AN ABSTRACT OF THE THESIS OF

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Title: BEHAVIOR AND SURVIVAL OF COHO SALMON, ONCORHYNCHUS KISUTCH (WALBAUM), IN SASHIN CREEK, SOUTHEASTERN ALASKA

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Carl E. Bond

Behavior and survival in fresh water were studied for three brood years of coho salmon in Sashin Creek, Alaska, from October 1963, until September 1966. Investigations of spawning adults were conducted to determine numbers of spawners, distribution on the spawning grounds, effects on pink salmon, age composition, redd life, fecundities, and egg retention. Juvenile coho were studied to determine changes in population size, distribution in the stream, age composition of the population, food habits, and rates of mortality during fresh-water life.

The number of coho spawners counted into Sashin Creek each year normally varied from 50 to 300. Weir counts and estimations of the number of spawners determined from observed spawning effort and redd life were not accurate methods of estimating the coho

escapement into Sashin Creek. In 1965, a more accurate estimate was obtained by tagging a portion of the run and recording marked to unmarked ratios on the spawning grounds. I estimated that less than two percent of the viable pink salmon embryos were destroyed in 1965 by the spawning activities of coho salmon.

Most coho spawners returned to Sashin Creek in 1965 and 1966 in their fourth year of life after having migrated to sea in their third year (designated 4_3). Smaller numbers of 3_2 and 5_4 individuals composed the remainder of the spawning population. The mean redd life of 56 females was 13 days. A small sample of coho from Sashin Creek examined for fecundity in 1966 gave a mean of 2,868 eggs per female.

A weir or fyke net was fished in the spring to estimate emigration of juvenile coho. Coho smolts left Sashin Creek from April through July; peak emigration occurred in late May or early June. Coho fry left the stream in the spring and summer in widely varying numbers from year to year. I estimated from growth data, population estimates, and analysis of scale samples that most coho juveniles remained in Sashin Creek for two growing seasons before migrating to sea.

Analysis of scales from juvenile coho indicated that some reabsorption of scales occurs during the winter. The possibility of reabsorption of circuli makes back-calculation of the length of younger

age-groups of coho from scale measurements unreliable.

Diptera were represented more often than any other order of insects in the stomachs of juvenile coho. Hemiptera were important as food items to juvenile coho in a tributary stream. The estimated survival from egg deposition to immediately prior to emergence varied between 17.5 and 34.9 percent for the three brood years, and averaged 27.8 percent. Early summer populations of fry were variable in size and dependent on the size of the egg deposition of the brood. Populations of fry declined rapidly during July and early August. Instantaneous mortality rates were much higher for this period than during any other time in the fresh-water life of coho salmon in Sashin Creek. Mortality dropped to a low level during the following winter period.

Behavior and Survival of Coho Salmon, Oncorhynchus kisutch (Walbaum), in Sashin Creek, Southeastern Alaska

by

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I was employed by the Auke Bay Laboratory of the United States Bureau of Commercial Fisheries during the conduct of this study.

Photographs of juvenile coho salmon on page 42 were taken by Dr. Raymond C. Simon.

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INTRODUCTION

Coho salmon (Oncorhynchus kisutch [Walbaum]) are abundant in the eastern Pacific Ocean from northern California to northwestern Alaska (Godfrey, 1965). They reproduce in large and small streams, sometimes near and sometimes distant from the sea. Their young may migrate from spawning streams soon after emerging from spawning beds as fry or remain in spawning streams one or two years before migrating to sea as smolts.

Fluctuations in numbers of coho salmon spawners are not as pronounced as those of pink (O. gorbuscha [Walbaum]), chum (O. keta [Walbaum]), or sockeye (O. nerka [Walbaum]) salmon spawners. The relative stability of the spawning populations of coho may result from their widespread use of streams as nursery areas. Studies at Minter Creek in Washington State (Salo and Bayliff, 1958), Spring Creek in Oregon (Oregon Fish Commission, Progress Report, as cited in Chapman, 1962) and Hooknose Creek in British Columbia (Hunter, 1959) demonstrate that similar numbers of coho migrate to sea as smolts from year to year, regardless of the number of parent spawners or fry emerging from spawning beds. Conversely, the numbers of coho migrating as fry tend to increase with increased potential egg

deposition (Chapman, 1962), suggesting that the amount of space or food in the stream greatly influences the number of smolts that can be produced.

In the southern one-third of their range, coho salmon typically migrate to sea in their second year of life, i.e. they are in fresh water one summer (Pritchard, 1940; Briggs, 1953; Smoker, 1953). Farther north, in Alaska, coho remain one or two, and occasionally three summers in fresh water (Exploitation..., 1962; Godfrey, 1965). In the Yukon River and some streams in Kamchatka, those coho salmon which remain in fresh water for two summers may represent a larger percentage of the population than those which live one year in fresh water (Gilbert, 1922; Semko, 1954).

Previous studies of behavior and survival in fresh water have been conducted on coho salmon in the southern part of their range in the eastern Pacific, primarily California, Oregon, Washington, and British Columbia (Neave, 1948; Wickett, 1951; Briggs, 1953; Smoker, 1953; Shapovalov and Taft, 1954; Foerster, 1955; Salo and Bayliff, 1958; Chapman, 1962 and 1965; Koski, 1966), and in Kamchatka (Kuznetsov, 1928; Gribanov, 1948; Semko, 1954). This study was undertaken in the center of the eastern Pacific range of the coho salmon to clarify possible differences in the life history of populations in this area as compared to southern populations. The study stream, Sashin Creek, drains a small, mountainous watershed on Baranof

Island, Southeastern Alaska (Figure 1).

In this thesis I describe observations on the fresh-water migration and age of coho spawners and the survival of their progeny from the time of egg deposition through the second summer of stream residence. Observations on the adult spawners were made in summer and autumn 1963, 1964, and 1965. Survival in spawning beds was studied in spring 1964, 1965, and 1966. Observations on the juveniles were made in summer 1964, 1965, and 1966.

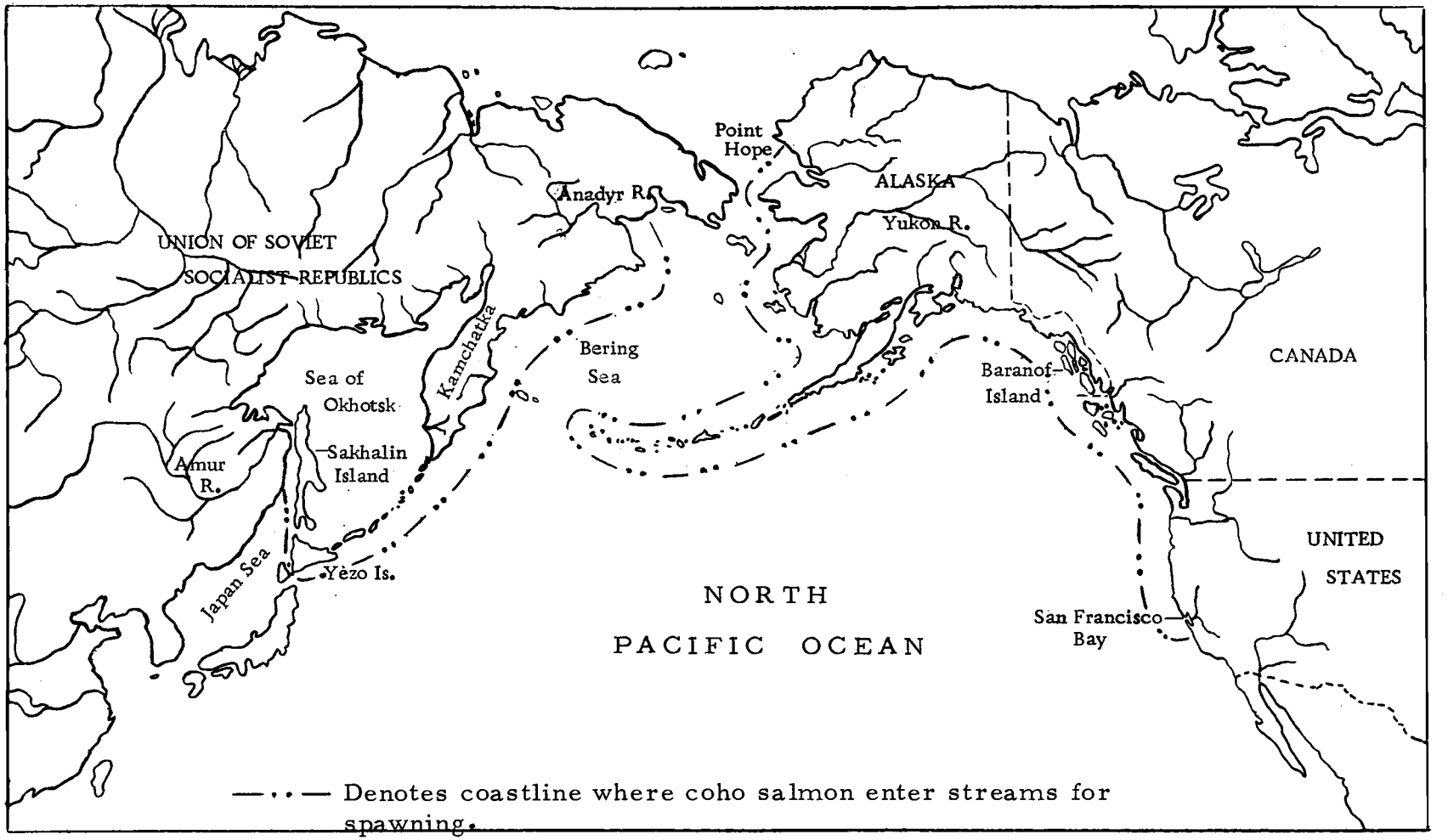


Figure 1. Distribution of coho salmon in relation to Baranof Island, Southeastern Alaska.

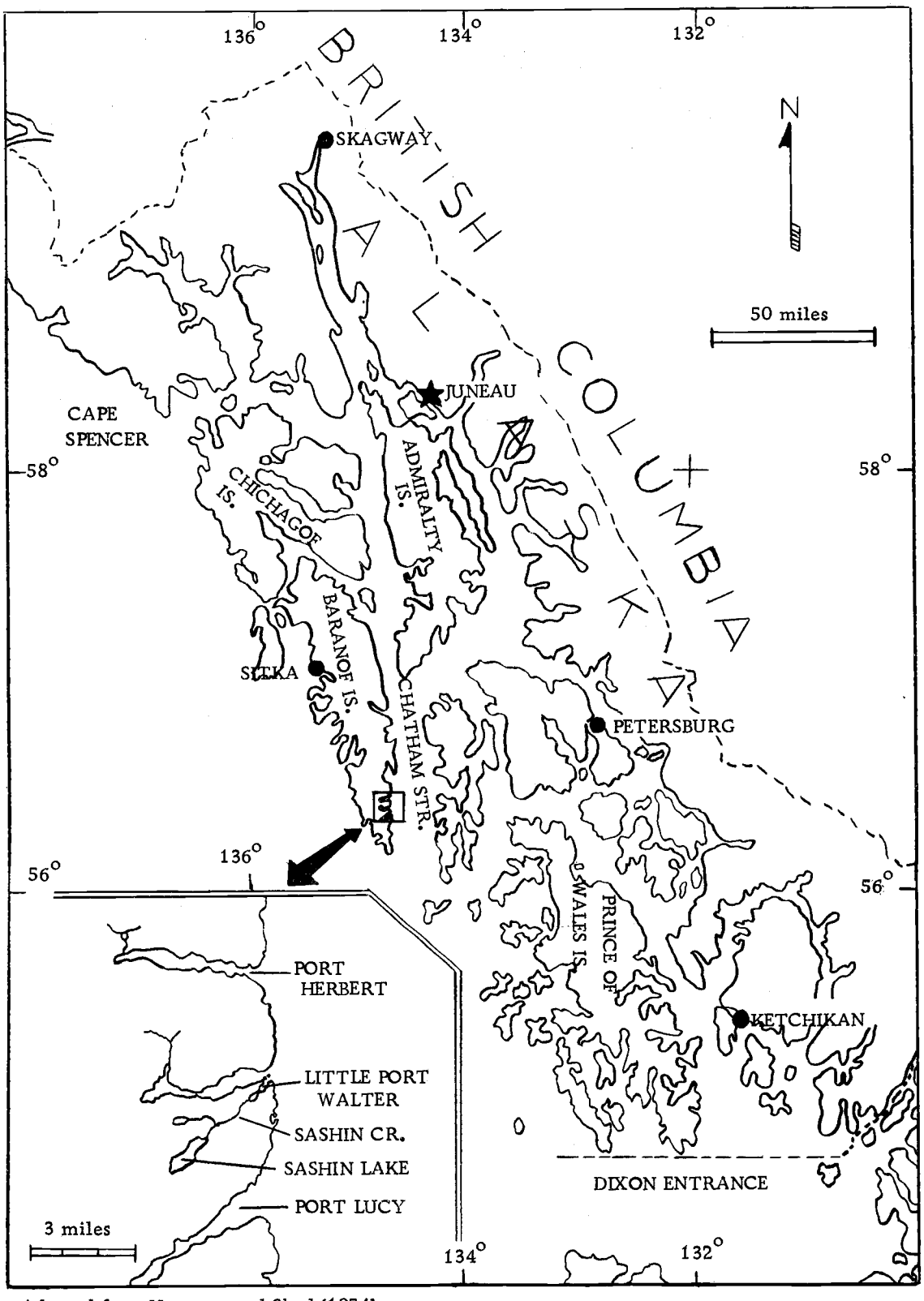
STUDY AREAS

Sashin Creek empties into Chatham Strait at Little Port Walter on the southeastern shore of Baranof Island. A United States Bureau of Commercial Fisheries Research Field Station is located at Little Port Walter, approximately 55 air miles from Sitka and 130 air miles from Juneau (Figure 2).

Sashin Creek drains five square miles of virgin watershed (Davidson and Hutchinson, 1942). Its discharge varies from 10 to 600 cubic feet per second. For the ten-year period, 1956-65, annual precipitation at Little Port Walter averaged 228 inches (U.S. Weather Bureau, 1956-1965).

Sashin Creek has its origin at Sashin Lake, 2.7 miles from the head of tide. Salmon have access to only the lower 0.7-mile section of stream which lies downstream from a high waterfall and use this section for spawning (Davidson, et al., 1943). Coho salmon do not spawn in the intertidal stream channel because of its steep gradient and bedrock bottom.

Of the 0.7-mile section of stream accessible to salmon, the lower 0.6-mile is used extensively for spawning by salmon. The 0.1-mile section immediately below the waterfall is used infrequently for spawning because it has a steep gradient and very coarse bottom materials. Juvenile coho salmon live in this area, however.



Adapted from Hanavan and Skud (1954).

Figure 2. Southeastern Alaska and the Little Port Walter region.

A base line for the identification of sampling stations passes through the spawning ground in the lower 0.6-mile of stream channel. This base line is marked at 100-ft (30.5-m) intervals with cork floats attached to large rocks or to pipes driven into the stream bottom. To facilitate comparison with other density and yield studies, stream measurements will be given in metric units.

The spawning ground is divided into three areas (upper, middle, and lower), which have different physical characteristics. The upper area encompasses 2,945 m^2 of spawning ground, and has the steepest gradient and coarsest spawning gravel. The middle area includes 4,067 m^2 of spawning area, has an intermediate gradient, and finer gravels than the upper area. The lower area encompasses 6,072 m^2, has the shallowest gradient, and the finest gravels. Table 1 describes the composition of bed materials in the three areas.

