LIFE HISTORY OF COHO SALMON, *ONCORHYNCHUS KISUTCH*, IN SASHIN CREEK, SOUTHEASTERN ALASKA

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ABSTRACT

The freshwater life of coho salmon, *Oncorhynchus kisutch*, in Sashin Creek, southeastern Alaska, was studied from the fall of 1963 through the summer of 1968. Additional information on age composition and fecundity of adults returning to Sashin Creek and a nearby stream was collected through the fall of 1972. Some pre-1963 data on coho salmon entering and leaving Sashin Creek were used. Weir counts and estimates of numbers of adult salmon determined from spawning ground counts and mean redd life were poor measures of the total escapement of coho salmon in Sashin Creek; an estimate made from tagging a portion of the escapement and subsequently determining tagged-to-untagged ratios of spawners on the riffles proved to be a more reliable measure. The number of spawning coho salmon varied for the years 1963 through 1967 from 162 to 916; the dominant age group was 4_3. The salinity of the surface water of the estuary of Sashin Creek usually is less than 10-15‰; bioassays of salinity tolerance indicated that coho salmon fry can survive in these salinities. In 1964, 44,000 coho salmon fry migrated to the estuary soon after emergence, although none of the scales collected from returning spawners in subsequent years showed less than 1 yr of freshwater residence. Survival curves constructed from periodic estimates of the stream populations of juvenile coho salmon for the years 1964-67 showed that mortality was highest in midsummer of the first year of life, when 62% to 78% of the juveniles were lost in a 1-mo period. Most coho salmon smolts migrated from Sashin Creek in late May or early June. In the spring of 1968, 1,440 smolts left Sashin Creek—37% were yearlings, 59% were 2-yr-olds, and 4% were 3-yr-olds. The average fork lengths were 83 mm for yearlings, 105 mm for 2-yr-olds, and 104 mm for 3-yr-olds.

Coho salmon, *Oncorhynchus kisutch* (Walbaum), occur over a broad geographic range in the North Pacific Ocean and Bering Sea. They spawn in coastal streams from northern California to northwestern Alaska and from northern Hokkaido, Japan, to the Anadyr River, USSR (Figure 1). The young usually remain in fresh water for 1 to 3 yr before migrating to sea as smolts; they are sexually mature after about 14 to 18 mo in the sea. In some systems some fry emigrate to salt water in their first spring or summer of life, but they apparently do not contribute significantly to the adult return (Chamberlain 1907; Gilbert 1913; Pritchard 1940; Wickett 1951; Foerster 1955).

Among the numerous populations of coho salmon, there are differences in freshwater life history that appear to be related to latitude. In the southern one-third of their range, coho salmon typically remain in fresh water about 1 yr before they migrate to sea in their second year of life—15 to 18 mo from egg deposition (Pritchard 1940; Briggs 1953; Smoker 1953). Farther north, in Alaska, coho salmon remain 1, 2, or 3 yr (occasionally 4) in fresh water after they emerge from the gravel (International North Pacific Fisheries Commission 1962; Godfrey 1965; Drucker 1972). In some of the Alaska streams and in Kamchatka, USSR, coho salmon that remain in fresh water for 2 yr may represent a larger percentage of the population than those that remain for 1 yr (Gilbert 1922; Semko 1954; Andrews 1962; Logan 1963; Engel 1966; Kubik 1967; Redick 1968; Armstrong 1970; Drucker 1972).

Most studies of coho salmon behavior and survival in fresh water have been conducted in the southern and central parts of the range: California, Oregon, Washington, and British Columbia in the eastern Pacific (Neave 1948; Wickett 1951; Briggs 1953; Smoker 1953; Shapovalov and Taft 1954; Foerster 1955; Salo and Bayliff 1958; Chapman 1962, 1965; Koski 1966); and Kamchatka in the western Pacific (Kuznetsov 1928; Gribanov 1948; Semko 1954). Information on more northerly stocks is much less detailed.

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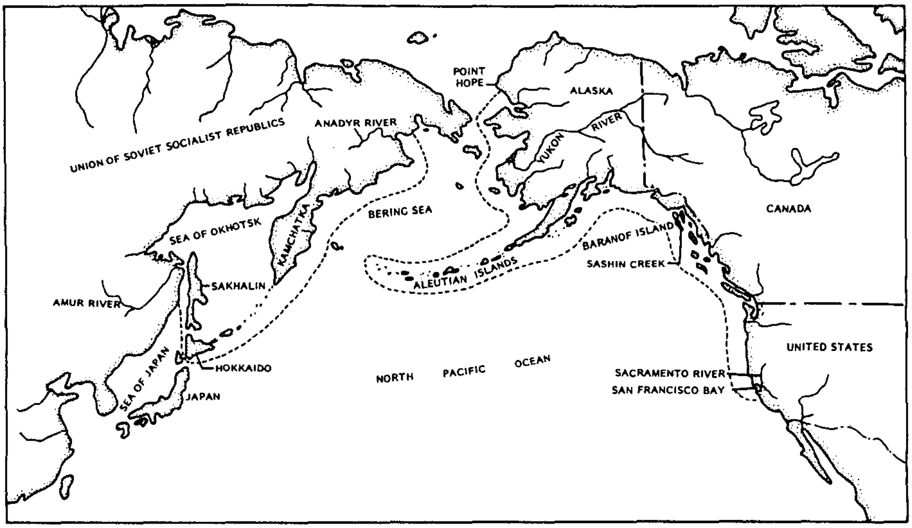

FIGURE 1.–Geographic range of coho salmon in North Pacific Ocean and Bering Sea. Dashed line indicates coastline where coho salmon enter streams for spawning.

In our studies at Sashin Creek, southeastern Alaska, we have attempted to determine important aspects of the life histories of populations of the coho salmon near the center of its range (southeastern Alaska). We have compared our findings with life histories of populations in other parts of the range and have emphasized 1) characteristics of adult spawners (including time of stream entry and time of spawning, longevity on the spawning grounds, age structure, and fecundity), 2) survival of eggs and alevins in the gravel, and 3) survival and growth of juveniles up to the time of seaward migration.

STUDY AREAS

Sashin Creek empties into Chatham Strait in the inner bay of Little Port Walter on the southeastern shore of Baranof Island (Figure 2). The stream originates in Sashin Lake about 3 km from tidewater and drains about 10 km^2 of forested watershed–mostly western hemlock. *Tsuga heterophylla*, and Sitka spruce, *Picea sitchensis* (U.S. Geological Survey 1972).

The discharge pattern of Sashin Creek is governed by seasonal rainfall and the rate of melting of accumulated snow. For the 10-yr period 1963-72, annual precipitation at Little Port Walter averaged about 587 cm (231 inches).[3] Although Sashin Lake intercepts part of the runoff and tends to even out flows in Sashin Creek, discharge varies from less than 0.3 m^3/s in midwinter to as much as 34 m^3/s after heavy rains in September and October.

Salmon have access to the 1,100 m of stream between the weir at the upper limits of salt water and a high waterfall upstream. Coho salmon rarely spawn in the 160 m of stream immediately below the waterfall or in the intertidal stream channel; both areas have a steep gradient and coarse bottom material.

The spawning ground is divided into three areas (upper, middle, and lower) which have different physical characteristics but in total contain about 13,000 m^2 of spawning gravels (Table 1). The upper area contains about 25% of the stream's suitable spawning gravels and is characterized by a steep gradient (relative to the other sections) and coarse bottom materials. The middle area has about 30% of the spawning gravel and an intermediate gradient with a higher proportion of smaller gravel and fines. The lower area is the largest and contains about 45% of the spawning gravel; it has a low gradient and a high proportion of fines in the bottom materials.

Rearing areas of juvenile coho salmon include the three spawning areas plus pools, backwaters, and to a limited extent, the 160-m section of stream in the canyon immediately downstream from the waterfall. In our investigation of juvenile coho salmon, the three ecologically distinct study areas were maintained. An additional 3,473 m^2 were included in the study areas to incorporate

[3]This average was computed from data from volumes 49-58 of the U.S. Weather Bureau's "Climatological Data, Alaska, Annual Summary." However, because precipitation for August 1967 (vol. 53) was reported incorrectly as 6.99 inches, we used the figure from the original records at Little Port Walter of 19.08 inches for August 1967 in computing the 10-yr average precipitation.

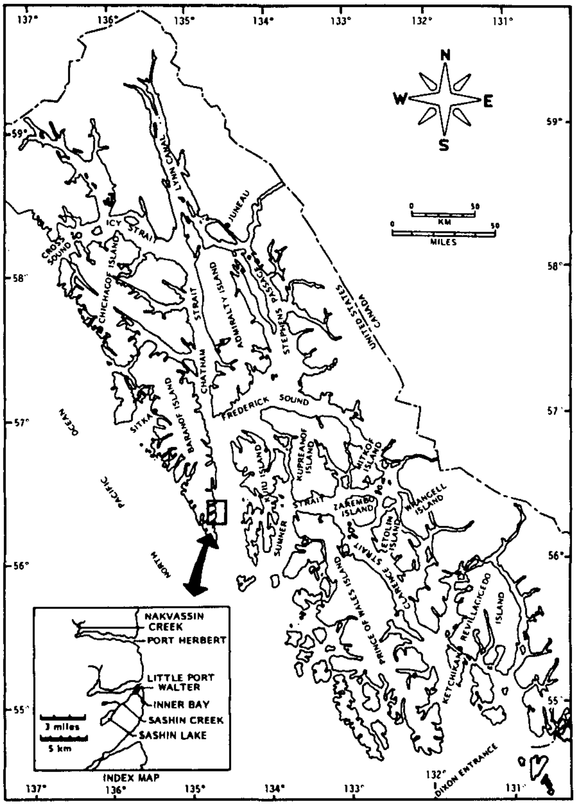

FIGURE 2.—Southeastern Alaska and Little Port Walter region, site of coho salmon study.

pools and backwaters, for a total of 16,557 m^2 (Table 1).

In 1965-67, part of Funny Creek, a small tributary of Sashin Creek near tidewater, was added to the study area. Funny Creek is about 1.5 m wide on the average and slow flowing; the bottom is mostly mud and detritus but has a few gravel areas that are used by coho salmon for spawning. The Funny Creek study area included 441 m^2 of stream from its junction with Sashin Creek upstream 290 m; the first 215 m flows through a muskeg meadow and the most upstream 75 m flows through forest.

The fish fauna of Sashin Creek consists of pink salmon, *O. gorbuscha*; coho salmon; chum salmon, *O. keta*; rainbow trout, *Salmo gairdneri*; Dolly Varden, *Salvelinus malma*; and coastrange sculpin, *Cottus aleuticus*. A few adult sockeye salmon, *O. nerka*, occasionally stray into the stream.

ADULT COHO SALMON STUDIES

In our studies of adult coho salmon we determined: 1) size of escapement, i.e., the number of coho salmon spawners that returned to Sashin Creek; 2) average redd life of females; 3) distribution and density of spawners in each study section; 4) interspecific competition between coho and pink salmon; 5) age structure of spawners; 6) fecundity of females; and 7) egg retention of spent females. In addition, for comparison with data from Sashin Creek, we obtained data on the age and fecundity of adult coho salmon from Nakvassin Creek in Port Herbert, a 7-km-long fiord about 5 km north of Little Port Walter (Figure 2). Nakvassin Creek, about 0.4 km long, is the outlet stream from 30-hectare Nakvassin Lake. Coho and sockeye salmon, Dolly Varden, rainbow trout, coastrange sculpin, and threespine stickleback, *Gasterosteus aculeatus*, inhabit the lake. These species plus pink and chum salmon inhabit Nakvassin Creek.

Size of Escapement

Adult coho salmon generally enter Sashin Creek from early August to early November, but the greatest numbers enter from late August to mid-October. Spawning usually begins early in October and ends in mid-November.

Adult salmon have been counted in Sashin Creek since 1934 through a weir at the head of tidewater. From 1934 to 1969, counts of coho salmon at the

TABLE 1.—Surface area, average gradient, and size composition of bottom materials less than 15.2 cm in diameter in three study areas of Sashin Creek.[1]

Study area	Spawning area (m^2)	Total area[2] (m^2)	Average gradient (%)	Percentage of spawning area composed of: Cobbles (> 12.7 mm)	Pebbles and granules (1.68-12.7 mm)	Sands and silts (< 1.68 mm)
Upper	2,945	4,049	0.7	81	16	3
Middle	4,067	4,441	0.3	61	26	13
Lower	6,072	8,067	0.1	47	36	17
Total	13,084	16,557	0.3	—	—	—

[1]Table adapted from McNeil (1966).
[2]This area includes pools and backwaters.

weir ranged from 0 to 567 (Table 2). The weir counts are not accurate measures of the number of coho salmon in the escapements, however, because the weir was maintained primarily to count pink salmon and the panels were usually removed at the end of the pink salmon run near the end of September. Moreover, coho salmon can jump over the weir panels and many did so each year and were therefore not counted.

