483

Intertidal Ecology and Life History of Pink Salmon at Olsen Creek, Prince William Sound, Alaska

by John H. Helle, Richard S. Williamson, and Jack E. Bailey

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ABSTRACT

Intertidal spawning of pink salmon is of major importance in Prince William Sound. Studies were initiated at Olsen Bay in 1960 to ascertain how much these intertidal spawners contributed to the total production of pink salmon.

Olsen Creek is inundated with tidewater about 80 percent of the time at the 3-foot tide level and about 7 percent of the time at the 11-foot level. Saline water was shown to penetrate the gravel at redd depth during high tides. The highest concentration at the 11-foot tide level was 9.3 $^{\circ}/oo$ during a 14.5-foot tide. Temperature changes of up to 10° F. would occur within 1 hour at elevations up to the 8-foot level on floodtide.

The occurrence of spawners in 1960 and 1961 was bimodal; however, in 1960 the late run utilized only the intertidal spawning area, while in 1961 the late run utilized both the intertidal and fresh-water areas. During the 2 years the early run spawned in both environments. In 1960, 98,574 pink salmon spawned in Olsen Creek and in 1961, 135,905 spawned. During both years 74 percent of the total run spawned in the intertidal portion of the stream.

Temporal and spatial distribution of spawners, size differences, and seasonal changes in sex ratios provide evidence for the existence of discrete spawning groups or races.

Live egg densities and survival over winter to the preemergent fry stage were progressively greater from the lower to the higher levels in the intertidal area. Overwinter survival between egg and fry stages below the 4-foot level was 0. Survival at the 7- to 9-foot level and the 10- to 11-foot level was 20 and 54 percent respectively.

INTRODUCTION

Pink salmon (Oncorhynchus gorbuscha) reproduce in intertidal (defined here as the portion of stream inundated by periodic tidal flow) as well as strictly fresh-water portions of many streams along the southern and southeastern coast of Alaska. Hunter (1959) reports the occurrence of intertidal spawning in British Columbia, Canada. In many streams, steep gradients or waterfalls occur at the high tide level and only the intertidal zones are available to spawners; but even when both types of environment are present and upstream areas are uncrowded or barren of spawners, pink salmon will reproduce in the intertidal zone (Conkle).[1]

Hanavan and Skud (1954) in their study of intertidal spawning of pink salmon at Lover's Cove stream in Southeastern Alaska found that survival of spawn in the area between the 4- and 11.5-foot tide levels was as high as or

[1] Temporal and spatial relationships of spawning pink salmon in a Prince William Sound stream. A paper read at the Twelfth Alaskan Science Conference, College, Alaska, 1961. On file Bureau of Commercial Fisheries Biological Laboratory, Auke Bay, Alaska.

higher than survival in fresh-water areas. Their study also showed that the salinity of the water in the gravel at redd depth was dependent on the salinity of the water covering the area. This saline water in the gravel was thoroughly flushed out by fresh water as the tide ebbed.

Rockwell (1956) demonstrated in laboratory experiments with pink salmon that at salinity concentrations up to 18 parts per thousand ($^{0}/oo$) fertilization was not inhibited, and that even at $30^{0}/oo$ some fertilization could take place. He also showed that better growth, survival, and activity were attained by larvae in dilute sea water as opposed to those in fresh water. At Herman Creek in Southeastern Alaska, Rockwell found survival of pink salmon to the eyed egg stage higher in some intertidal areas than in upstream areas.

Pink salmon mature at 2 years of age, with rare exceptions (Anas, 1959). Adults spawn in streams in the summer or fall and like all Pacific salmons (Oncorhynchus spp.) die shortly after spawning. The resultant fry emerge from the gravel after absorbing the yolk sac and migrate directly to sea. They return as adults after about 1 year in salt water. Because of their strict adherence to a 2-year life cycle, pink salmon from consecutive years do not interbreed. This results in two genetically distinct stocks.

Royce (1962) reports the pink salmon pack in Prince William Sound from 1910 to 1960. He demonstrates that several reversals in odd- and even-year dominance have taken place. After 1950, the even year has been the strong cycle; however, the unexpected large return of pink salmon in 1961 might be indicative of the strengthening of the odd-year cycle.

Studies were begun at Olsen Bay, Alaska, in 1960 to study life history, ecology, and survival of pink salmon in an intertidal spawning area. Olsen Bay is located in Prince William Sound where intertidal spawning (more than 50 percent) is of major importance. The ultimate objective is to determine the contribution of the intertidal spawners to the total production of pink salmon.

This paper covers the first 2 years of investigations which were undertaken as an inventory to describe the environment, assess the characteristics and magnitude of the fish populations, and measure rates of survival of eggs and larvae.

OLSEN BAY DRAINAGE

General Area

Location.--Olsen Bay is located on the east shore of Prince William Sound in the northern part of Port Gravina at lat. 60° 45' N. and long. 146°12' W. A research field station was constructed at the head of the bay where two forks of Olsen Creek join to become the main intertidal stream (fig. 1).

The surrounding terrain is steep timbered mountains, the tops of which are snow covered most of the year. Streamflows are maintained entirely by runoff and ground-water depletion.

Climate.--Olsen Bay is close enough to the open sea for the climate to be tempered by oceanic influence. Cordova, 30 miles southwest, is the nearest place where daily weather records are kept. These records show precipitation to be high (annual average, 98.64 inches), with the greatest amounts occurring in the fall months (U.S. Weather Bureau, 1959).

Records of precipitation and air temperature were kept during the summer months the station was in operation in 1960 and 1961; and during those periods in both years, Olsen Bay had less precipitation than Cordova (table 1). The total annual precipitation at Cordova was 89 inches in 1960 and 97 inches in 1961. Probably Olsen Bay has less annual precipitation than Cordova. Daily maximum and minimum air temperatures for Olsen Bay and Cordova are quite similar.

Intertidal Study Area

The Olsen Bay intertidal study area contains three streams: Olsen Creek (the main stream), Middle Slough, and Little Creek (fig. 1). The main stream is formed by the convergence at the 11-foot tide level of its two streams, East Fork and West Fork, which make up the principal Olsen Creek drainage system. The 12-foot tide level (approximately mean high tide) on the main stream was chosen as the separation point between the intertidal study area and the fresh-water area. Middle Slough is a small stream with low velocity, and only the intertidal portion is available to spawning salmon. Little Creek, also a small stream with low velocity, drains from the east side of the drainage and is utilized by spawners only in its intertidal area. The surface flow of both these streams freezes in winter and stops for unknown periods. One small tributary joins the West Fork at the 11-foot tide level, and another joins Olsen Creek at the 5-foot tide level.

Table 2 shows the average intertidal area of each of the spawning streams and the total for the combined areas. An area of 39,375 square feet bounded by the 9- and 10-foot tide levels contains the only pool in the intertidal portion of the main stream. The pool takes up approximately 30 percent of the area and seems to discourage spawning by pink salmon, although chum salmon (O. keta) have been observed spawning there. The width of each stream and hence the area available for salmon spawning varies independently with fluctuations in flow.

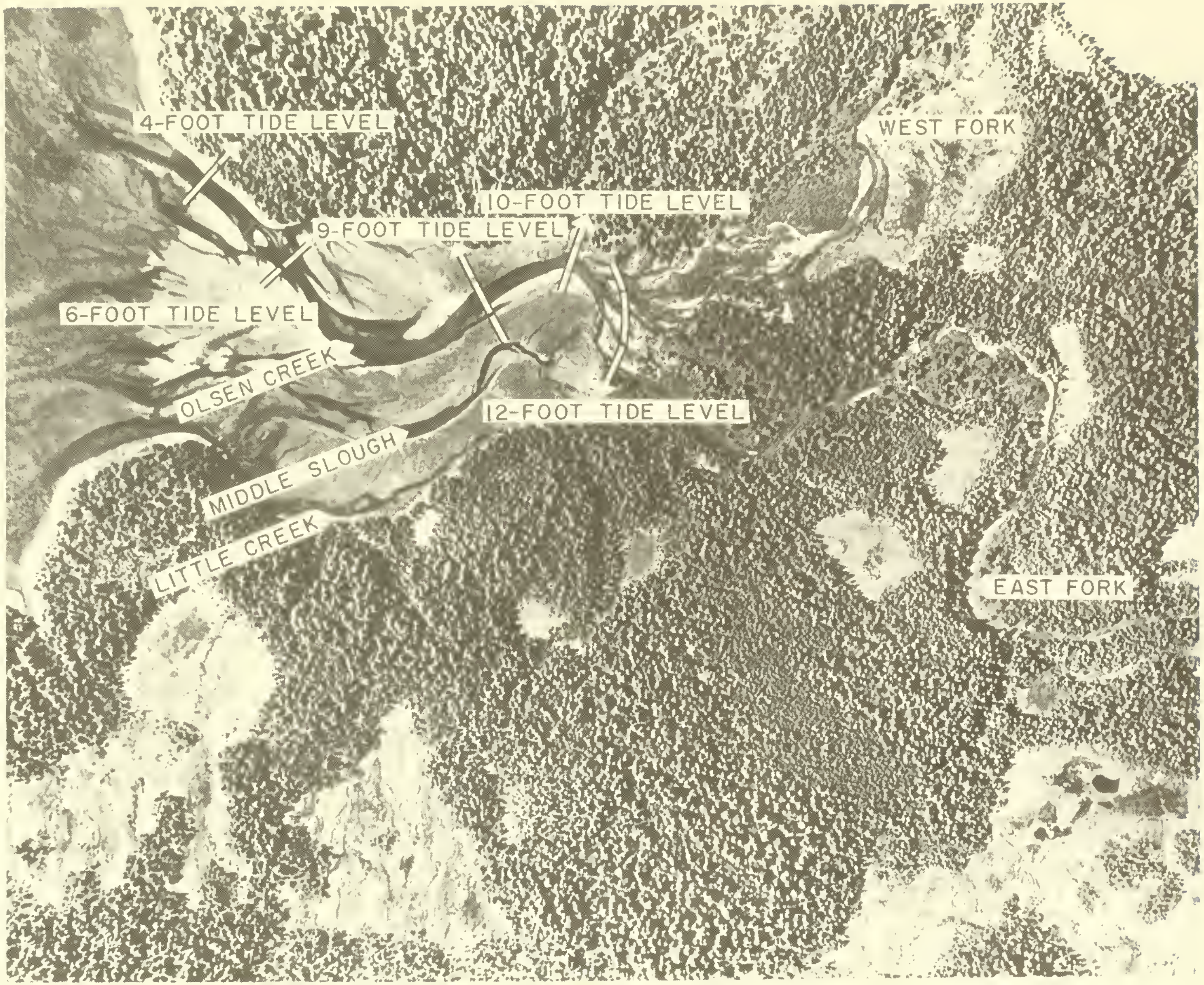

Figure 1.--Olsen Creek study area.

Table 1.--Precipitation and mean maximum and minimum temperature at Olsen Bay and Cordova,[1] July, August, and September, 1960 and 1961

Year	July				August				September			
	Olsen Bay		Cordova		Olsen Bay		Cordova		Olsen Bay		Cordova	
	Precipitation (inches)											
1960	8.19		9.10		8.49		13.65		15.47		26.33	
1961	[2] 3.88		[2] 9.77		13.20		15.43		12.75		13.51	
	Temperature °F.											
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1960	--	--	60	46	64	45	61	48	56	42	55	43
1961	60	50	62	49	57	45	59	43	51	38	56	37

[1] Cordova data from Climatological Data, Alaska, published by Weather Bureau, Department of Commerce.
[2] Beginning July 10.

