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VARIABILITY IN PINK SALMON ESCAPEMENTS ESTIMATED FROM SURVEYS ON FOOT

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CONTENTS

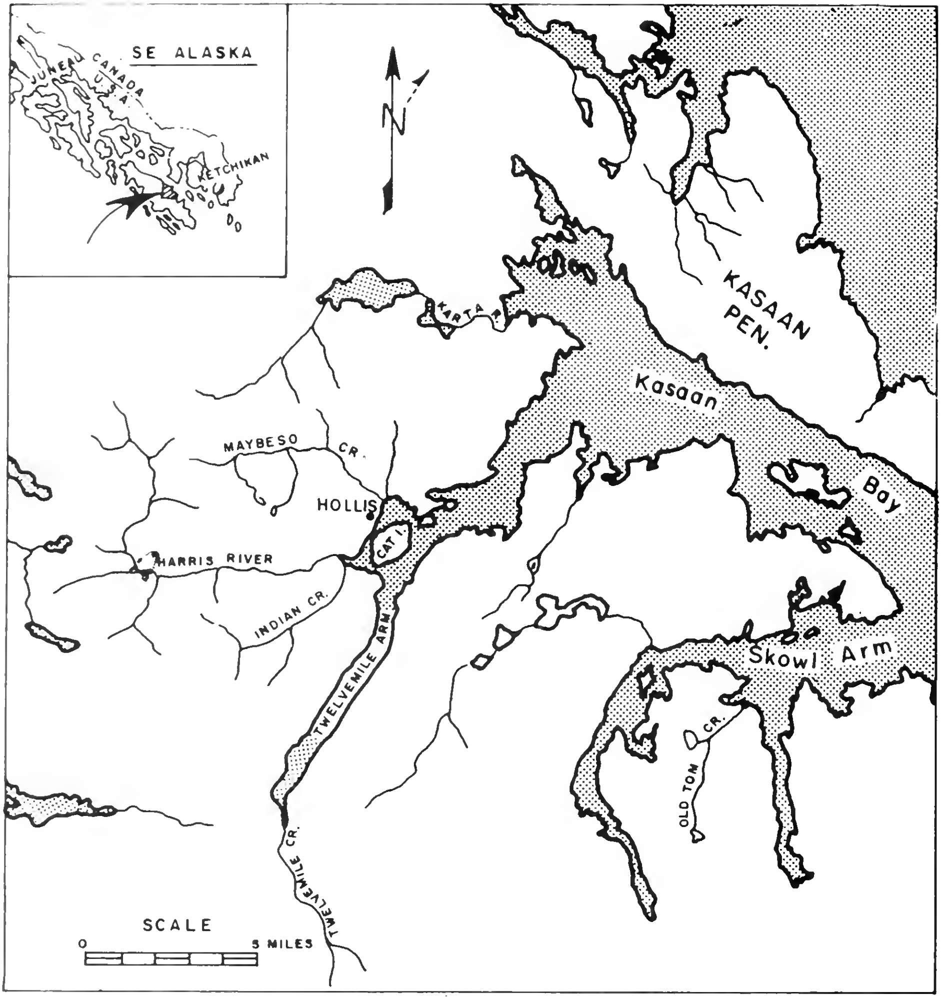

Figure 1.--Area of biological investigations of effects of logging on salmon by Fisheries Research Institute, 1956-58.

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ABSTRACT

Spawning pink salmon were enumerated in five study streams in the Hollis area of Southeastern Alaska. One stream was logged, two were being logged, and two were unlogged. Because enumeration required the ground survey as well as other methods, tests were made to assess variability in estimates of pink salmon abundance from surveys on foot between different observers and between successive counts by the same observer. Variability was lower when observers counted spawning salmon in well-defined riffle areas than when they counted in both pools and riffles. A method is proposed for obtaining more reliable indices of abundance from routine foot surveys.

INTRODUCTION

Because of increased logging in Southeastern Alaska, a need arose to evaluate the effects of logging on salmon. To satisfy this need the Alaska Forest Research Center began a study of physical changes in logged and unlogged streams in 1949, and the Fisheries Research Institute started biological investigations in 1956 under a contract awarded by the U.S. Fish and Wildlife Service utilizing Saltonstall-Kennedy funds.