Because of the problems with weir counts, an effort was made to obtain accurate estimates of the coho salmon escapements in 1963-65 and 1967 on the basis of repeated observations of the number and distribution of salmon in the three study areas (Table 3). Adults on the spawning riffles were counted by periodic visual censuses, and the counts were recorded separately for each area. In 1963 and 1964, salmon were counted only when water conditions were most favorable for observing fish; spawners were not recorded separately by sex. In 1965 and 1967, visual surveys were conducted daily, except for 6 days in 1965 when the water was too high to make observations; males and females were recorded separately. Funny Creek was included in the surveys in 1965 and 1967.

Spawners on the riffle areas were usually counted between 1000 and 1400 h, when light conditions were most favorable for observing fish. The observer (wearing polarizing glasses to reduce glare at the water surface) began counting at the upstream end of the spawning area and continued downstream. In 1965 and 1967, the observer recorded the location of individual females with reference to section markers spaced at 30.5-m intervals and a baseline running longitudinally between markers in the stream. The number of

TABLE 2.—Number of adult coho salmon counted into Sashin Creek at the weir by 2-wk intervals, 1934-69.[1]

	Two-week period							
Year	1-14 Aug.	15-28 Aug.	29 Aug.-11 Sept.	12-25 Sept.	26 Sept.-9 Oct.	10-23 Oct.	24 Oct.-7 Nov.	Total
1934	—	—	—	[2]1	—	—	—	1
1935	—	—	—	([2])	—	—	—	0
1936	—	2	2	[2]36	—	—	—	40
1937	—	3	[2]5	—	—	—	—	8
1938	—	—	1	([2])	—	—	—	1
1939	—	16	94	12	([2])	—	—	122
1940	—	—	—	[2]1	—	—	—	1
1941	—	—	—	[2]1	—	—	—	1
1942	—	—	—	[2]2	—	—	—	2
1943	—	5	2	9	[2]12	—	—	28
1944	—	6	1	10	249	[2]62	—	328
1945	—	—	18	98	219	[2]232	—	567
1946	—	—	1	82	6	[2]22	—	111
1947	—	—	21	40	[2]50	—	—	111
1948	—	9	36	19	138	[2]6	—	208
1949	—	—	27	170	[2]5	—	—	202
1950	—	19	7	37	[2]3	—	—	66
1951	1	21	50	10	[2]53	—	—	135
1952	—	20	24	138	30	([2])	—	212
1953	4	3	65	8	[2]35	—	—	115
1954	—	—	46	108	([2])	—	—	154
1955	4	6	74	74	[2]10	—	—	168
1956	—	—	12	73	3	([2])	—	88
1957	—	6	28	—	[2]36	—	—	70
1958	—	16	79	65	[2]19	—	—	179
1959	5	5	33	37	58	[2]133	—	271
1960	—	27	57	19	5	1	([2])	109
1961	51	27	11	5	4	([2])	—	98
1962	—	2	3	29	3	([2])	—	37
1963	—	2	202	[2]107	—	—	—	311
1964	—	10	13	—	([2])	—	—	23
1965	—	—	100	1	[2]23	—	—	124
1966	—	—	82	[2]8	—	—	—	90
1967	—	30	49	[2]4	—	—	—	83
1968	—	14	100	[2]70	—	—	—	184
1969	4	—	3	([2])	—	—	—	7
Total	69	249	1,246	1,274	961	456	—	4,255
Percent of all fish counted	1.6	5.9	29.3	29.9	22.6	10.7	—	—

[1]Daily counts for 1934-63 from Olson and McNeil (1967).
[2]Weir discontinued during this period.

males near each female and the number of males on the riffles but not with females also were recorded.

The estimates of the total number of spawners based on the periodic counts on the spawning riffles were obtained in the following manner. The counts of both sexes were plotted against time (Figure 3). In the figure each point for 1965 and 1967 represents the average of three successive daily counts of spawners, and each point for 1963 and 1964 represents a daily count. A curve was drawn by eye through each set of points, and the resulting area under the curve represents the spawning effort in fish-days (see Table 3 and section on Redd Life). The estimates of the total number of spawners were then derived by dividing the total number of fish-days by the average redd life (the number of days a female spends on the spawning site or redd). The method was modified from McNeil (1966). The average of the mean redd life computed for coho salmon females in 1965 and 1967 was used to calculate total number of spawners in 1963 and 1964.

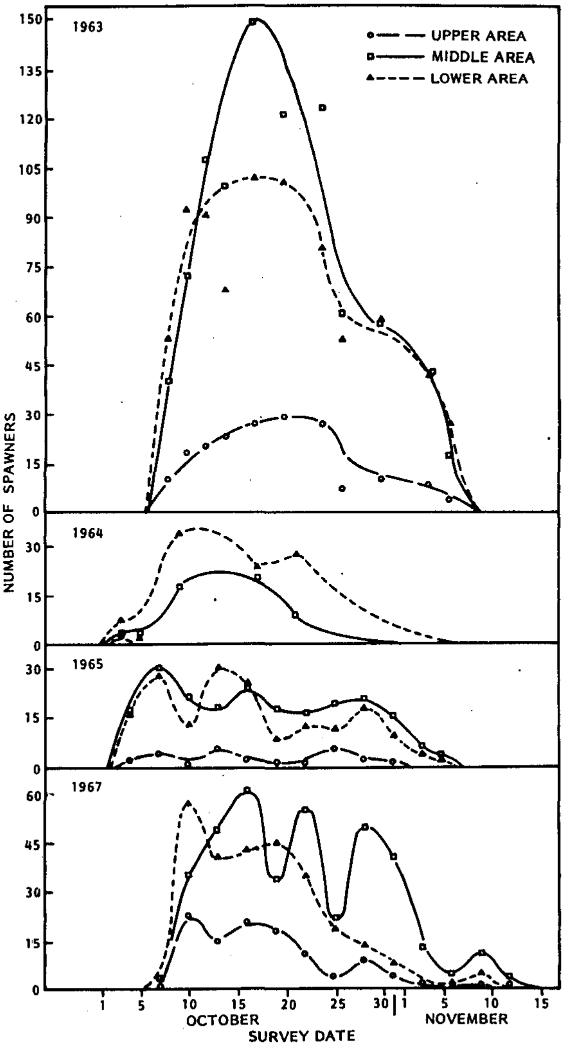

FIGURE 3.–Stream survey estimates of numbers of spawning coho salmon in Sashin Creek, based on periodic counts on spawning riffles, 1963-65 and 1967. Area under each curve is spawning effort, expressed in fish-days.

As indicated in the following tabulation, estimates of the total number of spawners derived from the stream survey data were much higher than the counts at the weir, except for 1965.

Year	*Counted at weir*	*Derived from stream survey (spawning effort-redd life)*
1963	311	458
1964	23	81
1965	124	94
1967	83	209

We also estimated the size of the escapement in 1965 and 1967 by conducting a mark-recapture experiment using the Bailey modification of the Petersen formula as given by Ricker (1958). In 1965, 46 adult coho salmon (32 females and 14 males) were tagged before spawning; in 1967, 73 unspawned coho salmon (28 females and 45 males) were tagged. The tags used were plastic Petersen disks. Marked-to-unmarked ratios were obtained from observations made during the visual censuses and these were used to estimate the populations. Based on the marked-to-unmarked ratios, the estimated number of coho salmon spawners (both sexes) in Sashin Creek was 221 in 1965 and 370 in 1967 (Table 4).

The estimates of escapement size in 1965 and 1967 based on marked-to-unmarked ratios were much higher than either the counts at the weir or the estimates based on spawning effort and redd life (Table 4). Several possible sources of error existed in estimating numbers of spawners from spawning effort and redd life: 1) The levels of spawning activity were lower at low streamflows, when visibility was good, and higher at high streamflows (Figure 4), when visibility was restricted. (In other words, the least accurate counts of spawners occurred when the greatest numbers were spawning.) 2) Some redds were occupied only at night (indicated from our limited observations). 3) The assumption that the mean spawning life of females was equal to that of males could be invalid.

TABLE 3.—Distribution and density of spawning coho salmon in three areas of Sashin Creek in 1963-65 and 1967.

Brood year	Distribution: % of total salmon observed, Upper area	Middle area	Lower area	Distribution: Spawning effort (fish-days), Upper area	Middle area	Lower area	Total	Density of spawning (fish-days per square meter), Upper area	Middle area	Lower area	Total
1963[1]	10	48	42	553	2,652	2,289	5,494	0.19	0.65	0.38	0.42
1964	1	35	64	5	297	674	976	<0.01	0.07	0.11	0.07
1965	6	51	43	74	607	543	1,224	0.03	0.15	0.09	0.09
1967	14	50	36	320	1,151	828	2,299	0.11	0.28	0.14	0.18

[1]W. J. McNeil, unpublished notes on 1963 coho studies. On file at Auke Bay Fisheries Laboratory, Auke Bay, AK 99821.

TABLE 4.—Estimates of coho salmon escapements to Sashin Creek, 1963-65 and 1967, based on three methods of estimation.

Method of estimation	Number of coho salmon each year: 1963	1964	1965	1967
Weir count	311	23	124	83
Spawning effort and redd life	458	81	94	209
Marked to unmarked ratios	—	—	221	370
(95% confidence interval)	—	—	197-250	342-403
Spawner escapement assumed in this report	[1]916	[1]162	221	370

[1]Based on observations in 1965 and 1967 that spawning ground counts and redd life estimates were about one-half the estimates based on marked-to-unmarked ratios of spawners.

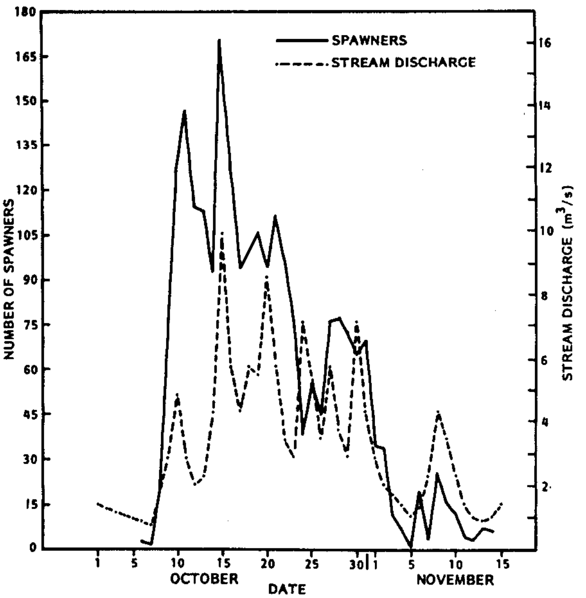

FIGURE 4.—Spawning ground counts of coho salmon in relation to stream discharge, Sashin Creek, 1967.

We believe that the best estimates of abundance of spawners are those based on tagging and observing marked-to-unmarked ratios, but such estimates are not available for 1963 and 1964. Therefore, because the estimates derived from spawning effort and redd life in 1965 and 1967 were approximately one-half the estimate from marked-to-unmarked ratios, the assumption was made that in 1963 and 1964, only 50% of the spawners in Sashin Creek were estimated from spawning effort and redd life. Our best estimates of the numbers of coho salmon spawners are 916 in 1963, 162 in 1964, 221 in 1965, and 370 in 1967 (Table 4). These values are used in the remainder of this report.

The population estimates of coho salmon spawners in Sashin Creek do not include jack coho salmon (precocious males of various freshwater ages but only one summer of marine life) because none were tagged; without tags, their presence on the spawning riffles would have been difficult to detect. Apparently, only a few jack coho salmon enter Sashin Creek; none were seen during the 1965 surveys of the spawning grounds, and only five were seen during underwater observations in 1967.

Redd Life

The estimates of mean redd life used in our calculations of escapement size were based on experiments with marked females in Sashin Creek in 1965 and 1967. Many untagged females that could be identified from natural markings, such as wounds, fungused areas, color, and size, were used along with the tagged females. A female had to be observed at the same location on two consecutive days before she was considered to have selected a permanent spawning site. One day was added to the observed redd life for females, on the assumption that they began to construct a redd an average of one-half day before first being observed and remained on the redd for an average of one-half day after last being observed.

The mean redd life of female coho salmon varied between tagged and untagged (identified from natural markings) females in both 1965 and 1967. In 1965 the mean redd life for 56 females (18 tagged and 38 untagged) was 13 days (range of 6 to 21 days). In 1967, 151 females (21 tagged and 130 untagged) remained an average of 11 days on the spawning riffles (range of 3 to 24 days). Tagged females had shorter mean redd lives than untagged females–12 versus 13 days in 1965 and 9 versus 11 days in 1967. The difference between tagged and untagged fish may have been due to difficulty in positively identifying untagged females with short redd lives, thus biasing the mean toward a greater value. Also, handling and tagging might have resulted in a shorter mean redd life for tagged females.

Tagged male coho salmon in Sashin Creek and both sexes in Funny Creek had shorter spawning lives than tagged females in Sashin Creek. Because males in Sashin Creek in 1965 were all tagged with the same color and could not be recognized individually on the spawning grounds as they moved from female to female, their spawning life could not be calculated. In 1967, however, the males in Sashin Creek had a mean spawning life of 9 days. The spawning life of coho salmon (males and females combined) was from 3 to 7 days in Funny Creek in 1965 and 1967. Rapidly rising and falling water levels, which caused some spawners to leave the area at low flows, and predation by brown bears, *Ursus arctos*, probably contributed to the shorter spawning life in Funny Creek.

