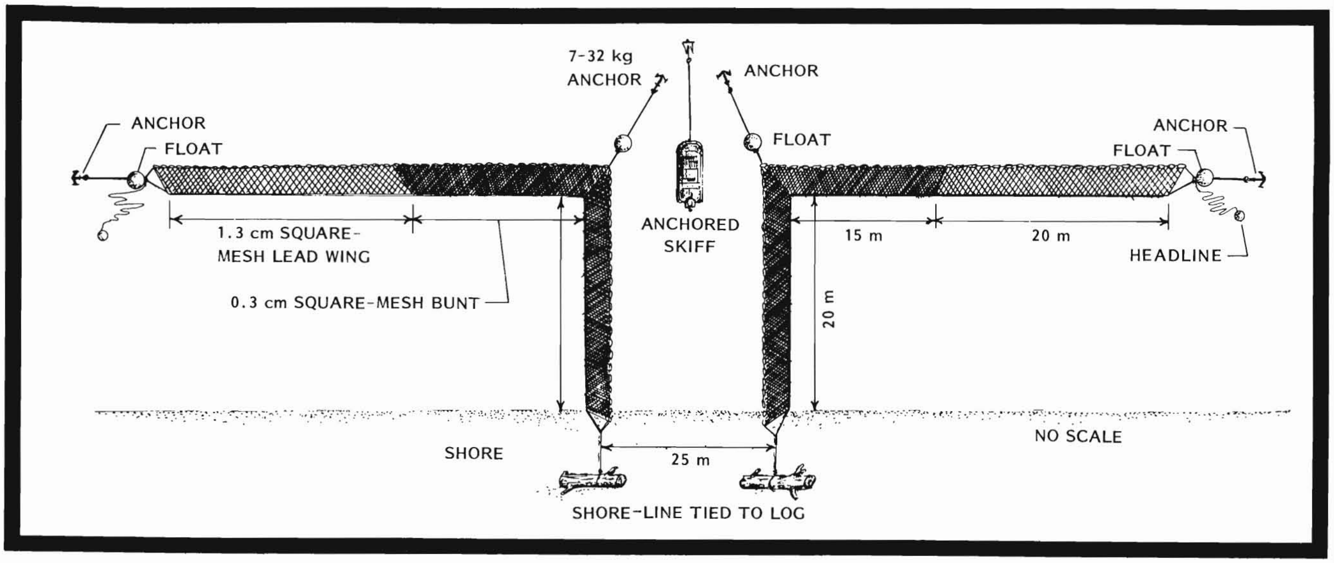

Figure 2.—Specifications and position of the paired beach seines used.

along beaches to determine the direction of movement and timing of nearshore pink salmon fry migrations.

The validity of the method depends on careful selection of beaches. Pink salmon fry spend more time milling about and feeding in protected waters along the shoreline than actively migrating (Healey, 1967). Therefore, our hypothesis is that salmon fry actively migrate along transition beaches—beaches that are long, straight, and smooth, have little protection from current, and offer few opportunities for feeding[1]. Fry caught by directional seining on transition beaches should reveal the predominant direction the fry are migrating.

In this paper, we describe a beach seining technique using directional seines and present preliminary results from 1981 and 1982 that support its validity for determining directional nearshore movements of pink salmon.

Selecting the Beaches

The coast of southeastern Alaska is rocky, and seinable beaches are difficult to find. Ten sites along lower Lynn Canal, Icy Strait, and upper Chatham Strait were chosen (Fig. 1). Most sites were moderately sloped (6-9°), 170-400 m long, unobstructed stretches of sand, gravel, or rubble. Some were sampled often; others only a few times. Results of only two sites in upper Chatham Strait, False Bay and South Passage Point, are described in this paper.

Materials and Methods

Each seine was 55 m long, 3 m deep, and consisted of two sections of nylon web: A lead wing and bunt (Fig. 2). The lead wing was 20 m long and made of white 1.3 cm square mesh (16 kg test). The bunt was 35 m long and made of green 0.3 cm square mesh (20 kg test). The float line was a 1.3 cm diameter blend of polyester polypropylene with a breaking strength of 2,273 kg. The 1.1 cm diameter lead core line weighed 0.3 kg/m and had a breaking strength of 364 kg. The 7.6 cm × 12.0 cm plastic floats had 0.3 kg buoyancy and were spaced 30 cm apart center-to-center on the float line. A 25 m long, 1.1 cm diameter headline was attached to the end of the lead wing, and a variable length shore line was attached to the bunt wing.