Table 2.--Average intertidal length, width, and area of streams in Olsen Creek drainage between 3- and 12-foot tide levels

Stream and tide level (feet)	Length	Average width	Area
	Feet	Feet	Square feet
West Fork			
11-12	113	25	2,825
East Fork			
11-12	100	25	2,500
Main Stream			
10-11	150	75	11,250
9-10	525	75	39,375
8-9	225	85	19,125
7-8	187	75	14,025
6-7	212	72	15,264
5-6	200	50	10,000
4-5	275	63	17,325
3-4	300	75	22,500
Middle Slough			
3-10	1,825	35	63,875
Little Creek			
3-10	1,475	17	25,075
Total			243,139

Streamflow.--Stream level recorders were operated on the East Fork in 1960 and 1961, and on the West Fork in 1961. Rating curves for stream discharges of each fork were developed using a Price current meter (Welch, 1948). Gage height and volume-of-flow data are presented in appendix figures 1, 2, and 3. Discharges varied from 10 to about 500 cubic feet per second (c.f.s.), with the summer averages for each fork about 33 c.f.s. Olsen Bay streams are typical of the short coastal streams in Prince William Sound; they are subject to rapid fluctuations in flow, depending on the amount of rainfall. Frequent floods occur and at times cause minor changes in the riffle areas because of gravel shift, especially in the lower part of the stream.

Tidal movements.--We used tide predictions for Cordova (U.S. Coast and Geodetic Survey, 1960) to estimate tidal movements at Olsen Bay. Differences in time and tide height between the two points, if any, are not known and no corrections were made. The mean tidal range is 10 feet, and the diurnal range is 12.4 feet. In 1961 the lowest predicted tide was -3.3 feet and the highest was 15.4 feet. One-foot elevations from the 2-foot to the 12-foot tide level were surveyed by transit and permanently marked. Using the predicted tides for 1961, we calculated the percent of time that each elevation from the 3-foot to the 12-foot tide level was covered with tide water (fig. 2).

Salinity.--During summer 1961, we began preliminary investigations of the salt-water intrusion into the intertidal area of the creek. Salinity determinations were made with a hydrometer calibrated in parts per thousand. At high tide water samples were taken at the water surface and gravel surface at each 1-foot level between the 4- and 12-foot tide levels. A few samples were also taken from

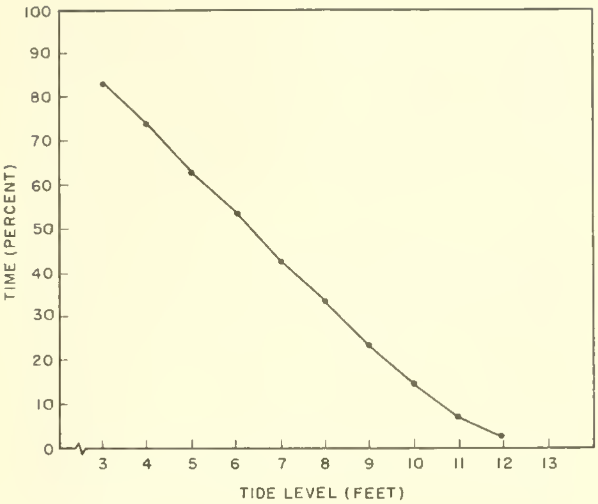

Figure 2.--Percent of time different tide levels in Olsen Creek were covered with tide water.

standpipes buried 8 to 10 inches in the gravel at the 8-, 9-, 10-, and 11-foot tide levels. The standpipes were too short to obtain samples at lower tide levels. A description of the methods used to sample intragravel water from standpipes and a comparative evaluation of the hydrometer method of salinity determinations is given in Hanavan and Skud (1954). When samples were taken from both the gravel surface and from beneath the gravel surface, the salinity of the intragravel water generally was higher than the gravel surface water. Salinity in the gravel surface water between the 8- and 12-foot tide levels was not measurable unless the tide covered the level to a depth of more than 2 feet. On one occasion samples were collected at the 6- and 8-foot tide levels during an ebbing tide. Within 1 hour after the creek water level had returned to normal fresh-water discharge, salinity of the intragravel water dropped from 22°/oo to less than 1°/oo.

Not enough samples were taken to show the effects of tide height and stream discharge on the salt-water intrusion into the stream and intragravel water. During average stream discharge and with a 13.3-foot tide, the salinity of the intragravel water was 1.2°/oo at the 10-foot tide level and was 0 at the 11-foot tide level. No intragravel water samples were obtained at higher tides. The only gravel surface water sample at the 12-foot tide level was obtained during a 14.6-foot tide when the salinity was 1.6°/oo. During this same tide, the salinity of the gravel surface water at the 11-foot tide level was 2.0°/oo. The highest salinity sample from the 11-foot tide level, 9.3°/oo. was obtained during a 14.5-foot tide. Stream discharge at this time was approximately one-half as much as during the 14.6-foot tide.

Gravel temperature.--Pink salmon eggs in the intertidal area are subjected to temperature variations caused by tidal movement. The temperature variations in the gravel at any particular point depend on the temperature of the creek water and the tidal water, the height of the tide at that point, permeability of the streambed, and the amount of fresh water discharged from the creek.

Temperature records from the Olsen Bay intertidal area during two complete tide cycles on July 20 and August 30, 1961, are shown in figures 3 and 4.

Electronic thermometer probes were buried 8 to 10 inches deep at each foot of elevation from the 3- to the 10-foot tide level, and the leads were brought to a central point so that simultaneous temperature readings could be made. Probes at the 6-, 7-, and 9-foot levels were broken and could not be used for the full study period.

Elevations up to the 8-foot level were subject to temperature variations up to 10° F., depending on the height of the tide. Temperature changes of this magnitude occurred within a 1-hour period.

The 10-foot tide level was affected less and for shorter periods than lower levels. No

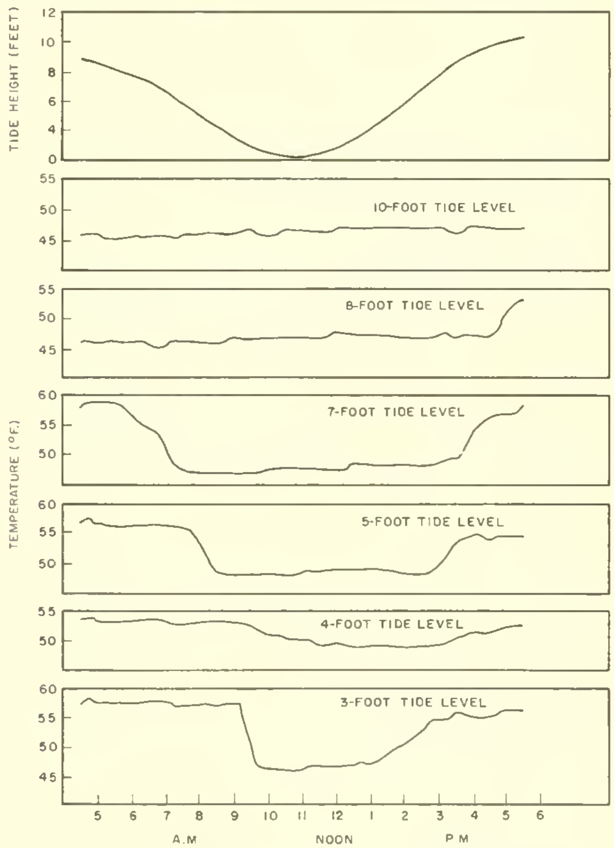

Figure 3.--Simultaneous temperature readings in the gravel (8-10 inches deep) at various tide elevations in Olsen Creek on an ebbing tide cycle, July 20, 1961.

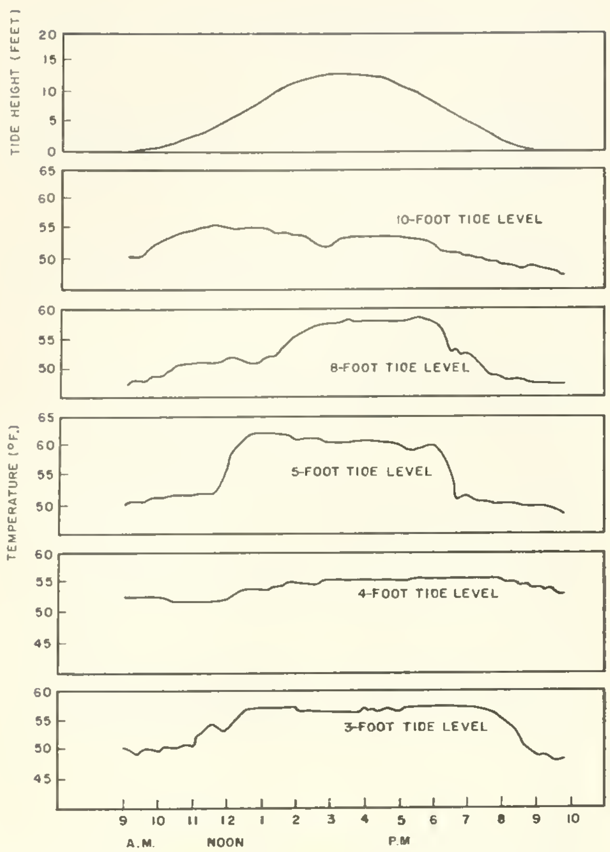

Figure 4.--Simultaneous temperature readings in the gravel (8-10 inches deep) at various tide elevations in Olsen Creek on a flooding tide cycle, August 30, 1961.

temperature variations over 5° F. were recorded at the 10-foot level. During low waterflows in the creek, the gravel at the 10-foot-level thermometer probe was covered by only a few inches of water and was subject to warming by the sun. This is evident from the temperatures taken on August 30 (fig. 4) when a rise of 5° occurred at the 10-foot level before the incoming tide had reached the 5-foot level. The creek water temperature rose 1° at this time.

The temperature did not usually fluctuate as much at the 4-foot level as at the 3- and 5-foot levels. We believe this was caused either by fresh-water seepage from a nearby bog or by poor circulation through the gravel.

Gravel composition.--Twenty-four gravel samples were taken from the 3-foot through the 11-foot tide levels with equipment similar to that described by McNeil and Ahnell.[2] The core of the sampler excluded all streambed materials more than 4 inches in diameter. Samples were washed through a series of seven sieves with mesh sizes graduated from 50.8 to 1.0 mm. All material passing through the smallest sieve was collected in a settling funnel, and that portion settling out in 10 minutes was measured by volume. The volume of the materials left in each sieve and in the settling funnel is expressed as percent of the total volume for each sampling site (table 3).

Not enough samples were obtained for a complete analysis of gravel sizes at different tide levels, but they do show a decrease in the amounts of the largest gravel size from higher to lower levels and an increase of materials smaller than 1.0 mm. To define more clearly the proportions of sand and silt, a more extensive gravel sampling program will be undertaken with smaller meshed sieves.

Fauna.--Intertidal inhabitants common to the area were collected at low tides during July and August 1961. Three habitats were sampled: the main stream, Middle Slough, and the exposed tideflat between. The distribution of organisms by tide level is given in figure 5.

[2] Measurement of gravel composition in salmon streambeds. Circular 120, Fisheries Research Institute, University of Washington, Seattle, 1960. On file at the Bureau of Commercial Fisheries Biological Laboratory, Auke Bay, Alaska.