In Sashin Creek, stream life and spawning life are not the same length because many coho salmon enter the stream and mature in pools for a month or more before they spawn. In Oregon, the mean length of time that female coho salmon spent in a tributary of Wilson River, Spring Creek, before death was 11 days (Willis 1954). Adults migrating into Spring Creek frequently begin spawning as soon as they enter the tributary; apparently they stay in the larger Wilson River until they are ripe (Willis 1954). Koski (1966) reported mean stream lives of 13.7 and 13.1 days for coho salmon that spawned in two tributaries to Drift Creek, Oreg.

Distribution and Density of Spawners

The distribution and density of spawners on the Sashin Creek spawning grounds were observed in 1963, 1964, 1965, and 1967 (Table 3). Distribution in each study area is expressed as the percentage of the total number of salmon observed spawning and as total spawning effort (fish-days) observed in each area. Density is the observed spawning effort divided by the square meters of spawning area.

In each of the 4 yr, the density of spawning coho salmon was higher in the middle and lower study areas than in the upper. In 1963, 1965, and 1967, the middle area had the highest density of spawners; in 1964 the lower area had the highest.

In Funny Creek a few coho salmon were seen spawning in 1965 and 1967. In those 2 yr about 4% of the estimated escapement of coho salmon to Sashin Creek spawned in Funny Creek.

The distribution and escapement of pink and coho salmon in Sashin Creek are shown in Table 5. Pink salmon usually were distributed more evenly throughout the creek than coho salmon. Merrell (1962) and McNeil (1966) reported that spawning pink salmon used the upper area extensively only in years when spawning escapements were large; when pink salmon escapements were small, spawning was concentrated in the lower area. The fact that relatively few coho salmon used Sashin Creek may explain why such a small proportion spawned in the upper area. In addition, ecological features of that area such as steep gradient and coarse bottom materials may limit its usefulness for spawning.

TABLE 5.–Distribution and escapement of spawning coho and pink salmon in three study areas of Sashin Creek, 1963-67.

Year and species of salmon	Escapement	Percentage of total salmon observed: Upper area	Middle area	Lower area
1963				
Coho	916	10	48	42
Pink	16,757	19	41	40
1964				
Coho	162	1	35	64
Pink	2,193	3	30	67
1965				
Coho	221	6	51	43
Pink	14,813	24	39	37
1966				
Coho	([1])	—	—	—
Pink	5,761	4	41	54
1967				
Coho	370	14	50	36
Pink	38,067	27	35	38

[1]The weir count of coho salmon was 90 when the weir gates were removed in md-September.

Interspecific Competition

Pink salmon are the most abundant fish in Sashin Creek–the number of adult pink salmon ranged from about 2,000 to 72,000, and their progeny ranged from about 0.3 to 3.6 million for the years of this study, 1963-72.

Because pink salmon complete their spawning in Sashin Creek before coho salmon spawning begins, spawning by coho salmon could be detrimental to pink salmon embryos. In 1965, we tried in each of the three study areas to assess the effect of coho salmon superimposing their redds on those of pink salmon. The densities of live pink salmon embryos, which were estimated from routine sampling of the spawning riffles with a hydraulic sampler prior to coho salmon spawning (McNeil 1964), were used in conjunction with the average size of a coho salmon redd to estimate the total number of pink salmon embryos that could have been destroyed in gravel disturbed by spawning coho salmon. At 13 redds throughout the stream the average area of gravel disturbed by spawning coho salmon was 2.6 m^2 per redd.

The possible effect of coho salmon spawning on pink salmon embryos in October 1965 is shown in Table 6. The estimated spawning population of 110 female coho salmon would have disturbed a total of 286 m^2 of spawning gravel. Hydraulic sampling of the spawning grounds in late September before the coho salmon spawned indicated an average density of 680 live pink salmon embryos per square meter (see footnote 1, Table 6). About 200,000 live pink salmon embryos resided in areas disturbed by coho salmon spawners.

In years when the numbers of coho and pink salmon spawners are similar to those of 1965, it is doubtful that coho salmon spawning has a significant detrimental effect on the survival of pink salmon embryos. Even assuming complete mortality of pink salmon embryos in gravels utilized by spawning coho salmon, the impact on survival of pink salmon in 1965 would have been slight—about 2% of the viable pink salmon embryos present. Mortality of pink salmon eggs from redd superimposition by coho salmon could be significant if the number of coho salmon spawners were to greatly increase by natural or artificial processes.

Age Determination

We determined the age structure of samples of adult coho salmon in Sashin Creek in 1965-67 and 1969 and in Nakvassin Creek in 1966-72 by scale analysis (Table 7). Most of the salmon had spent two summers and two winters in fresh water after emergence from the gravel, had migrated to sea in the beginning of their third year, and had then spent two summers and one winter in the ocean (designated in the Gilbert-Rich system as age 4_3). A smaller portion of those sampled had spent 1 yr in fresh water after emergence, had entered the sea at the beginning of their second year, and had then remained two summers in the ocean (age 3_2). Adults that had migrated to sea at the beginning of their fourth year of life and spent two summers in salt water (age 5_4) usually constituted the smallest fraction of each year's run.

The presence of a large and dominant brood year of coho salmon in Nakvassin Creek is indicated by the percentage age distribution of returning adults. In 1967, 40% of the adults sampled for scales were age 3_2—1964 brood coho salmon that had spent 1 yr in fresh water before migrating as smolts; in 1968, 94% of the adults

TABLE 7.—Age structure as determined from samples of scales of adult coho salmon from Sashin Creek, 1965-67 and 1969, and Nakvassin Creek, 1966-72.

Source and year of sample	No. of fish sampled	Percentage age distribution 3_2	4_3	5_4
Sashin Creek:				
1965	27	18	78	4
1966	17	29	59	12
1967	76	25	64	11
1969	16	37	62	0
Nakvassin Creek:				
1966	25	28	68	4
1967	20	40	55	5
1968	16	6	94	0
1969	28	11	61	29
1970	46	15	76	9
1971	78	8	88	4
1972	92	9	71	21

TABLE 6.—Possible effect of coho salmon spawning on pink salmon embryos in Sashin Creek steambed in October 1965.

Area	Percentage of observed coho salmon spawning effort	Estimated coho salmon females	Area of gravel disturbed by coho salmon (m^2)	Live pink salmon embryos/m^2 before coho salmon spawned[1]	Estimated viable pink salmon embryos disturbed by coho salmon	Estimated viable pink salmon embryos in study areas	Percentage of total pink salmon embryos disturbed by coho salmon
Upper	6	7	18	750	14,000	2,209,000	0.6
Middle	51	56	146	1,200	175,000	4,880,000	3.6
Lower	43	47	122	300	37,000	1,822,000	2.0
Total	100	110	286	[2]680	226,000	8,911,000	[3]2.2

[1]W. J. McNeil, Auke Bay Fisheries Laboratory, (pers. commun.).
[2]Mean density, weighted according to area size.
[3]Mean percentage, weighted according to area size.

were 4_3–1964 brood coho salmon that had spent 2 yr in fresh water; and in 1969, 29% of the adults were 5_4–1964 brood coho salmon that had spent 3 yr in fresh water. Another large brood year indicated by the ages of returning adults is the 1967 brood. No similar patterns of a strong brood year are evident in the 4 yr of data from Sashin Creek coho salmon (Table 7).

Direct comparison of the many studies on age composition of coho salmon must be done with caution because of year-to-year variations and different sampling techniques, but a general clinal change in freshwater and total age with latitude is suggested—southerly populations are predominantly age 3_2 and northerly populations predominantly age 4_3. In British Columbia, Washington, Oregon, and California, coho salmon (exclusive of jacks) are almost all age 3_2 (Pritchard 1940; Marr 1943; Smoker 1953; Shapovalov and Taft 1954; International North Pacific Fisheries Commission 1962). Gilbert (1922) reported that about 60% of the coho salmon of the Yukon River were age 4_3; the remainder were age 3_2. Coho salmon populations in most streams studied in the Cook Inlet-Kenai Peninsula area of Alaska are composed of 60% to 95% age 4_3 fish (Andrews 1962; Logan 1963; Engel 1966; Kubik 1967; Redick 1968). In the Karluk River system on Kodiak Island, Alaska, age 4_3 fish also are dominant but age 5_4 fish, rather than age 3_2, are the second most abundant (Drucker 1972). Semko (1954) listed age composition of coho salmon from the Bolshaya River, Kamchatka, for 8 yr; in two of the years (1946 and 1947) age 4_3 adults outnumbered age 3_2. The highest percentage of age 4_3 fish reported by Semko (1954) was 64.7%. The age composition of coho salmon from the commercial fisheries of the Taku and Stikine rivers in southeastern Alaska in 1955 was 68.0% age 3_2 and 28.2% age 4_3 (International North Pacific Fisheries Commission 1962). A later report on Stikine River coho salmon caught in 1955 gives age composition as 45.2% age 3_2 and 51.9% age 4_3 (Godfrey 1965). Of several thousand coho salmon represented by scales collected from the commercial fisheries in southeastern Alaska, about half spent one winter in fresh water (age 3_2) and half spent two winters in fresh water (age 4_3) (Smoker 1956). Nearly equal numbers of ages 3_2 and 4_3 also were reported for coho salmon at Hood Bay Creek in southeastern Alaska (Armstrong 1970).

Fecundity

We determined the fecundity of female coho salmon from Sashin Creek in 1966, 1970, and 1971 and, for comparison, from nearby Nakvassin Creek in 1966-72 (Table 8). Most of the females from Sashin Creek were collected at the weir and the rest were collected with sport fishing gear in the estuary (a total of 3 to 22 each year). All samples from Nakvassin Creek were collected with sport fishing gear in the estuary (6 to 45 females each year). Ovaries from individual females were placed in containers of water and boiled until the eggs hardened and separated from the ovarian tissues. The mean of the annual fecundity samples from Sashin Creek was 3,186 eggs per female (33 fish); the fish from Nakvassin Creek were slightly smaller and the mean of the samples was 2,326 eggs (116 fish).

The relation between number of eggs and fork length for Sashin Creek and Nakvassin Creek coho salmon was calculated by the method of least squares regression. The regressions for Sashin Creek and Nakvassin Creek are $\hat{Y} = -441.48 + 51.633X$ ($r = 0.31$) and $\hat{Y} = -824.59 + 47.686X$ ($r = 0.37$), respectively. $\hat{Y}$ is the estimated number of eggs and X is the fork length in centimeters of females. Log transformations of number of eggs and fork length did not increase the values of r significantly.

Average fecundities of coho salmon reported for other streams range between 1,983 and 5,343 (Table 9). Although these values were derived in many different ways and therefore are not strictly comparable, a general trend of increasing fecundity from south to north and east to west does appear.

TABLE 8.—Mean and range of fecundity and length of female coho salmon from Sashin Creek in 1966, 1970, and 1971 (3 to 22 fish) and Nakvassin Creek in 1966-72 (6 to 45 fish).

Creek and year	No. of females sampled	Number of eggs		Fork length (cm)	
		Mean	Range	Mean	Range
Sashin Creek:					
1966	8	2,868	1,195-4,418	70.5	64.8-73.7
1970	3	3,472	3,277-3,581	65.6	64.3-68.2
1971	22	3,217	2,537-4,665	69.6	63.1-79.8
Nakvassin Creek:					
1966	7	2,463	1,853-2,931	67.8	64.8-70.0
1967	8	2,143	1,737-2,565	65.6	61.3-70.8
1968	6	2,545	2,086-3,301	66.3	60.0-68.6
1969	15	2,228	1,664-3,120	66.4	56.0-69.5
1970	22	2,294	1,259-3,127	64.1	57.0-67.5
1971	13	2,414	2,000-2,816	66.7	63.5-69.9
1972	45	2,194	1,182-3,574	63.9	56.0-71.0

Retained Eggs

In 1965 and 1967, dying and dead spent female coho salmon were examined for retained eggs

TABLE 9.–Summary of available data on fecundity of coho salmon throughout most of the geographic range.[1] The data are not strictly comparable among the various published and unpublished sources because of differences in methodology. Localities arranged in counterclockwise order from California to Sakhalin Island, USSR.