The Hollis area of Kasaan Bay in Southeastern Alaska was the principal location for the Institute's research (fig. 1). Study streams were Harris River and Twelvemile Creek, which are being logged; Maybeso Creek, which had been logged; and Indian and Old Tom Creeks, which are unlogged and were used as control streams.

One of the factors studied was the size of yearly escapements of spawning salmon. This information was needed to define levels and patterns of escapements before and after logging so that postlogging changes might be detected. The abundance of spawners was assessed by various methods, such as surveys from the air and on foot, counting from towers, and mark and recovery techniques.

Surveys on foot have been used extensively to determine abundance of salmon in streams in Alaska and other West Coast States for many years. Although it has been recognized that variability existed in estimates made on such surveys, seldom has this variability been evaluated quantitatively.

Since we were using foot surveys as one of our methods, we tested variability in estimates of pink salmon (*Oncorhynchus gorbuscha*) made on foot surveys by different observers under different conditions.

GENERAL DESCRIPTION OF STREAMS

Streamflow in all five of the streams studied is subject to wide and rapid variation because of precipitation, which is usually heavy in October and November. In all but Old Tom Creek most pink salmon spawn in intertidal zones, and chum (*O. keta*) and coho (*O. kisutch*) salmon usually spawn above tidal influence.

Harris River, the largest of the five streams is 40 to 150 feet wide and has a watershed of 32 square miles. About 8 miles of the stream is used by salmon. Average gradient for the first 3.3 miles is 0.30 percent (James, 1956).

Indian Creek, 15 to 50 feet wide, is confluent with the Harris River at approximately the 12-foot tide level. It has a watershed of 9 square miles and an average gradient of 1.0 percent for 1.8 miles (James, 1956). Only

Note.--The author is presently with the Alaska Department of Fish and Game, Kodiak.

about one-half of this stream is used by pink and chum salmon.

Maybeso Creek is 20 to 60 feet wide, and has a watershed of 15 square miles. More than 5 miles of stream are accessible to salmon. Average gradient is probably higher than for the other study streams (James, 1956, gives the gradient for 500 feet as 4.66 percent, but this high gradient does not prevail upstream from the area measured). This stream has an obstruction which may block salmon. A stepped falls at the mouth has, on periods of low stream discharge and small high tides, caused pink and chum salmon to die unspawned because they could not enter the stream.

Twelvemile Creek is 30 to 70 feet wide and has a watershed of 14 square miles. About 5 miles are accessible to salmon, but spawning occurs mostly in the lower reaches. Average gradient for 8,750 feet from lower intertidal zone upstream is 0.12 percent (personal communication from G. A. James, Alaska Forest Research Center).

Old Tom Creek has a watershed of 7.5 square miles. It is the only stream of the five that is connected to lakes, of which there are two: one is 85 acres, the other 62 acres. The stream forks about a mile above tidewater. Average gradient is about 0.79 percent (James, 1956).

VARIABILITY IN ESTIMATES

Counts made on foot surveys give rough indices of numbers of salmon using the streams. Foot surveys have usually been conducted in Alaska by making two to five visits to a stream during a spawning season. Stream surveyors walk up a stream and estimate total numbers of live salmon in pools and on riffles. Spawners are not a static population because they continually move in and die throughout the season. Therefore, although periodic counts give a point estimate in time, a peak count is a reliable index only insofar as escapement curves are the same shape year after year. However, if we know the average duration of life of spawning salmon and if we confine counts to riffles, by conducting several surveys we can correct for this type of error (Gangmark and Fulton, 1952). Counts must be restricted to riffles because (1) numbers of fish in deep pools cannot be estimated reliably and (2) variability in length of life of salmon in pools is probably greater than variability in length of life of salmon after they commence spawning and are on the riffles (we have observed tagged pink salmon in pools for weeks, while average length of time on riffles is 5 to 12 days).

In this paper differences between estimates and the true population are not considered. Discussion is limited to variability between estimates of different observers and between successive estimates by the same observer. Although this type of variability has been discussed by Bevan (1961) for aerial surveys, it has not been evaluated for foot surveys.