Table 3.--Mean percent by volume of stream bottom materials retained by sieves and settling funnel

Tide level	Volume of materials retained by sieve with opening (in mm.) of--							Volume retained by settling funnel
	50.8	25.4	12.7	6.35	3.36	1.68	1.0	
Feet	Percent							
10-11.......	11.5	17.0	15.4	16.9	14.0	9.0	4.8	11.1
7-9........	15.0	18.6	14.8	14.5	12.9	8.0	4.6	11.3
5-6........	8.0	23.7	14.5	13.3	11.9	6.9	5.0	16.4
3-4........	6.1	15.0	19.0	15.1	14.9	7.5	5.1	17.2

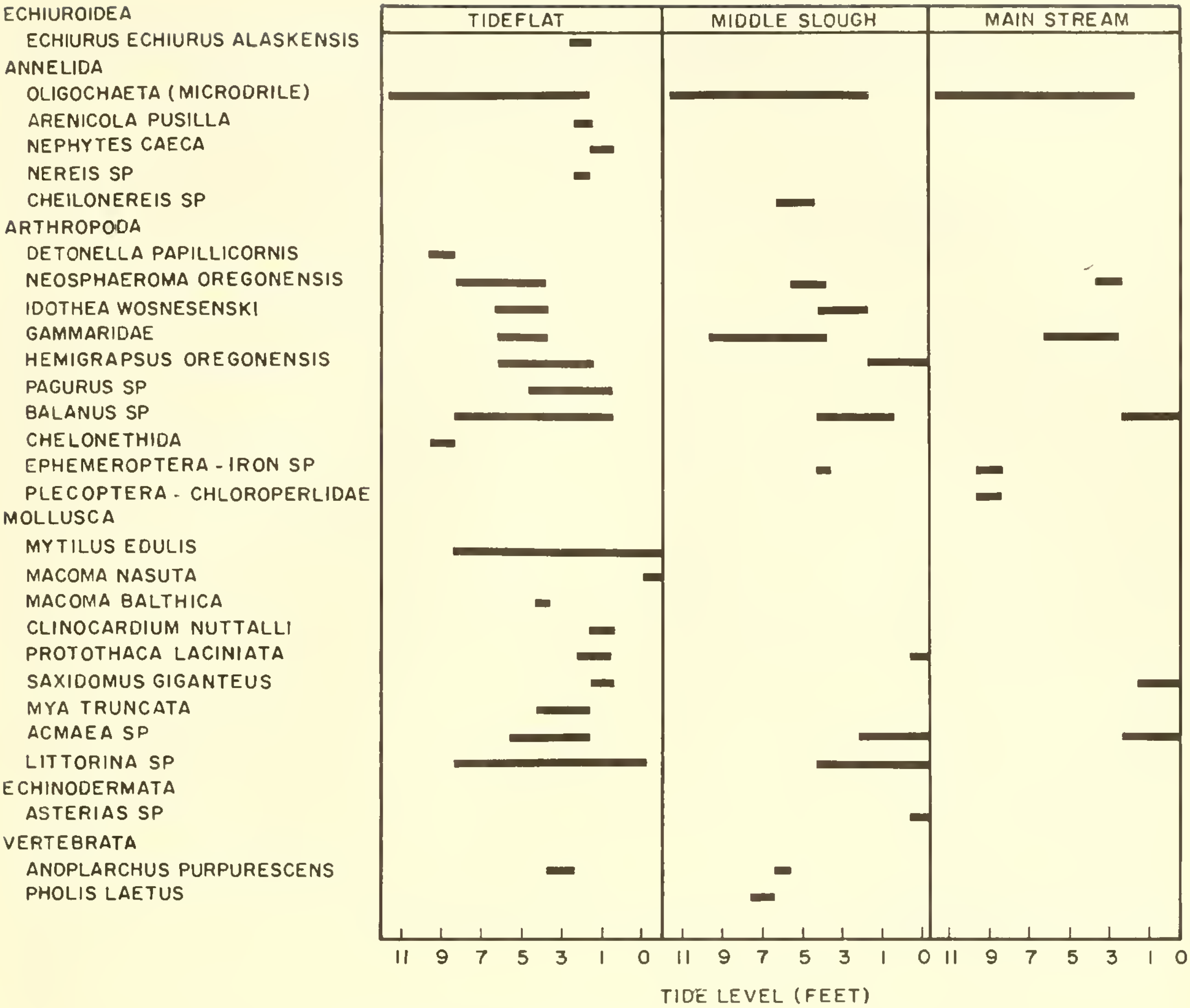

Figure 5.--Distribution of organisms by tide level, Olsen Creek drainage, 1961.

At each tide level an approximate area of 400 square feet was paced off, and from a table of random numbers 10 sample sites, each 1-foot square, were selected. In the exposed tideflat area, organisms visible from the surface and from 6 to 8 inches below the surface were collected by hand. In collecting stream samples each site was dug and all loosened organisms were washed into a screen of 12 meshes to the inch placed just downstream from the site. Although more thorough collecting methods would yield more species, the present collection was probably representative of the larger, most abundant intertidal residents.

The tideflat between the two streams yielded the greatest number of species, Middle Slough the next greatest, and the main stream the least. The greater volume and velocity of the water and the spawning activity in the main stream could have contributed to the scarcity of bottom inhabitants.

Large numbers of unidentified microdrile oligochaetes were found between the 11- and 2-foot levels of both streams. Fucus, the dominant alga in each habitat, was found from the 9- to 2-foot tide levels on the tideflat, from the 7-foot to 0 level in Middle Slough, and from the 2-foot to 0 level in the main stream. Eelgrass (Zostera) was most abundant at the 1-foot to 0 tide level in each habitat. Fry and fingerling coho salmon (Oncorhynchus kisutch) and Dolly Varden (Salvelinus malma) were found in all the intertidal streams above the 7-foot level. A few fingerling chum and pink salmon were found in Middle Slough and Little Creek during July. Coastrange sculpin (Cottus aleuticus), Pacific staghorn sculpin (Leptocottus armatus), and threespine stickleback (Gasterosteus aculeatus) were more numerous in Middle Slough. During higher high tides starry flounder (Platichthys stellatus) and Pacific tomcod (Microgadus proximus) were observed just above the 9-foot level in the main stream.

CHARACTERISTICS OF THE SPAWNING MIGRATION

Timing

The timing of the pink salmon spawning migrations to Olsen Creek demonstrated different patterns with regard to utilization of fresh-water and intertidal spawning areas on the even- and odd-year cycles (1960 and 1961). In the 1960 run, the peak of the fresh-water migration occurred about July 25 (fig. 6), and by August 10 it was practically over. The intertidal migration was bimodal, the first peak occurring about August 8 and the second September 4. The distinct separation of intertidal and fresh-water spawners in relation to time and space that occurred during the 1960 run did not take place in 1961 (fig. 6). A small early run of both intertidal and fresh-water spawners occurred in early July, but the greatest portion of the migration developed in late August and early September.

The daily migrations of spawners into the East and West Forks of Olsen Creek are compared in figure 7. In both years the daily migrations were almost identical.

Federal management agents operated a weir to count spawning escapement at Olsen Bay in 1931 and 1932 (Bower, 1932 and 1933); and in 1953, 1954, and 1955 (Thompson, 1955, 1956, 1957). Because of the position of the weir in the intertidal area, data on the numbers of fish for these years are probably inaccurate. However, they do provide comparative information on the timing of the runs (fig. 8).

The counts for 1932 are not shown in the figure because heavy rains washed out the weir on August 14 after only 331 pink salmon had been counted. Up to August 6 only 14 pink salmon had been counted, but from August 7 until the washout the count was increasingly daily. Complete counts are available for only 2 even years (1954 and 1960) but in these the run was bimodal. The peak of the "early" run occurs in late July and of the "late" run in late August or early September. Periodic stream surveys, from 1952 to 1956,[3] also have demonstrated the bimodal occurrence of spawners at Olsen Creek on the even-year cycle. Because of facts presented in these more recent data it would seem that the "early" run in 1932 was extremely depressed or nonexistent.

The location of the weir before 1960 in the intertidal zone between the 9- and 10-foot tide level makes separation of timing of intertidal and fresh-water spawners impossible. The records state, however, that when fish were present considerable spawning took place below the weir.

The timing of the late run in the odd-year cycle in 1931, 1953, and 1955 (fig. 8) was similar to the timing of the late run in the even-year cycle, i.e., a gradual buildup of spawners peaking in late August or early September. No early run was evident in 1931, 1953, and 1955, but a small early run did appear in 1961 (fig. 6). This was similar to the even-year migration in 1932 when the early run was either nonrecognizable or nonexistent.

Conkle[4] stated that the commercial fishery in Prince William Sound historically caught mostly early-run fish, allowing a greater number of late-arriving fish to spawn. On the even-year cycle at Olsen Creek these late-arriving pink salmon are predominantly intertidal spawners. Conkle suggested that the concentration of the commercial fishery on the early run depleted that run, allowing a subsequent buildup of intertidal spawners.

There is some evidence that the late-run fish in the odd-year cycle are available to the commercial fishery. The weir attendant at Olsen Creek in 1931[5] stated that a large school of pink salmon appeared in the bay on July 25 and did not start upstream until about August 13. This same phenomenon was observed at Olsen Creek in 1961. Most of the fish in the early run spawned and died by the first week in August, when large numbers of pink salmon again appeared in the bay. They stayed there for almost 2 weeks before migrating upstream. When the upstream migration did start the fish were ready to spawn. This is in contrast to the early-run fish which enter the stream while not yet mature, and do not spawn immediately.

Magnitude of Fresh-water Migration

In 1960 and 1961 wooden picket weirs were installed across the East Fork (fig. 9) and the West Fork (fig. 10) of Olsen Creek at approximately the 12-foot tide level. Both upstream and downstream movements of pink salmon through the weir gates were recorded from counting houses located on the bank at each

[3] Wallace H. Noerenberg of the Fisheries Research Institute, University of Washington, made spawning ground surveys of streams in Prince William Sound from 1953 to 1956. The results are reported in Fisheries Research Institute Circulars 46, 58, 69, 81, and 90 (Fisheries Research Institute, University of Washington, Seattle).

[4] See footnote 1, p. 1

[5] Unpublished management reports, 1931, on file at the Bureau of Commercial Fisheries Biological Laboratory, Auke Bay, Alaska.

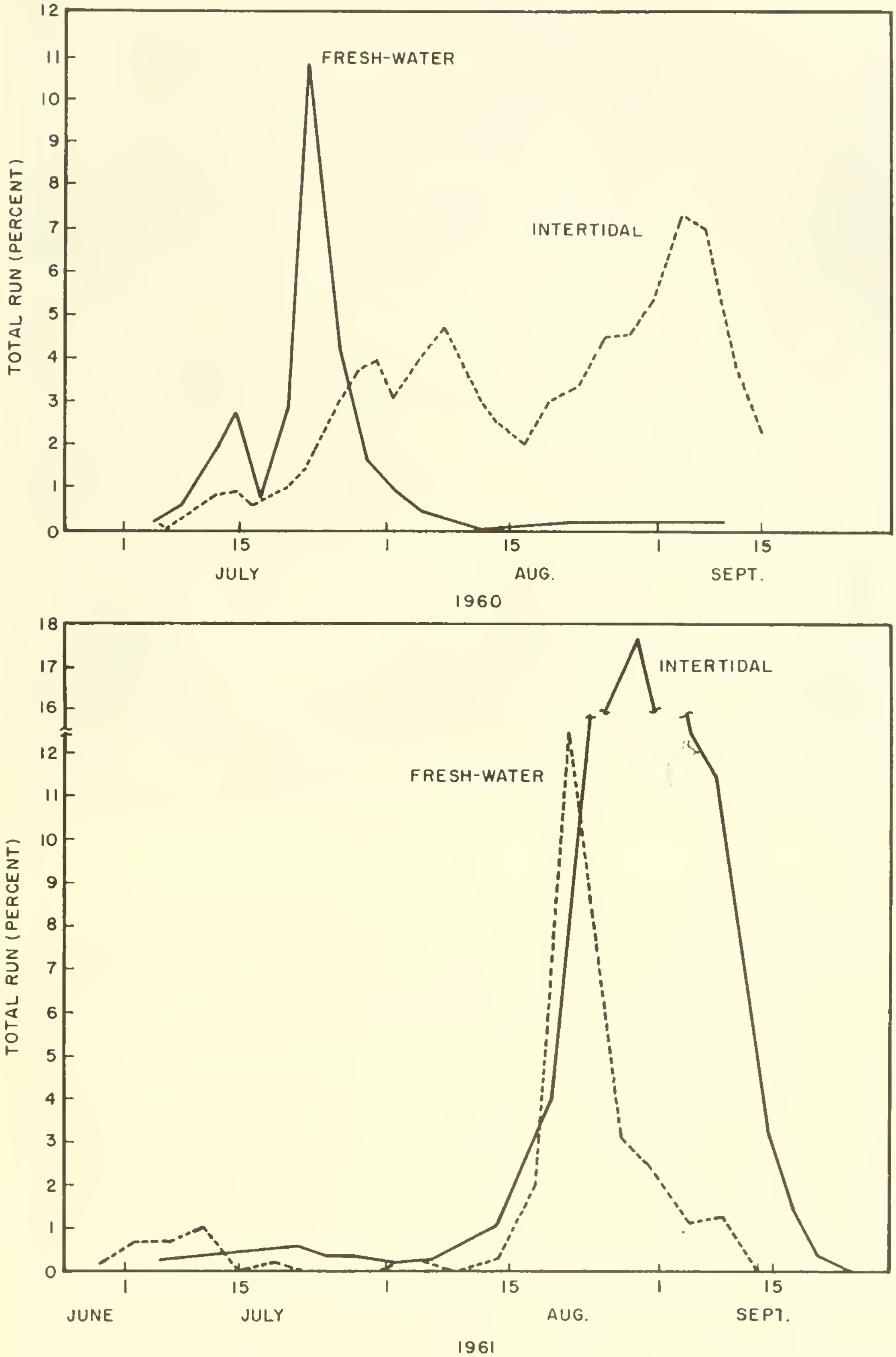

Figure 6.--Relation of timing and distribution of Olsen Creek pink salmon escapement, 1960-61.