Area	Average no. of eggs	No. of fish in sample	Average fork length (cm)	Source of data
California:				
Scott Creek	[2]2,616	65	[3]66.3	Shapovalov and Taft (1954)
Oregon:				
Fall Creek, Alsea River	1,983	92	[2]66.2	Koski (1966)
Big Creek	3,030	74	70.2	James R. Graybill (pers. commun. 31 May, 1973)
Washington:				
Minter Creek	2,500	1,120	—	Salo and Bayliff (1958)
University of Washington, Seattle	3,100	63	63	Allen (1958)
British Columbia:				
Cowichan River, Vancouver Island	2,329	—	—	Neave (1948)
Oliver Creek (tributary to Cowichan River)	2,267	—	—	Foerster (1944)
Beadnell Creek (tributary to Cowichan River)	2,789	—	—	Foerster (1944)
Sweltzer Creek	2,300	—	—	Foerster and Ricker (1953)
Fraser River	3,152	48	[4]65.3	Foerster and Pritchard (1936)
Nile Creek	2,310	([5])	—	Wickett (1951)
Namu Cannery	3,002	21	[4]69.8	Foerster and Pritchard (1936)
Port John Creek	2,313	3	—	Hunter (1948)
Alaska:				
Sashin Creek, southeastern	3,186	33	68.6	Present study
Nakvassin Creek, southeastern	2,326	116	65.8	Present study
Bear Creek, Cook Inlet	4,115	193	—	Lawler (1963, 1964)
Bear Creek, Cook Inlet	[6]3,595	179	66.9	Logan (1968)
Dairy Creek, Cook Inlet	4,177	155	72.8	Lawler (1963), Engel (1965) combined
Cottonwood Creek, Cook Inlet	2,346	220	55.1	Andrews (1961), McGinnis (1966) combined
Fish Creek, Cook Inlet	2,426	112	—	Calculated from Andrews (1962)
Swanson River, Cook Inlet	3,448	1,019	62.3	Calculated from Engel (1967)
Lake Rose Tead, Kodiak Island	4,201	—	—	Marriott (1968), Van Hulle (1970) combined
Lake Miam, Kodiak Island	4,209	277	—	Van Hulle (1971)
Karluk River, Kodiak Island	4,706	49	[7]62.1	Drucker (1972)
Union of Soviet Socialist Republics:				
Kamchatka River, Kamchatka	4,883	—	[8]60.4	Kuznetsov (1928)
Bolyshaya River, Kamchatka	4,300-5,343	—	[8]56.5	Semko (1954)
Paratunka River, Kamchatka	4,350	—	[8]59.1	Gribanov (1948)
Tymi River, Sakhalin Island	4,570	—	—	Smirnov (1960)

[1]Table adapted from Rounsefell (1957) and Allen (1958).
[2]Value calculated from regression curve.
[3]Mean length determined from 338 females.
[4]Total length.
[5]Three to eight specimens per year.
[6]After introduction of Swanson River coho salmon stocks into Bear Lake.
[7]Mideye to fork length.
[8]Lengths given by Gribanov (1948), not from females sampled for fecundity.

during daily stream surveys. Only seven spent females were examined each year because high water washed most dying spawners from the stream. The number of eggs ranged from 0 to 64 and averaged 8 per female for the two seasons. Koski (1966) examined 30 spent female coho salmon in an Oregon stream and found an average of four eggs per female. In streams of Kamchatka, Semko (1954) found that coho salmon retained 0.3% of the actual fecundity (about 7 to 16 eggs per female).

JUVENILE COHO SALMON STUDIES

With anadromous salmon, the result of freshwater production is a juvenile migrating to the ocean–a smolt or fry physiologically adapted to enter salt water, where most growth takes place. Our studies were designed to measure the yield of coho salmon smolts and to determine some of the factors that bear on this yield. We counted and sampled the juvenile coho salmon at a weir as they left Sashin Creek and entered the estuary, and also sampled juveniles in the stream with seines. In addition, after determining that many fry of unknown physiological capabilities entered salt water, we performed experiments to determine the ability of these fry to survive the salinities existing in the estuary. For studies in the stream coho salmon juveniles were considered as two groups–fry (age 0) and fingerlings (age I and older).

Specific topics considered here are: 1) the numbers of coho salmon smolts and fry entering the estuary from Sashin Creek each year, 1956-68; 2) the migration of fry to the estuary and their ability to survive in salt water; 3) age and growth of juveniles in the stream; 4) survival through various life stages (potential egg deposition to fry emergence and as juveniles in the stream); and 5) mortality in fresh water.

Juveniles Entering the Estuary

In Sashin Creek the emergence of coho salmon fry from the gravel usually begins in April and is completed by the end of May, although in especially cold years emergence may not start until June or July. Juvenile coho salmon usually live in Sashin Creek for 1 to 3 yr before migrating to salt water as smolts, but some migrate to the estuary during their first spring or summer as fry. The migration of fry to salt water soon after they emerge has been reported in several other streams (Chamberlain 1907; Gilbert 1913; Pritchard 1940; Wickett 1951; Foerster 1955), but none of these authors reported a substantial return of adult salmon from such early-migrating fry. All of the scale samples from adult coho salmon at Sashin Creek indicated that the fish had spent at least 1 yr in fresh water. The absence of adults originating from early-migrating fry suggests very poor survival of fry entering the estuary at a small size (usually <35 mm from Sashin Creek), which could be the result of heavy predation or some failure to adapt physiologically to the marine environment. We have assumed that we can identify adults derived from early-migrating fry on the basis of the pattern of circuli on their scales. However, if fry surviving in the estuary developed scale patterns indistinguishable from those of fry spending a year or more in fresh water, our assumption that age 0 emigrants did not contribute to the adult run could be incorrect.

Numbers of Fry and Smolts

Counts and estimates of the numbers of juvenile coho salmon migrating from Sashin Creek ranged from 218 to 44,023 fry and 928 to 2,865 smolts between 1956 and 1968 (Table 10). In 1964, 44,023 fry left the stream between 19 April and 28 August, and most migrated in a 2-wk period in mid-June–the greatest migration was 3,528 fry on 15 June. The smolt migration in Sashin Creek varied about threefold from 1956 through 1968 (excluding 1965-66–Table 10). The relatively low counts of smolts in 1964 probably resulted from a change in the trapping procedures at the weir. Before 1964, all fish migrating from Sashin Creek were captured. The procedures used in 1964 were designed to capture a portion of the emigrating fry and did not retain smolts well. Because of high water and ice damage to the weir, complete counts of emigrating fry and smolts were not made for 1965-67. In 1965 and 1967, estimates of fry and smolts were based on catches in fyke nets that sampled the migrants at the weir site. No estimates were obtained in 1966.

A comparison of the time of smolt migration from Sashin Creek with the time of migration from streams and lakes along the eastern Pacific coast from south-central Alaska to central coastal California indicates that there is a tendency

TABLE 10.–Numbers and times of migration of coho salmon fry and smolts past the Sashin Creek weir and yield of smolts, 1956-68.[1]

Year	Number counted at weir[2]		Counting period	Date of largest migration		Date last fish was observed to emigrate		Yield of smolts per 100 m^2 of rearing area
	Fry	Smolts		Fry	Smolts	Fry	Smolts	
1956	—	928	16 Apr.-30 June	—	15 June	—	20 June	5.5
1957	373	1,961	10 Apr.-29 June	17 June	24 May	27 June	27 June	11.5
1958	2,854	1,015	7 Mar.-3 June	4 May	20 May	31 May	2 June	6.0
1959	218	1,587	1 Apr.-21 July	14 July	27 May	15 July	3 July	9.3
1960	9,923	1,258	17 Mar.-2 July	12 June	10 June	30 June	30 June	7.4
1961	2,699	2,489	22 Mar.-19 June	21 May	28 May	17 June	17 June	14.6
1962	1,209	2,865	11 Mar.-4 July	14 June	27 May	4 July	3 July	16.9
1963	1,236	1,599	11 Mar.-8 July	30 May	24 May	1 July	3 July	9.4
1964	44,023	[3]334	15 Mar.-28 Aug.	15 June	24 May	28 Aug.	6 July	—
1965[4]	12,000	—	11 Apr.-30 July	24 June	—	15 July	—	—
1967[4]	10,000	1,400	10 Apr.-8 Aug.	28 June	25 May	8 Aug.	5 July	8.2
1968	1,665	1,440	26 Mar.-3 Aug.	5 June	24 May	3 Aug.	5 July	8.5

[1]The year 1966 is not included because the weir was damaged and substitute sampling was not conducted.
[2]Daily counts for 1956-64, available from Olson and McNeil (1967).
[3]Counting procedure changed from total to partial counts; holding facilities were inadequate for retaining all smolts captured.
[4]Weir not functional; fyke net(s) fished to sample a portion of the spring emigration. Numbers of fry and smolts presented are estimates made from fyke net catches.

toward earlier migration in the southern part of the range (Table 11).

To compare yields of coho salmon smolts between streams, we express yield in numbers per unit area. Estimates of the annual yield of coho salmon smolts from Sashin Creek for the period 1956-68 (except 1964-66) ranged from 5.5 to 16.9/100m^2 of rearing area (Table 10). The yield of smolts for a 5-yr period in three streams tributary to Drift Creek ranged from 18 to 67/100 m^2 (Chapman 1965). The much lower yield of smolts from Sashin Creek probably reflects increased mortality accompanying the additional 12 mo of freshwater residence for most smolts from Sashin Creek. The number of nonmigrant yearling coho salmon in Sashin Creek in early summer (determined from population studies) approximates the yield of smolts from Drift Creek tributaries more closely than does the yield of smolts (all ages) from Sashin Creek.

Early Emigration and Salinity Tolerance of Fry

The number of fry entering the estuary is great enough (Table 10) that the question of their fate in salt water is important. Many factors such as predation, failure to find adequate food, failure to adjust physiologically to salt water, and disease may act alone or in combination to determine the survival of fry entering marine waters. We had opportunity to explore adjustment to salt water as a factor in survival of migrating fry.

Early-migrating coho salmon fry might have reentered Sashin Creek undetected, although they could not have done so while the fry and smolt weir was in operation. In addition, a low waterfall immediately downstream from the weir is a barrier to upstream migration of coho salmon fry except for several days each year when above-average high tides inundate the falls. Our popula-

TABLE 11.—Timing of seaward migration of coho salmon smolts from streams and lakes in Alaska, British Columbia, Washington, Oregon, and California.

Location	Migration period	Peak of migration	Source of data
South-central Alaska:			
Fire Lake (lat. 61°21′N)	Mid May-early July	Late May-early June	Wallis (1967, 1968)
Bear Lake (lat. 60°12′N)	Late May-early Aug.	Early June	Logan (1963)
Little Kitoi Lake, Afognak Island (lat. 58°12′N)	Late May-late July	Mid June	Parker and Vincent (1956)
Karluk Lake, Kodiak Island (lat. 57°27′N)	Mid May-early July	Late May-early June	Drucker (1972)
Lake Margaret (lat. 57°46′N)	Mid Mar.-early July	Late May-early June	Van Hulle (1971)
Lake Genivieve (lat. 57°46′N)	Mid May[1]-mid July	Late May-early June	Van Hulle (1971)
Souhteastern Alaska:			
Taku River (lat. 58°33′N)	Mid Apr.-mid June[2]	Mid May-early June	Meehan and Siniff (1962)
Eva Lake (lat. 57°24′N)	Mid May-mid June	Late May	Armstrong (1970)
Hood Bay Creek (lat. 57°20′N)	Early May-late June	Mid May-early June	Armstrong (1970)
Sashin Creek (lat. 56°23′N)	Apr.-early July	Late May-early June	Table 10, this report
Central coastal British Columbia:			
Port John (Hooknose Creek) (lat. 52°08′N)	Mid Apr.-early June	May	Hunter (1948, 1949)
Southern British Columbia:			
Cultus Lake (lat. 49°03′N)	Apr.-June	Late May-early June	Foerster and Ricker (1953)
West-central Washington:			
Minter Creek (lat. 47°22′N)	Feb.-early June	May	Salo and Bayliff (1958)
Northwestern Oregon:			
Gnat Creek (lat. 46°12′N)	Apr.-early June	May	Willis[3]
Northern coastal Oregon:			
Spring Creek (lat. 45°36′N)	Late Feb.-May	Late Mar.-early May	Willis et al.[4]
Central coastal Oregon:			
Drift Creek tributaries: Deer, Flynn, and Needle Branch Creeks (lat. 44°32′N)	Feb.-May	Late Mar.-early Apr.	Chapman (1962, 1965)
Crooked Creek (lat. 44°25′N)	Feb.-early June	Apr.-May	Harry H. Wagner (pers. commun. 9 July 1973)
Southern coastal Oregon:			
Sixes River (lat. 42°51′N)	Mar.-June	Apr.-May	Reimers[5]
Central coastal California:			
Waddell Creek (lat. 37°06′N)	Apr.-early June	Late Apr.-May	Shapovalov and Taft (1954)

[1]Trapping facilities were completed after the beginning of the migration.
[2]Period when a sampling trap was operated.
[3]Willis, R. A. 1962. Gnat Creek weir studies. Final Rep., BCF Contract 14-17-0001-469, Fish Comm. Oreg., Res. Div., 71 p.
[4]Willis, R. A., R. N. Breuser, A. L. Oakley, and R. W. Hasselman. 1959. Coastal Rivers Investigations Prog. Rep., August 1957-June 1958, Fish Comm. Oreg., 24 p.
[5]Reimers, P. E. 1971. The movement of yearling coho salmon through Sixes River estuary. Coastal Rivers Investigations Prog. Rep. 71-2, Fish Comm. Oreg., 15 p.

tion studies of juvenile coho salmon in Sashin Creek suggest that no large-scale reentry of coho salmon fry occurs.