Two open seines were simultaneously fished for hour-long sets during the day in 1981 from mid-April through mid-June and in 1982 from late March through mid-June. Both seines were set in the shape of an L, with the opening of one seine facing one direction and the opening of the other seine facing the opposite direction (Fig. 2). After fishing the seines for 1 hour, we closed and brailed them and identified, counted, and released the catches between the seines. The seines were then reset, and the process was repeated up to seven times each day. This seining method requires at least four people and a skiff powered by an outboard motor (15 hp minimum). Activities were minimized near the nets so that migrating fish were not disturbed. Wave lengths over 0.3 m made seining hazardous and injured small fish in the bunt of the seine.

Before the seines were set, each was stacked lead wing first in the bow of a 5.1 m skiff. The end of the bunt was tied to a line attached to a log on the beach. During flood tide, the end of the bunt was tied 1-7 m above the edge of the water, just above where

[1]J. E. Bailey and C. Mattson. Unpubl. data on file at the Auke Bay Laboratory, Northwest and Alaska Fisheries Center, NMFS, NOAA, P.O. Box 210155, Auke Bay, AK 99821.

the tide would reach in 1 hour; thus, fish were prevented from swimming past the net along the shore. During ebb tide, the end of the bunt was tied at the edge of the water. After the seine was tied, one person backed the skiff perpendicular from shore while another person set the seine over the bow. At 20 m from shore, a float, line, and anchor were fastened to a ring on the float line and tossed overboard to become the corner anchor for the seine. The motor operator then backed the skiff in a 90° turn, and the rest of the seine was set parallel to shore. Another float and anchor were then fastened at the end of the net to hold it open (Fig. 2). Ten minutes later, the second seine was tied and set similarly but open in the opposite direction. Each seine in a paired set fished about the same distance offshore at any tidal stage. For each paired set in 1982, the direction the current was moving at the net was noted. When not in use, the skiff was anchored between the two seines.

To close the net, the boat operator ran the skiff to the open end of the seine that had been set first and threw the headline ashore. The person in the bow removed the anchor and float from the open end of the net, and then the shore crew pulled in the headline and lead wing. The corner anchor and float were then removed from the seine, and the skiff was beached. The two crews then pulled both ends of the bunt ashore. Once the catch was put in buckets of water, the seine was restacked in the skiff and set again. The other seine was then closed, the catch removed, and the net reset. Closing, stacking, and resetting a seine required 10-15 minutes.

Table 1.—Catch and size range of the most abundant salmonids caught in paired beach seines in the northern part of southeastern Alaska, April to June 1981, and March to June 1982.

Species	Year	Catch	Fork length range (cm)
Pink salmon	1981	117,018	2.4-8.5
	1982	57,774	2.6-10.5
Chum salmon	1981	15,276	3.1-8.1
	1982	2,401	3.2-6.8
Coho salmon	1981	357	
	1982	1,300	7.5-13.5
Dolly Varden	1981	612	10.5-36.5
	1982	1,511	6.5-46.5

Fish Catches

In 261 paired sets, the open beach seines were successful in catching nearshore salmonids, especially pink and chum salmon, *O. gorbuscha,* fry, and to a lesser extent coho salmon, *O. kisutch*, smolts and Dolly Varden, *Salvelinus malma*, smolts and adults (Table 1). All these fish migrate close to shore for several weeks after leaving freshwater (Scott and Crossman, 1973; Armstrong and Morrow, 1980; Healey, 1980). In 1981 and 1982, we caught 42 species: 8 species of salmonids and 34 other species. In 1982, 91 percent of the catch at all sites consisted of salmonids (mostly pink salmon, Table 2).

The open beach seines were effective in sampling salmon fry up to a mean fork length of 4.5 cm. Pink salmon fry caught in April at False Bay had a mean length of 3.2 cm; chum salmon fry had a mean length of 3.9 cm. In mid-May or early June, when fry were most abundant at this site, mean length of pink salmon fry was 3.6 cm, and mean length of chum salmon fry was 4.5 cm. Few fish larger than 4.5 cm were caught, probably because these fish move offshore, a behavioral change in pink and chum salmon apparently associated with size (LeBrasseur and Parker, 1964; Healey, 1980).