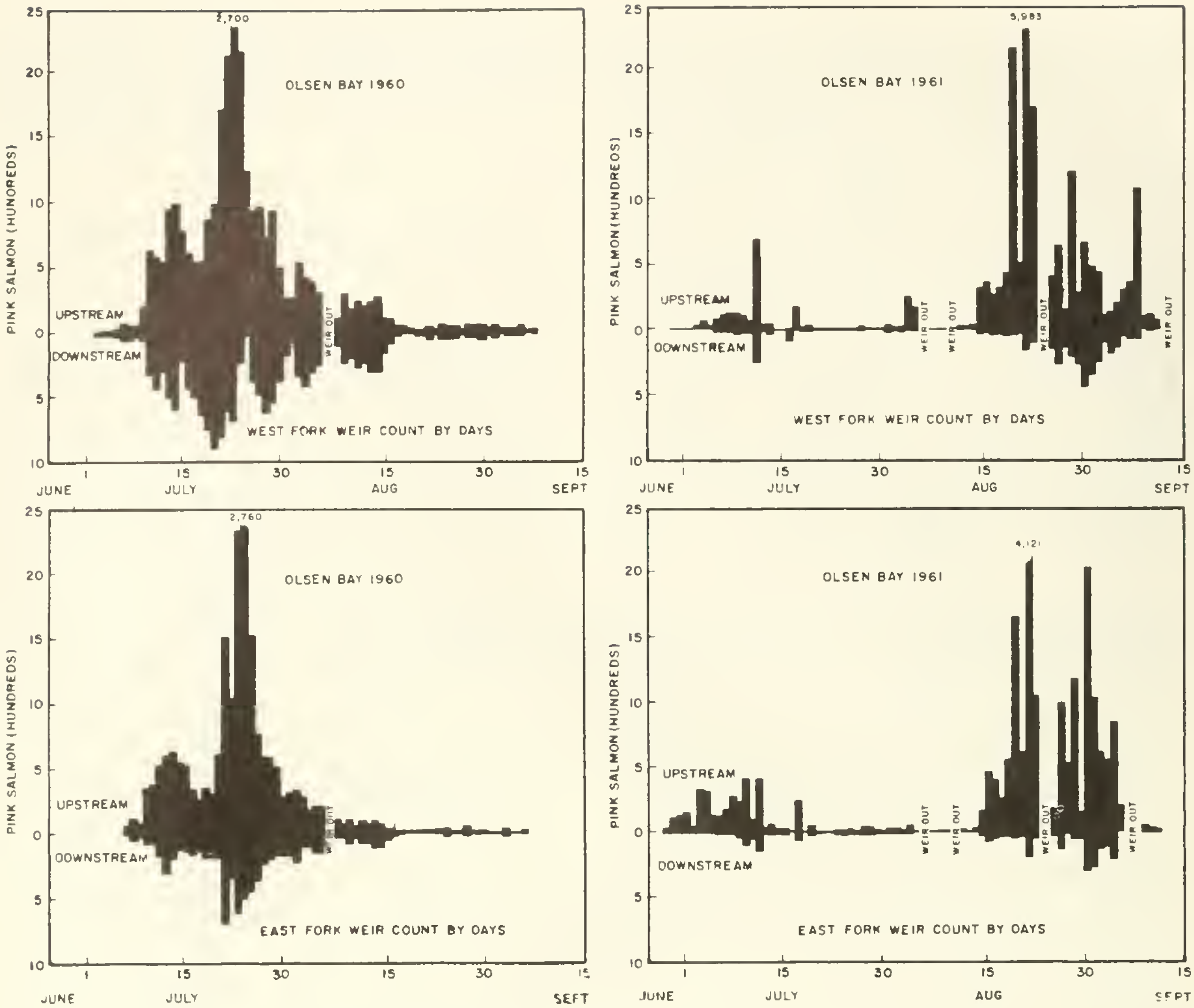

Figure 7.--Daily migration of spawners into East and West Forks, Olsen Creek, 1960-61.

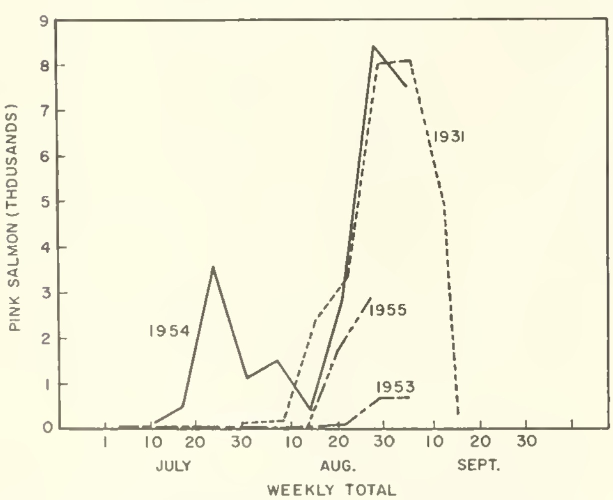

Figure 8.--Weekly pink salmon escapement counts at Olsen Bay weir, 1931, 1953, 1954, 1955.

weir site. Weir gates were opened periodically during daylight hours to allow passage of fish. In 1961 observers tabulated pink salmon by sex, except during high water when visibility was poor.

Even-year cycle (1960).--Weirs were operated in 1960 from June 18 to the first week in September, when high water forced their removal. The migration was virtually completed by that time (fig. 7). Upstream migrants were first counted through the East Fork weir on July 6 and through the West Fork weir on July 2. The total numbers counted for the season were: East Fork weir, 12,392 pink and 238 chum salmon; West Fork weir 13,565 pink and 272 chum salmon. A few coho salmon were also counted through the weirs.

Odd-year cycle (1961).--The weirs were in operation in 1961 from June 25 until the runs

Figure 9.--Weir site at West Fork, Olsen Creek.

were completed in the second week of September. High water forced temporary removal of both weirs on several occasions. One such occasion, August 22-24, coincided with a known migration of salmon (fig. 7). Upstream migrants were first counted through both weirs on June 26. The total numbers counted were: East Fork weir, 18,870 pink and 256 chum salmon; West Fork weir, 16,888 pink and 290 chum salmon. As in 1960, a few coho salmon were counted through the weirs.

Magnitude of Intertidal Migration

Because of periodic inundation of the area by tidewater, weirs could not be used to measure numbers of intertidal spawners. Moreover, because two techniques for population censusing would have to be used as long as weirs were in operation and also because of their high operational costs and possible detrimental effects on fish migration, a single method that could be used to estimate numbers of both intertidal and freshwater spawners was needed. Therefore, in 1961 a system of sample tag ratios was used in addition to weir counts to estimate the spawning populations.

The method of estimating animal populations from the ratio of marked to unmarked members has been employed by many investigators. Howard (1948) and Schaefer (1951) thoroughly discuss the theory and procedures involved in an enumeration problem of this type. Both of these investigators demonstrated that a high degree of precision could be obtained if live fish were tagged close to the site of recovery. One of the basic assumptions in an emumeration problem of this type is that tagged fish are distributed randomly in the population. According to Howard, this need not be so if the dead fish are sampled thoroughly enough to obtain an accurate account of the overall tag ratio.

Figure 10.--Weir site at East Fork, Olsen Creek.

In our studies, pink salmon for tagging were captured with a seine in the stream at the 3- to 5-foot tide level at low tide and were subsequently recovered dead on the spawning grounds. Tagging was done at 4-day intervals with Petersen disk tags. Different color combinations were used for each sample. The number tagged each time varied from 11 to 191, depending on availability of the fish. The first sample was tagged on July 4 and the last on September 11. The intertidal area was patrolled daily for tagged and untagged carcasses. To prevent duplication of counts each dead fish was cut in half. Tags were removed from carcasses only during these daily surveys.

Tag ratios of fresh-water carcasses obtained on weekly stream surveys were used rather than ratios from the daily removal of carcasses off the weirs. Pink salmon spawned more than a mile above each weir site, and hence carcasses that drifted against the weirs were probably not representative of the total fresh-water population.

Twelve pink salmon streams in Port Gravina in addition to Olsen Creek were surveyed once a week to check for emigrant tags (fig. 11). A summary of the recovery data is given in table 4. Tagged fish taken in the commercial fishery and those found in the Port Gravina streams were considered emigrants and were subtracted from the total tagged to correct population estimates.

The following formula was used to estimate the total spawning population from the ratio of tagged to untagged carcasses:

$$N = \frac{nt}{s}$$

N = total number in population
n = number of carcasses sampled
t = number of fish tagged
s = number of tagged carcasses in sample

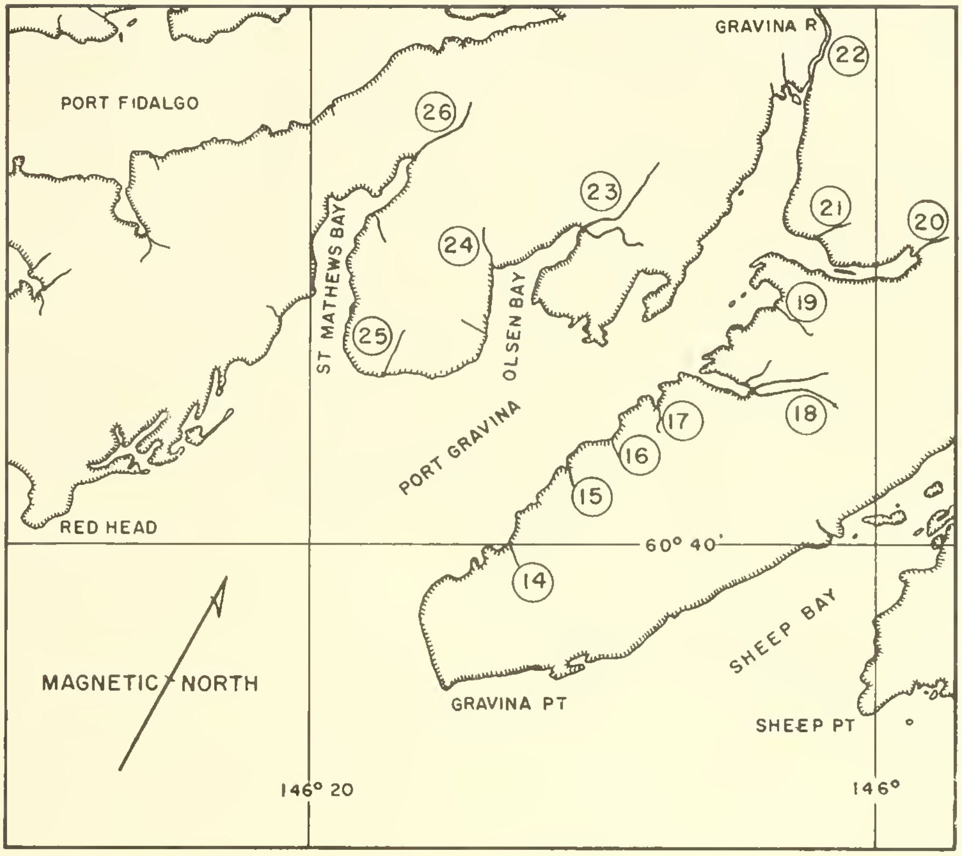

Figure 11.--Location and U.S. Fish and Wildlife Service reference number of spawning streams in Port Gravina, Prince William Sound.