Juvenile coho salmon occupy the three areas of spawning ground described above plus pools, backwaters, and to a limited extent the 0.1-mile section of stream lying in the canyon immediately downstream from the waterfall. A total of 2,892 m^2 was added to the three study areas to incorporate pools and backwaters as well as spawning ground in the investigation of juveniles: 1,016 m^2 were added to the upper area, 374 m^2 to the middle area, and 1,502 m^2 to the lower area. The upper-most 160-m section of stream was not included in these studies because relatively few fish occurred there and

access was limited on all stages of stream flow except extreme low flow. Table 2 lists additions to each study area and the resulting total area in each section.

Table 1. Size composition of bottom materials[1] and average gradient in three areas in Sashin Creek.[2]

Area	Average gradient	Bottom materials composed of: Cobbles[3]	Pebbles and granules[4]	Sands and silts[5]
	Percent	Percent	Percent	Percent
Upper	0.7	81	16	3
Middle	0.3	61	26	13
Lower	0.1	47	36	17

[1] Procedures for sampling bed materials to measure size composition are described by McNeil and Ahnell (1964). Materials > 15.2mm diameter are excluded.

[2] Table from McNeil, 1966.

[3] Cobbles are > 12.7 mm diameter.

[4] Pebbles and granules are 1.68 to 12.7 mm diameter.

[5] Sands and silts are < 1.68 mm diameter.

A small tributary, known locally as Funny Creek, enters Sashin Creek near the head of tide. It meanders 215 m through a meadow above the confluence. Funny Creek is approximately 1.5 m wide, slow flowing, and has mostly a mud and detritus bottom. There are limited gravel areas used by coho spawners. Funny Creek was added as a fourth study area in the summer of 1965. The Funny Creek study

area comprised 441 m^2 and included that portion of the stream flowing through the meadow plus a 75-m length of stream flowing through a forested area upstream from the meadow.

Table 2. Surface areas of the study areas used in studies of juvenile coho salmon, 1964-1966.

Study area	Area of spawning riffles (in m^2)	Area of pools and backwaters (in m^2)	Total area (in m^2)
Sashin Creek			
U	2,945	1,016	3,961
M	4,067	374	4,441
L	6,072	1,502	7,574
Total	13,084	2,892	15,976
Funny Creek			441

The fish fauna of Sashin Creek consists of coho salmon, rainbow trout (Salmo gairdneri Richardson), Dolly Varden char (Salvelinus malma [Walbaum]), coastrange sculpin (Cottus aleuticus Gilbert), pink salmon, and chum salmon. Adult sockeye salmon occasionally stray into the stream. Only rainbow trout have been transplanted above the falls.

Since 1934, adult salmon have been counted through a weir near the mouth of the stream as they migrated into Sashin Creek. The weir is constructed of concrete pillars positioned across the width of the stream. Gates constructed of vertical steel rods, about 3 cm

apart, are positioned between the pillars.

The weir is opened for passage of salmon only during daylight and only when salmon are observed in a pool immediately downstream from the structure. At other times all gates remain closed, preventing access of salmon to the stream. Salmon passing through the weir cross a white panel to facilitate their identification by an observer positioned directly above the panel.

BEHAVIOR

Studies of behavior centered mainly on movement and distribution of adults and juveniles. Adults were observed during summer and autumn from the time they migrated to the stream to the time they spawned and died. Juveniles were observed in spring, summer, and autumn. No observations were made in winter, when water temperatures are often near freezing, and when there is little evidence of fish activity in the stream.

Spawners

Size of Escapement

Adult coho salmon begin to enter Sashin Creek in late August, with the peak of migration in mid-September (Table 3). Counts of adult salmon at the weir are usually terminated in late September or early October after the migration of pink salmon has ended. Termination of the weir counts also coincides approximately with the beginning of high autumn freshets which make continued operation of the weir difficult. Some coho salmon enter the stream after the weir has been opened, and the counts are, therefore, incomplete. In addition, a few coho salmon have been observed to jump over the weir.

Table 3. Number of adult coho salmon counted into Sashin Creek at the weir, 1934-1965, summed by two-week intervals.[a]

	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Aug. 1-14												
Aug. 15-28			2	3		16				5	6	
Aug. 29-Sept. 11			2	5*	1	94				2	1	18
Sept. 12-25	1*	*	36*		*	12	1*	1*	2*	9	10	98
Sept. 26-Oct. 9						*				12*	249	219
Oct. 10-23											62*	232*
Oct. 24-Nov. 7												
Total	--	--	--	--	--	122	--	--	--	28	328	567

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
Aug. 1-14						1		4		4		
Aug. 15-28			9		19	21	20	3		6		6
Aug. 29-Sept. 11	1	21	36	27	7	50	24	65	46	74	12	28
Sept. 12-25	82	40	19	170	37	10	138	8	108	74	73	
Sept. 26-Oct. 9	6	50*	138	5*	3*	53*	30	35*	*	10*	3	36*
Oct. 10-23	22*		6*				*				*	
Oct. 24-Nov. 7												
Total	111	111	208	202	66	135	212	115	154	168	88	70

	1958	1959	1960	1961	1962	1963	1964	1965	Totals
Aug. 1-14		5		51					65
Aug. 15-28	16	5	27	27	2	2	10		205
Aug. 29-Sept. 11	79	33	57	11	3	202	13	100	1,012
Sept. 12-25	65	37	19	5	29	107*		1	1,192
Sept. 26-Oct. 9	19*	58	5	4	3		*	23*	961
Oct. 10-23		133*	1	*	*				456
Oct. 24-Nov. 7			*						0
Total	179	271	109	98	37	311	28	124	

[a] Adapted from Bond (1964).

* Weir opened.

Counts of adult coho salmon have been recorded since 1934, and they have ranged from 0 to 567 fish. These incomplete counts give an indication of the magnitude of the escapements..

In 1965 and again in 1966, the coho migration into Sashin Creek began and reached its peak with the first late-summer freshet, which in both years occurred during the last few days of August. In 1963, 1964, and 1965, spawning commenced in the first week of October, peaked near mid-October, and ended by early November.

Special efforts were made to obtain an accurate estimate of the coho escapements in 1963, 1964, and 1965, by conducting periodic visual censuses of the study areas to determine the number and distribution of spawners. Counts of spawners in each area were recorded separately, and included only those adults on the spawning riffles. In 1963 and 1964, counts were made only when water conditions were most favorable for observing fish, and spawners were not separated by sex. In 1965, the number of spawning males and females was recorded separately, and surveys were conducted daily, with the exception of six days when high water made conditions unfavorable for the observations. The area covered by the surveys included Funny Creek only in 1965.

Counts of spawners were made by an observer once each morning unless changing water conditions made it desirable to wait until afternoon. The observer wore polaroid glasses to reduce glare at the

water surface. The stream survey began at the upstream end of the upper study area and continued downstream to the weir, a distance of approximately 915 m. The observer walked slowly downstream counting coho on the spawning riffles. For the 1965 studies, the observer recorded the location of individual females. The location of each female was recorded with reference to the base line and the 100-ft (30.5-m) section markers. Also recorded was the number of males near each female, and the number of males on the riffles but not with females. Males not with females were assumed to be moving among females. Females which recently arrived on the riffles were easily recognized by the presence of three to seven males lined up in single file downstream from the female.

To obtain an estimate of the number of spawners from surveys of the spawning riffles, the periodic counts of spawning coho (both males and females) were plotted against a time scale (Figure 3). For 1965, each point represents the average of three successive daily counts of spawners. A curve was drawn through the points, and the area under the curve, representing spawning effort, was reported in fish-days (Table 4). The total number of fish-days was divided by the computed mean spawning life (termed redd life for females) in days, giving an estimate of the total number of spawners (males and females).

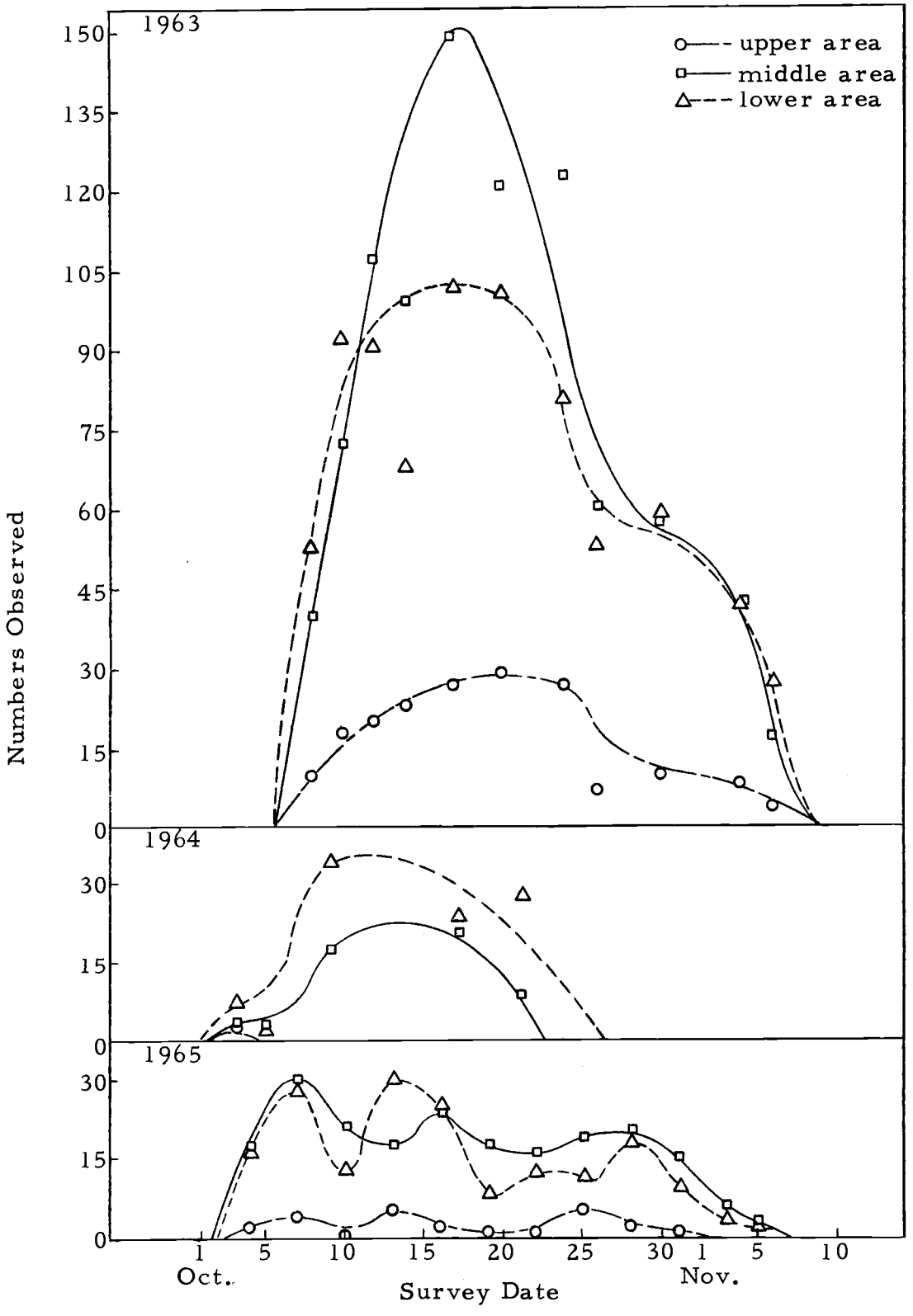


Figure 3. Stream survey estimates of numbers of spawning coho salmon. Area under each curve is spawning effort, expressed in fish-days.

Table 4. Distribution and density of spawning coho salmon in Sashin Creek.

Brood year	Distribution (percentage of total observed)			Spawning effort (fish-days)				Spawning density (fish-days per square meter)			
	Area										
	U	M	L	U	M	L	Total	U	M	L	Total
1963[a]	10	48	42	553	2652	2289	5494	0.19	0.65	0.38	0.42
1964	1	35	64	4	275	566	845	<0.01	0.07	0.09	0.06
1965	6	51	43	74	607	543	1224	0.03	0.15	0.09	0.09

[a] W.J. McNeil. Unpublished notes on 1963 coho studies. U.S. Bureau of Commerical Fisheries. Auke Bay, Alaska.

The method of estimating coho escapement from spawning effort, in fish-days, divided by mean redd life has been used successfully by McNeil (1966) for estimating numbers of pink salmon. His method differed in that spawning effort was given in female-fish-days, and the resulting population estimate was for females, which was doubled to obtain total escapement.

In the fall of 1963, a comparatively large run of 311 coho was counted at the weir. Using the method described above, I estimated that 423 coho spawned in Sashin Creek. In 1964, a comparatively small run of 23 coho was counted at the weir, but by dividing spawning counts by redd life I estimated that 65 spawned. It was apparent that many coho entered Sashin Creek in 1963 and 1964 after the weir had been opened.

My estimate of the number of spawners based on observed spawning effort and redd life was less than the number counted at the

weir in 1965. There were 124 coho counted at the weir and 94 estimated on the spawning ground. However, I was able to make an independent estimate of the number of spawners in 1965 by conducting a mark-recapture experiment using the formula (Ricker, 1958, p. 84):

$$N = \frac{M(C + 1)}{R + 1}$$

Prior to spawning, 46 coho (32 females and 14 males) were tagged with plastic Petersen disc tags and released into the stream. A plastic tub filled with water containing tricaine methanesulfonate (MS 222) was used to hold and immobilize the fish prior to tagging. The discs were placed high on the sides of the fish, directly below the dorsal fin, and were connected by a nickel pin.

Using marked to unmarked relationships, I estimated 205 coho spawners (both sexes) utilized Sashin Creek in 1965. I also used this procedure to estimate the number of females. Here I considered only those females which had occupied redds, and my estimate was 96 females. Godfrey (1965) reports that the proportions of the sexes among the returning adults are usually nearly equal. Shapovalov and Taft (1954) gave a nearly equal sex ratio of male and female coho when jack males (precocious two-year-old males) are excluded (44.2% adult females; 39.8% adult males; 16.1% jack males). No jacks were observed on the 1965 surveys of the Sashin Creek spawning grounds. Assuming an even sex ratio, and doubling the estimated number of

females results in an estimated escapement that agrees closely with the marked-to-unmarked ratio estimate of total population.

Conflicting estimates for the 1965 escapement raise questions about the validity of using spawning effort divided by mean redd life for estimating coho escapement into Sashin Creek. Several possible sources of error exist in the method. Most surveys of the spawning ground were conducted when visibility was good, i.e. when the stream level was low. The highest spawning densities most likely occurred during high water periods, when visibility was restricted. As water levels receded between freshets, redds located in the shallows were abandoned. Sometimes the abandoned redds were reoccupied by the original female when water levels rose again. Counts of coho spawners made during low stream flows would not include spawners that temporarily abandoned a redd, and would result in a minimal estimate of the spawning effort.

Another source of error may result from an assumption that was made when using data on spawning effort and redd life to estimate spawner escapement. Either the mean spawning life of females was assumed to be equal to that of males or the observed spawners were assumed to be made up equally of males and females. The mean spawning life of male coho in Sashin Creek was not determined. However, Willis (1954) found that male coho spent an average of 12 days in Spring Creek (a tributary to the Wilson River in Oregon) before death,

while females lived an average of 11 days after entering the stream. However, the male may spend less time on spawning riffles and more time in pools than the female. In 1965, 57 percent of all coho observed on surveys of the spawning grounds were females. Daily totals varied between 36 and 79 percent females. Counts conducted during low stream flow conditions usually resulted in higher percentages of female spawners observed.

From the results of the fall 1965 investigations I calculated that only 50 percent of the spawners present in Sashin Creek in 1963 and 1964 were estimated from data on spawning effort and redd life. Therefore, estimates of spawners obtained by this method were doubled to yield estimated escapements of 846 and 130 in 1963 and 1964, respectively.