Testing Procedures

Tests of variability were conducted under two sets of conditions in Hollis area streams in 1956 and 1957. The first set of conditions is termed "ideal" and the second, "normal."

In the first set counts were made only on shallow spawning riffles where salmon were clearly visible, boundaries were clearly defined, and there was little in and out movement. Counting was done from the bank so that fish would not be disturbed. Each observer made a series of counts, one immediately following the other; each used the same path and had the same angle of vision. Light or other conditions changed little in the short time needed to complete an experiment (usually less than one-half hour). In most cases Polaroid glare shields were worn.

In the second set counts were made on either a large part or the entire length of a stream that included both pools and riffles. This method is similar to that used on routine foot surveys in the past.

Observers were coded by number in all tests. Veeder-Root hand counters with the tabulation covered with tape were used, and results were recorded without informing observers of the number on the counter. All observers were briefed on proper procedure.

Results of First Set of Tests

Basic data, mean, standard deviation (s), and coefficient of variation (C.V.) for four tests conducted under ideal conditions show the variation to be expected between observers and between successive counts by the same observer when 30 to 250 salmon are on a riffle (table 1). When the number of salmon to be estimated is low, variation is high. It decreases with increasing numbers of salmon up to a point and then again increases with increasing numbers of salmon.

Analysis of variance (table 2) shows a significant F value (95 percent) only once out of eight times, and this in relation to difference between observers in test IB. In all four experiments variance ratio was higher between observers than between successive counts by the same observer.

TABLE 1.--Results of four tests of variability between counts of observers and between successive counts by same observer, Hollis area streams, 1956-57

Test IA - Twelvemile Creek study area 2, September 1, 1956

Observer	Count (no. of fish)			Combined	Mean	s	C.V.
	1	2	3				
1.......	110	112	109		110.3	1.6	1.4
2.......	121	129	124		124.7	4.1	3.3
3.......	111	122	136		123.0	12.5	10.2
4.......	118	137	111		122.0	13.5	11.0
5.......	107	111	124		114.0	8.9	7.8
Combined					118.8	[1] 9.3	[2] 7.8
Mean	113.4	122.2	120.8	118.8			
s	5.8	11.1	11.1	[3] 9.7			
C.V.	5.1	9.1	9.2	8.2			

Test IB - Harris River study area 1, September 7, 1956

Observer	Count (no. of fish)			Combined	Mean	s	C.V.
	1	2	3				
1.......	200	170	210		193.3	20.8	10.8
3.......	171	178	168		172.3	5.1	3.0
4.......	210	212	195		205.7	9.3	4.5
5.......	203	250	254		235.7	28.4	12.0
Combined					201.8	[1] 18.4	[2] 9.1
Mean	196.0	202.5	206.8	201.75			
s	17.2	36.5	36.0	[3] 31.2			
C.V.	8.8	18.0	17.4	15.5			

Test IC - Harris River study area 1, September 10, 1957

Observer	Count (no. of fish)			Combined	Mean	s	C.V.
	1	2	3				
1.......	35	21	36		30.7	8.4	27.4
2.......	33	40	43		38.7	5.1	13.3
6.......	25	35	31		30.3	5.1	16.7
7.......	21	30	32		27.7	5.9	21.2
8.......	31	49	44		41.3	9.3	22.5
Combined					33.7	[1] 7.0	[2] 20.8
Mean	29.0	35.0	37.2	33.7			
s	5.8	10.5	6.1	[3] 7.8			
C.V.	20.1	30.1	16.3	23.1			

Test ID - Old Tom Creek, September 12, 1957

Observer	Count (no. of fish)				Combined	Mean	s	C.V.
	1	2	3	4				
2.......	206	217	245	259		231.8	23.8	10.3
6.......	215	269	240	236		240.0	22.2	9.3
7.......	229	196	191	227		210.8	20.1	9.5
Combined						227.5	[1] 22.3	[2] 9.8
Mean	216.7	227.3	225.3	240.7	227.5			
s	11.6	37.6	29.9	16.5	[3] 26.0			
C.V.	5.4	16.5	13.3	6.9	11.4			

[1] A measure of variability between replications obtained from the combined sums of squares of the deviations from the respective row means.
[2] Coefficients of variation (in percent) for combined data are average standard deviations divided by overall means.
[3] A measure of variability between different observers obtained from the combined sums of squares of the deviations from the respective column means.