Calculation of the intertidal spawning population required the subtraction of the number of tagged fish passing through the weirs and also the subtraction of the total number of emigrants from the total number of fish tagged. Eighty-seven tagged fish were counted through the West Fork weir and 111 through the East Fork weir.

Fifteen pink salmon tagged in Olsen Creek were found in the three streams on the west shore of Port Gravina (fig. 11). Nine of these were found in stream number 24, which is in Olsen Bay. No tagged fish were found in any of the streams on the east shore of Port Gravina.

In the intertidal area 37,524 pink salmon carcasses were examined (339 bore tags), in the West Fork 9,216 were examined (45 bore tags), and in the East Fork 12,688 were examined (34 bore tags).

Calculating escapement at Olsen Creek from sample tag ratios resulted in the following estimates, where N represents the population estimate, $\overline{N}$ the upper confidence interval, and $\underline{N}$ the lower confidence interval:

Intertidal

N = 100,147
$\overline{N}$ = 111,341
$\underline{N}$ = 90,088

West Fork:

N = 17,730 (weir count: 16,888)
$\overline{N}$ = 20,736
$\underline{N}$ = 11,604

East Fork:

N = 26,620 (weir count: 18,870)
$\overline{N}$ = 37,182
$\underline{N}$ = 19,064

Confidence intervals ($\overline{N}$, $\underline{N}$) at the 95-percent level were calculated using the normal hypergeometric approximation. According to Chapman (1948), this approximation is preferable for larger values of n (5,000-10,000 or larger).

The tag ratio estimate for the West Fork came quite close to the weir count, but the estimate for the East Fork was much greater

Table 4.--Number of recoveries from 1,142 pink salmon tagged in enumeration study, Olsen Bay, 1961

Area of recovery	Number recovered
Intertidal..................	339
West Fork:	
Weir......................	29
Above weir................	45
East Fork:	
Weir......................	43
Above weir................	34
Port Gravina streams:	
No. 24....................	9
No. 25....................	3
No. 26....................	3
Commercial fishery..........	16
Total..................	521

than the weir count. It should be kept in mind, however, that the weirs were taken out several times because of floods, and the counts represent only minimum numbers.

The intertidal estimates of 100,147 pink salmon represent 74 percent of the total escapement at Olsen Creek in 1961.

In 1960, 72,617 pink salmon were estimated to have spawned in the intertidal zone, representing an identical 74 percent of the total migration. The 1960 estimate was obtained by taking the maximum live count of 30,395 on September 4 and adding to it a figure of 42,222, which represents the accumulated dead count to that date. This is a minimum figure because a substantial number of carcasses may have been removed by bears, and an unknown number were washed out of the intertidal zone by high water, coincident with peak counts of dead fish. Also, emigrants which may have entered the stream after the maximum live counts have not been included. It is therefore concluded that the number of pink salmon that spawned in the intertidal zone in 1961 was probably more than 74 percent of the total spawning population.

Analysis of the tagging data demonstrated that population estimates of sufficient accuracy could be obtained by sample tag ratios; consequently, the use of weirs, which are more costly in time and money and which at best only give estimates at Olsen Creek, will be discontinued.

Duration of Intertidal Stream Life

To determine their length of life after they entered the stream, pink salmon in 1961 were tagged at the stream mouth and were subsequently recovered dead on daily surveys of the intertidal area (table 5). Although the ranges of the duration of stream life overlap, the means exhibit a definite trend (fig. 12). A progressive seasonal reduction in stream life is evident, ranging from over a month early in the season to about 5 days at the end of the season. The experiments on July 24, August 1, August 6, and August 9 deviate from the trend; however, pink salmon tagged during these experiments left Olsen Creek and were not observed again in the stream until 3 or 4 weeks later.

To measure the relation between length of stream life and season, the data were tested by a regression analysis (Snedecor, 1956). The four aberrant experiments mentioned above were omitted. A negative regression is demonstrated (fig. 13), the regression coefficient being ($b = -0.049$) which is significant at the 90-percent level ($t = -1.70$). The mean duration of stream life for the entire season was 11.1 days.

SEPARATION OF RACES

The Olsen Bay complex offers several possibilities for detecting the existence of pink salmon races, if they are present. The necessary degree of genetic separation could conceivably occur between early and late spawners or between stocks consistently homing to specific areas such as the East Fork and the West Fork upstream areas or the Little Creek, Middle Slough, and Olsen Creek intertidal areas (fig. 1). Preliminary attempts to discern racial identities of Olsen Bay spawners involved studies of size and sex ratios.

Size Differences

Size differences associated with certain portions of the Olsen Bay complex or time of spawning season could be indicative of more than one race of pink salmon or could be the result of varying oceanic histories of more or less discrete groups of migrants. In either case, knowledge of such groups is of value to research and management of pink salmon.

Length measurements were taken from mideye to the posterior end of the hypural plate (fig. 14) of 2,549 adult pink salmon in 1960 and 3,117 in 1961. Randomly collected fresh carcasses from each weir and from the main stream intertidal area were measured at weekly intervals.

For convenience in analyzing size measurements with respect to time, adults measured on August 13 or earlier were termed "early" spawners and those measured on August 14 or later were termed "late" spawners. This time break coincided with observed changes in timing of the runs and spatial distribution of the spawning adults.

Because of certain differences in size characteristics of males and females, length

Table 5.--Mean days of intertidal stream life of tagged pink salmon

Date of tagging	Fish tagged	Intertidal recoveries		
		Range	Mean stream life	Tags recovered
	Number	Days	Days	Number
July				
4..........	50	12-29	21.2	5
8..........	42	15-19	16.7	7
12.........	11	13-21	17.8	5
16.........	35	10-28	17.1	16
24..........	74	25-47	36.9	14
28.............	32	11-21	15.8	5
August				
1.............	100	6-46	28.6	19
6.............	51	17-41	39.7	11
9.............	65	13-47	26.0	18
15.............	191	7-29	13.0	51
19.............	87	4-17	12.1	29
22.............	106	3-20	11.3	49
31.............	107	2-17	7.0	25
Sept.				
7.............	100	2-13	7.6	35
11.............	51	2-11	4.6	26

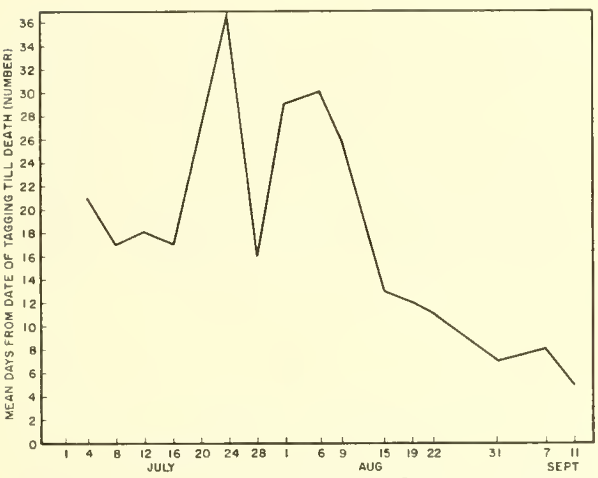

Figure 12.--Seasonal variation in intertidal stream life of pink salmon in Olsen Creek, 1961.

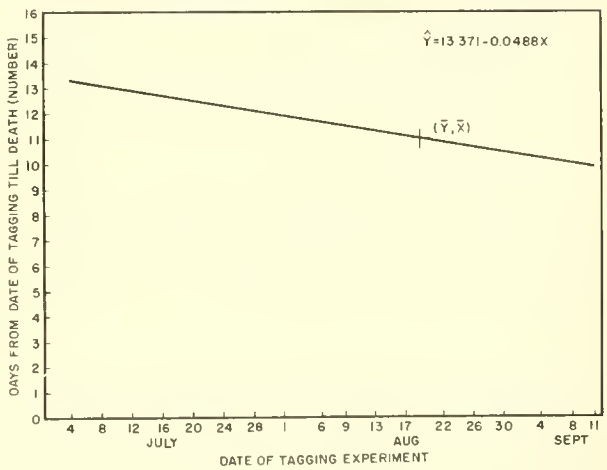

Figure 13.--Regression of seasonal change in length of stream life of pink salmon in Olsen Creek, 1961.

measurements were treated separately by sex. Measurements of males were more widely dispersed from the mean, as indicated by length frequency polygons, ranges in lengths, and standard deviations from the means (figs. 15, 16, and 17). The graphic method of comparing measurements devised by Dice and Leraas (1936) is used to show differences in size of spawners. Vertical overlap or lack of overlap of the black bars (figs. 16 and 17), which represent two standard errors of the mean on either side of the mean, provide a measure of statistical significance. This method is reliable only if the sample sizes are large. For smaller samples sizes the modification of the Dice-Leraas diagram by Simpson, Roe, and Lewontin (1960) gives more precise results.

In 1960 the mean length of 1,381 males was 42 cm., and the mean length of 1,168 females was also 42 cm. In 1961 the mean length of 1,901 males was 44 cm., and the

Figure 14.--Samples of pink salmon measured from mideye to posterior end of hypural plate.

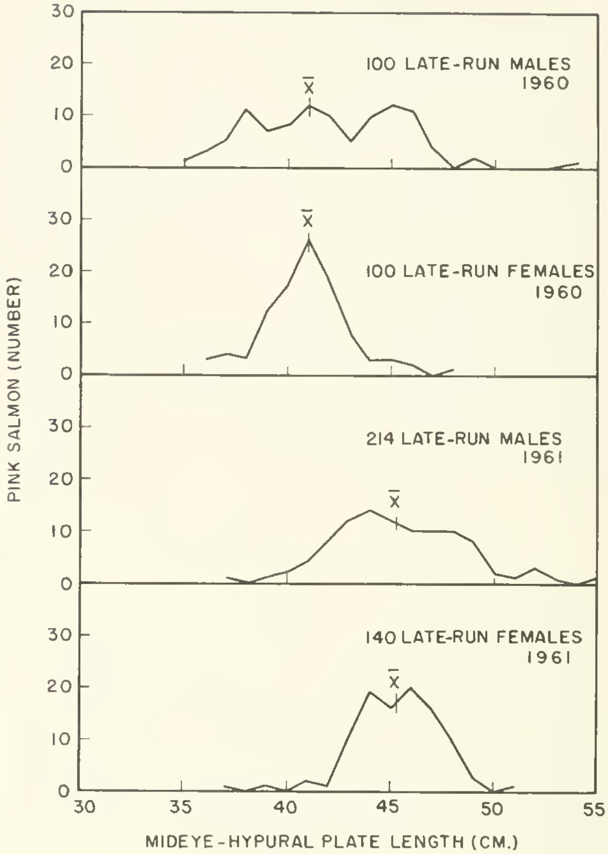

Figure 15.--Length frequency distributions of adult pink salmon from the West Fork of Olsen Creek, 1960-61.

mean of 1,216 females was 45 cm. Although the means for combined samples indicated similarity in size of sexes of both years, the mean lengths for early females were significantly larger in 1961 than the means for early males from the same areas (figs. 16 and 17).