Seasonal Occurrence of Fry

Seasonal migration of the juvenile pink and chum salmon was most ap-

Table 2.—Total abundance of fish and percent composition of catches in paired beach seines at seven sites sampled in southeastern Alaska in March-June 1982. The sites sampled were False Bay, South Passage Point, Homeshore, Pt. Marsden, Iyoukeen Cove, Marble Bluff, and Parker Point.

Scientific name	Common name	Total number	Percentage composition
1. *Oncorhynchus gorbuscha*	Pink salmon	57,774	83.19
2. *Ammodytes hexapterus*	Pacific sand lance	3,136	4.52
3. *Oncorhynchus keta*	Chum salmon	2,401	3.46
4. *Salvelinus malma*	Dolly Varden	1,511	2.18
5. *Oncorhynchus kisutch*	Coho salmon	1,300	1.87
6. *Trichodon trichodon*	Pacific sandfish	1,044	1.50
7. *Gadus macrocephalus*	Pacific cod	634	0.91
8. *Lepidopsetta bilineata*	Rock sole	314	0.45
9. *Icelus* sp.	Thorny sculpin	227	0.33
10. *Myoxocephalus* sp.	Great sculpin	213	0.31
11. *Enophrys bison*	Buffalo sculpin	200	0.29
12. *Hexagrammos* sp.	Greenling	199	0.29
13. *Pholis laeta*	Crescent gunnel	144	0.21
14. *Clupea harengus pallasi*	Pacific herring	122	0.18
15. *Oligocottus maculosus*	Tidepool sculpin	37	0.05
16. *Liparis callyodon*	Spotted snailfish	34	0.05
17. *Blepsias cirrhosus*	Silverspotted sculpin	29	0.04
18. *Leptocottus armatus*	Pacific staghorn sculpin	18	0.03
19. *Psychrolutes paradoxus*	Tadpole sculpin	18	0.03
20. *Salmo gairdneri*	Steelhead trout	18	0.03
21. *Hexagrammos decagrammus*	Kelp greenling	11	0.02
22. *Salmo clarki*	Cutthroat trout	11	0.02
23. *Gasterosteus aculeatus*	Threespine stickleback	9	0.01
24. *Hexagrammos stelleri*	Whitespotted greenling	6	0.01
25. *Platichthys stellatus*	Starry flounder	5	0.01
26. *Mallotus villosus*	Capelin	4	0.01
27. *Oncorhynchus nerka*	Sockeye salmon	3	0.00
28. *Pallasina barbata*	Tubenose poacher	3	0.00
29. *Hemilepidotus hemilepidotus*	Red Irish lord	2	0.00
30. *Blepsias bilobus*	Crested sculpin	2	0.00
31 *Eumicrotremus orbis*	Pacific spiny lumpsucker	2	0.00
32. *Stichaeus punctatus*	Arctic shanny	2	0.00
33. *Anoplarchus* sp.	High cockscomb	1	0.00
34. *Apodichthys flavidus*	Penpoint gunnel	1	0.00
35. *Aulorhynchus flavidus*	Tube-snout	1	0.00
36. *Ophiodon elongatus*	Lingcod	1	0.00
37 *Hemilepidotus* sp.	Irish lord	1	0.00
Total		69,438	100.00

parent at False Bay (Fig. 1), the only site frequently seined in both 1981 and 1982. A few recently emerged pink and chum salmon fry were migrating seaward when we started seining in late March 1981 (during exploratory fishing) or early April 1982. In 1981, most of the fry were caught in mid-May; in 1982, most were caught in early June. As many as 27,000 juvenile pink salmon were caught in a single haul. Usually, however, 200-4,500 pink salmon fry and 10-400 chum salmon fry were caught in a paired set during the peak of the nearshore seaward migration. By mid-June in 1981 and 1982, few pink salmon fry or chum salmon fry were being caught.

Table 3.—Directional movement of pink salmon fry at False Bay in 1981 and 1982 and at South Passage Point in 1982.