Table 2.--Summary of analysis of variance data for tests conducted under ideal field conditions, Harris River, 1956-57

Test	Between observers		Between counts	
	df	F	df	F
IA	4	1.471 n.s.[1]	2	1.250 n.s.
IB	3	5.178 [2]	2	0.021 n.s.
IC	4	2.230 n.s.	2	2.049 n.s.
ID	2	1.574 n.s.	3	0.505 n.s.

[1] N.s. means not significant.
[2] Statistically significant at the 5-percent level.

Results indicate that under ideal conditions, variability in riffle counts was low between different observers and between successive counts by the same observer.

Results of Second Set of Tests

Test IIA.--Five observers counted live pink salmon in the Harris River intertidal zone (containing both pools and riffles), first in an upstream direction and then in the same area in a downstream direction. Results are given in table 3.

Analysis of variance of these data shows no significant difference (95 percent) either between observers or between counts.

Test IIB.--Three observers counted live pink salmon in Harris River from the 13-foot tide level to the Fisheries Research Institute terminus (about 8,000 feet; such a terminus marks the end of a survey area and is usually located upstream from greatest abundance of spawners). The counting area was divided into three sections and subdivided into pools and riffles (some variability may have occurred because of an observer's idea of what constituted a pool and what a riffle, but these were fairly well defined). Results are given in table 4.

In this test variability between observers was generally high and was higher in estimates of numbers of salmon in pools than on riffles. Very high variation in counts of salmon in pools in section 2 (C.V. almost 100 percent) is an indication of what we can expect from pool estimates.

Test IIC.--The observers who conducted test IIB counted live pink salmon in the same portion of the Harris River again on September 11, 1957. Results are shown in table 5.

Table 3.--Test IIA conducted in Harris River intertidal zone, September 10, 1957

Observer	Count upstream (no. of fish)	Count downstream (no. of fish)	Mean	s[1]	C.V.[2]
2	258	220	239	26.9	11.2
6	192	205	199	9.2	4.6
7	163	177	170	9.9	5.8
8	181	242	212	43.1	20.3
10	170	188	179	12.7	7.1
Mean	192.8	206.4			
s	38.08	25.79			
C.V.	19.8	12.5			

[1] Standard deviation.
[2] Coefficient of variation (in percent).

Table 4.--Test IIB conducted in Harris River for a distance of 8,000 feet, September 2, 1957

Observer	Section 2		Section 3		Section 4		Total for stream
	Pools	Riffles	Pools	Riffles	Pools	Riffles	
8	515	104	110	46	45	8	
9	93	128	46	21	121	9	
10	127	67	79	37	128	17	
Mean	245	100	78	35	98	11	567
s[1]	233	31	32	13	46	5	227
C.V.[2]	95.3	30.8	40.9	36.6	47.0	43.8	39.9

[1] Standard deviation.
[2] Coefficient of variation (in percent).

Table 5.--Test IIC conducted in Harris River for a distance of 8,000 feet, September 11, 1957

Observer	Section 2		Section 3		Section 4		Total for stream
	Pools	Riffles	Pools	Riffles	Pools	Riffles	
8	10	148	100	13	60	35	
9	66	129	0	0	79	47	
10	22	164	32	23	94	55	
Mean	33	147	44	12	78	46	359
s[1]	29	18	52	12	17	10	35
C.V.[2]	90.1	11.9	117.2	96.5	21.9	22.1	9.8

[1] Standard deviation
[2] Coefficient of variation (in percent)

Variability of estimates was again high in pools in section 2 and was also high in riffles in section 3. It is difficult to explain why observer 9 saw no fish in section 3, particularly since section division points were well marked. Apparently this was an error on the part of the observer.

Differences in variation between pool and riffle estimates by three observers in particular sections on September 2 and 11 appear random.