Racial indications by time of spawning.--There were few pronounced differences in mean lengths of fish relative to time of spawning season in 1960; however, late females were significantly smaller than early females from the same areas (fig. 16). In 1961 there were more obvious seasonal differences in size of spawners. Late males were significantly larger than early males in mean length (fig. 17), and late females were significantly larger than early females.

Racial indications by location of spawning.--Samples of 100 males and 100 females from Middle Slough and Little Creek areas were measured August 9 and 11, 1960. These fish were significantly smaller in mean length than early spawners from other portions of Olsen Bay spawning grounds (fig. 16). In 1961, pink salmon spawned in Middle Slough and Little Creek during the late run but not during the early run. They were not different in size from other late spawners at Olsen Bay.

Sex Ratios

Males generally predominate on the spawning grounds during the early stages of salmon runs, but as the run progresses, females gradually increase in relative abundance until they outnumber males. Sometimes the typical progression in sex ratios is followed by a second such progression the same season, giving a clear indication of so-called early- and late-run salmon. Proof of true racial or genetic identities should be sought by other means, such as serological studies. Nevertheless, seasonal changes in sex ratios at Olsen Bay were examined for indications of racial identities.

Weir carcass counts, 1960.--In 1960, 8,744 pink salmon carcasses that drifted downstream onto the weirs were tallied by sex (table 6). Carcasses were observed over an 8-week period extending from July 17 to September 5. There were no important differences in total

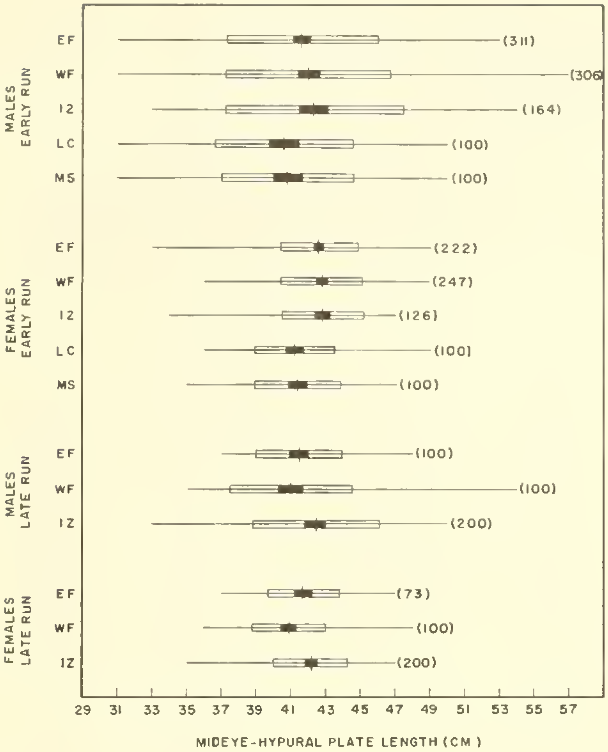

Figure 16.--Length composition of pink salmon adults entering Olsen Creek in 1960. Horizontal line represents range in length; short vertical line represents mean length; black bar includes two standard errors of the mean on either side of the mean. One half of each black bar plus the white bar at either end outline one standard deviation on either side of the mean. Standard deviation indicates dispersion; two standard errors of the mean reliability. N equals number of specimens in each sample. EF = East Fork, WF = West Fork, IZ = Mainstream intertidal zone, LC = Little Creek, and MS = Middle Slough spawning areas respectively. Number of fish measured is shown in parentheses.

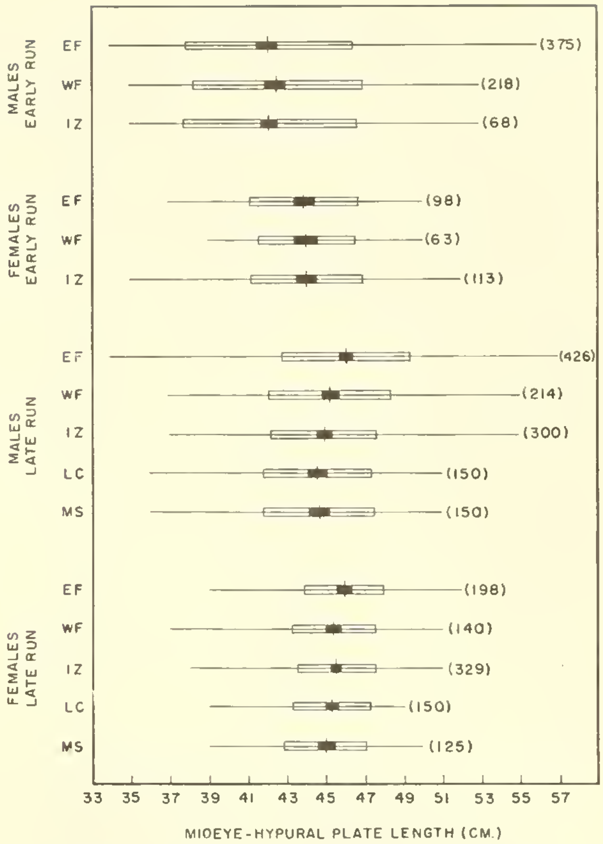

Figure 17.--Length composition of pink salmon adults entering Olsen Creek in 1961 (for explanation see fig. 16).

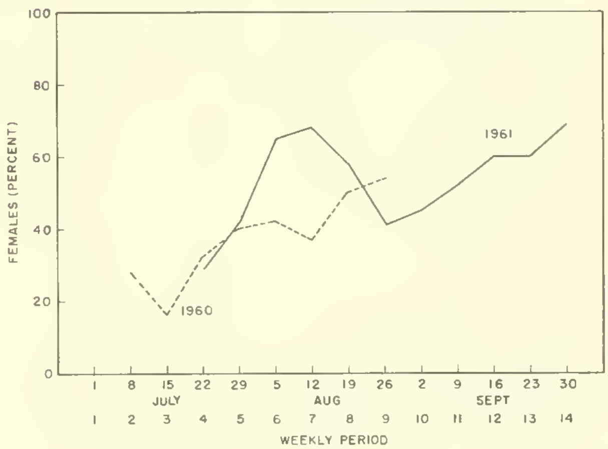

Figure 18.--Percentage of female carcasses at Olsen Bay weir, 1960, and in intertidal area, 1961.

numbers or sex ratios of fish between counts at the two weirs. Of all dead pink salmon removed from the weirs, 3,221, or 37 percent, were females. The apparent preponderance of males did not present a true picture of sex ratios in the upstream areas. Spawned-out females tended to remain in the immediate vicinity of their redds until death, while males were more likely to drift downstream before dying. Therefore, more male than female carcasses were observed at the weirs. Except for the first sample the sex ratio changed progressively from 16 percent females July 24 to 30 to a maximum of 54 percent females September 4 to 10 (fig. 18).

Intertidal carcass counts, 1960.--Daily counts of salmon carcasses in the intertidal zone were made from July 13 through September 22. Of the 50,630 carcasses tabulated (table 6), 28,080, or 55 percent, were females. As in the upstream areas, a seasonal progression of increasing percentage of females was

Table 6.--Seasonal changes in percentage of females among pink salmon adults at Olsen Bay in 1960 and 1961[1]

[Total numbers of adults in parentheses]

Weekly period	1960		1961			
	Weir carcasses	Intertidal carcasses	Weir carcasses	Upstream carcasses	Weir live fish	Intertidal carcasses
1[1]..........		62 (13)	(1)		40 (459)	
2...........	28 (64)	33 (134)	(1)		46 (1,931)	
3...........	16 (639)	36 (1,684)	10 (49)		59 (1,190)	
4...........	32 (2,383)	37 (2,001)	5 (402)	27 (82)	48 (274)	29 (229)
5...........	40 (2,423)	48 (10,454)	21 (409)	53 (389)	100 (54)	42 (665)
6...........	42 (2,471)	53 (6,430)	28 (212)	79 (462)	32 (503)	65 (459)
7...........	37 (472)	57 (6,112)	55 (56)		45 (95)	68 (310)
8...........	51 (237)	61 (8,182)	36 (239)	83 (132)	29 (6,798)	58 (246)
9...........	54 (55)	63 (8,633)	31 (420)	49 (694)	50 (14,877)	41 (2,938)
10..........		64 (5,901)	29 (3,110)	58 (5,326)	72 (6,611)	45 (9,657)
11..........		40 (1,086)	45 (3,673)	59 (6,900)	68 (2,894)	52 (8,737)
12..........			55 (935)	58 (2,100)	78 (72)	60 (6,594)
13..........						60 (7,302)
14..........						69 (48)
Total.....	3,221 (8,744)	28,080 (50,630)	3,507 (9,507)	9,610 (16,385)	18,396 (35,758)	19,563 (37,185)
Percent females......	37	55	37	59	51	53

[1] Weekly periods start on July 1.

indicative of a single run or stock with no evidence of early and late races. There was a steady increase in relative abundance of females from a minimum of 33 percent, July 17-23, to a maximum of 64 percent, September 11-17.

Weir carcass counts, 1961.--In 1961, 9,507 pink salmon carcasses were counted at the weirs, and 3,507 specimens, or 37 percent, were females (table 6). As in the previous years the excess of male carcasses at the weirs was not indicative of true sex ratios in the upstream areas. During the 10-week period from July 9 through September 16, females were in the minority in two cycles, followed by a gradual progression until females were predominant. Thus, early and late runs of pink salmon were clearly indicated by seasonal changes in sex ratio in 1961.

Upstream carcass counts, 1961.--Also in 1961, upstream dead fish were tallied by sex to determine whether females stayed close to their redds till death, while dying males drifted downstream to the weirs. Dead pink salmon totaled 16,385 in the upstream areas (table 6) with no important differences in total numbers or sex ratios between the two forks.

Of the total, 9,610, or 59 percent, were females, thus confirming the hypothesis of downstream displacement of spawned-out males. Therefore, carcass counts at the weirs were combined with carcass counts in the upstream areas for a more accurate representation of the true sex ratio. Of the 25,892 total carcasses thus obtained, 13,117, or 51 percent, were female. Again, a study of seasonal change in sex ratios indicated two distinct runs of pink salmon in 1961.

Weir live fish counts, 1961.--Adult salmon were tallied by sex in 1961 as they migrated upstream through the weir gates. Sex was determined from secondary sexual characteristics observed from overhead as the fish swam over a light-colored contrasting bottom. Of the 35,758 pink salmon tallied in this manner, 18,396, or 51 percent, were females (table 6). Two consecutive peaks in relative abundance of females were indicative of two discrete runs into the upstream areas (fig. 19). No important differences were observed in total numbers, timing, or sex ratios in the two forks.

Intertidal carcass counts, 1961.--Carcasses tallied by sex in the intertidal areas in 1961 totaled 37,185 of which 19,563, or 53 percent, were females (table 6). In contrast to the 1960 intertidal counts when sex ratios indicated only a single spawning stock for the season, there was a progression through two distinct periods of maximum relative abundance of females (fig. 18). These coincided in time with similar maxima observed for dead fish at the weirs and upstream areas. Therefore, both the early run and the late run utilized intertidal as well as upstream spawning grounds in 1961.

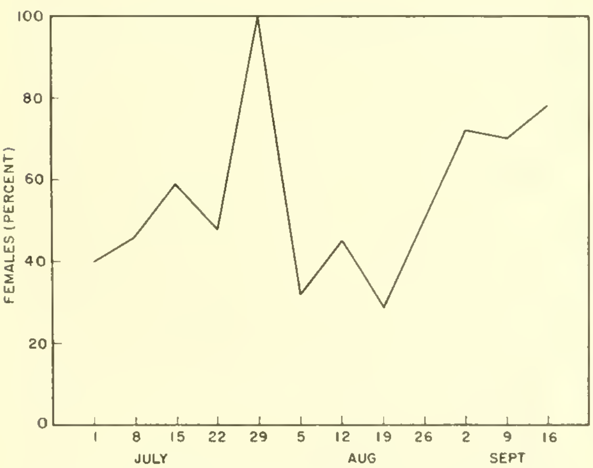

Figure 19.--Percentage of females among pink salmon moving upstream through the weirs, Olsen Bay, 1961.