Coho salmon fry from an Oregon coast stream adjusted to water of moderately high salinities in laboratory tests (Conte et al. 1966). Our field observations, live-box experiments, and bioassays at Little Port Walter confirm that ability for fry from Sashin Creek. In July 1964, after about 44,000 coho salmon fry had migrated from Sashin Creek, schools of fry were seen near the surface of the inner bay. Most of them appeared to be in water of low salinity above a density interface about 30 cm deep, but they retreated to deeper more saline waters when disturbed.

To study the ability of coho salmon fry to adjust to the saline conditions in the Little Port Walter estuary, some fry were confined in live-boxes in the inner bay during the summer of 1964. Two sizes of live-boxes were used: six small boxes (86 by 86 by 122 cm deep) were arranged so that the water depth in the box was 81 cm, and two large boxes (122 by 122 by 244 cm deep) were suspended from a floating frame so that water depth was 235 cm. The small boxes were arranged in three sets of two boxes each, and 60 fry were placed in each box; the fry were from the weir trap, the inner bay, and Sashin Creek. Twenty-five fry from the inner bay were placed in each of the large boxes.

Initially, the Sashin Creek and weir trap fry in the live-boxes entered high-salinity water for short periods only, whereas some inner bay fry remained in the high-salinity water for long periods. Most of the fry stayed at or near the density interface close to the top of the box where the salinity was 14‰ or less; but some, especially those from the inner bay, swam for extended periods near the bottom of the box where salinity was 28 to 29‰.

Survival and growth of the fry seemed to be related more to the size of the live-box and the resulting competition for food than to the fry's ability to adjust to the saline water of the bay. In the small live-boxes, during the first 5 days 3% of the fry died and in 30 days 26% had died; in the large live-boxes in 35 days only 8% of the fry died (Table 12). The general comparison is true both for the entire small-box group versus the large-box group and for the small-box group of fish from the inner bay versus the large-box group (also from the inner bay). No supplemental food was provided, and the fry in the small boxes grew very little or not at all, whereas those in the large boxes grew about 5 mm (Table 12).

Tests were conducted in July 1964 to measure the ability of coho salmon fry to survive abrupt transfer to higher salinity waters. Salinities were determined with hydrometers. Plastic buckets were used as test containers, and as in the live-box studies, coho salmon fry were taken from Sashin Creek, the weir trap, and the inner bay. For each test, 10 fish were abruptly transferred from their source water to the test water. The fry from all three sources survived 48 h in salinities up to 23.5‰ (Table 13). In 29‰ water, the fry from the inner bay lived for 48 h, but none of those from the weir trap and only 50% of those from Sashin Creek survived 48 h. Of seven fry from the weir trap that survived 96 h in 17.6‰ salinity, three were transferred to 31‰ for 48 h, and one survived; four were transferred to 23.5‰ and three survived for 48 h. Seven fry that survived 96 h in 23.5‰ salinity were transferred to 31‰—four of these fry were still alive 48 h later when the experiment was

TABLE 12.–Mortality and growth of coho salmon fry held in live-boxes in the inner bay of Little Port Walter in the summer of 1964.

Size of live-box and no. of fish	Source of fish	Total mortality after			Average initial fork length of fry (mm)	Average fork length at end of experiment (mm)
		5 days	30 days	35 days		
Small:						
60	Weir trap	2	13	(1)	36.8	35.9
60	Inner bay	2	15	(1)	38.6	38.6
60	Weir trap	6	24	(1)	36.8	35.7
60	Sashin Creek	1	18	(1)	36.8	36.8
60	Inner bay	0	13	(1)	38.6	38.9
60	Sashin Creek	0	11	(1)	36.8	36.4
Large:						
25	Inner bay	(2)	(2)	1	40.0	44.7
25	Inner bay	(2)	(2)	3	40.0	45.4

[1]Experiment terminated after 30 days.
[2]No observations until day 35.

TABLE 13.–Cumulative deaths of coho salmon fry taken from the inner bay of Little Port Walter, the weir trap at the mouth of Sashin Creek, and Sashin Creek and held in waters of various salinities, July 1964.

Salinity (°/oo)	Number of fish	Source of fish	Size range (fork length, mm)	Cumulative deaths at				
				24 h	48 h	72 h	96 h	144 h
0	10	Weir trap	32-38	0	0	0	0	0
0	10	Inner Bay	37-45	0	0	([1])	—	—
0	10	Weir trap	35-39	0	0	([1])	—	—
0	10	Sashin Creek	35-41	0	0	0	—	—
2.2	10	Inner Bay	36-47	0	0	([1])	—	—
12.5	10	Inner Bay	35-40	0	0	([1])	—	—
12.5	10	Weir trap	35-42	0	0	0	—	—
12.5	10	Sashin Creek	38-45	0	0	0	—	—
17.6	10	Weir trap	33-39	0	0	1	3	[2]6
19.3	10	Weir trap	34-39	0	0	0	—	—
19.3	10	Sashin Creek	34-63	0	0	0	—	—
23.5	10	Weir trap	33-40	0	0	0	0	0
23.5	10	Weir trap	32-40	0	0	3	3	[3]6
29	10	Inner Bay	31-42	0	0	2	—	—
29	10	Weir trap	29-35	8	10	—	—	—
29	10	Sashin Creek	33-52	1	5	([1])	—	—
31	20	Weir trap	31-42	18	20	—	—	—

[1]Accidentally discontinued before 72 h.
[2]Of seven survivors in 17.6°/oo at 96 h, three were transferred to 31°/oo for 48 h, and one survived; four were transferred to 23.5°/oo, and three survived for 48 h.
[3]Period from 96 to 144 h at 31°/oo salinity.

ended (Table 13). Otto (1971) found that salinity tolerance of juvenile coho salmon was increased by a 35-day exposure to water of lower salinity.

The inner bay has horizontal and vertical salinity gradients (Powers 1963), which are excellent for acclimation of young salmon to salt water. Much of the surface of the inner bay is usually less than 10-15°/oo salinity. Our bioassays show that fry able to survive 48 h in 23°/oo salinity should be able to acclimate fully to salinities encountered in the inner bay if they have access to the low salinity refuge. Our observation of coho salmon fry in live-boxes confirms this ability.

Juveniles in the Stream

Age Determination

Because length frequencies of different age-groups can overlap broadly at some times of the year (Figures 5-7), scales of juvenile coho salmon were analyzed to assign age-groups. Analysis of scale samples indicated that an average of 11% of all fingerlings (age I and older) collected from the stream were age II. Sizes of the various age-groups sampled by month for 1964-67 are shown in Figure 5.

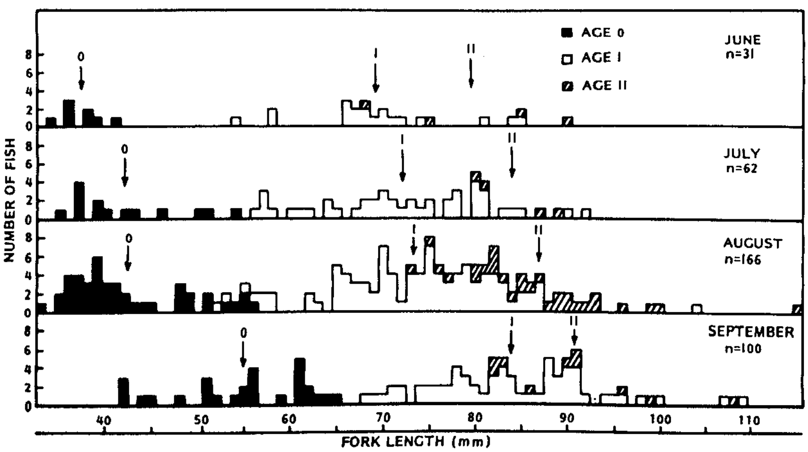

FIGURE 5.–Length frequencies and ages of coho salmon juveniles from Sashin Creek grouped by month of collection, June to September 1964-67. Ages were determined by analysis of scale samples, and lengths were measured on preserved fish. Arrows indicate location of mean lengths for each age class.

Most coho salmon fry (age 0) collected in June were under 40 mm in fork length and had not formed scales. Gribanov (1948) found that the scale covering usually appeared on young coho salmon from Kamchatka at 40 mm long.

Growth and Age Characteristics

Growth of juvenile coho salmon in Sashin Creek was determined from fork lengths (measured to the nearest millimeter) of samples of fry and fingerlings. Fry were collected periodically during summer 1964, and fry and fingerlings were captured during each of several population estimates of juveniles in Sashin Creek during 1965-67. An additional 50 fry from each of the three study areas of Sashin Creek were measured in mid-July 1966 and mid-August 1967. Samples of fingerlings from the three study areas were measured in early July, early August, and mid-September 1968.

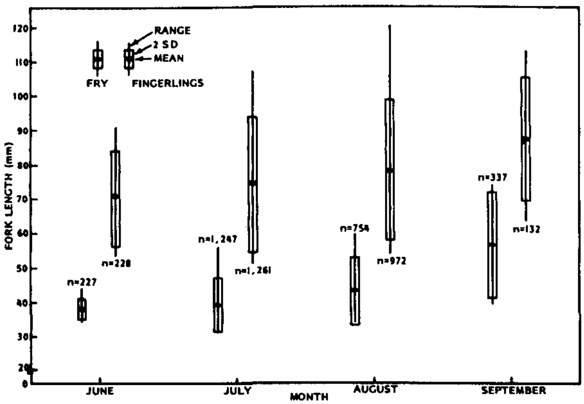

FIGURE 6.—Mean and range of fork lengths of fry (age 0) and fingerling (ages I and II) coho salmon, Sashin Creek, 1964-68. Lengths were measured from live fish.

There was no consistent difference in the mean fork lengths of corresponding age groups of juvenile coho salmon captured in the upper, middle, or lower areas in any sampling period (Table 14). Juveniles from Funny Creek were usually slightly smaller than those from Sashin Creek during a corresponding period.

The length data for juvenile coho salmon sampled in Sashin Creek for 1964-68 have been combined by month for fry and fingerlings (Figure 6). The difference between the fork length of fry and fingerlings was pronounced in early summer, but by July the lengths of fast-growing fry and slow-growing fingerlings overlapped (Figure 6). Occasionally it was difficult to assign the proper age-group to juveniles in the overlapping sizes, although they could usually be separated by the brightly colored and proportionally longer fins and smaller eyes of the fry.

The average fork length of coho salmon fry in Sashin Creek in October is about 60 mm. The average length of those that do not become smolts the following spring but remain in the stream a second year is usually 65-75 mm by July. In the 1968 migration, age I smolts averaged 83 mm, age II smolts 105 mm, and age III smolts 104 mm (Figure 7). In comparison, in 1968 coho salmon from Hood Bay Creek in southeastern Alaska averaged 83 mm fork length as age I smolts and 96 mm as age II smolts; in 1969 age I smolts averaged 79 mm and age II smolts 91 mm (Armstrong 1970). For the years 1956, 1965, and 1968, coho salmon smolts migrating from Karluk Lake, Kodiak Island, Alaska, averaged 111 mm as age I smolts, 139

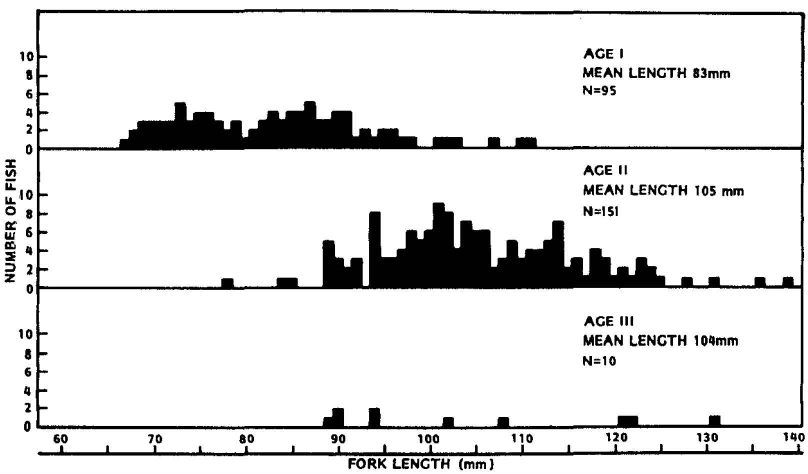

FIGURE 7.—Length frequencies of ages I, II, and III coho salmon smolts, Sashin Creek, 1968. Total sample was 256 fish, of which 37% were age I, 56% age II, and 4% age III. Ages were determined by analysis of scale samples, and lengths were measured on live fish.

TABLE 14.–Fork length (mm) of coho salmon fry and fingerlings captured in three study areas of Sashin Creek and Funny Creek, 1964-68.