Distribution and Density

Observations on the distribution of spawners over the Sashin Creek spawning grounds were initiated in 1963 and continued through 1965. The density of spawning coho in the study areas was determined from visual surveys of the spawning grounds. Distribution of spawners was expressed as the percentage of the escapement utilizing each of the study areas. The spawning density was computed by dividing the total surface area of the study area, in square meters, into the spawning effort (fish-days) that occurred in that area (Table 4).

In each of the three years studied, spawning coho made greater use of the middle and lower study areas than the upper area. In 1963 and 1965, the middle area had the highest density of spawners, but in 1964, the lower area contained the highest density.

Coho were observed to spawn in Funny Creek in 1965. In mid-June of the following year, several schools of coho fry were observed in pools directly downstream from sites used for spawning in 1965. Rapidly rising and falling water levels in the stream resulted in a short redd life for the coho spawners in Funny Creek. Eight females were observed in Funny Creek, and the longest redd life was six days, whereas, the mean was three days. A few spawners were observed to move into the stream on rising water levels, but they returned to Sashin Creek as water levels receded.

No coho were observed to spawn in the upper-most 160-m section of Sashin Creek. This area is seldom used except by pink salmon during years of very large escapements, when there is excessive crowding in the downstream spawning grounds.

In 1965, pink salmon were distributed more evenly throughout the spawning area than were coho (Table 5). Merrell (1962) and McNeil (1966) report that the upper area is used extensively by spawning pink salmon only in years when runs are large. When pink salmon are scarce, they concentrate in the lower area. The small numbers of coho spawners using Sashin Creek may explain why few coho spawn

in the upper area.

Table 5. Distribution of spawning salmon in Sashin Creek, 1965.

Species	Escapement	Spawning effort		
		Area U	Area M	Area L
Coho	≈205	6%	51%	43%
Pink	14,813	24%	39%	37%
Chum	22	13%	42%	45%

Interspecific Competition

Because pink salmon complete their spawning in Sashin Creek before coho spawning commences, it is desirable to determine if coho spawning activity has a detrimental effect on pink salmon embryos. In 1965, an attempt was made to assess the effect of coho salmon superimposing their redds on those of pink salmon. The number and distribution of coho redds was determined from visual surveys. The area of gravel disturbed by a spawning coho was measured at 13 redds located throughout the stream. The length of the redd is the distance of gravel disturbance parallel to the current; while the width is the distance of gravel disturbance at a right angle to the current.

Densities and survival of pink salmon embryos were estimated from routine sampling of the spawning riffles with a hydraulic sampler prior to and after coho spawning (McNeil, 1964). Densities of live pink salmon embryos prior to coho spawning were used in

conjunction with the average size of a coho redd to estimate the total number of pink salmon embryos that could have been destroyed in the gravel disturbed by spawning coho.

An average length of 140 cm and width of 183 cm were obtained for the 13 redds. The mean area of gravel disturbance was 2.6 m^2 per redd. Briggs (1953) reports coho redds in a northern California stream to be oblong with the long axis parallel to the stream flow. Gribanov (1948) found in two studies in Kamchatka that coho redds measured an average of 125 cm by 110 cm and 140 cm by 115 cm, with the longer measurement in each example representing the length of the redd parallel to the stream flow.

The distribution of coho redds, the number of viable pink salmon embryos in areas used by spawning coho, and the total number of viable pink salmon embryos in Sashin Creek before coho began spawning are given in Table 6.

Based on an estimated population of 96 females, a total of 250 m^2 of spawning gravel was disturbed by spawning coho in 1966. Hydraulic sampling of the spawning grounds in late September indicated that 9.8 million live pink salmon embryos were present in Sashin Creek before the coho salmon spawned (750 live pink salmon embryos per m^2).[1] A total of 187,000 live pink salmon embryos was estimated

[1] W.J. McNeil. Personal communication.

Table 6. Effect of coho salmon spawning on pink salmon embryos in Sashin Creek, 1965

Area	Coho spawning effort	Number of females	Area of gravel disturbed by coho	Number of live pink salmon embryos per square meter before coho spawned	Estimated number of viable pink salmon embryos disturbed by coho	Estimated number of viable pink salmon embryos in the study areas at time of coho spawning	Percentage of total viable pink salmon embryos disturbed by coho spawning activity
U	6%	6	16 m^2	750	12,000	2,209,000	0.5%
M	51%	49	127 m^2	1,200	152,000	4,880,000	3.1%
L	43%	41	107 m^2	300	32,000	1,822,000	1.8%
Total	100%	96	250 m^2	750	187,000	9,813,000	1.9%

therefore, to lie within areas later disturbed by coho spawners.

In years when the numbers of coho and pink salmon spawners approach the 1965 escapements, it is doubtful that coho have 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, the impact on survival of pink salmon in 1965 would have been slight, amounting to less than two percent of the viable pink salmon embryos present before coho spawning commenced. However, a more significant mortality from redd superimposition would result in years when relatively small numbers of pink salmon and large numbers of coho enter Sashin Creek.

A second method of assessing the effect of coho spawning activity on survival of pink salmon embryos was used in 1965. A comparison was made of the changes in survival rates of pink salmon embryos in those sections of Sashin Creek utilized sparingly by spawning coho with those sections used relatively heavily by coho. The survival rates of pink salmon embryos obtained from hydraulic sampling, were averaged over sections 61 m (200 ft) in length and grouped in four categories: (1) no coho spawners, (2) 2.6 to 5.2 m^2 disturbed by coho spawners per 61 m section, (3) 7.8 to 13.0 m^2 disturbed, and (4) 15.6 to 20.8 m^2 disturbed.

Figure 4 shows survival of pink salmon embryos grouped under each of the four categories. Inspection of the graph indicates that differences in coho spawning effort had no measurable effect on survival of pink salmon embryos. Observed differences in mean survival are accountable to sampling error. However, this assessment is only of the survival of those embryos in the gravel at the time of sampling. The estimates of mortality do not include pink salmon embryos uncovered by spawning coho and washed from the area by the stream current. If a comparison were made of the changes in the average number of viable pink salmon embryos per square meter before and after coho spawning, in the areas of various densities of coho spawners, a more valid estimate of the effect of coho spawners on pink salmon embryos would be obtained. Lack of accurate information about the surface areas of the individual 61-m sections prevented the use of this comparison in my studies.

Redd Life

Tagged females were used to determine the average number of days a female coho spent on a spawning site (I refer to this as redd life). Since over one-third of the females were tagged, identification of most of the untagged females was possible. Those untagged females that could be positively identified also were used in determining the average redd life. A female had to be observed at the same

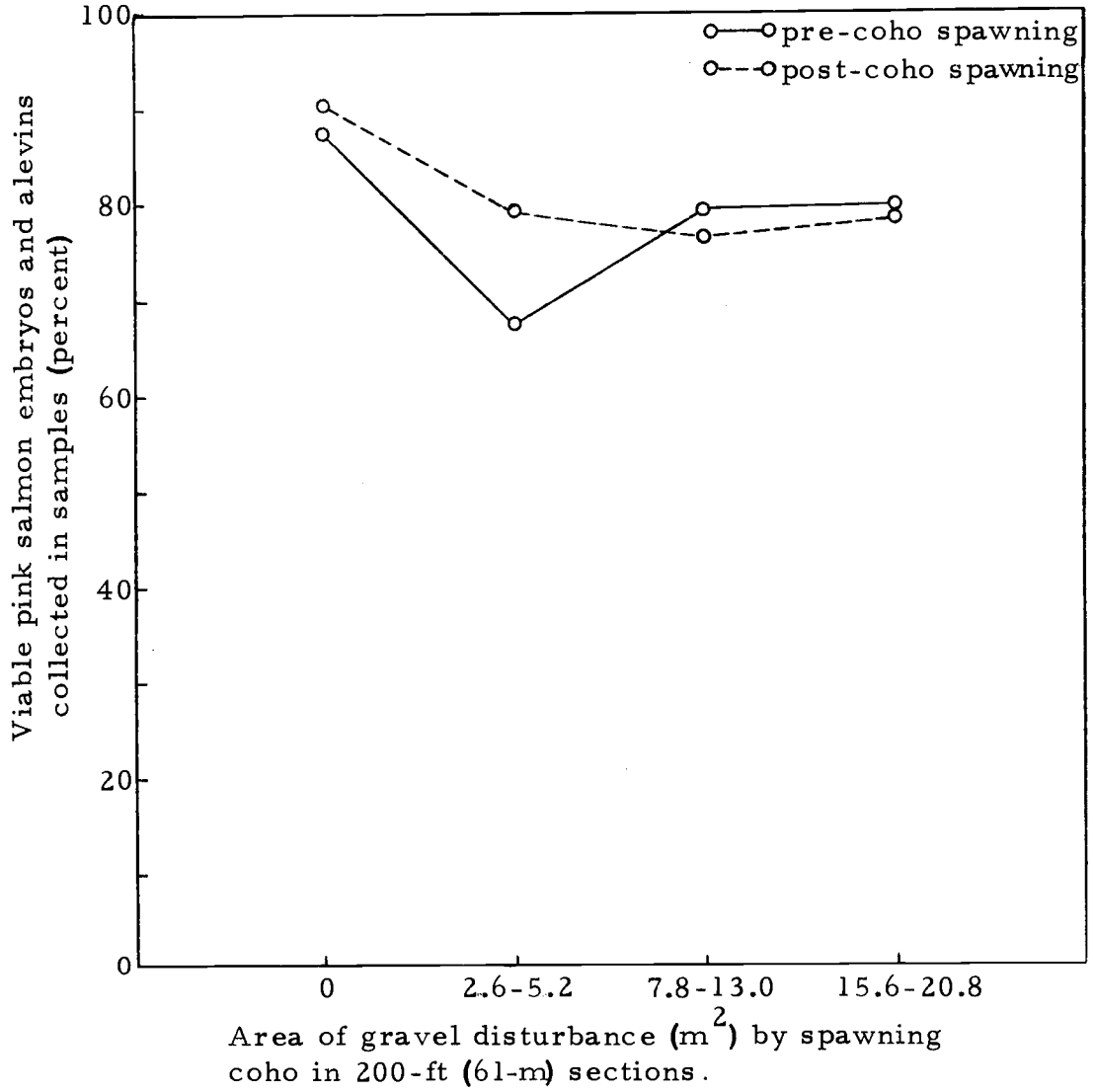


Figure 4. The effect of several levels of coho salmon spawning effort on ratios of live to total pink salmon embryos in spawning gravels, Sashin Creek, 1965.

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, on the assumption that the average female began to construct a redd one-half day before first being observed.

In 1965, the mean redd life for 56 female coho was 13 days, with a range of six to 21 days. The mean length of time that female coho spent in Spring Creek before death was 11 days (Willis, 1954). Many coho enter Sashin Creek and ripen in pools one month or more before spawning; however, coho migrating into Spring Creek frequently begin spawning immediately after entering the tributary, apparently ripening in the main Wilson River (Willis, 1954). Koski (1966) reports mean stream lives of 13.7 and 13.1 days for coho spawning in two tributaries to Drift Creek in Oregon.

Age

A sample of scales was taken mid-way between the lateral line and the origin of the dorsal fin on the left side of each adult coho handled in 1965 and 1966. Many of the scales came from coho caught off the mouth of a stream entering Port Herbert, a bay located approximately three miles north of Little Port Walter (Figure 2). Age and life history of the fish (including the total age, the length of time spent in fresh water, and the number of years in salt water) were determined from the pattern of growth of the scales, with the aid of an

Eberbach viewer.

Age analysis indicated that most coho returning to Sashin Creek and Port Herbert had remained in fresh water two summers and two winters before migrating to sea in the beginning of their third year (designated 4_3 by Koo, 1962) (Table 7). A smaller portion of the coho sampled had spent one year in fresh water, entering the sea at the beginning of their second year, followed by two summers in the ocean (designated 3_2). A few scales were collected from coho that lived three years in fresh water before migrating at the beginning of their fourth year of life, followed by two summers in the ocean (designated 5_4).

Table 7. Age structure of coho salmon sampled for scales 1965-66.

Source of the sample	Year	Size of the sample	Age structure 3_2	4_3	5_4
Sashin Creek	1965	27	7%	89%	4%
	1966	17	29%	65%	6%
Port Herbert	1965	1	---	100%	--
	1966	25	20%	76%	4%

Other studies of the fresh-water and ocean life of coho salmon report lower percentages of 4_3 individuals than I observed at Sashin Creek and Port Herbert. In more southerly parts of their range (British Columbia, Washington, Oregon, and California) coho are almost exclusively 3_2 fish (Pritchard, 1940; Marr, 1943; Smoker, 1953; Shapovalov and Taft, 1954; Exploitation..., 1962). The reported ages of coho in Alaska and Kamchatka show higher percentages of 4_3 individuals than found farther south (Gilbert, 1922; Gribanov, 1948; Semko, 1954; Exploitation..., 1962), but in only two instances were 4_3 coho reported to be more numerous than 3_2 coho. Gilbert (1922) reports that approximately 60 percent of the coho of the Yukon River are in the 4_3 age-group; the remainder belong to the 3_2 age-group. Semko (1954) lists age composition of coho from the Bolshaya River for eight years, and in two of the years reported (1946 and 1947) the 4_3 coho outnumbered the 3_2 age-group. The highest percentage of 4_3 coho reported by Semko (1954) was 64.7 percent. Age composition of coho from the Taku and Stikine Rivers in Southeastern Alaska was reported as 68.0 percent 3_2 and 28.2 percent 4_3 coho (Exploitation...., 1962).

Jack coho (arbitrarily segregated by being 20 inches or under in fork length) appear to be rare or lacking in the Sashin Creek run. No scales were collected from jack coho. One male sampled for scales in 1966 was 20 1/2 inches long, but was aged as belonging to the 3_2

age-group.

Fecundity

In 1966, the average number of eggs per female (fecundity) was determined for eight female coho from Sashin Creek, and for seven coho from Port Herbert (Table 8). No coho were sacrificed for fecundity determinations in previous years of the study in an effort to insure a maximum number of juvenile coho in the stream for summer studies. Most coho used for egg counts were obtained with sport fishing gear at the mouths of the two streams. The ovaries from individual females were placed in containers of water and boiled until hard. The boiling process separated the eggs from the ovarian tissues, making counting easier. A 150-hole counting board of plexiglass was used for enumerating the eggs. Females sacrificed for fecundity samples were measured for fork length.

Table 8. Coho salmon fecundity samples, 1966.

Sample number	Sashin Creek		Port Herbert	
	Fork length	Egg count	Fork length	Egg count
	Cm		Cm	
1	64.8	2292	----	1853
2	68.6	1195	68.6	2597
3	68.6	2932	64.8	2004
4	73.7	3332	68.6	2848
5	73.7	4418	70.0	2466
6	70.0	3164	66.0	2544
7	73.7	2673	68.6	2931
8	71.1	2940		
Mean	70.5	2868	67.8	2463

A mean fecundity of 2,868 eggs per female was obtained from the Sashin Creek samples. Coho from Port Herbert had a lower mean fecundity, 2,463 eggs per female, but were slightly smaller. There was a large variation in fecundity among the Sashin Creek samples, and therefore, the accuracy of the mean fecundity obtained from this small sample is uncertain.

Table 9 gives average fecundity data reported in the literature for coho salmon throughout its range. The average fecundities range from 1,983 to 5,343 eggs per female.

Retained Eggs

In 1965, all spent females observed on the daily stream surveys were examined for retained eggs. The average number of eggs per female was subtracted from the fecundity to calculate potential egg deposition.