FECUNDITY

Fifty female pink salmon were collected during the 1960 spawning season and 100 during the 1961 season to determine fecundity of Olsen Bay fish. The 1960 samples were collected a few at a time by seining at 4-day intervals along the beach area near the stream mouth from July 31 to August 14. In 1961, 100 females were taken in two collections of 50 fish each. The first 50 fish were taken between July 5 and 8 with a dip net from areas immediately below the East and West Fork weirs. The second 50 fish were taken between August 17 and 19 in the same manner from below the West Fork weir. Ovaries were removed from each fish and boiled for at least 10 minutes until eggs were separated from skeins. The eggs were preserved in 10-percent formalin. Before being counted they were placed in sieves and rinsed in water to remove formalin. Total counts were made for all ovaries, using egg counting boards (fig. 20).

Egg Counts in Relation to Size, 1960

The 1960 females ranged from 38.4 to 47.5 cm. long (average, 43.0 cm.) and contained

Figure 20.--Board used for making total counts of eggs from ovaries of pink salmon, Olsen Creek, 1960-61.

Table 7.--Length and number of eggs in pink salmon at Olsen Bay, 1960-61

Dates samples taken	Females	Size		Eggs		Regression coefficient
		Mean	Range	Mean	Range	
1960	Number	Cm.	Cm.	Number	Number	
July 31-Aug. 14.....	50	43.0	38.4-47.5	1,815	879-2,346	0.210
1961						
July 5-8............	50	45.5	41.1-50.3	2,092	1,367-2,812	.718
Aug. 17-19..........	50	47.0	43.4-50.2	2,096	1,604-2,467	.165
Combined sample, 1961....	100	46.3	41.1-50.3	2,094	1,367-2,812	.518

879 to 2,346 eggs per female (average, 1,815 eggs) (table 7). The regression analysis with the 50 fish indicated no relation between length and number of eggs per female (r = 0.210). This result may have been due to the relatively small size range of pink salmon females at Olsen Bay or to sampling more than a single stock.

Egg Counts in Relation to Size, 1961

The 1961 females ranged from 41.1 to 50.3 cm. (average, 46.3 cm.) and contained 1,367 to 2,812 eggs per female (average, 2,094 eggs) (table 7). The regression analysis indicated a direct correlation between length and number of eggs for the 100 fish (r = 0.518) and for the 50 fish taken between July 5 and 8 (r = 0.718). There was no relation between length and number of eggs for the 50 fish taken between August 17 and 19 (r = 0.165). Again, as in 1960, this result may have been due to the relatively small size range of pink salmon females in Olsen Bay or to sampling more than a single stock. Foerster and Pritchard (1941) found a positive correlation between number of eggs and length but noted that the correlation coefficients were lower for pink than for sockeye salmon. They also suggest the relatively small size range as a partial explanation.

Rounsefell (1957) tested the relation between the average number of eggs in pink salmon females and the summer sea temperature at Ketchikan, Alaska, with a covariance analysis using the data of Foerster and Pritchard (1941). This analysis demonstrated a significant negative correlation. Rounsefell concluded that annual differences in mean fecundity of pink salmon are a function of sea temperature, which is the principal factor determining average fish length.

Egg Retention, 1960

To determine the number of eggs retained in the body cavity after spawning, 364 female pink salmon were examined. Randomly selected fresh carcasses were examined between July 6 and August 3, and included fish from both forks as well as the main stream intertidal area. Carcasses were opened and an estimate made of the percent of eggs voided. Of the females counted 317 (87 percent) had voided virtually all eggs before death; 19 had voided 75 percent; 7, 50 percent; 10, 25 percent; and 11 had voided no eggs before death. Using the 1,815 average number of eggs per female in 1960, egg mortality due to retention was calculated to be approximately 7 percent.

Egg Retention, 1961

Between July 22 and September 8, 737 female pink salmon were examined for egg retention. Fresh carcasses, randomly selected at the East and West Fork weirs and in the main stream intertidal area, were examined. Actual counts of eggs were made for all but nine females that had obviously retained all their eggs. An average figure of 2,094 eggs was used as a basis for calculating the percentage of eggs retained. Egg retention was low during July and August, amounting to 2.7 percent at the West Fork weir, 5.1 percent at the East Fork weir, and 3.1 percent in the main stream intertidal area (table 8). Egg retention for the combined July and August samples was only 3.8 percent. However, the 29 females from the main stream intertidal area September 8 and 9 had retained 41.5 percent of their eggs. This retention was associated with overcrowding and competition for redd areas among females during the peak runs of late August and early September. Length of stream

Table 8.--Egg mortality caused by retention of eggs, Olsen Bay, 1961

Date and area sample taken	Females	Length[1]	Eggs retained[2] per female (mean)	Egg mortality[2]
July-August	Number	Cm.	Number	Percent
West Fork weir	97	44.7	56.4	2.7
East Fork weir	147	44.7	106.2	5.1
Intertidal	100	46.3	64.1	3.1
Total	344	45.1	79.9	3.8
September				
Intertidal	29	54.7	849.5	41.5

[1] Mideye to hypural plate.
[2] Based on 2,094 eggs in complete ovaries.

life was relatively brief for all spawners at that time, as evidenced by recovery of tags (fig. 12). Most of the females that had retained a high proportion of their eggs bore no visible evidence of disease or bear wounds. Hunter (1959) reported average egg retention ranged from 0.1 to 2.7 percent for female pink salmon in Hook Nose Creek, British Columbia, and he saw no evidence of increased egg retention associated with high spawning densities. Hanavan and Skud (1954) observed egg retention of 0 to 51 percent for females confined in pens, and retention was greater in the more crowded pens.

SURVIVAL OF EGGS AND LARVAE

Sampling Procedure

Egg densities in intertidal gravels were determined with the aid of egg pumping equipment and sampling procedures similar to those described by McNeil.[6] Tidal strata were located and defined as areas bounded by elevations above mean lower low tide. Sample plots 4 square feet in area were chosen at random by the following procedure: Two random numbers were drawn, one for the linear distance along the stream channel from a base point, and the other for the distance from the left bank measured perpendicularly to streamflow. Sampling was continued in each stratum until the variation of the mean number of pink salmon eggs per plot was less than 20 percent at the 90-percent confidence level, or when it became apparent that further sampling would result in little reduction in the variation. Digging in each plot within a stratum was terminated only when negligible numbers of eggs were displaced by repeated efforts. Pink and chum salmon eggs were tabulated separately. Chum salmon eggs made up less than 10 percent of all eggs dug both years, and data for them are not included in this report.

Eggs or fry were dug in the autumn and again in the spring at the 3- to 4-foot, 7- to 9-foot, and 10- to 11-foot intertidal strata of Olsen Creek each year. Additional samples were dug from all strata between the 2- and 12-foot levels of the Little Creek area in October 1960. The autumn egg samples were taken soon after spawning was finished, October 4 to 13, 1960, and September 28 to October 4, 1961. This schedule allowed a minimum time to elapse before eggs could disappear because of predation or disintegration, but sufficient embryonic development had occurred so that the difference between live and dead eggs could be recognized.

Egg Deposition

The Olsen Creek, Little Creek, and Middle Slough intertidal areas (fig. 1), measured from the 3- to the 12-foot tide levels, had a total low-flow stream bottom area of 243,139 square feet. It was estimated that the intertidal runs comprised 41,580 females, with an average egg content of 1,815 eggs per female in 1960 and 53,000 females with 2,094 eggs per female in 1961. From this information it was calculated that potential egg deposition per square foot was 300 in 1960 and 450 in 1961.

Egg densities actually encountered in autumn egg pump samples ranged from a mean number of 21 eggs per square foot at the 3- to 4-foot stratum in 1960, to 336 at the 10- to 11-foot stratum in 1961 (table 9).

Average egg deposition was slightly higher in the 7- to 9-foot stratum (with densities of 213 to 285 per square foot) than in the 10- to 11-foot stratum (with densities of 151 to 336). At the

[6] William J. McNeil. A method of estimating total mortality of pink salmon eggs and larvae. Unpublished manuscript on file at the Bureau of Commercial Fisheries Biological Laboratory, Auke Bay, Alaska.

Table 9.--Pink salmon egg densities in intertidal gravel at Olsen Bay approximately 2 weeks after spawning season (90-percent confidence intervals to the nearest digit)

Item	3- to 4-foot stratum	7- to 9-foot stratum	10- to 11-foot stratum
1960			
Mean number of live eggs per square foot	10±10	176±30	136±25
Mean number of dead eggs per square foot	11±7	37±9	15±5
Total	21±16	213±34	151±26
Percent alive	48	83	90
1961			
Mean number of live eggs per square foot	7±5	112±29	136±31
Mean number of dead eggs per square foot	24±9	173±26	200±39
Total	31±13	285±42	336±59
Percent alive	23	39	40

3- to 4-foot stratum, however, egg densities of 21 per square foot in 1960 and 31 per square foot in 1961 were only about one-tenth the densities in the upper strata. The stream bottom at the 3- to 4-foot stratum was covered by tidewater approximately 83 percent of the time (fig. 2). Spawning activity ceased and was replaced by a milling about of adults while tides covered the spawning areas. This periodic interruption of spawning activity probably explains in part the low egg densities in the 3- to 4-foot stratum.

The greater total egg deposition in 1961 did not result in higher live egg densities. Live egg densities ranged from 10 to 136 per square foot in 1960 and from 7 to 136 per square foot in 1961 (table 9).

The lower percentage of live eggs in 1960 at the 3- to 4-foot stratum (48 percent compared with 83 and 90 percent in the upper strata (table 9)), was indicative of poor survival from adverse environmental conditions at the lower tide level.

Survival Over Winter

Survival over winter was estimated by comparing live fry densities in the spring of 1961 with live egg densities the previous fall. No pink salmon fry were seen in the estuary in March 1961, and it was assumed that few if any fry had emerged before the 1961 spring sampling between March 23 and 29.

No fry or dead eggs were found in the 3- to 4-foot stratum; 35 live fry per square foot were found in the 7- to 9-foot stratum; and 73 fry per square foot were found in the 10- to 11-foot stratum (table 10). Only a few dead eggs were dug from the upper two strata.

Table 10.--Pink salmon egg and fry densities in intertidal gravel at Olsen Creek, March 23-29, (90-percent confidence intervals)

Item	3- to 4-foot stratum	7- to 9-foot stratum	10- to 11-foot stratum
Live fry per square foot	0	35±9.2	73±18.2
Dead eggs per square foot	0	12±3.0	3± 1.7
Total	0	47±9.6	76±17.9
Percent alive	0	74	96
Survival from fall sampling to spring	0	20	54

Further studies would be needed to determine whether the dead eggs were removed by shifting gravel or by predation in the 3- to 4-foot stratum and to determine whether some fry emerged prior to sampling because of higher water temperatures at that tide level.

The 35 fry per square foot at the 7- to 9-foot stratum and the 73 per square foot at the 10- to 11-foot stratum represent 20 and 54 percent respectively of the mean live egg densities in those areas the previous fall.

SUMMARY

1. A field research station was established at Olsen Bay in Prince William Sound in 1960 to compare life history, ecology, and survival of pink salmon in intertidal and fresh-water spawning areas.

2. Olsen Creek is subject to rapid fluctuations in flow, depending on amount of rainfall. Discharge during summer months ranged from 10 to about 500 c.f.s. (average, about 33) for each fork.

3. Mean tide range at Olsen Bay is 10 feet, and diurnal range is 12.3 feet. The stream is covered with tide water more than 80 percent of the time at the 3-foot tide level and about 3 percent at the 12-foot level.