Date[1] and type of sample	Sashin Creek												Funny Creek		
	Upper area			Middle area			Lower area			Total					
	Range	Mean	No.	Range	Mean	No.	Range	Mean	No.	Range	Mean	No.	Range	Mean	No.
1964:															
7 July:															
Fry	—	—	—	—	—	—	—	—	—	31-46	36.8	43	—	—	—
15 July:															
Fry	—	—	—	—	—	—	—	—	—	33-49	39.8	92	—	—	—
21 July:															
Fry	—	—	—	—	—	—	—	—	—	32-46	37.0	34	—	—	—
28 July:															
Fry	—	—	—	—	—	—	—	—	—	34-50	39.2	91	—	—	—
31 July:															
Fry	—	—	—	—	—	—	—	—	—	33-52	38.9	39	—	—	—
18 Aug.															
Fry	—	—	—	—	—	—	—	—	—	37-59	45.1	56	—	—	—
1965:															
17 July:															
Fry	34-44	38.5	37	34-44	38.0	43	35-45	38.1	103	34-45	38.2	183	—	—	—
Fingerlings	55-80	67.7	71	53-90	68.8	99	51-86	69.7	147	51-90	69.0	317	—	—	—
1 Aug.:															
Fry	—	—	—	—	—	—	—	—	—	—	—	—	37-43	39.1	29
Fingerlings	—	—	—	—	—	—	—	—	—	—	—	—	47-80	62.1	28
11 Aug.:															
Fry	39-47	41.9	17	37-46	40.5	12	35-49	40.3	99	35-49	40.5	128	35-46	39.1	84
Fingerlings	56-84	73.4	24	56-90	70.6	96	54-91	70.2	102	54-91	70.7	222	49-91	63.8	43
30 Sept.:															
Fry	45-74	62.2	73	59-69	64.3	7	49-69	60.4	7	45-74	62.2	87	39-70	53.4	61
Fingerlings	76-104	88.0	11	84	84	1	75-97	86.0	2	75-104	87.4	14	71-105	85.8	44
1966:															
27 June:															
Fry	35-40	37.0	34	34-43	37.4	133	35-44	39.3	60	34-44	37.9	227	34-39	36.6	61
Fingerlings	60-89	71.9	24	53-85	67.6	69	56-91	71.8	135	53-91	70.6	228	50-98	72.1	78
8 July:															
Fry	35-43	37.7	24	33-47	37.7	95	34-50	40.3	101	33-50	39.0	220	34-50	38.0	102
Fingerlings	62-93	77.9	48	58-95	75.4	45	56-104	77.5	56	56-104	77.0	149	50-102	70.6	105
14 July:															
Fry	34-44	37.8	50	33-46	38.9	50	36-47	39.5	50	33-47	38.7	150	36-47	39.9	50
29 July:															
Fry	34-56	46.4	50	36-53	42.4	53	36-55	43.0	51	34-56	43.9	154	33-56	40.8	54
Fingerlings	55-98	76.3	63	65-105	79.1	58	68-102	81.6	45	55-105	78.7	166	61-105	75.5	50
14 Aug.:															
Fry	38-58	48.1	100	36-59	46.2	100	37-60	46.2	100	36-60	46.8	300	32-63	44.7	100
Fingerlings	60-102	82.0	89	63-107	84.2	100	65-106	84.6	100	60-107	83.7	289	56-119	81.1	100
8 Sept.:															
Fry	44-68	57.3	50	39-67	49.6	100	46-68	58.0	100	39-68	54.5	250	40-68	52.1	100
Fingerlings	67-102	86.7	50	63-95	81.5	10	69-113	87.8	36	63-113	86.6	96	61-108	85.3	100
1967:															
23 July:															
Fry	33-41	36.5	50	34-45	37.9	71	33-52	38.8	120	33-52	38.0	241	36-42	37.9	50
Fingerlings	52-104	70.8	100	53-93	69.5	105	53-92	72.8	112	52-104	71.1	317	52-103	77.1	107
4 Aug.:															
Fry	—	—	—	—	—	—	34-49	38.6	116	34-49	38.6	116	35-50	40.2	75
Fingerlings	—	—	—	—	—	—	57-104	76.2	228	57-104	76.2	228	55-104	74.3	50
17 Aug.:															
Fry	36-46	40.7	50	35-50	40.9	54	37-55	41.1	50	35-55	40.9	154	—	—	—
5 Sept.:															
Fry	—	—	—	—	—	—	—	—	—	—	—	—	38-64	46.3	38
Fingerlings	—	—	—	—	—	—	—	—	—	—	—	—	72-90	81.0	3
17 Oct.:															
Fry	—	—	—	—	—	—	—	—	—	—	—	—	45-69	59.5	159
Fingerlings	—	—	—	—	—	—	—	—	—	—	—	—	70-97	79.8	27
1968:															
2 July:															
Fingerlings	56-96	74.6	110	59-103	80.0	98	59-107	83.2	104	56-107	79.2	312	57-103	77.9	74
1 Aug.:															
Fingerlings	59-101	76.9	68	57-104	82.2	80	66-120	81.3	85	57-120	80.3	233	59-107	82.4	62
20 Sept.:															
Fingerlings	79-100	88.7	22	—	—	—	—	—	—	79-100	88.7	22	—	—	—

[1]Dates given for 1965, 1966, 1967, and 1968 measurements are middates of the measuring period.

mm as age II smolts, 151 mm as age III smolts, and 175 mm as age IV smolts (Drucker 1972). Kamchatka streams at about the same latitude as Sashin Creek produce 40- to 70-mm coho salmon fry by September (Gribanov 1948), 85-mm age I smolts, and 130-mm age II smolts (Semko 1954). In

California (Shapovalov and Taft 1954) and British Columbia (Foerster and Ricker 1953), the mean lengths of coho salmon smolts (mostly age I) usually ranged from 110 to 120 mm.

In coho salmon, attaining the smolt stage is apparently more a function of size than age. Data on lengths and numbers of juvenile coho salmon in Sashin Creek during September and early summer suggest that most require two summers of freshwater residence to reach smolt size. Coho salmon can grow much faster; some juveniles in a brackish pond in Oregon grew from about 40 mm (890 to the pound) to about 120 mm and became smolts in only 3 mo instead of the usual 1 yr (Garrison 1965).

The growth of juvenile coho salmon in Sashin Creek varies from year to year. During summer 1966, for instance, fry were larger than in 1964, 1965, and 1967 (Figure 8). In the summers of 1966 and 1968, fingerlings (mainly age I) were larger than in 1965 and 1967 (mainly age I). The number of fingerlings in 1966 and 1968[4] (≈3,000 on 1 July) was less than in either 1965 (≈5,000 on 1 July) or 1967 (≈3,500 on 1 July), and less competition for food would be expected and could account for the larger size of the fingerlings in 1966. Also, the presence of fewer fingerlings in summer 1966 may have allowed the fry to reach a larger size because of less competition for food or space. Food abundance, controlled by factors other than coho salmon population size, may have an important influence on coho salmon growth in Sashin Creek. We have no information on possible year-to-year differences in food supply independent of fish populations which could result in differences in growth of juvenile coho salmon.

[4]An estimate of 2,960 fingerlings in Sashin Creek was made on 2 July 1968.

Survival from Potential Egg Deposition to Emergence

The estimated potential egg depositions for brood years 1963, 1964, and 1965 were determined by multiplying the mean fecundity (determined from 1966, 1970, and 1971 samples) by the estimated number of females (one-half of the estimated population of spawners). These estimates are considered to be only rough approximations: 1,460,000 for 1963; 260,000 for 1964; and 350,000 for 1965.

Estimates of the numbers of preemerged salmon alevins in the streambed were obtained in the early spring by hydraulic streambed sampling (McNeil 1964). In Sashin Creek this sampling is done to estimate the number of pink salmon alevins, but after relatively large escapements of coho salmon reliable estimates of the number of coho salmon alevins in the streambed also can be made. No coho salmon alevins were found during the hydraulic streambed sampling in the spring of 1966, so the estimate of the alevin population was zero. Because many age 0 fry were in the stream in the summer of 1966, we have estimated the number of alevins that were in the gravel that spring by interpolation of the survivorship curves.

The numbers of preemerged coho salmon alevins for 1964-66 estimated from the results of hydraulic sampling or interpolation of survivorship curves are: 214,000 in spring 1964 (1963 brood year), 58,000 in spring 1965 (1964 brood year), and 100,000 in spring 1966 (1965 brood year). From these figures and estimates of potential egg deposition, we calculated survival from potential egg deposition to just before fry emergence to be 15%, 22%, and 26% for the 1963, 1964, and 1965 brood years, respectively.

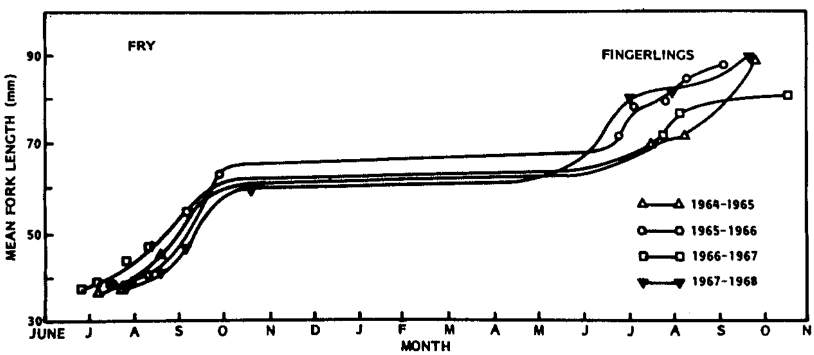

FIGURE 8.—Mean fork lengths of coho salmon fry measured several times each summer, 1964-67, and resulting fingerlings (≈90% age I and 10% age II) the next summer, 1965-68, Sashin Creek.

Survival of Juveniles in Sashin Creek

We estimated the population periodically during the summers from 1964 through 1967 to establish curves depicting changes in the number of juvenile coho salmon by brood year during their freshwater life. In 1964 the numbers of fry were estimated in July and August. In 1965 the numbers of fingerlings (predominantly age I, the balance age II) and fry were estimated in July and August. In 1966 the numbers of fingerlings and fry were estimated in June, July, and September. In 1967 estimates were made of coho salmon fingerlings and fry in Sashin Creek in July and in Funny Creek in July and August.

Juvenile salmon in the stream were captured by a combination of baiting and seining. A homogenized mixture of salmon eggs, ovarian tissue, and water was prepared with an electric blender and injected into the stream at the seining site (Figure 9). Underwater observations indicated that several squirts of the egg solution from a plastic squeeze bottle were adequate to attract rainbow trout, Dolly Varden, coastrange sculpins, and coho salmon fingerlings and large fry from at least 30 m downstream. The downstream sides of gravel bars, logs, and rocks were chosen as collecting sites because these obstructions formed slow-water areas in which the bait would linger for several minutes. In some instances it was necessary to construct a rock barrier to divert the current and create a suitable site. During early summer, when coho salmon fry are quite small, they congregate along the shallow edges of the stream and in backwaters. These small fry will not travel far in response to bait, and we often had to seine for them along the stream edges and backwaters near the baiting site.

Captured fish were anesthetized with MS-222 Sandoz[5] and marked by removing part of one fin. A different fin clip was used for each marking date within a summer. When they recovered from the anesthetic, the marked fish were released at the collection site.

To allow the marked juveniles to become redistributed, we did not begin to recapture them until several days after they were marked. To reduce bias in the population estimate, we selected random points as seining sites during the recapture portion of the experiment. Random numbers between 0 and 99 were chosen from a table of random numbers (Snedecor 1956) for each of the 30.5-m (100-foot) sections of stream. The numbers chosen represented the distance in feet downstream from the origin of each section to the sites that would be baited. These distances were paced off, and one or several places across the width of the stream at the site were baited. A site was repeatedly baited and seined until only a few fish could be taken in each seine haul. All fish captured at a site were anesthetized and examined for marks. When they recovered from the anesthetic, the fish were released. The numbers of unmarked and marked coho salmon juveniles were recorded for each site.

The Bailey-Petersen mark-and-recapture method (Ricker 1958) was used to make all population estimates, except in August 1964 when a Schnable multiple mark-and-recapture method (Ricker 1958) was used for fry. In 1966 and 1967 the numbers of juveniles to be marked and recaptured were predetermined to obtain preassigned levels of accuracy and precision of population estimates (Robson and Regier 1964). We tried to mark and recapture enough fish to be 95% certain that the error in estimating the population was not more than 10% (Table 15). Confidence limits to population estimates were obtained by methods given by Ricker (1958) and Robson and Regier (1968).

The number of coho salmon fry decreased greatly between the first and second estimate (Tables 15, 16). In the month between estimates, the population dropped by 71% in 1964, 78% in 1965, and 62% in 1966. Weir counts of emigrant coho salmon fry, which were continued until mid-August in 1964, showed that only about 2,000 fry (4% of the first population estimate) left Sashin Creek between mid-July and mid-August population estimates. Fyke net catches indicated that even fewer fry migrated from the stream in 1965 and 1966 than in 1964. Therefore, we attribute the large decrease in number of fry each year to mortality rather than emigration. Observation of the activities of fish and avian predators led us to believe that predation probably accounted for the major portion of the mortality. The number of fingerling coho salmon also decreased as the summer progressed, although not as rapidly as the number of fry (Table 17).