Only seven spent female coho were examined for retained eggs because high water washed most dying spawners from the stream before they could be examined. A mean of six retained eggs per female was observed. Individual observations ranged from one to 24 retained eggs per female. Koski (1966) examined 30 spent female coho and obtained an average of four retained eggs per female. In Kamchatka, Semko (1954) found that 0.3 percent of the actual fecundity was retained by coho salmon.

Table 9.[a] Average fecundity of coho salmon.

Average number of eggs	Size of sample	Average fork length (cm)	Area	Reference
1,983	92	[b]66.2	Fall Cr., Alsea R., Ore.	Koski (1966)
2,267	--	----	Oliver Cr., B.C.	Foerster (1944) as cited in Shapovalov and Taft (1954)
2,310	[c]	----	Nile Cr., B.C.	Wickett (1951)
2,313	3	----	Port John Cr., B.C.	Hunter (1948)
2,329	--	----	Cowichan River, B.C.	Neave (1948)
2,463	7	67.8	Port Herbert, Alaska	Present Study
2,500	65	65.3	Scott Cr., Calif.	Shapovalov and Taft (1954)
2,500	1,120	[b]62.7	Minter Cr., Wash.	Salo and Bayliff (1958)
2,789	--	----	Beadnell Cr., B.C.	Foerster (1944) as cited in Shapovalov and Taft (1954)
2,868	8	70.5	Sashin Cr., Alaska	Present Study
3,002	21	[d]69.8	Namu Canner, B.C.	Foerster and Pritchard (1936)
3,100	63	63.0	Univ. of Washington	Allen (1958)
3,152	48	[d]65.3	Fraser River, B.C.	Foerster and Pritchard (1936)
4,350	--	[e]58.8	Paratunka R., Kamchatka	Gribanov (1948)
4,883	--	----	Kamchatka R., Kamchatka	Kuznetzov (1928)
2,300 to 5,343	--	[e]57.3	Bolshaya R., Kamchatka	Semko (1954)

[a] Table adapted from Rounsefell (1957) and Allen (1958).
[b] Length calculated from regression curve.
[c] Three to eight specimens per year.
[d] Total length.
[e] Lengths given by Gribanov (1948); not listed as from females sampled for fecundity.

Juveniles

Coho salmon fry begin to emerge in April, and most of the surviving alevins have emerged by the end of May.[2] Some fry migrate to the estuary in spring and summer; others remain in fresh water for a year or longer. Those that remain in fresh water grow into smolts after one to three years.

Other investigators have reported coho fry migrating to salt water soon after they emerge (Chamberlain, 1907; Gilbert, 1913; Pritchard, 1940; Wickett, 1951; Foerster, 1955; Godfrey, 1965); however, none reported a substantial return of adult coho from early migrating fry. These fry are possibly lost to predation or cannot survive the early transfer to salt water. All of the adult coho scales which I examined in this study had a pattern of circuli showing at least one year of fresh water residence.

Spring Weir Counts

A fry weir of fine-meshed steel screens is positioned in Sashin Creek near the head of tidewater during the spring migration period (Figure 5). Counts at the fry weir show that smolts leave Sashin Creek in April, May, June, and July; peak migration usually occurs in late May or early June (Table 10). Similarly, coho smolts migrate

[2] W.J. McNeil. Personal communication.

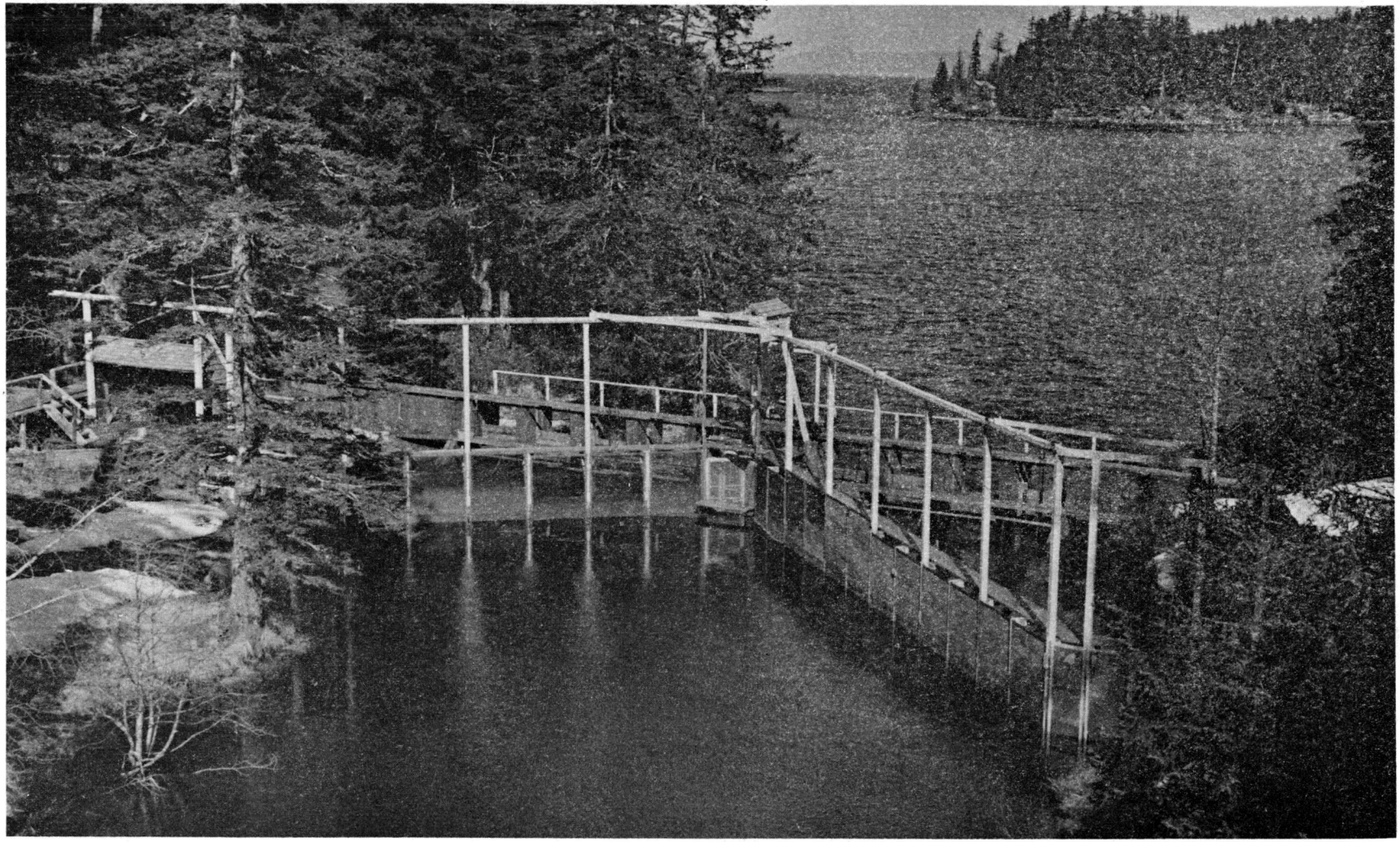


Figure 5. Fry weir near mouth of Sashin Creek. Adult weir spans stream behind V-shaped fry weir. Little Port Walter bay at high tide is in the background.

from Hooknose Creek, British Columbia, from April to August, with the peak emigration in May (Hunter, 1948).. Foerster and Ricker (1953) reported that coho smolts migrate from Cultus Lake, British Columbia, in greatest numbers in late May and early June.

The smolt migration from 1956 through 1963 varied approximately three-fold and the corresponding parent escapements varied approximately four-fold (Table 10). The relatively low count of smolts obtained in 1964 may have resulted from a change in the trapping procedures employed at the weir. The old procedures were designed to capture all of the fish migrating from Sashin Creek. The new procedures were designed to capture only a small portion of the outmigrating fry and were not designed to capture and retain smolts.

A total of 44,023 coho fry and 334 smolts was counted through the fry weir as they migrated from Sashin Creek in the spring and summer of 1964. Migrant coho fry were counted from April 19 until the fry weir was removed on August 28. Most fry left the stream during the middle two weeks of June, when more than 1,000 migrants per day were counted. The peak migration occurred on June 15, when 3,528 fry left the stream (Bond, 1964).

Table 10. Weir counts of coho salmon smolts and fry, Sashin Creek.

Year	Total count		Date of largest migration		Counting period	Date last fish was observed to emigrate	
	Fry	Smolts	Fry	Smolts		Fry	Smolts
1956	---	928	---	June 15	April 16-June 30	---	June 20
1957	373	1,961	June 17	May 24	April 10-June 29	June 27	June 27
1958	2,854	1,015	May 4	May 20	March 7-June 3	May 31	June 2
1959	218	1,587	July 14	May 27	April 1-July 21	July 15	July 3
1960	9,923	1,258	June 12	June 10	March 17-July 2	June 30	June 30
1961	2,699	2,489	May 21	May 28	March 22-June 19	June 17	June 17
1962	1,209	2,865	June 14	May 27	March 11-July 4	July 4	July 3
1963	1,236	1,599	May 30	May 24	March 11-July 8	July 1	July 3
1964	44,023	[a]/ 334	June 15	May 24	March 15-Aug. 28	Aug. 28	July 6

[a]/ Counting procedure changed from total to partial count; holding facilities may have been inadequate for retaining smolts.

Damage to the fry weir in the springs of 1965 and 1966 prevented total enumeration of migrating fry and smolts. In 1965, a fyke net which selected a portion of all migrants was fished at the weir from April 11 until July 30. A total of 1,524 pink salmon fry and 58 coho fry were collected with the trap. From results of spring hydraulic sampling, an estimated 310,000 pre-emerged pink salmon fry were present in Sashin Creek before fry emigration began. Assuming the emigration of pink salmon fry was 310,000, and the trap did not fish selectively for pink salmon or coho fry, an estimate of the age-group 0 coho migrants can be made from the ratio of 1,524 pink to 58 coho salmon emigrants. An estimate of approximately 12,000 outmigrating coho fry results.[3] An insufficient number of coho smolts was captured by the fyke net to make an estimate of total emigration.

In 1966, several fyke nets were fished at the weir from June 17 until September 13, to moniter emigration of coho from the stream. Because the fyke nets were not installed until after the migration of pink salmon fry, no estimate of the total number of migrant coho could be made.

Yield of Smolts

An estimate of the yield of coho smolts from Sashin Creek was

[3] W.J. McNeil. Personal communication.

made for the period 1956-1963 from the total number counted at the weir. A range of 5.8 to 17.9 smolts per 100 m^2 was obtained. In comparison, the yield of smolts for three streams tributary to Drift Creek in Oregon is reported to range from 18 to 67 smolts per 100 m^2 for a five-year period (Chapman, 1965).

Because the smolts from Sashin Creek remain in fresh water one year longer than those from Drift Creek, the number of yearlings from Sashin Creek might provide a better comparison of yield. The potential yield of yearling coho was determined for Sashin Creek from the population sizes of yearlings in mid-July 1965 and late June 1966. An estimated yield of 23.8 and 15.0 yearlings per 100 m^2 was obtained.

Growth

The pattern of growth on adult scales suggested that most of the coho salmon returning to Sashin Creek spent two summers in fresh water before migrating to sea (Table 7). To confirm that juvenile coho salmon typically remain in Sashin Creek two years before they become smolts, I studied the growth of juveniles in the stream.

Before scales of adults had been examined, it was thought that coho in Sashin Creek included two groups; fry in the first summer of life (age-group 0) and yearlings in the second summer (age-group I). Later scale analysis revealed the presence of juveniles in their third

summer of life (age-group II). However, only the fry and a second group which I call fingerlings (age - groups I and II combined), were recognized for population estimates and growth studies.

Lengths from the tip of the snout to the fork of the tail were measured to the nearest millimeter from samples of coho fry collected periodically during the summer of 1964, and from samples of coho fry and fingerlings captured during each of the population estimate experiments conducted in the 1965 and 1966 summer studies. An additional 50 fry from each area were measured in mid-July, 1966, between the first and second population estimates of the summer.

When length measurements were taken, all coho captured from a collecting site were measured to avoid biasing the estimate of mean fork length. Mean fork lengths were calculated for the juveniles in the Sashin Creek and Funny Creek study areas on each of the sampling dates.

There was no consistent difference in the mean fork lengths of corresponding age-groups of coho captured in the upper, middle, or lower areas of Sashin Creek in any sampling period (Appendix A). Coho collected in Funny Creek were usually slightly smaller than those from Sashin Creek collected during the corresponding period.

The difference between the fork length of fry and fingerlings was pronounced in early summer (Figure 6). However, by July the lengths of the faster growing fry and the slower growing fingerlings

overlapped. Difficulty was experienced in assigning the proper age-group to juveniles in the overlapping sizes, but differences in coloration and fin size made separation possible in most cases. Fins of fry were much larger in relation to body size and more highly colored than fins of fingerlings. An illustration representing the sizes of fry and fingerlings in early and late summer is presented in Figure 7.

Fry in Sashin Creek were less than 70 mm in mean fork length by the end of September (Figure 8). Fingerlings did not reach 70 mm in mean fork length until late June or early July of the second summer. By September, coho fry from Kamchatka streams range from 40 mm to 60 or 70 mm (Gribanov, 1948). Semko (1954) found the length of yearling smolts in Kamchatka averaged 85 mm; whereas, two-year-old smolts averaged 130 mm. Investigations in California (Shapovalov and Taft, 1954) and British Columbia (Foerster and Ricker, 1953) list the mean length of coho smolts as 110 to 120 mm. Some juvenile coho held in a brackish-water pond in Oregon attained a length of approximately 120 mm and became smolts after three months instead of the normal one-year rearing period (Garrison, 1965), suggesting that smolting is a function of size rather than age. Data on mean lengths and population sizes of juvenile coho in Sashin Creek during September and early summer indicate that most require two summers of fresh-water residence to reach smolt size.