	Pink salmon fry			Number of paired sets		
Site	Moving north	Moving south	Total	Predominantly northward movement	Predominantly southward movement	Total
False Bay, 1981						
Number	63,675	14,153	77,828	20	6	26
Percent	82	18	100	77	23	100
False Bay, 1982						
Number	39,104	1,873	40,977	47	10	57
Percent	95	5	100	82	18	100
South Passage Point, 1982						
Number	4,485	3,883	8,368	23	17	40
Percent	54	46	100	58	42	100

Analysis for Directionality and Results

We analyzed the data to determine movement of schools of fish rather than movement of individual fish. Our analysis of directionality treats each paired set of seine catches as a separate observation, and all paired sets are weighted equally. Random movement of fish at a site was used as the null hypothesis, and the probability of a paired set indicating a direction of movement from a choice of two possible directions was 0.5. We grouped the paired sets according to the predominant direction of movement of each species at each site and tested for deviation from the predicted value of 0.5. If there were <25 paired sets, we used the binominal test (two-tailed) for equality (Table D in Siegel, 1956). For analyses with >25 paired sets, the binomial distribution approaches the normal distribution; therefore, we used the normal approximation test corrected for continuity (Siegel, 1956):

$$z = \frac{(x \pm 0.5) - NP}{(NPQ)^{1/2}},$$

where z is the standardized random variable, x is the number of paired sets indicating a certain direction of movement at a site, N is the number of paired sets at that site, and P and Q are the probabilities associated with each direction of movement ($P=Q=0.5$). If $x<NP$, $x + 0.5$ was used; if $x>NP$, $x - 0.5$ was used.

Pink salmon fry at the most intensively fished site, False Bay (Fig. 1), migrated northward in 1981 ($P<0.01$) and 1982 ($P<0.001$) (Table 3). A predominant direction of migration was not evident at a nearby site, South Passage Point, which was fished only in 1982 ($P<0.43$) (Table 3).

Discussion

This beach seining technique must be used on long, unobstructed beaches that have a gradient of at least 6°. This gradient allows the net to fish for 1 hour without going dry during ebb tide. The beach must be longer than 170 m so that the seines can be fished next to each other and the crew can maneuver the skiff around the nets.

Pink salmon fry showed the strongest directionality along a beach where the nearshore current was simple, consistent, and predictable with changing tides. Paired sets at sites close to points, shoals, and reefs showed weaker directionality because these obstructions produced nearshore back eddies from the main current that apparently affected fish movement. Paired sets at sites near entrances of large inlets had weak directionality because strong tidal currents helped produce turbulent and complicated current patterns. In 1982, patterns of surface currents at False Bay and South Passage Point were determined by tracking drogues. The nearshore currents at False Bay were usually parallel to the beach (Fig. 3) and were more consistent with the direction of currents in upper Chatham Strait than at South Passage Point, as predicted by the U.S. Department of Commerce (1980). At South Passage Point, however, located only 1 n.mi. (1.8 km) from the entrance of Tenakee Inlet, currents were variable (sometimes circular, sometimes parallel to the beach) because a nearby point deflected the main current (Fig. 3). Most pink salmon fry were migrating north at both sides (Table 3), but the simpler, more consistent current patterns at False Bay apparently resulted in significant directional data there ($P<0.001$) compared with South Passage Point ($P<0.43$).

In 1982, pink salmon fry were not apparently being carried by the prevailing currents. At False Bay, current direction was usually consistent throughout the sets, and fry were predominantly migrating against it ($P<0.05$, Table 4). At South Passage Point, however, the current often changed direction during the sets, and the direction fry were migrating during a paired set was not significantly related ($P<0.86$) to the direction of the current (Table 4). Continuous measurements of nearshore currents are needed to better understand the influence of currents on juvenile salmon migration.