The fry population was greater in 1964 than in 1965, 1966, or 1967 as a result of the large number of spawners entering Sashin Creek in the fall of 1963. The population of fingerlings in 1965 was also greater than in 1966 or 1967; the fingerlings in 1965

[5]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

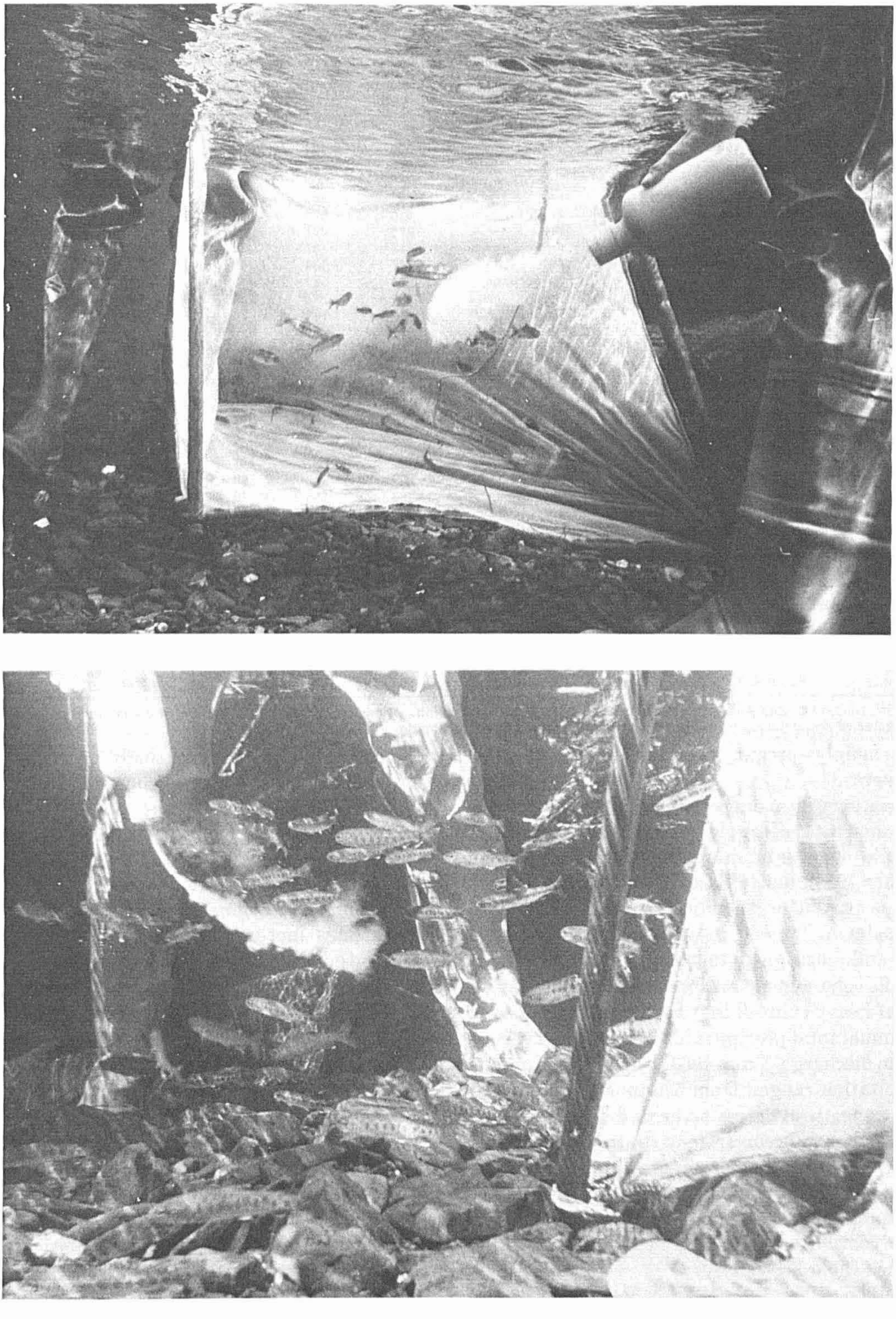

FIGURE 9.–Underwater views of technique used to capture juvenile coho salmon, Sashin Creek. Bait is a blended mixture of salmon eggs, ovarian tissue, and water.

TABLE 15.—Population estimates of juvenile coho salmon from mark-and-recapture experiments in Sashin Creek and Funny Creek, 1964-67.

Middate of estimate	Location	Fin clip used[1]	Age-group	Number marked	Census sample size	Number of marked fish recaptured	Population estimate	95% confidence interval
1964:								
12 July	Sashin Creek	LV&RV	Fry	1,454	4,421	123	51,852	43,939-62,216
12 Aug.	Sashin Creek	ULC	Fry	1,475	1,929	174	15,185	12,530-17,840
1965:								
17 July	Sashin Creek	RV	Fry	1,801	485	42	20,355	14,849-28,039
17 July	Sashin Creek	RV	Fingerlings	510	520	57	4,581	3,659- 5,960
1 Aug.	Funny Creek	LLC	Fry	276	221	50	1,201	900- 1,601
1 Aug.	Funny Creek	LLC	Fingerlings	213	107	26	852	565- 1,283
11 Aug.	Sashin Creek	LV	Fry	847	804	149	4,546	3,965- 5,294
11 Aug.	Sashin Creek	LV	Fingerlings	949	581	143	3,836	3,356- 4,459
11 Aug.	Funny Creek	LV	Fry	221	244	54	984	762- 1,300
11 Aug.	Funny Creek	LV	Fingerlings	106	141	26	557	370- 841
1966:								
27 June	Sashin Creek	ULC	Fry	2,263	2,541	163	35,077	30,436-40,951
27 June	Sashin Creek	ULC	Fingerlings	332	520	59	2,883	2,312- 3,731
27 June	Funny Creek	ULC	Fry	716	509	225	1,616	1,474- 1,793
27 June	Funny Creek	ULC	Fingerlings	78	160	49	251	187- 328
29 July	Sashin Creek	LLC	Fry	3,002	2,957	660	13,434	12,584-14,394
29 July	Sashin Creek	LLC	Fingerlings	816	817	420	1,585	1,488- 1,701
29 July	Funny Creek	LLC	Fry	208	338	67	1,037	816- 1,300
29 July	Funny Creek	LLC	Fingerlings	223	257	147	389	354- 442
8 Sept.	Area U[2]	Anal	Fry	227	378	93	915	757- 1,081
8 Sept.	Area U[2]	Anal	Fingerlings	63	155	20	468	293- 755
8 Sept.	Funny Creek	Anal	Fry	287	314	146	615	552- 700
8 Sept.	Funny Creek	Anal	Fingerlings	110	100	34	317	221- 451
1967:								
23 July	Sashin Creek	ULC	Fry	1,604	1,015	131	12,346	10,616-14,604
23 July	Sashin Creek	RV	Fingerlings	1,431	890	418	3,043	2,848- 3,274
23 July	Funny Creek	ULC	Fry	202	213	53	801	622- 1,092
23 July	Funny Creek	RV	Fingerlings	289	359	206	503	459- 551
17 Aug.	Sashin Creek	Anal	Fry	996	—	—	—	—
17 Aug.	Sashin Creek	Anal	Fingerlings	807	—	—	—	—
17 Aug.	Funny Creek	Anal	Fry	249	158	18	2,084	1,383- 3,381
17 Aug.	Funny Creek	Anal	Fingerlings	354	27	7	1,239	745- 3,218

[1]LV, RV, ULC, LLC, and Anal refer to left pelvic, right pelvic, upper lobe of caudal, lower lobe of caudal, and anal fin clips, respectively.
[2]Estimates of population size in the whole of Sashin Creek were not made.

were mainly progeny of the abundant 1963 spawners.

Variations in average annual streamflow have been shown to affect significantly the number of juvenile coho salmon in Washington streams (Smoker 1953), but in Sashin Creek, other factors such as parent escapement, original number of coho salmon fry, and competition probably have more influence on determining the number of juvenile coho salmon. Sashin Creek is located in an area of heavy rainfall that has small variations in the annual total precipitation and annual average stream discharge. From 1964 through 1967, annual precipitation ranged from 546 to 643 cm. Greater variations in average stream discharge for a specific month occur from year to year. Annual variations in stream discharge during the 1-mo period in midsummer when populations of juvenile coho salmon decreased most rapidly do not appear to be correlated with the rates of population decline (Table 17).

In 1965, 1966, and 1967, when estimates of juvenile coho salmon populations were made in each study area, the highest densities of coho salmon in Sashin Creek usually occurred in the lower study area, which is characterized by slow water. Densities of coho salmon fry and fingerlings were even higher in Funny Creek, another slow-water habitat (Table 18).

Funny Creek was unique in our study areas in that the populations of juvenile coho salmon sometimes increased during the summer. The estimated number of coho salmon fingerlings increased from 251 to 389 between late June and late July in 1966 (1964 brood year) and from 503 to 1,239 between mid-July and mid-August in 1967 (1965 brood year); the number of fry increased from 801 to 2,084 between mid-July and mid-August in 1967 (1966 brood year) (Table 16). The 95% confidence interval estimates (Table 15) indicate that the populations did increase, and the additional coho salmon juveniles must have immigrated to this area from Sashin Creek. On all other occasions, in both streams the populations of fry and fingerlings decreased between estimates. The movement of juvenile coho salmon from Sashin Creek into Funny Creek during midsummer suggests the use of this small tributary stream as a

TABLE 16.—Population estimates of juvenile coho salmon of brood years 1963-66[1] in Sashin Creek and Funny Creek in the summers of 1964-67. Separate estimates are included for three areas of Sashin Creek.

Brood year and area	Number of fish (by brood year) on									
	12 July 1964	12 Aug. 1964	17 July 1965	1 Aug. 1965	11 Aug. 1965	27 June 1966	29 July 1966	8 Sept. 1966	23 July 1967	17 Aug. 1967
1963:										
Sashin Creek:										
Upper	—	—	668	—	593					
Middle	—	—	1,216	—	1,115					
Lower	—	—	2,533	—	2,079					
Stream estimate	51,852	15,185	4,581	—	3,836					
Funny Creek	—	—	—	852	557					
1964:										
Sashin Creek:										
Upper			2,979	—	254	402	509	468		
Middle			2,195	—	951	690	555	—		
Lower			14,738	—	3,477	1,562	555	—		
Stream estimate			20,355	—	4,546	2,883	1,585	[2]1,350		
Funny Creek			—	1,201	984	251	389	317		
1965:										
Sashin Creek:										
Upper						1,192	1,497	915	810	—
Middle						7,759	5,091	—	801	—
Lower						26,662	7,851	—	1,453	—
Stream estimate						35,077	13,434	[2]8,000	3,043	—
Funny Creek						1,616	1,037	615	503	1,239
1966:										
Sashin Creek:										
Upper									1,828	—
Middle									1,862	—
Lower									8,627	—
Stream estimate									12,346	—
Funny Creek									801	2,084

[1]The estimated populations of fish of a brood year at age I (second summer of life) include an average of 11% age II fish from the preceding brood year.
[2]Estimate of population from expansion of estimated populations in upper area and Funny Creek.

TABLE 17.—Mean stream discharge and percentage decrease in numbers of juvenile coho salmon between a first estimate (late June to late July) and a second estimate (mid-July to mid-August) in Sashin Creek, 1964-67.

Year	Mean stream discharge (m^3/s)	Decrease in population size	
		Fry	Fingerlings
1964	[1]1.70	71% (51,852 to 15,185)	([2])
1965	0.99	78% (20,355 to 4,546)	16% (4,581 to 3,836)
1966	0.82	62% (35,077 to 13,434)	45% (2,883 to 1,585)
1967	1.42	([3]) (12,346)	([3]) (3,043)

[1]Stream discharge data for August 1964 not measured. An estimate of mean stream discharge for the period was calculated from July 1964 stream discharge and rainfall data in conjunction with the August 1964 rainfall pattern.
[2]Size of fingerling population not estimated in 1964.
[3]First population estimate; second population estimate was not completed.

feeding area or refuge from undesirable conditions in Sashin Creek, such as competition or predation. Fall migration of juvenile coho salmon into small tributary streams in Oregon has been reported (Skeesick 1970).

Estimates of the number of coho salmon fry and fingerlings were used to construct curves depicting the changes in the sizes of the populations of three of the brood years studied (Figures 10, 11). Estimates of the total number of fry and fingerlings in Sashin Creek in early September 1966 are projected from estimates of population size obtained in the upper area and in Funny Creek. In these two study areas in early September the number of fry averaged 60% and the number of fingerlings 85% of their populations in late July. We assumed that these percentages pertained also to the lower and middle areas of Sashin Creek.

Survival and Instantaneous Mortality Rates

We compared survival and instantaneous mortality rates of juvenile coho salmon of three brood years by dividing their freshwater lives into the following five periods between the time of egg deposition and late in the second summer of life:

Period	*Time covered*
1	Egg deposition to just before emergence (mid-October to late March or early April).

TABLE 18.–Densities of juvenile coho salmon by brood year (1963-66)[1] on dates of population estimates in Sashin Creek and Funny Creek. Separate estimates are included for three areas of Sashin Creek.