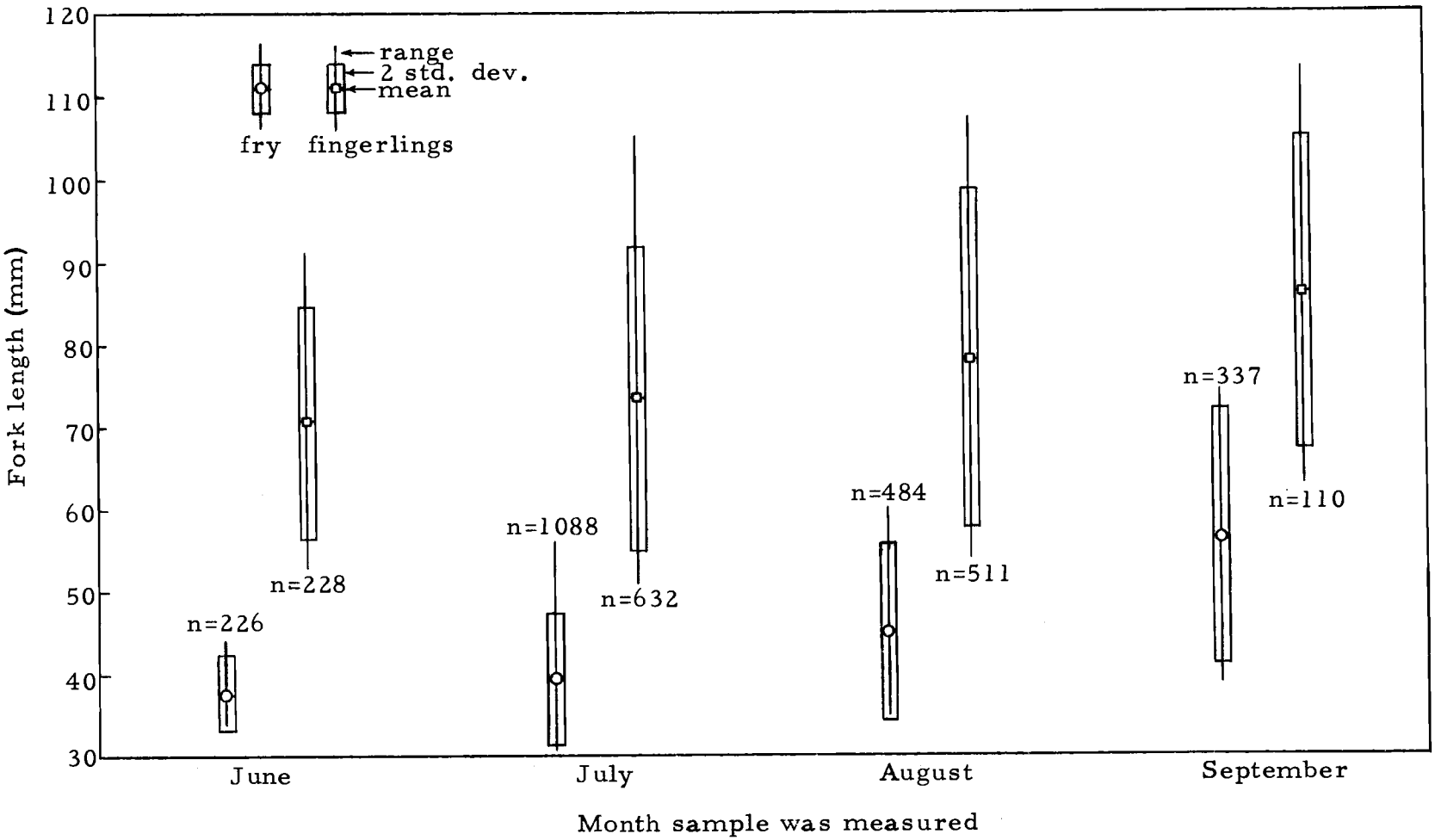
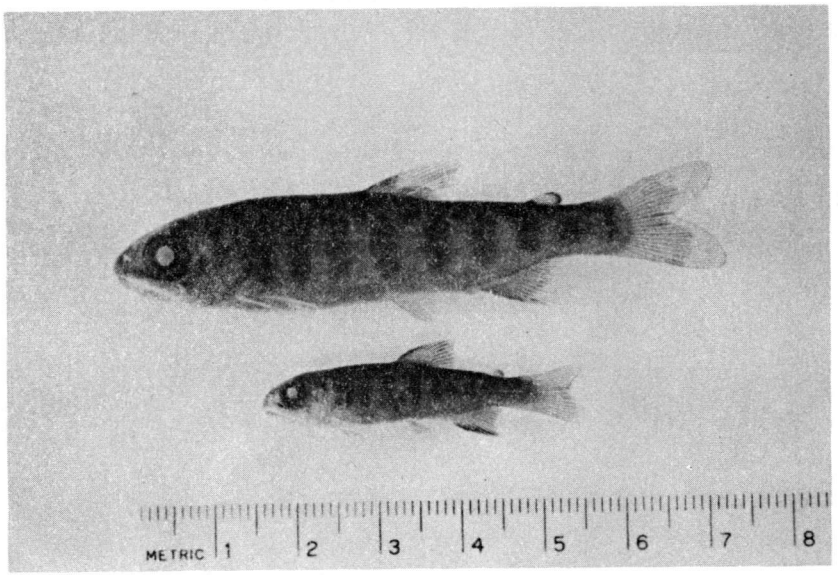


Figure 6. Mean and range of fork lengths of juvenile coho salmon in Sashin Creek, 1964, 1965, and 1966.



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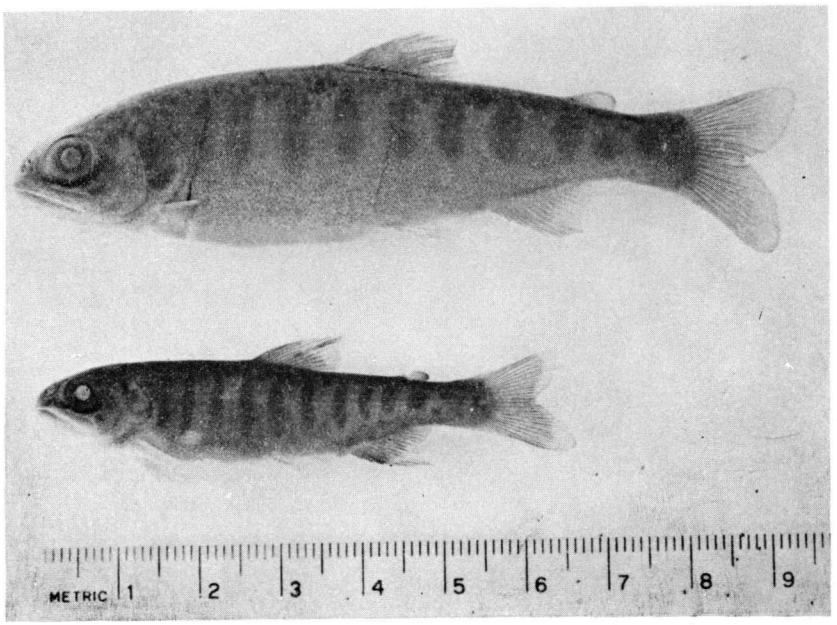

B

Figure 7. Juvenile coho representing the average size of fry and fingerlings in (A) late June and (B) early September in Sashin Creek. Units are cm.

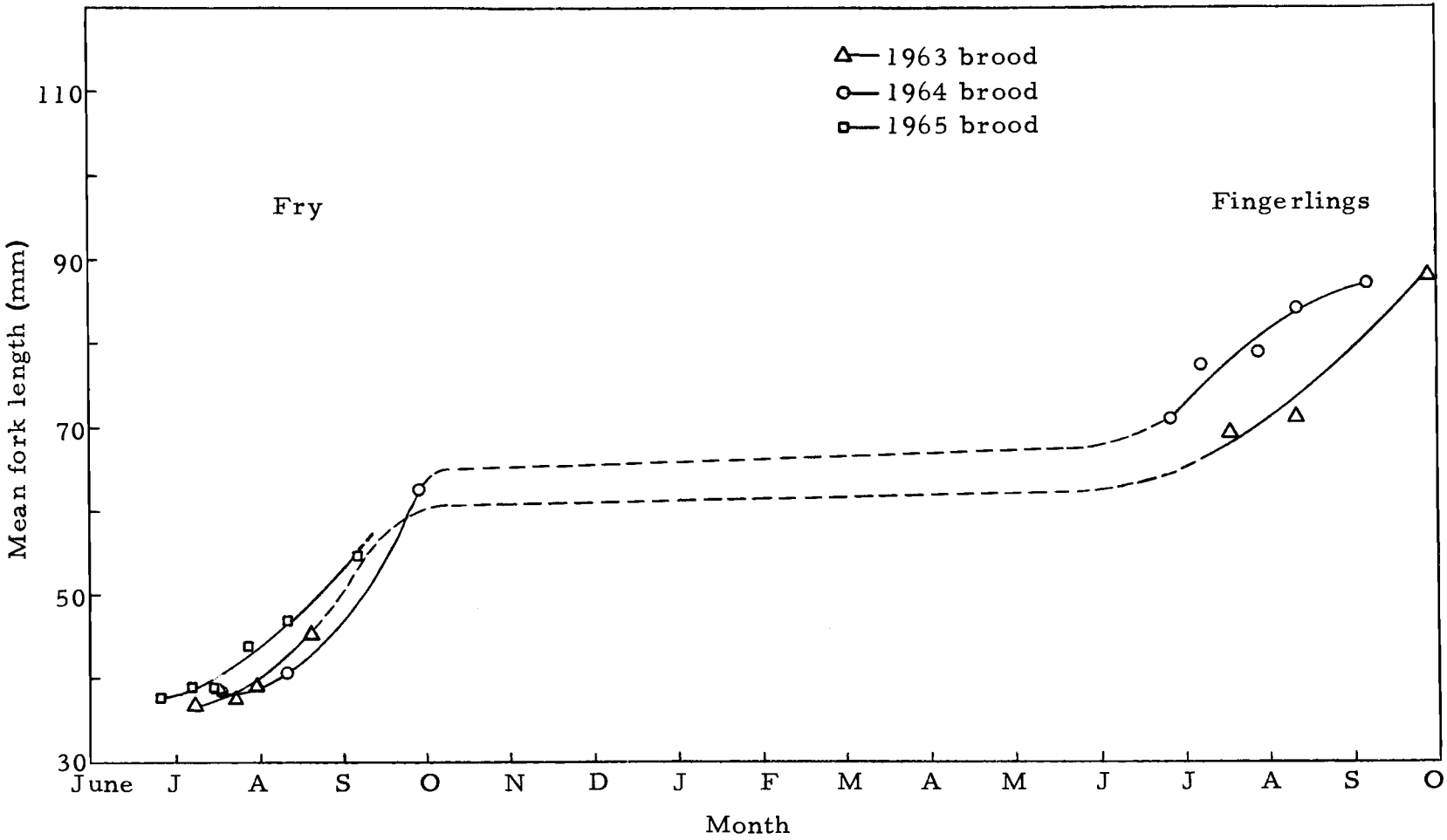

Figure 8. Increase in the mean fork length of three brood years of coho salmon, from fry (age-group 0) to fingerlings (age-groups I and II combined).

Coho fry of the 1965 brood year were larger at a given date than those of the 1963 or 1964 broods (Figure 8). Fingerlings in the summer of 1966 (mainly 1964 brood) were larger than fingerlings in 1965 (mainly 1963 brood). In the summer of 1966, the number of fingerlings was approximately one-half the number in 1965, which may account for the larger size of coho fingerlings in 1966. The smaller population of fingerlings in 1966 also may have allowed the fry present that summer (1965 brood) to reach a larger size because of reduced competition for food among the broods.

Mean lengths obtained for a brood year during its second summer (age-group I), are increased by the presence of age-group II fingerlings, which tend to be larger, but are visually inseparable from age-group I fingerlings.

Scale and Stomach Samples

Samples of juvenile coho were collected for scale and stomach analysis on several occasions during the field seasons of 1964, 1965, and 1966. All fish sampled were measured for fork length. Scales were analysed with the aid of an Eberbach viewer to learn the age of the fish and the pattern of circuli laid down during fresh-water life. The stomach was removed from each fish and the contents were classified into categories of salmon eggs, salmon fry, and taxonomic orders of insects.

Analysis of scale samples indicated that approximately 12 percent of all fingerlings collected belonged to age-group II. Seventeen percent of the fingerlings sampled for scales in June, July, and August were in age-group II; whereas six percent of the fingerlings sampled in September were in age-group II. Sizes of the various age-groups sampled are depicted in Figure 9.

Most coho fry collected in June were under 40 mm fork length and had not formed scales. Similarly, Gribanov (1948) found that the scale covering usually appeared on young coho from streams in Kamchatka at a length of 40 mm.

By September, most scales from fry were composed of seven or eight circuli. Fingerlings sampled during the three summers of the study had an average of only six circuli before the first annulus (Figure 10), indicating some scale reabsorption had taken place during the winter. Back-calculation of lengths of younger age-groups from scale measurements could be misleading, because of possible scale reabsorption in coho from streams which support little or no fish growth during the winter, such as Sashin Creek.

A total of 204 coho stomachs was examined for food contents (155 from Sashin Creek and 49 from Funny Creek). Results of the analysis are presented in Table 11. Insects of the Order Diptera were found in almost 50 percent of the stomach samples from Sashin Creek and 80 percent of the stomach samples from Funny Creek. Several

investigators have listed Diptera larvae and adults, or aerial insects in general, as the most important food items to juvenile coho (Gribanov, 1948; Roos, 1960; Demory, 1961; Godfrey, 1965).

Hemiptera were found in the stomachs of 51 percent of the coho sampled from Funny Creek, and in the stomach of only one coho from Sashin Creek. Coleoptera and Collembola were more important in the diet of coho from Sashin Creek. The larger number of relatively important insect orders in the diet of coho residing in Funny Creek, in comparison to those living in Sashin Creek, probably is due to the different environments in and around the two streams.

More than one-half of the stomachs from coho sampled from Sashin Creek in September contained salmonid eggs. In September 1965, almost all of the coho stomachs examined contained salmonid eggs or shells; whereas, 11 of 38 stomachs examined in September 1966 contained eggs or shells. Many of the samples collected in September contained only eggs. Larger juvenile coho in the streams of Kamchatka feed on salmon eggs during the spawning season (Semko, 1954).

In 1965, approximately 14,000 pink salmon spawned in Sashin Creek, while in 1966, about 6,000 utilized the stream. The total number of pink salmon eggs available presumably was greater in 1965 than in 1966. The difference in egg consumption by juvenile coho probably was related to the availability of eggs. Few pink salmon

spawned in Funny Creek in these years (probably less than ten females) and no salmonid eggs were found in the stomachs of juvenile coho collected there.

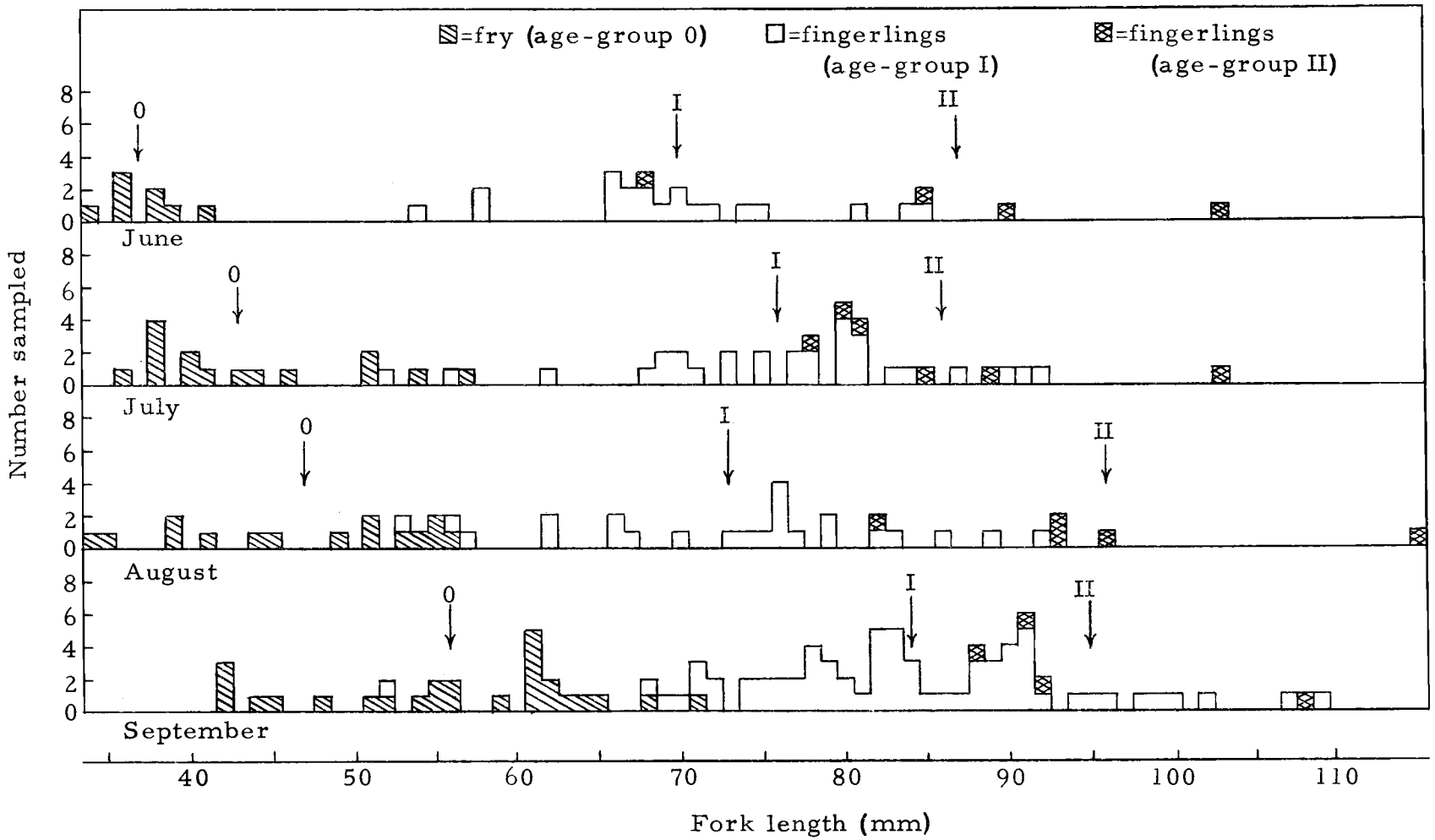

Figure 9. Age-group and (preserved) fork length of coho salmon juveniles sampled for scales, 1964-1966. Samples are grouped by the month of collection. Arrows indicate mean lengths of age-groups.