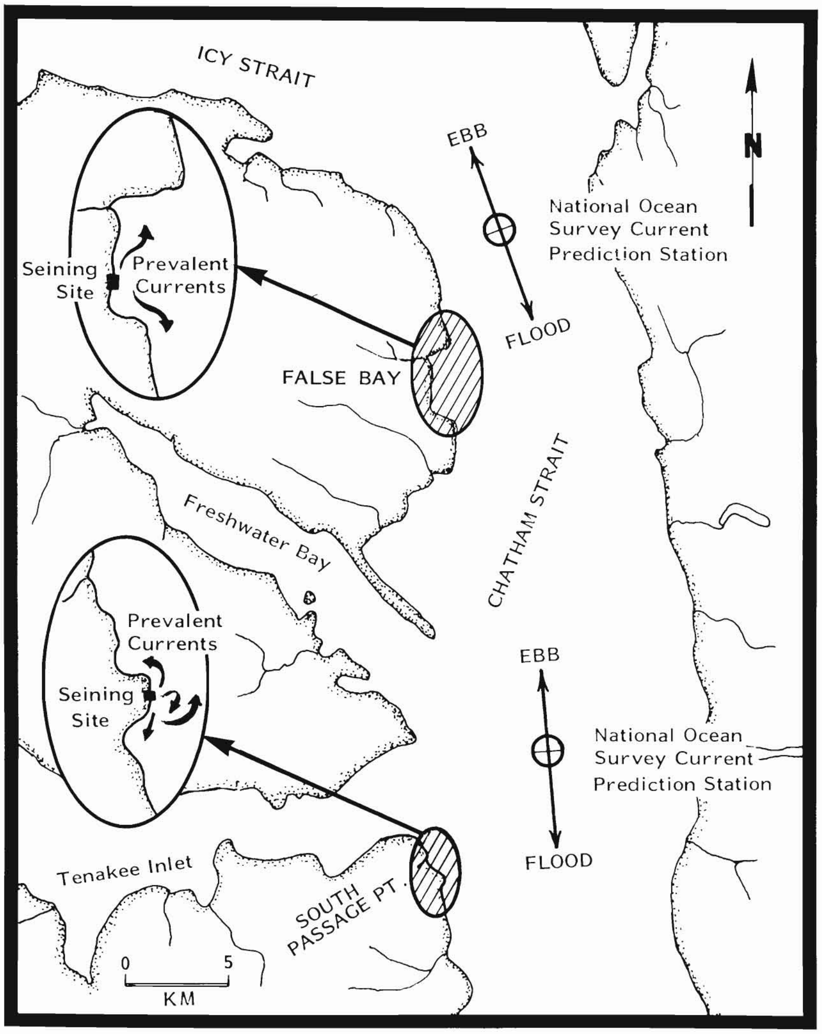

Figure 3.—Direction of nearshore currents at False Bay and South Passage Point in relation to currents in upper Chatham Strait.

Furthermore, the study sites for using paired beach seines must be in areas where salmonids are actively migrating rather than milling, as shown by data from False Bay in 1981 (Table 5). On 12 and 14 May 1981 at False Bay, 75 percent of the pink salmon fry were moving north ($P<0.45$) at Site 1, a 100 m long beach bordered by steep cliffs to the south and a huge boulder to the north (Fig. 4). The cliffs provided protection from wind, waves, and strong currents. Because large numbers of salmon fry were milling about the cliffs, we moved our seining location 260 m to the north to Site 2, a 170 m long unobstructed beach. Catches at Site 2 during the next 2 days indicated 98 percent of the pink salmon fry were moving north ($P<0.004$).

Each year, more juvenile salmonids are marked and released. Little information is available on the location, migration, and size of these fish during their early marine life. Paired beach seines can be used to study nearshore migrations of juvenile salmonids, and recoveries of marked fish will provide valuable data on the origin, migration routes, nearshore residence, behavior, and growth of individual stocks. Directional seining can also be used to study the nearshore migrations of other fishes in estuaries, lakes, and reservoirs.

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Table 4.—Number of paired sets with pink salmon fry moving predominantly with or against the nearshore currents at False Bay and South Passage Point in 1982.

Site	Number of paired sets with predominant direction of pink salmon fry movement	
	With current	Against current
False Bay	10	22
South Passage Point	18	16

Table 5.—Directional movement of pink salmon fry at two sites in False Bay 1981.