Brood year and area	Density of fish (per square meter) on 12 July 1964	12 Aug. 1964	17 July 1965	1 Aug. 1965	11 Aug. 1965	27 June 1966	29 July 1966	8 Sept. 1966	23 July 1967	17 Aug. 1967
1963:										
Sashin Creek:										
Upper	—	—	0.16	—	0.15					
Middle	—	—	0.27	—	0.25					
Lower	—	—	0.31	—	0.26					
Stream estimate	3.13	0.92	0.28	—	0.23					
Funny Creek	—	—	—	1.93	1.26					
1964:										
Sashin Creek:										
Upper			0.74	—	0.06	0.10	0.13	0.12		
Middle			0.49	—	0.21	0.16	0.12	—		
Lower			1.83	—	0.43	0.19	0.07	—		
Stream estimate			1.23	—	0.27	0.17	0.10	[2]0.08		
Funny Creek			—	2.72	2.23	0.57	0.88	0.72		
1965:										
Sashin Creek:										
Upper						0.29	0.37	0.23	0.20	—
Middle						1.75	1.15	—	0.18	—
Lower						3.31	0.97	—	0.18	—
Stream estimate						2.12	0.81	[2]0.48	0.18	—
Funny Creek						3.66	2.35	1.39	1.14	2.81
1966:										
Sashin Creek:										
Upper									0.45	—
Middle									0.42	—
Lower									1.07	—
Stream estimate									0.75	—
Funny Creek									1.82	4.73

[1]The estimated populations of fish of a brood year at age I (second summer of life) include an average of 11% age II fish from the preceding brood year.

[2]Estimate of density calculated from population obtained from expansion of estimated populations in upper area and Funny Creek.

2 Just before emergence to first estimate of fry population (end of period 1 to late June or mid-July).

3 First to second estimate of fry population during first summer (end of period 2 to late July or mid-August).

4 Second estimate of fry population to first estimate of population as yearlings (end of period 3 to late June or mid-July of the following year).

5 First to second estimate of yearling population (end of period 4 to late July or mid-August).

Although the lengths of the corresponding periods for the three brood years are similar, they varied according to when the population estimates were made.

We compared the estimates of the population at the end of each of the five periods with the original population (potential egg deposition) to obtain percentage survival during nearly 2 yr of their freshwater life for the brood years 1963-65 (Table 19). Survival from potential egg deposition to just before fry emergence (period 1) was estimated to be 15%, 22%, and 26% (mean of 21%) for the 1963, 1964, and 1965 broods, respectively. Other investigators have found similar survival to emergence for coho salmon. A range in survival to emergence in terms of counted fry of 11.8% to 40.0% (mean of 21.0% and 26.5%) is reported for two tributaries of the Cowichan River, British Columbia (Pritchard 1947). Koski (1966) obtained survival values to fry emergence of 0% to 78% (mean of 27.1%) for individual redds of coho salmon in three streams tributary to Drift Creek. For Karymaisky Spring on Kamchatka, Semko (1954) reports survival to emergence of 0.8% to 21.4% (mean 10.6%).

TABLE 19.–Survival through five periods[1] in the freshwater life of three brood years of coho salmon in Sashin Creek, expressed as a percentage of potential egg deposition.

Brood year	Percentage survival through period 1	2	3	4	5
1963	14.66	3.55	1.04	0.28	0.23
1964	22.31	7.83	1.75	0.99	0.54
1965	25.71	10.02	3.84	0.77	—

[1]See text for explanation of time covered in each period.

Because the lengths of the five periods were not equal and a specific period was not the same length

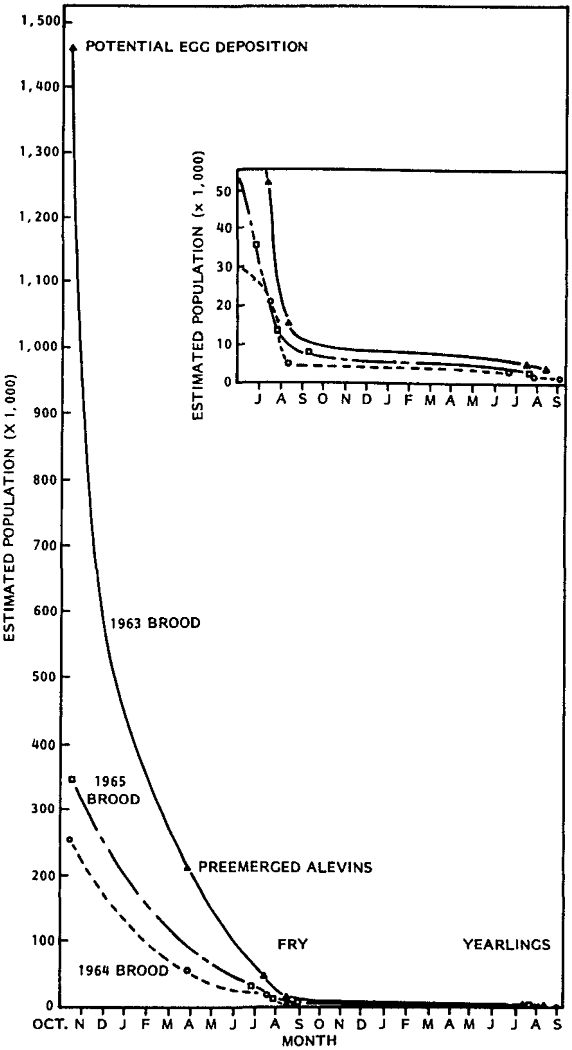

FIGURE 10.–Estimated populations of juvenile coho salmon of three brood years, Sashin Creek, from potential egg deposition to late summer of second year. (Arithmetic plot.)

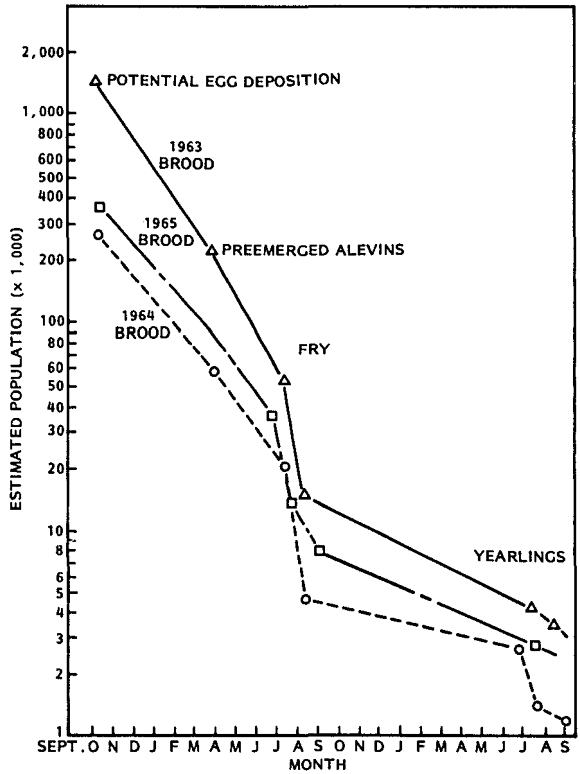

FIGURE 11.–Estimated populations of juvenile coho salmon of three brood years, Sashin Creek, from potential egg deposition to late summer of second year. (Semilogarithmic plot to indicate mortality rate.)

TABLE 20.–Instantaneous mortality coefficients during five periods[1] in the freshwater life of three brood years of coho salmon in Sashin Creek.

Brood year	Instantaneous mortality coefficient in period 1	2	3	4	5
1963	0.37	0.38	1.23	0.12	0.25
1964	0.27	0.30	1.88	0.05	0.55
1965	0.25	0.32	0.87	0.14	—

[1]See text for explanation of time covered in each period.

for each of the three brood years, instantaneous mortality coefficients (Ricker 1958) were computed to compare mortality for the periods and years (Table 20). The equation for determining the instantaneous mortality coefficient,

$$M_{jn} = \frac{-\ln (S_{jn})}{t},$$

follows the notation of McNeil (1966), where t, the interval of time, is in months (one unit is equal to 1 mo); the symbol ln represents the natural logarithm; j is the brood year; and n is the study period. S_n is the survival within the nth period and is calculated from the formula,

$$S_1 \cdot S_2 \cdot \ldots \cdot S_n = S,$$

or

$$S_n = \frac{S}{S_1 \cdot S_2 \cdot \ldots \cdot S_{(n-1)}},$$

where S is survival through n study periods expressed as a percentage of potential egg deposition (Table 19).

Instantaneous mortality was higher through periods 1 and 2 for the 1963 brood than for the 1964 and 1965 broods. We estimated that eggs of the 1963 brood were over four times as abundant as those of the 1965 brood and over five times as abundant as those of the 1964 brood. Resulting density-dependent factors such as superimposition of redds, selection of inferior redd sites, and emigration of fry from the stream because of lack of living space could be the cause of the higher initial mortality of the 1963 brood.

For all three broods the highest instantaneous mortality occurred in period 3—between the first and second population estimates of the first summer of life—during July and the first half of August (Table 20). Predation from fishes (both intraspecific and interspecific) is thought to be a major cause of this high mortality. In period 2 the fry live in the backwater and shallow edges of the stream where larger piscivorous fish do not regularly occur. During period 3 the fry move into deeper parts of the main channel where current is still relatively slow, but here larger fish occur and the fry may be more subject to predation.

Instantaneous mortality during the winter (period 4) was much less than that of the first summer. Predation probably was less during this period for two reasons: 1) in winter the feeding rate of cold-blooded predators is slowed, and 2) restricted access because of ice and snow and lowered activity and availability of the juvenile coho salmon combine to lessen the hunting success of warm-blooded predators.

Mortality increased during the second summer (period 5) but only to a third or less of the corresponding part of the first summer (period 3).

Some of the estimated mortality of fry and fingerlings might have been due to undetected emigration from the creek. When the fry weir or fyke nets were fished in summer (periods 3 and 5), however, only a few fry and fingerlings emigrated and the low mortality rate in period 4 also suggests that only a few fry emigrated in fall and winter. Some age I smolts probably migrated from the stream in the spring of period 4 in each of the 3 yr studied. The drop in population of a brood year due to age I smolt emigration is included as part of period 4 mortality. Age composition of smolts in 1965, 1966, and 1967 was not determined. The age composition of returning adults in 1966 and 1967 (25% and 29% age 3_2, respectively) indicates that some age I smolts emigrated in the spring of 1965 and 1966. In 1968 the smolts were sampled for age composition; about 500 yearling smolts migrated. Scale samples for age analysis were not collected from adults in 1968.

SUMMARY

The number of adult coho salmon that enter Sashin Creek varies from year to year. Coho salmon have been counted at the weir as they enter Sashin Creek each year since 1934, but this count has usually been incomplete.

Several methods were used to estimate coho salmon escapements to Sashin Creek for the years 1963-65 and 1967. These included weir counts, adults on spawning riffles, mean redd life, and marked-to-unmarked ratios of spawners. The last system produced the most accurate estimates, resulting in 916, 162, 221, and 370 salmon for the respective study years.

In the 4 yr that spawning ground studies were made, the density of coho salmon on the spawning grounds in Sashin Creek tended to be greater in the middle and lower study areas than in the upper area.

The effect of coho salmon spawning on the survival of pink salmon embryos was insignificant in 1965 relative to the population ratios of coho and pink salmon present. Significant numbers of pink salmon embryos might be killed if relatively large numbers of coho salmon utilized Sashin Creek for spawning.

The 4_3 age-group of coho salmon made up 78%, 59%, 64%, and 62% of the adults that returned to Sashin Creek in 1965, 1966, 1967, and 1969—higher percentages of this age group than reported for most other streams. In California, Oregon, Washington, and southern British Columbia, adult coho salmon are almost exclusively age 3_2. Studies of growth and scales of fry, fingerlings, and smolts and estimates of the population sizes of juveniles indicate that most coho salmon remain in Sashin Creek for two summers and winters.

In some years, substantial numbers of coho salmon fry enter the estuary of Sashin Creek shortly after emergence. These fry were tested and found to be able to survive in salinities encountered in the inner bay of the Little Port Walter estuary. However, analysis of scales of adult coho salmon returning to Sashin Creek revealed none that had migrated to the estuary at the fry stage, suggesting no fry (or at best very few) that migrate to the ocean survive to return as adults. This agrees with studies of other stocks of coho salmon.

Estimates of populations of fry in the early summer for the 4 yr studied ranged from about 12,000 to 52,000, and apparently varied directly with potential egg deposition of the brood year. However, by early in the second summer of freshwater life, the three broods studied had been reduced to a relatively narrow range of 3,000 to 4,500. Weir counts indicate 1,000 to 3,000 coho salmon smolts migrate from Sashin Creek each year.

The survival of coho salmon from potential egg deposition to just before the emergence of fry in Sashin Creek averaged 21%; this percentage is similar to survival reported for stocks from other areas in the eastern Pacific. Mortality of embryos and alevins was highest for the large 1963 brood, which suggests that some of the mortality before emergence was due to compensatory factors such as selection of inferior redd sites and superimposition of redds.

Highest mortality during the freshwater life of coho salmon from Sashin Creek occurred in July and early August of the first summer in all three broods studied. The lowest mortality occurred over winter.

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