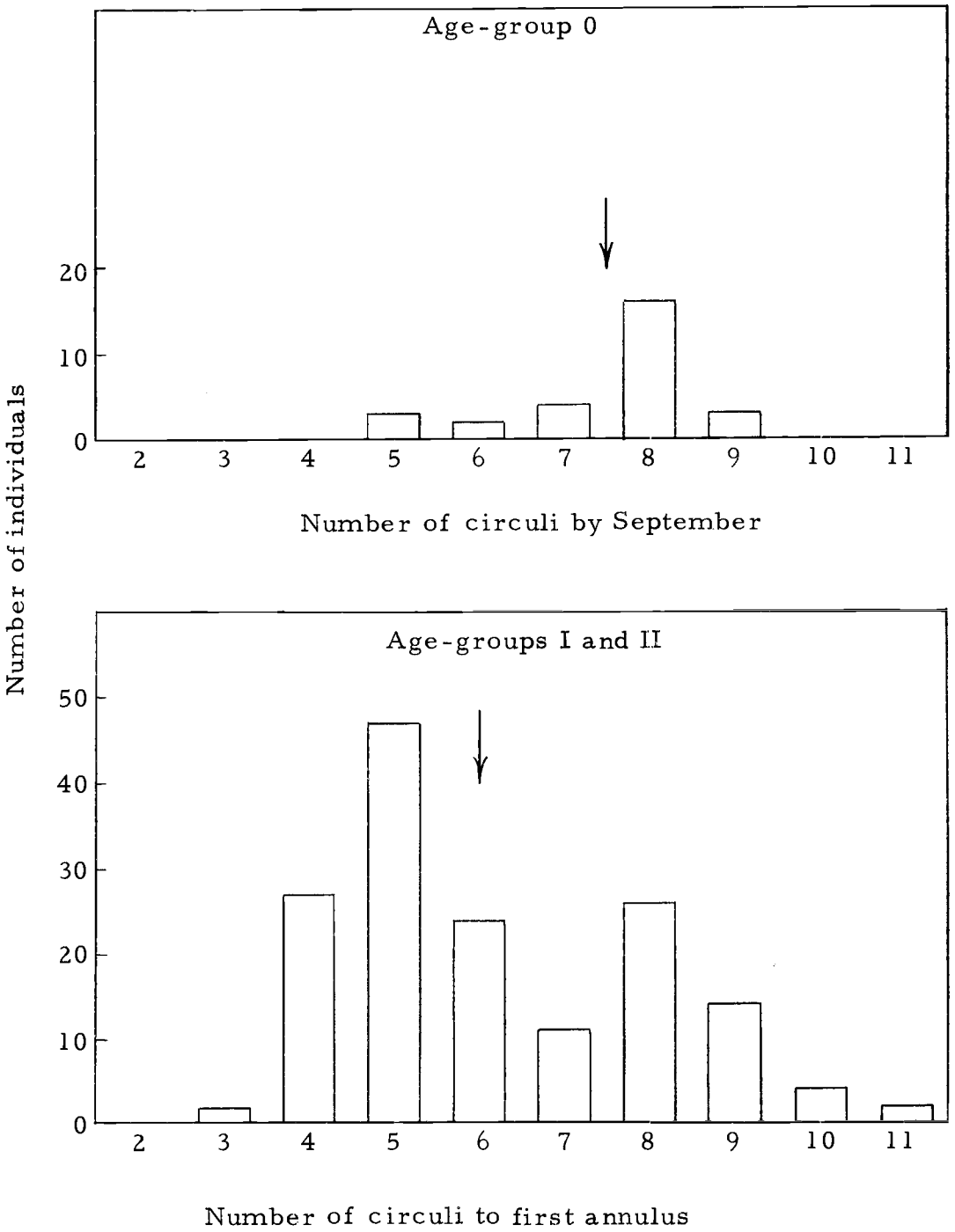

Figure 10. Number of first-year circuli on scales from juvenile coho salmon from Sashin Creek. Arrows indicate mean number of circuli for the groups.

Table 11. Contents of stomachs of Sashin Creek and Funny Creek juvenile coho salmon collected in 1964, 1965, and 1966. Samples are grouped by the month of collection.

Stream and month	Number of stomachs examined	Number of stomachs containing: Diptera	Hemiptera	Coleoptera	Collembola	Plecoptera	Hymenoptera	Trichoptera	Other insects	Salmon eggs	Salmonid fry
Sashin Creek											
June	13	12	0	0	0	6	1	1	2	0	0
July	42	37	1	5	0	5	1	2	1	0	0
August	13	5	0	0	0	2	3	2	0	0	1
September	73	17	0	4	0	5	9	2	1	39	0
October	14	0	0	0	0	0	0	0	0	4	0
Total	155	71 (45.8%)	1 (0.6%)	9 (5.8%)	0 (0%)	18 (11.6%)	14 (9.0%)	7 (4.5%)	4 (2.6%)	43 (27.7%)	1 (0.6%)
Funny Creek											
June	13	9	0	2	0	2	0	1	0	0	0
July	--										
August	21	18	13	12	12	0	0	0	0	0	1
September	15	12	12	4	2	1	0	4	0	0	0
October	--										
Total	49	39 (79.6%)	25 (51.0%)	18 (36.7%)	14 (28.6%)	3 (6.1%)	0 (0%)	5 (10.2%)	0 (0%)	0 (0%)	1 (2.0%)

SURVIVAL

My studies have allowed me to approximate survivorship curves for three brood years of coho salmon in Sashin Creek (1963, 1964, and 1965). The curves begin with potential egg deposition and end with late summer estimates of populations of fingerlings (mostly age-group I).

Egg Deposition to Emergence

An estimated egg deposition for each brood year was determined by multiplying the mean fecundity, adjusted for the mean number of retained eggs, by the estimated number of female coho. The estimate of female escapement for 1963 and 1964 was based upon the estimated spawner population obtained by dividing the observed spawning effort by the mean redd life, and multiplying by two, as discussed earlier in the text. Although inaccuracies exist, the method is the best available for estimating the 1963 and 1964 escapements. The estimate of female escapement for 1965 was obtained from marked-to-unmarked ratios observed on the spawning grounds.

The value of mean fecundity used in estimating total egg deposition was determined from the small sample of females examined in 1966. Because of high variability in fecundity and the uncertainty of the estimates of the 1963 and 1964 spawner escapements, the resulting estimates of egg deposition are considered to be rough approximations. My estimates of egg deposition in 1963, 1964, and 1965 are

1,211,000, 186,000, and 275,000, respectively.

Routine hydraulic sampling (McNeil, 1964) of the Sashin Creek spawning areas in the spring is used to estimate the population of pre-emerged pink salmon alevins. Estimates of the population of pre-emerged coho alevins are obtained from data collected during the spring sampling. However, these estimates are considered to be reliable only in years of relatively large parent escapements. Hence, an estimate of the pre-emerged alevin population of the 1963 brood is considered to be the most reliable. No coho alevins were collected in spring 1966 (1965 brood), so there is no estimate for that brood.

A population of 214,000 pre-emerged coho alevins was estimated in the spring of 1964 (1963 brood) and a population of 58,000 in spring 1965 (1964 brood).

Juveniles

Population estimates were made periodically during the three summers of the study to establish a curve depicting changes in the number of juvenile coho from fry emergence through smolt migration. In 1964, the fry (1963 brood year) population size was estimated, once in July and again in August. In the following summer, the populations of fingerlings (predominantly 1963 brood, with some remaining 1962 brood) and fry (1964 brood) were estimated in July and in August. In 1966, the fingerling (1964 and 1963 broods) and fry (1965 brood) populations were estimated in June, July, and September.

The Bailey-Petersen mark-and-recapture method of population

estimation, as given by Ricker (1958, p. 84), was used for all population size experiments except the August estimate of 1964, when a Schnabel multiple mark-and-recapture estimate was employed (Ricker, 1958, p. 101). For the 1966 studies, numbers of juveniles to be marked and recaptured were predetermined from methods reported by Robson and Regier (1964) to obtain preassigned levels of accuracy and precision of population estimates. An attempt was made to mark and recapture sufficient numbers to be 95 percent certain that the error in estimating the population was not more than 10 percent (Appendix B).

The density of coho fry, in fish per square meter of stream area, was determined for the 1964 estimates of fry numbers in Sashin Creek. In 1965 and 1966, numbers and densities of coho juveniles were computed for the three study areas and the entire stream. In 1965 and 1966, Funny Creek was added as a separate study area for population and density estimates. Confidence limits to population estimates were obtained by methods given by Schumacher and Eschmeyer (1943) and Chapman (1948).

To facilitate capture, juvenile coho were attracted to an area for seining by introducing homogenized salmon eggs and ovarian tissue into the stream. An electric blender was used to prepare the mixture. The salmon egg scent drifted downstream, attracting the young coho to the baiting site, where they were allowed to concentrate

for approximately five minutes. The downstream sides of gravel bars, logs, and rocks were chosen as sites for baiting. Such obstructions to the current formed a slow-water area 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 baiting site. Several squirts of the egg solution from a plastic squeeze bottle were adequate to attract coho from distances of at least 30 m downstream. Rainbow trout, Dolly Varden char, and sculpins were also attracted to the baiting sites.

After juvenile coho had accumulated at the baiting site, they were captured with a seine. Captured fish were placed into a plastic holding tub containing creek water, anesthetized with MS 222, and marked by removal of one fin. A different fin-clip was used for each marking date within a summer. After marking, the fish were held in fresh creek water until they had recovered from the anesthetic. Upon recovery, the young coho were released at the site of collection.

No attempt was made to randomize the collection of juveniles during the marking phase of a mark-recapture experiment. The purpose was to collect as many fish from the entire length of the stream as was possible during the days allotted for marking.

A waiting period of several days was observed between the marking and recapture phases of the experiment to allow the marked coho to become redistributed. In an attempt to obtain an unbiased

population estimate, random points were selected and used as baiting sites during the recapture portion of the experiment. Two random numbers between 0 and 99 were chosen from a random numbers table (Snedecor, 1956, p. 10) for each of the 30 100-ft (30.5-m) sections of stream. The numbers chosen signified the distance, in feet, downstream from a 100-foot base line marker to the sites that would be baited. These distances were paced off, and sites across the width of the stream were baited with the salmon egg preparation. After baiting, the area was seined until only a few fish could be taken for each seine haul. As fish were captured, they were placed in a holding tub, anesthetized, and examined for fin clips. The number of unmarked and the number of marked coho were recorded for each collection site. After having been examined for marks, the juveniles were held in fresh stream water until they had recovered from the anesthetic, then they were released at the place of capture.

No mortality resulted from the handling and marking of test-marked fish. On several occasions 20 marked and 20 unmarked fry, and 10 marked and 10 unmarked fingerlings, were held in screened live-boxes, positioned in the stream for the duration of the marking experiment. There were no deaths among the captive fish.

Numbers of coho fry declined rapidly between the first and second population estimate of each summer (Table 12 and Appendix B). In the one month between estimates, the estimated population dropped

by approximately 75, 75, and 65 percent in 1964, 1965, and 1966, respectively. Weir counts of emigrant fry were continued until mid-August in 1964. Approximately 500 fry left Sashin Creek between the mid-July and mid-August population estimates. Fyke net catches indicated there were fewer emigrants in 1965 and 1966, than in 1964. Therefore, the large decline in fry numbers was attributed to mortality rather than emigration from the study areas. Fish and avian predators probably accounted for the major portion of the mortality. Populations of fingerling coho also declined as the summer progressed, although not as rapidly as fry.

In 1965 and 1966, when population studies included estimates of coho population size in the individual study areas, the highest densities of coho in Sashin Creek occurred in the lower study area (area L); but densities of coho fry and fingerlings were even higher in Funny Creek (Table 13). Both Funny Creek and area L of Sashin Creek are low-gradient areas, which may account for these high densities.

The fry population in 1964 was larger than in 1965 and 1966, a result of the large number of spawners entering Sashin Creek in the fall of 1963. The number of fingerlings in 1965 was higher in Sashin Creek, and much higher in Funny Creek, than in 1966. The fingerling group in 1965 was composed mainly of progeny from the large 1963 spawning.

The estimated number of fingerlings in Funny Creek increased

Table 12. Mean estimates of populations of juvenile coho salmon in summer, 1964-1966, Sashin Creek.

Brood year	Area	Mid-date of estimate							
		July 12, 1964	August 12, 1964	July 17, 1965	August 1, 1965	August 11, 1965	June 27, 1966	July 29, 1966	September 8, 1966
1963	Sashin								
	U			668	---	593			
	M			1,216	---	1,115			
	L			2,533	---	2,079			
	Total	51,852	14,711	4,581	---	3,836			
	Funny Creek			---	852	557			
1964	Sashin								
	U			2,979	---	254	402	509	468
	M			2,195	---	951	690	555	---
	L			14,738	---	3,477	1,562	555	---
	Total			20,355	---	4,546	2,883	1,585	≈1,350
	Funny Creek			---	1,201	984	251	389	317
1965	Sashin								
	U						1,192	1,497	915
	M						7,759	5,091	---
	L						26,662	7,851	---
	Total						35,077	13,434	≈8,000
	Funny Creek						1,616	1,037	615

Table 13. Densities (number/m^2) of juvenile coho salmon on dates of population estimates, Sashin Creek.

Brood year	Area	Mid-date of estimate: July 12, 1964	August 12, 1964	July 17, 1965	August 1, 1965	August 11, 1965	June 27, 1966	July 29, 1966	September 8, 1966
1963	Sashin								
	U			0.17	--	0.15			
	M			0.27	--	0.25			
	L			0.33	--	0.27			
	Total	3.25	0.92	0.29	--	0.24			
	Funny Creek			--	1.93	1.26			
1964	Sashin								
	U			0.75	--	0.06	0.10	0.13	0.12
	M			0.49	--	0.21	0.16	0.12	--
	L			1.95	--	0.46	0.21	0.07	--
	Total			1.27	--	0.28	0.18	0.10	≈0.08
	Funny Creek			--	2.72	2.23	0.57	0.88	0.72
1965	Sashin								
	U						0.30	0.38	0.23
	M						1.75	1.15	--
	L						3.52	1.04	--
	Total						2.20	0.84	≈0.50
	Funny Creek						3.66	2.35	1.39

from 251 to 389 between the late June and the late July estimates in 1966. The 95 percent confidence interval estimates of the means (Appendix B) suggest that fingerlings may have immigrated to the area from Sashin Creek. On all other occasions, the number decreased between estimates.