Tests IIA, IIB, and IIC all involved more than two observers. Four additional tests, IID, IIE, IIF, and IIG, were made to compare one observer's estimate with another's. Variability between observers in these tests is apparent (table 6). Data were analyzed on the bases of significance of differences of means and by analysis of variance. In some instances difference between means of observers was significant, in others not. Analysis of variance showed a significant difference between observers in only one test, IID. The degree of variation is more apparent from the data in table 6 than it would be from analyses of variance of the data, and therefore no analyses are presented.

Evaluation and Recommendation

Variability between different observers estimating numbers of live pink salmon was higher under normal than under ideal conditions. Under normal conditions variability

Table 6.--Results of tests IID through IIG where one observer's estimate of number of fish is compared with another's, Hollis area streams, 1956

Test IID - Twelvemile Creek, September 1, 1956

Section	Observer 2	Observer 3
1	512	403
2	0	0
3	14	6
4	17	22
5	200	141
6	200	53
7	34	35
8	120	90
9	178	139
10	112	86
11	596	420
12	103	64
Total	2,086	1,459

Test IIE - Twelvemile Creek, September 11, 1956

Section	Observer 3		Observer 4	
	Pool	Riffle	Pool	Riffle
1	301	379	142	331
2	0	23	0	27
3	0	44	0	31
4	24	63	20	43
5	0	79	0	66
6	0	112	100	98
7	0	165	0	117
8	760	149	372	125
9	0	266	0	248
10	516	283	200	250
11	0	659	50	513
12	550	108	400	104
Total	2,151	2,330	1,284	1,953

Test IIF - Indian Creek, September 2, 1956

Section	Observer 2		Observer 3	
	Pool	Riffle	Pool	Riffle
1	124	74	73	69
2	0	5	0	4
3	573	1,164	428	918
Total	697	1,243	501	991

Test IIG - Indian Creek, September 10, 1956

Section	Observer 3		Observer 4	
	Pool	Riffle	Pool	Riffle
1	144	163	89	26
2	0	76	0	72
3	121	977	0	1,198
Total	265	1,216	89	1,296

was higher when observers estimated numbers of salmon in pools than when they estimated them on riffles. In addition, variation generally increased with increase of mean estimate.

Such results indicate that to obtain the best indices of abundance of salmon from foot surveys, pools should be ignored, and numbers of salmon should be estimated only on riffles.

Therefore, I suggest that in small streams a sufficient number of estimates should be made of salmon on riffles to form an abundance curve. If average length of time salmon remain on riffles is known (this can be determined from small-scale tagging experiments), then total number of salmon can be calculated for the season.

In larger streams where, for some reason, fish cannot be counted on all the riffles, well-defined spawning riffles should be chosen at random (in some streams stratification with regard to upstream and intertidal zone or other classifications may be desirable). Summation of estimates for each index riffle furnishes an index of abundance for the stream that is comparable from stream to stream and from year to year.

This type of enumeration decreases variability because numbers of salmon in pools are not estimated. Second, it allows surveyors (in large streams) to concentrate on a few index riffles rather than attempt to estimate the number of salmon in the entire stream. Finally, it does away with the need to use the peak count as an index.

Environmental conditions such as light differences, turbidity, rain dimpling water surface, and stream stage can increase variability in estimates. Hence, time of counting should be standardized as much as possible around these variables.

SUMMARY AND CONCLUSIONS

1. A cooperative research program between the Fish and Wildlife Service, the Forest Service, and the Fisheries Research Institute to study effects of logging on salmon streams in Alaska started in 1956. Part of the program involved estimating abundance and distribution of adult salmon in five streams in the Hollis area of Kasaan Bay, Southeastern Alaska.

2. Tests of variability of estimates of different observers and of the same observer counting the same area more than once were made in 1956 and 1957. Results showed that:

a. In tests made under ideal field conditions (riffles only), variability of estimates of pink salmon (between different observers and between successive counts made by the same observer) was low.

b. In tests conducted under normal conditions (pools and riffles), variability between observers counting salmon in pools was much higher.

Therefore, it is suggested that periodic counting be restricted to shallow riffle areas so that an index of abundance can be obtained by using a method such as Gangmark and Fulton's (1952). Further, counting should be standardized around such variables as amount of available light, stream levels, and others.

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