Site	Pink salmon fry			Number of paired sets		
	Moving north	Moving south	Total	Predominantly northward movement	Predominantly southward movement	Total
Site 1						
Number	38,235	12,738	50,973	5	2	7
Percent	5	25	100	71	29	100
Site 2						
Number	24,418	456	24,874	9	0	9
Percent	98	2	100	100	0	100

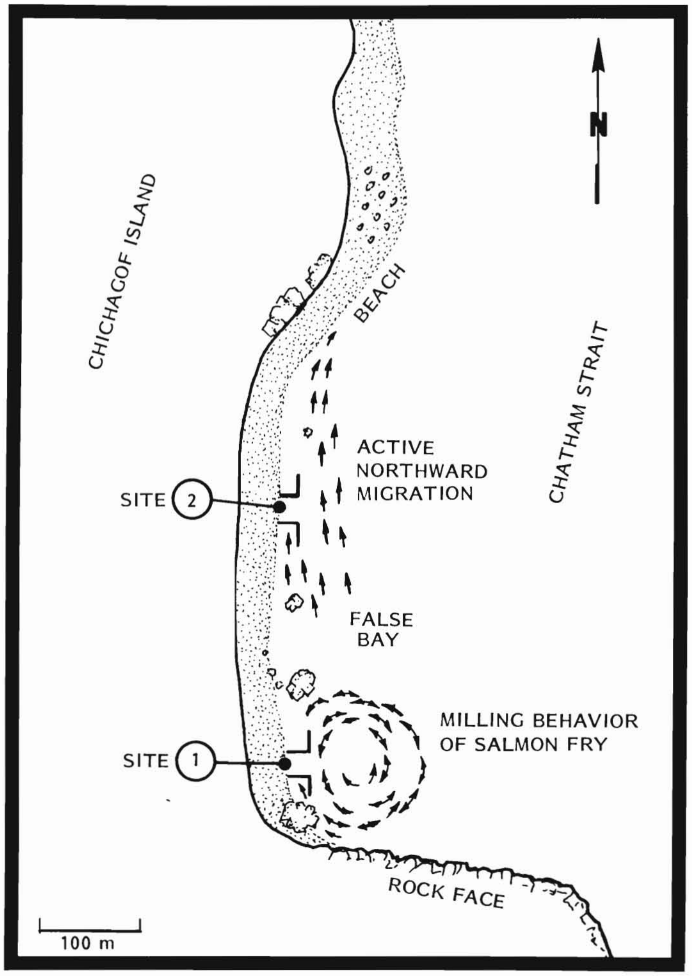

Figure 4. – Areas where juvenile salmon were milling or actively migrating northward at False Bay, southeastern Alaska.

research vessels *Murre II* and *John N. Cobb,* the U.S. Fish and Wildlife vessel *Curlew*, the Alaska Department of Fish and Game vessel *Kittiwake*, and the University of Alaska at Juneau vessel *Maybeso.*

Literature Cited

Armstrong, R. H., and J. E. Morrow. 1980. The Dolly Varden charr, *Salvelinus malma*. *In* E. K. Balon (editor), Charrs, salmonid fishes of the genus *Salvelinus*, p. 99-140. Dr. W. Junk, The Hague, Netherlands.

Barraclough, W. E., and A. C. Phillips. 1978. Distribution of juvenile salmon in the southern Strait of Georgia during the period April to July 1966-1969. Fish. Mar. Serv. Tech. Rep. 826, 47 p.

Healey, M. C. 1967. Orientation of pink salmon (*Oncorhynchus gorbuscha*) during early marine migration from Bella Coola River system. J. Fish. Res. Board. Can. 24:2321-2338.

Healey, M. C. 1980. The ecology of juvenile salmon in Georgia Strait, British Columbia. *In* W. J. McNeil and D. C. Himsworth (editors), Salmonid ecosystems of the North Pacific, p. 203-229. Oreg. St. Univ. Press, Corvallis.

LeBrasseur, R. J., and R. R. Parker. 1964. Growth rate of central British Columbia pink salmon (*Oncorhynchus gorbuscha*). J. Fish. Res. Board Can. 21:1101-1128.

Parker, R. R. 1968. Marine mortality schedules of pink salmon of the Bella Coola area, British Columbia. J. Fish. Res. Board Can. 25:757-794.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Board. Can. Bull. 184, 966 p.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. Mc-Graw-Hill, N.Y., 312 p.

U.S. Department of Commerce. 1980. Tidal current tables, 1981, Pacific coast of North America and Asia. U.S. Gov. Print. Off., Wash., D.C., 260 p.