Estimates of coho fry and fingerling populations were used to construct curves depicting the changes in the populations of the three brood years studied (Figures 11 and 12). Estimates of the fry and fingerling populations in Sashin Creek in early September 1966 are projected from estimates of population size obtained in the upper area of Sashin Creek and in Funny Creek. In these two study areas, the number of fry in early September averaged 60 percent, and the number of fingerlings, 85 percent, of the respective populations in late July. I, therefore, assumed that these percentages pertained, also, to the lower and middle areas of Sashin Creek.

Mortality Rates

For this study, the fresh-water life of juvenile coho salmon is divided into five periods. The periods are the intervals between estimates of population size (Table 14). Corresponding periods for each brood year are comparable but are not exactly the same in length of time.

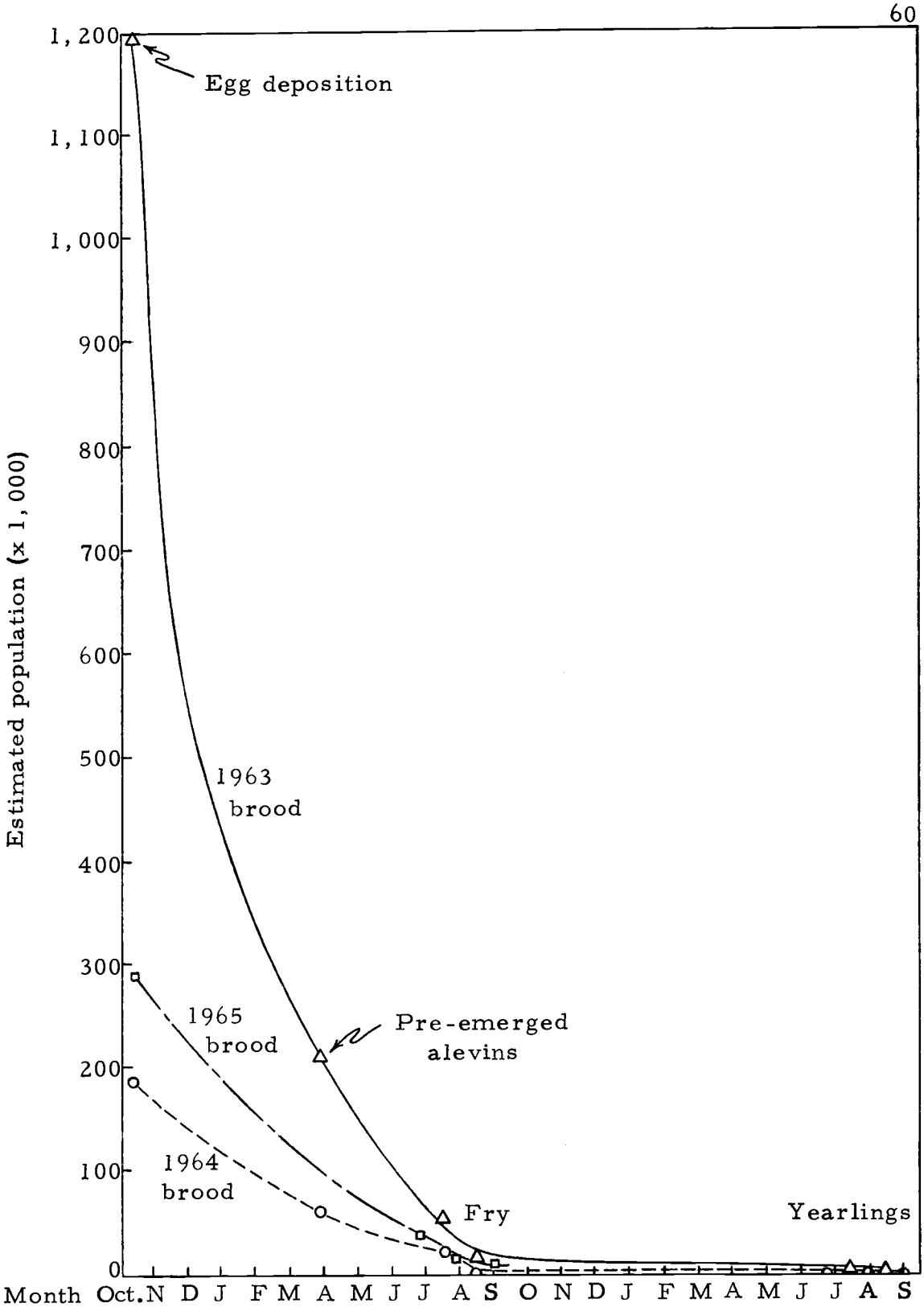

Figure 11. Changes in estimated population sizes of juvenile coho salmon from three brood years, Sashin Creek, Alaska. Arithmetic plot.

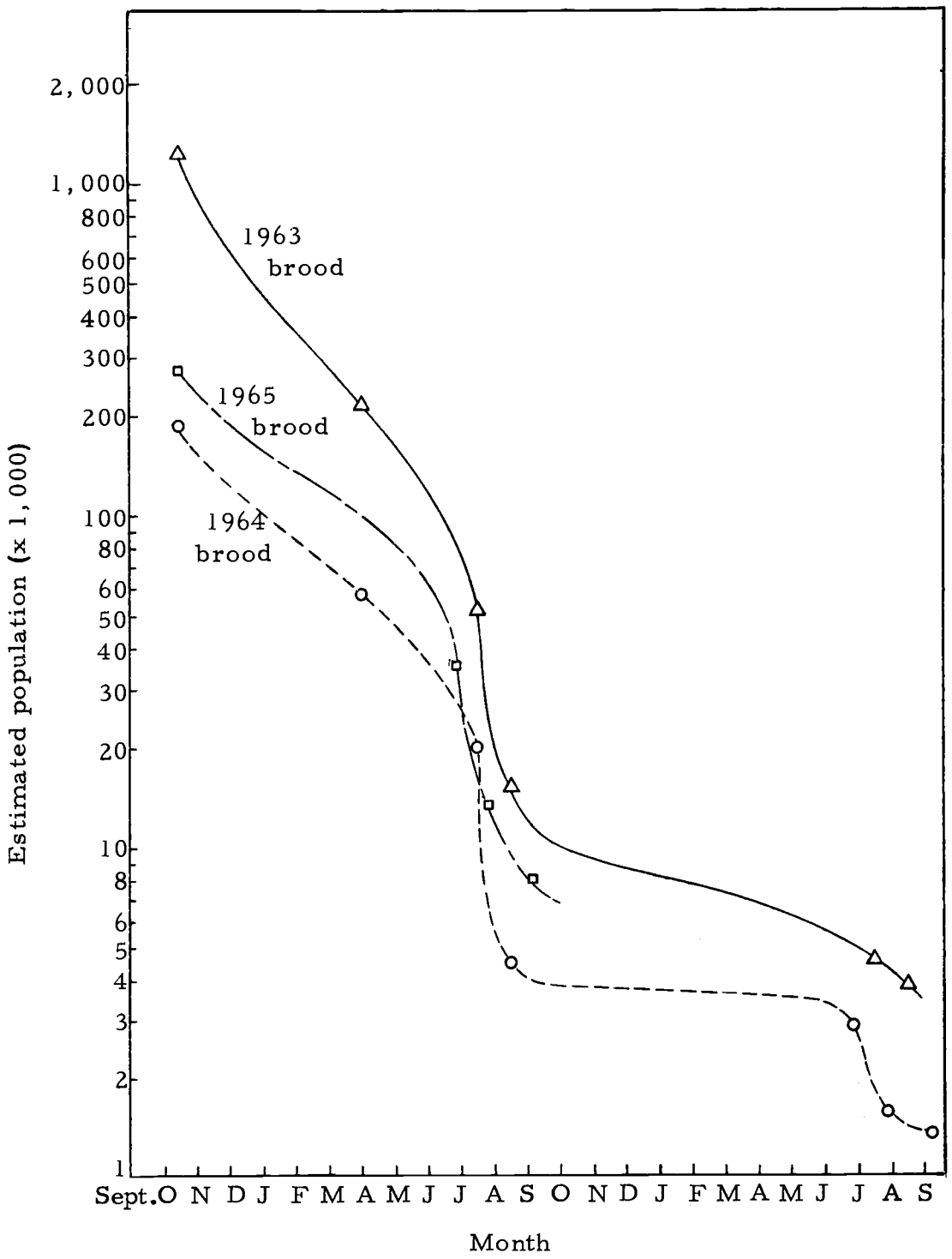

Figure 12. Changes in estimated population sizes of juvenile coho salmon from three brood years, Sashin Creek, Alaska. Semi-logrithmic plot to indicate mortality rate.

Table 14. Five periods in the fresh-water life of coho salmon in Sashin Creek.

Period	Brood year 1963	1964	1965
	Months		
1. Egg deposition to just prior to emergence (mid-October to late March or early April)	5.2	5.6	5.5
2. Just prior to emergence to first estimate of fry population (late March or early April to late June or mid-July)	3.7	3.5	2.9
3. First to second estimate of fry population during first summer (late June to late July or mid-July to mid-August)	1.0	0.8	1.1
4. Second estimate of fry population to first estimate of population as yearlings (late July or mid-August to late June or mid-July of the following year)	11.2	10.5	---
5. First to second estimate of yearling population (mid-July to mid-August)	0.8	1.1	---

Estimates of population size at selected intervals were used to determine the percentage of the egg deposition that survived as the population passed through two years of fresh-water life (Table 15).

Table 15. Estimates of percentage survival of three brood years of coho salmon during five periods, Sashin Creek.

Percentage survival of egg deposition to:	Brood year 1963	1964	1965
	Percent		
1. Just prior to fry emergence	17.53	31.09	34.87
2. First estimate of fry population	4.25	10.92	12.23
3. Second estimate of fry population	1.21	2.44	4.68
4. First estimate of yearling population	0.31	1.28	---
5. Second estimate of yearling population	0.26	0.70	---

Although no estimate was made by hydraulic sampling of the pre-emerged alevin population of the 1965 brood, an estimated population of 100,000 was obtained by inspection of survivorship curves (Figure 11). Estimates of survival and mortality in periods 1 and 2 for the 1965 brood are based upon this estimate of the pre-emerged alevin population.

Survival from egg deposition to just prior to fry emergence was estimated to be 17.5, 31.1, and 34.9 percent for the 1963, 1964, and 1965 brood years of coho salmon in Sashin Creek. A mean survival of 27.8 percent is estimated for the three brood years. 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 percent is reported for two tributaries of the Cowichan River in British Columbia (Pritchard, 1947). The mean survival in the two streams averaged 21.0 and 26.5 percent. Koski (1966) obtained survival values to fry emergence of zero to 78 percent for individual redds of coho salmon in three streams tributary to Drift Creek in Oregon. He obtained an overall average survival of 27.1 percent. In Kamchatka, lower survival rates (3.6 to 21.4 percent) have been reported for the period from fertilization to the beginning of the fry stage (Semko, 1954).

The survival during each period was calculated from the estimate of percentage survival given in Table 15. Survival within the

nth period was computed from the equation:

$$S_1 \cdot S_2 \cdots S_n = S \quad ,$$

or

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

where S is total survival in fresh water, and S_n is the survival within the nth period.

Because the time interval was not equal among the five periods, and a specific period was not exactly the same length for each of the three brood years, it was desirable to compute instantaneous mortality rates (Table 16) to place mortality into terms comparable among all periods and all brood years. The equation (McNeil, 1966):

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

was used for determining the instantaneous mortality coefficient; where t, the interval of time, is in months (1 unit is equal to 1 month), the symbol j represents the brood year, and n is the study period.

Higher mortality rates through most of the periods making up the first year of life were obtained for the 1963 brood than for the 1964 and 1965 broods. Density dependent factors, such as superimposition of redds and emigration of fry from the stream because of

lack of living space, may explain the high mortality of the 1963 brood. The population of eggs of the 1963 brood was estimated to be four times that of the 1965 brood and six times that of the 1964 brood.

Table 16. Estimated instantaneous mortality coefficients during five periods in the life of three brood years of coho salmon in Sashin Creek.

	Instantaneous mortality coefficient in period				
Brood year	1	2	3	4	5
1963	0.34	0.38	1.28	0.12	0.22
1964	0.21	0.30	1.89	0.06	0.56
1965	0.19	0.36	0.87	--	--

The highest rate of mortality for all three brood years occurred between the first and second population estimate of the first summer of life (period 3); during July and the first half of August. I consider predation as the major cause of this high rate of mortality.

The slightly lower mortality of the 1965 brood compared to the 1964 brood during period 3 may have resulted from the presence of fewer fingerlings in Sashin Creek in the summer of 1966 than in the summer of 1965; and therefore, fewer fry may have been lost to predation by fingerling coho in 1966 than in 1965.

Because the mortality was highest consistently in period 3, I feel that the first summer in the fresh-water life of coho salmon should receive emphasis in future studies of mortality.

The mortality rate from egg deposition to immediately before fry emergence (period 1) for the 1963 brood was about 1.5 times that for either the 1964 or 1965 broods. Since the egg deposition in 1963 was estimated to be considerably greater than in 1964 or 1965, an overestimation of egg deposition, or a compensatory mortality factor, such as selection of inferior redd sites or superimposition of redds, were probably causes of high mortality of the 1963 brood.

The over-wintering mortality (period 4) diminished considerably from the mortality of the first summer. Mortality due to predation probably declined during this period. In the winter months, the feeding rate of cold-blooded predators declines. In addition, ice and snow, and lowered activity and availability of the prey lessen the hunting success of warm-blooded predators feeding on young coho. The mortality rate increased again during the second summer, but only to a third or less of the rate during most of the first summer.

Mortality of fry in summer and winter could be overestimated by emigration from the creek. Fry emigration was estimated in summer by fishing the weir or a fyke net, and was found to be minor. Low mortality in period 4 suggests that few fry emigrated in fall, winter, or spring.

SUMMARY

Coho spawners enter Sashin Creek in variable numbers from year to year. Although a count of the number of coho entering Sashin Creek each year has been made at the weir since 1934, the total count has been incomplete in most years.

During the three years of this study, 311, 28, and 124 adult coho were counted at the weir in August and September. However, observations of the spawning effort for each year, and the mean redd life of coho females in 1965, were used to estimate that 423, 65, and 94 coho spawned in Sashin Creek in 1963, 1964, and 1965, respectively.

Tagging experiments conducted during the 1965 studies of adult coho, indicated that only one-half of the number of spawners were estimated using the redd-life method. Because two estimates of the 1965 population of coho spawners made from marked to unmarked ratios were in close agreement, and because the redd-life method of estimating the 1965 population of coho spawners was lower than the total observed passing through the weir, I feel that the weir counts and redd-life methods of estimation are not accurate estimators of the population of coho spawners in Sashin Creek. A more accurate estimate of spawner escapement can be obtained by tagging a portion of the escapement prior to spawning, and then making an estimate of

population size from marked to unmarked ratios obtained on periodic surveys of the spawning grounds.

Fewer coho spawners occupied the upper study area of Sashin Creek than either the middle or lower areas in all three years of this study. Between one and ten percent of the total escapement for each of the years was observed in the upper area.

The effect of coho spawning activity on the survival of pink salmon embryos was investigated in 1965, and found to be insignificant under population ratios of coho and pink salmon observed in 1965. A detrimental effect to the survival of significant numbers of pink salmon embryos might result when relatively large numbers of coho and small numbers of pink salmon utilize Sashin Creek for spawning.

The 4_3 age-group made up 89 and 65 percent of the coho spawners that returned to Sashin Creek in 1965 and 1966, higher percentages than reported by other investigators. Growth and scale studies, and estimates of the population sizes of juveniles indicate that most coho remain in Sashin Creek for two summers.

Comparison of the number of circuli laid down on scales by fry in their first summer with the number of circuli to the first annulus on the fingerling scales, indicated some reabsorption of scales occurred during the winter months. As a result, back-calculations of lengths using scale measurements would be unreliable for coho from Sashin Creek.