4. Preliminary investigations of salt-water intrusion into the intertidal area of the creek demonstrated that saline water penetrates the gravel at redd depth. The highest concentration at the 11-foot tide level was 9.3 ‰ during a 14.5-foot tide.

5. Temperatures of gravel water, 8 to 10 inches below the stream bottom, were determined at each foot of elevation between the 3- and 10-foot tide levels. Elevations up to the 8-foot level were subject to temperature variations as large as 10° F. within 1-hour periods.

6. Preliminary studies on gravel composition showed an increase in fine materials and a decrease in large gravel from high to low tide levels.

7. Random samples of intertidal inhabitants indicated that a greater number of species existed in the tideflat between streams than in the streams themselves. Large numbers of microdrile oligochaetes were found in stream gravels.

8. Occurrence of spawners in even- and odd-year cycles (1960 and 1961) was bimodal. The early run in 1960 utilized both intertidal and fresh-water areas; however, the late run was entirely intertidal. In 1961, both runs were divided between intertidal and fresh-water areas.

9. In 1960, 98,574 pink salmon spawned in Olsen Creek and in 1961, 135,905 spawned. During both years 74 percent of the total run spawned in the intertidal portion of the stream.

10. The period of time that spawners lived after entering the stream ranged from 21 days at the beginning of the season to 5 days at the end. Average duration of stream life for the entire season was 11.1 days.

11. In 1960, mean length of late females was significantly smaller than the mean for early females. In 1961, seasonal differences were more obvious, and late spawning males were significantly larger than early males and late females were significantly larger than early females. Pink salmon that spawned in the small intertidal creeks, Middle Slough and Little Creek, in 1960 were significantly smaller than spawners in the main stream.

12. Seasonal changes in sex ratios verified the presence of two distinct spawning groups of pink salmon in 1961 but not in 1960.

13. Average number of eggs per female in 1960 was 1,815. Regression analysis indicated no relation between length and number of eggs per female. In 1961, both the early and late runs were sampled for fecundity. Average number of eggs per female was 2,092 for the early run and 2,096 for the late run. Regression analysis showed that length and number of eggs were related for the early run but not for the late run.

14. In 1960, mortality due to egg retention was approximately 7 percent. In 1961, egg retention ranged from 2.7 to 41.5 percent.

15. Overwinter survival between egg and fry stages was 0 below the 4-foot level, 20 percent in the 7- to 9-foot level, and 54 percent in the 10- to 11-foot level.

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This paper is dedicated to the memory of the late Charles Y. Conkle who for his valuable contributions to the planning and field work while under the stress of a debilitating illness, earned the respect and admiration of his coworkers.

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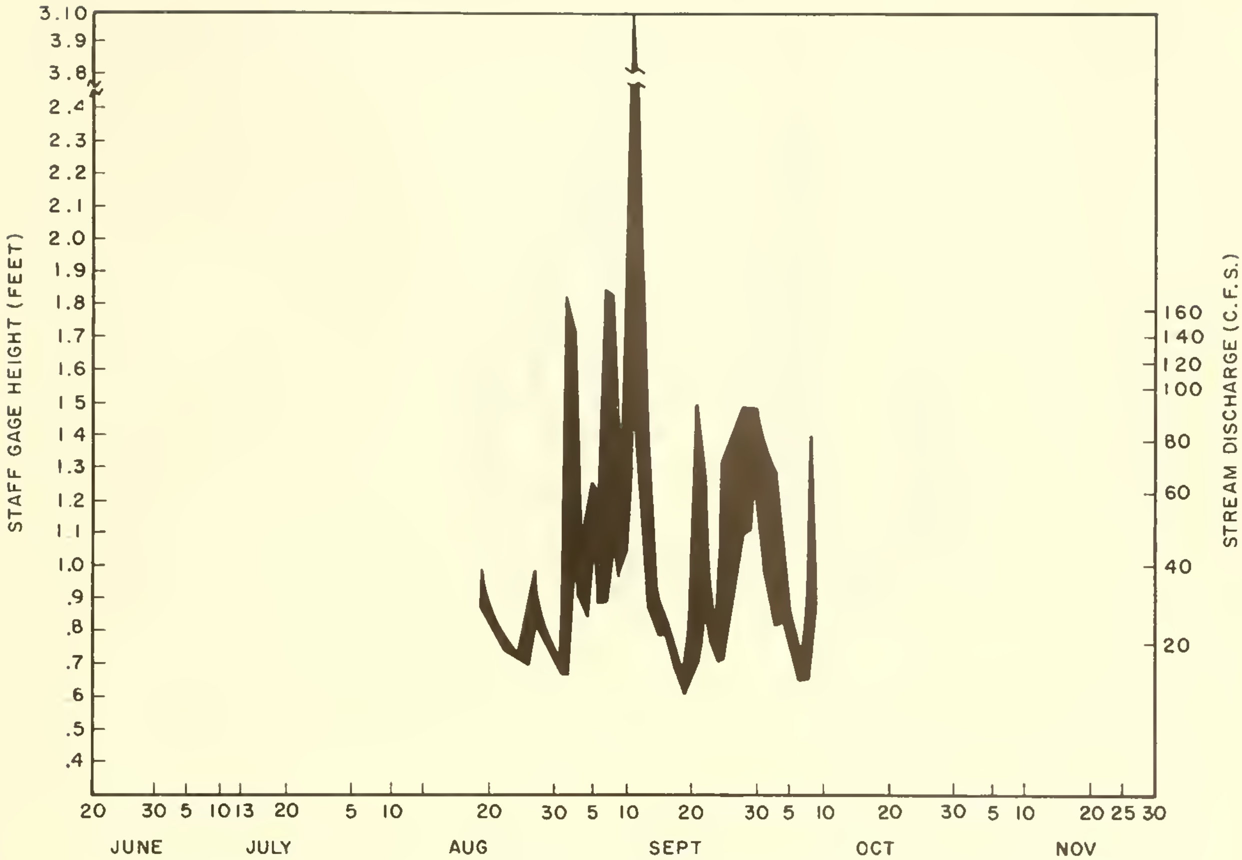
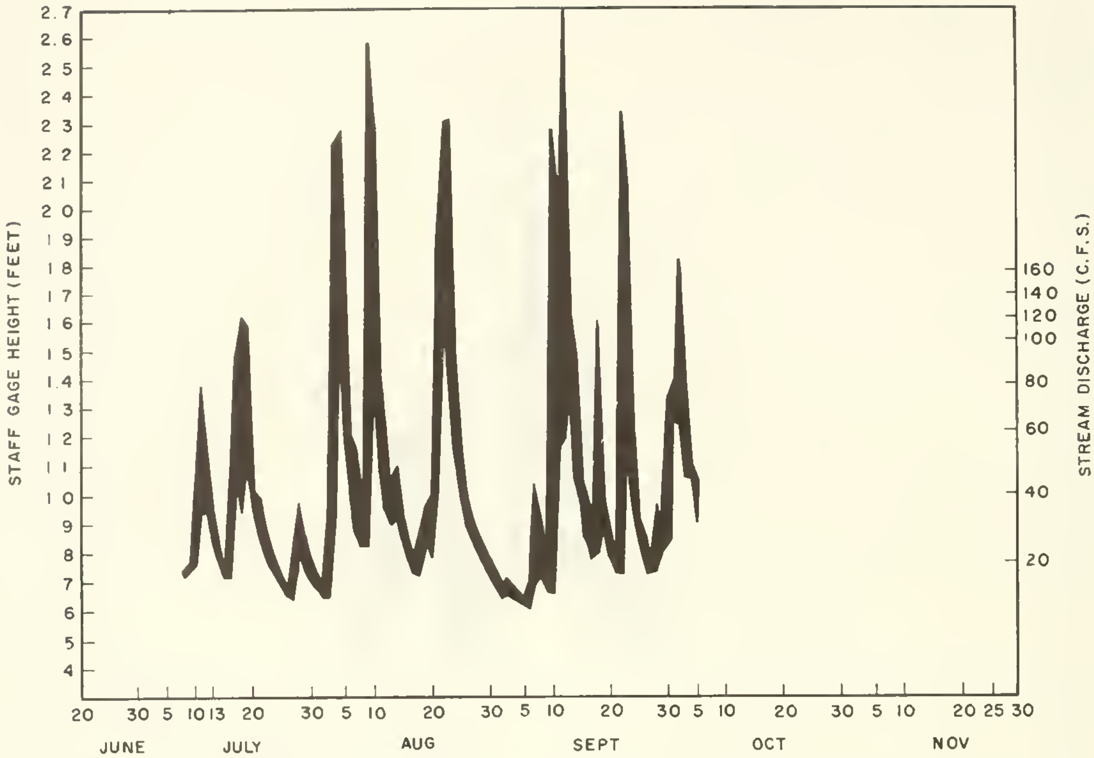
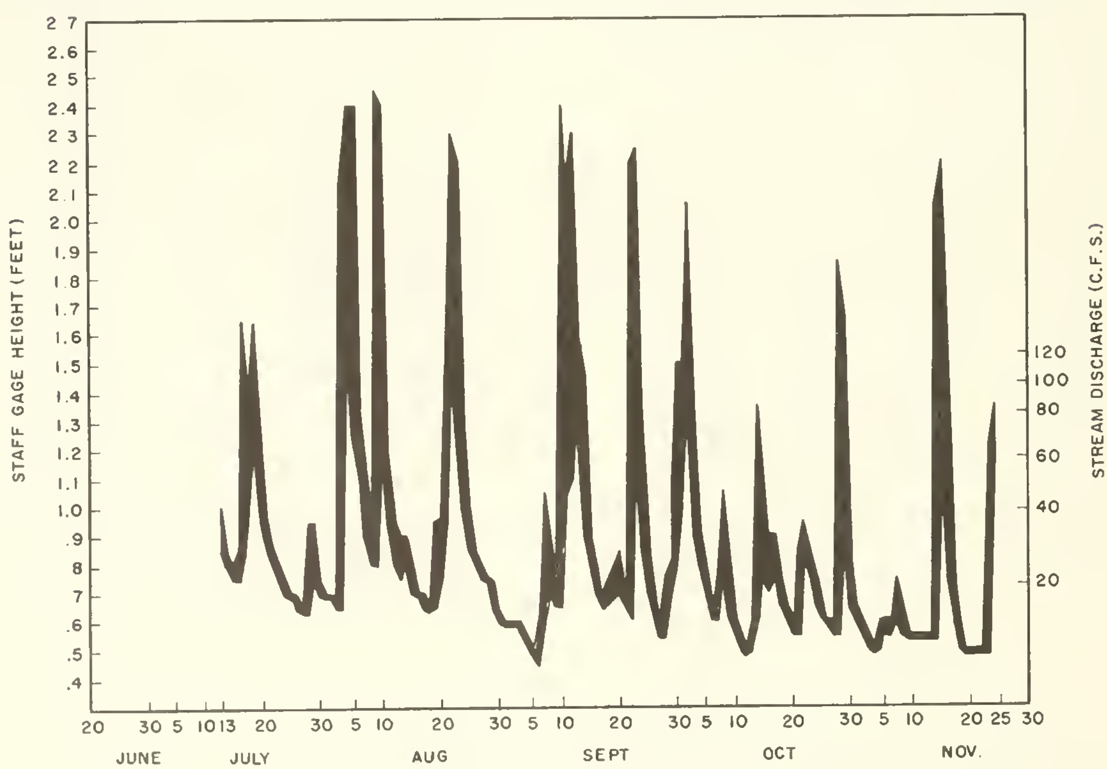


Appendix figure 1.--Daily maximum-minimum stream levels for East Fork, Olsen Creek, 1960.



Appendix figure 2.--Daily maximum-minimum stream levels for East Fork, Olsen Creek, 1961.



Appendix figure 3.--Daily maximum-minimum stream levels for West Fork, Olsen Creek, 1961.

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