Estimates of early summer populations of fry varied directly with potential egg deposition of the brood year. However, by early in the second summer of fresh-water life the 1963 and 1964 broods were approximately equal (3,000 and 4,500). Records of weir counts indicate that there is a relatively constant smolt migration from Sashin Creek (1,000 to 3,000).

Highest mortality during the fresh-water life of coho from Sashin Creek occurred in July and early August of the first summer in all three broods. The over-wintering mortality of fry was a small fraction of the mortality which occurred in any other period of the fresh-water life of the coho salmon. Mortality of embryos and pre-emerged alevins was highest for the large 1963 brood, suggesting that some of the mortality occurring before emergence is due to compensatory factors.

BIBLIOGRAPHY

Allen, George H. 1958. Notes on the fecundity of silver salmon (Oncorhynchus kisutch). Progressive Fish-Culturist 20:163-169.

Bond, Carl E. 1964. Professor, Fisheries and Wildlife. Unpublished data on 1964 studies of juvenile coho in Sashin Creek, Alaska. Corvallis, Oregon State University.

Briggs, John C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. Sacramento. 62 p. (California. Department of Fish and Game. Fish Bulletin no. 94)

Chamberlain, F. M. 1907. Some observations on salmon and trout in Alaska. Washington, D.C. 112 p. (U.S. Bureau of Fisheries. Document 627. Supplement to its 1906 Annual Report)

Chapman, Donald W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. Journal of the Fisheries Research Board of Canada 19:1047-1080.

_____. 1965. Net production of juvenile coho salmon in three Oregon streams. Transactions of the American Fisheries Society 94:40-52.

Chapman, Douglas G. 1948. A mathematical study of confidence limits of salmon populations calculated by sample tag ratios. International Pacific Salmon Fisheries Commission, Bulletin no. 2, p. 67-85.

Davidson, F.A. and S.J. Hutchinson. 1942. Natural reproduction of pink salmon studied at Little Port Walter, Alaska. Ecology 23: 234-235.

Davidson, F.A. et al. 1943. Factors influencing the upstream migration of the pink salmon (Oncorhynchus gorbuscha). Ecology 24:149-168.

Demory, Robert L. 1961. Foods of juvenile coho salmon and two insect groups in the coho diet in three tributaries of the Alsea River, Oregon. Master's thesis. Corvallis, Oregon State University. 68 numb. leaves.

Exploitation, scientific investigation and management of salmon (genus Oncorhynchus) stocks on the Pacific coast of the United States in relation to the abstention provisions of the North Pacific Fisheries Convention. 1962. International North Pacific Fisheries Commission, Bulletin no. 10, p. 53-60, 67-72, 77-78.

Foerster, R.E. 1955. The Pacific salmon (genus Oncorhynchus) of the Canadian Pacific coast, with particular reference to their occurrence in or near fresh water. International North Pacific Fisheries Commission, Bulletin no. 1, p. 1-56.

Foerster, R.E. and A. L. Pritchard. 1936. The egg content of Pacific salmon. Fisheries Research Board of Canada, Progress Reports of the Pacific Coast Stations no. 28, p. 3-5.

Foerster, R.E. and W.E. Ricker. 1953. The coho salmon of Cultus Lake and Sweltzer Creek. Journal of the Fisheries Research Board of Canada 10: 293-319.

Garrison, Robert L. 1965. Coho salmon smolts in ninety days. Progressive Fish-Culturist 27:219-220.

Gilbert, Charles H. 1913. Age at maturity of the Pacific coast salmon of the genus Oncorhynchus. U.S. Bureau of Fisheries, Bulletin 1912, vol. 32, document 767, p. 1-22.

_____. 1922. The salmon of the Yukon River. U.S. Bureau of Fisheries, Bulletin 1921-1922, vol. 38, document 928, p. 317-332.

Godfrey, Harold. 1965. Salmon of the north Pacific Ocean. Part IX. Coho, chinook and masu salmon in offshore waters. Coho salmon in offshore waters. International North Pacific Fisheries Commission, Bulletin no. 16, p. 1-40.

Gribanov, V.I. 1948. The coho salmon (Oncorhynchus kisutch)--a biological sketch. Nanaimo. 83 p. (Fisheries Research Board of Canada. Translation Series no. 370. Translated from Izvestiia Tikhookeanskogo N. - I. Instituta Rybnogo Khoziaistva i Okeanografii (TINRO) 28:43-101)

Hanavan, Mitchell G. and Bernard Einar Skud. 1954. Intertidal spawning of pink salmon. U.S. Fish and Wildlife Service, Fishery Bulletin 56:167-185.

Hunter, J.G. 1948. Natural propagation of salmon in the central coastal area of British Columbia. Fisheries Research Board of Canada, Progress Reports of the Pacific Coast Stations no. 77, p. 105-106.

_____. 1959. Survival and production of pink and chum salmon in a coastal stream. Journal of the Fisheries Research Board of Canada 16:835-886.

Koo, Ted S.Y. 1962. Age designation in salmon. In: Studies of Alaska red salmon, ed. by Ted S.Y. Koo. Seattle, University of Washington Press. p. 37-48.

Koski, K V. 1966. The survival of coho salmon (Oncorhynchus kisutch) from egg deposition to emergence in three Oregon coastal streams. Master's thesis. Corvallis, Oregon State University. 84 numb. leaves.

Kuznetsov, I. L. 1928. Some observations on spawning of the Amur and Kamchatka salmons. Nanaimo. 9 p. (Fisheries Research Board of Canada. Translation Series no. 22. Translated from Bulletin of the Pacific Scientific Fishery Research Station, Vladivostok, 2(3), 1928. Excerpts from p. 1-124)

Marr, John C. 1943. Age, length and weight studies of three species of Columbia River salmon (Oncorhynchus keta, Oncorhynchus gorbuscha, Oncorhynchus kisutch). Stanford Ichthyological Bulletin 2:157-197.

McNeil, William J. 1964. A method of measuring mortality of pink salmon eggs and larvae. U.S. Fish and Wildlife Service, Fishery Bulletin 63:575-588.

_____. 1966. Distribution of spawning pink salmon in Sashin Creek, Southeastern Alaska, and survival of their progeny. Washington, D.C. 12 p. (U.S. Fish and Wildlife Service. Special Scientific Report: Fisheries no. 538)

McNeil, William J. and W.H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. Washington, D.C. 15 p. (U.S. Fish and Wildlife Service. Special Scientific Report: Fisheries no. 469)

Merrell, Theodore R., Jr. 1962. Freshwater survival of pink salmon at Sashin Creek, Alaska. In: A Symposium on Pink Salmon, ed. by N.J. Wilimovsky. Vancouver, University of British Columbia, 1960. p. 59-72.

Neave, Ferris. 1948. Fecundity and mortality in Pacific salmon. Transactions of the Royal Society of Canada, ser. 3, 42(sec. V):97-105.

Pritchard, A.L. 1940. Studies on the age of the coho salmon (Oncorhynchus kisutch) and the spring salmon (Oncorhynchus tschawytscha) in British Columbia. Transactions of the Royal Society of Canada, ser. 3, 34(sec. V):99-120.

_____. 1947. Efficiency of natural propagation of Pacific salmon. Canadian Fish Culturist 1(2):22-26.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Ottawa. 300 p. (Fisheries Research Board of Canada. Bulletin no. 119)

Robson, D.S. and H.A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93:215-226.

Roos, J.F. 1960. Predation of young coho salmon on sockeye salmon fry at Chignik, Alaska. Transactions of the American Fisheries Society 89:377-379.

Rounsefell, George A. 1957. Fecundity of North American Salmonidae. U.S. Fish and Wildlife Service, Fishery Bulletin 57:451-458.

Salo, E.O. and William H. Bayliff. 1958. Artificial and natural production of silver salmon, Oncorhynchus kisutch, at Minter Creek, Washington. Olympia. 76 p. (Washington. Department of Fisheries. Research Bulletin no. 4)

Semko, R.S. 1954. The stocks of west Kamchatka salmon and their commercial utilization. Nanaimo. 131 p. (Fisheries Research Board of Canada. Translation Series no. 288. Translated from Izvestiia Tikhookeanskovo Nauchno-issledovatelskovo Instituta Rybnovo Khoziaistva i Okeanografii (Vladivostok) 41:3-109)

Shapovalov, Leo and Alan C. Taft. 1954. The life histories of the steelhead rainbow trout (Salmo gairdneri) and silver salmon (Oncorhynchus kisutch) with special reference to Waddell Creek, California, and recommendations regarding their management. Sacramento. 375 p. (California. Department of Fish and Game. Fish Bulletin no. 98)

Shumacher, F.X. and R.W. Eschmeyer. 1943. The estimate of fish population in lakes or ponds. Journal of the Tennessee Academy of Science 18:228-249.

Smoker, William A. 1953. Stream flow and silver salmon production in western Washington. State of Washington, Department of Fisheries. Fisheries Research Paper 1(1):5-12.

Snedecor, George W. 1956. Statistical methods. 5th ed. Ames, Iowa State University Press. 534 p.

U.S. Weather Bureau. 1956-1965. Climatological data. Alaska. Annual Summary. Vol. 42-51.

Wickett, W.P. 1951. The coho salmon population of Nile Creek. Fisheries Research Board of Canada, Progress Reports of the Pacific Coast Stations no. 89, p. 88-89.

Willis, Raymond A. 1954. The length of time that silver salmon spent before death on the spawning grounds at Spring Creek, Wilson River, in 1951-52. Fish Commission of Oregon, Research Briefs 5(1):27-31.

APPENDICES

APPENDIX A

Fork Length of Juvenile Coho Salmon (mm)

Area		1964						1965			
		July 7	July 15	July 21	July 28	July 31	August 18	[a] July 17		August 1	
Sashin Creek								fry	fingerlings	fry	fingerlings
	Range							34-44	55-80		
U	Mean							38.5	67.7		
	n							37	71		
	Range							34-44	53-89		
M	Mean							38.0	68.8		
	n							43	99		
	Range							35-45	51-86		
L	Mean							38.1	69.7		
	n							103	147		
	Range	31-46	33-48	32-55	34-50	33-52	37-59	34-45	51-89		
Total	Mean	36.8	38.8	37.5	39.1	38.8	45.1	38.2	69.0		
	n	43	92	35	91	39	56	183	317		
Funny Creek											
	Range									37-43	47-80
	Mean									39.1	62.1
	n									29	28

[a] Dates given for 1965 and 1966 measurements are mid-dates of the measuring period.

APPENDIX A (continued)

Area		1965				1966				
		August 11		September 29		June 27		July 8		July 14
		fry	fingerlings	fry	fingerlings	fry	fingerlings	fry	fingerlings	fry
Sashin Creek										
	Range	39-47	56-84	45-74	76-104	35-40	60-89	35-43	62-93	34-44
U	Mean	41.9	74.9	62.2	88.0	37.0	71.9	37.7	77.9	37.8
	n	17	24	73	11	33	24	24	48	50
	Range	37-46	56-90	59-69	84	34-43	53-85	33-47	58-95	33-46
M	Mean	40.5	70.6	64.3	84	37.4	67.6	37.7	75.4	38.9
	n	12	96	7	1	133	69	95	45	50
	Range	35-49	54-91	49-69	75-97	35-44	56-91	34-50	56-104	36-47
L	Mean	40.3	70.2	60.4	86.0	39.3	71.8	40.3	77.5	39.5
	n	99	102	7	2	60	135	101	56	50
	Range	35-49	54-91	45-74	75-104	34-44	53-91	33-50	56-104	33-47
Total	Mean	40.5	70.9	62.2	87.4	37.8	70.6	38.9	77.0	38.7
	n	128	222	87	14	226	228	220	149	150
Funny Creek										
	Range	35-46	49-91	39-70	71-105	34-39	50-98	34-50	50-102	36-47
	Mean	39.1	63.8	53.4	85.8	36.6	72.1	38.0	70.6	39.9
	n	84	43	61	44	61	78	102	105	50

APPENDIX A (continued)

Area		1966					
		July 29		August 14		September 8	
		fry	fingerlings	fry	fingerlings	fry	fingerlings
Sashin Creek							
	Range	34-56	55-98	38-58	60-102	44-68	67-102
U	Mean	46.4	76.3	48.1	82.0	57.3	86.7
	n	50	63	100	89	50	50
	Range	36-53	65-105	36-59	63-107	39-67	63-95
M	Mean	42.4	79.1	46.2	84.2	49.6	81.5
	n	53	58	100	100	100	10
	Range	36-55	68-102	37-60	65-106	46-68	69-113
L	Mean	43.0	81.6	46.2	84.6	58.0	87.8
	n	51	45	100	100	100	36
	Range	34-56	55-105	36-60	60-107	39-68	63-113
Total	Mean	43.9	78.7	46.8	83.7	54.5	86.6
	n	154	166	300	289	250	96
Funny Creek							
	Range	33-56	61-105	32-63	56-119	40-68	61-108
	Mean	40.8	75.5	44.7	81.1	52.1	85.3
	n	54	50	100	100	100	100

Appendix B

Estimates of Number of Juvenile Coho Salmon

Mid-date of estimate	Location	Fin clip used	Age-group	Number marked	Census sample size	Number of marked fish recaptured	Population estimate	95% Confidence interval
7/12/'64	Sashin Creek	[a] LV & RV	fry	1,454	4,421	123	51,852	43,939-62,216
8/12/'64	Sashin Creek	ULC	fry	1,475	1,929	174	14,711	12,725-16,697
7/17/'65	Sashin Creek	RV	fry	1,801	485	42	20,355	14,849-28,039
"	"	RV	fingerling	510	520	57	4,581	3,659- 5,960
8/1/'65	Funny Creek	LLC	fry	276	221	50	1,201	900- 1,601
"	"	LLC	fingerling	213	107	26	852	565- 1,283
8/11/'65	Sashin Creek	LV	fry	847	804	149	4,546	3,965- 5,294
"	"	LV	fingerling	949	581	143	3,836	3,356- 4,459
"	Funny Creek	LV	fry	221	244	54	984	762- 1,300
"	"	LV	fingerling	106	141	26	557	370- 841
6/27/'66	Sashin Creek	ULC	fry	2,263	2,541	163	35,077	30,436-40,951
"	"	ULC	fingerling	332	520	59	2,883	2,312- 3,731
"	Funny Creek	ULC	fry	716	509	225	1,616	1,474- 1,793
"	"	ULC	fingerling	78	160	49	251	187- 328

[a] LV, RV, ULC, LLC, and Anal refer to left ventral, right ventral, upper lobe of caudal, lower lobe of caudal, and anal fin clips, respectively.

APPENDIX B (continued)

Mid-date of estimate	Location	Fin clip used	Age-group	Number marked	Census sample size	Number of marked fish recaptured	Population estimate	95% Confidence interval
7/29/'66	Sashin Creek [a]	LLC	fry	3,002	2,957	660	13,434	12,584-14,394
"	"	LLC	fingerling	816	817	420	1,585	1,488- 1,701
"	Funny Creek	LLC	fry	208	338	67	1,037	816- 1,300
"	"	LLC	fingerling	223	257	147	389	354- 442
9/8/'66	[b] Area U	Anal	fry	227	378	93	915	757- 1,081
"	"	Anal	fingerling	63	155	20	468	293- 755
"	Funny Creek	Anal	fry	287	314	146	615	552- 700
"	"	Anal	fingerling	110	100	34	317	221- 451

[a] LV, RV, ULC, LLC, and Anal refer to left ventral, right ventral, upper lobe of caudal, lower lobe of caudal, and anal fin clips, respectively.

[b] Estimates of population size in the whole of Sashin Creek were not made.