TIME OF MIGRATION AND AGE GROUP STRUCTURE OF SOCKEYE SALMON (*ONCORHYNCHUS NERKA*) SPAWNING POPULATIONS IN THE NAKNEK RIVER SYSTEM, ALASKA [1]

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ABSTRACT

The annual sockeye salmon (*Oncorhynchus nerka*) migration to the Naknek River system, Alaska, was studied to determine to what extent major spawning populations were segregated by their time of occurrence in the run. The extent of segregation by age in the run and on the spawning grounds was also studied.

Daily tagging on the Naknek River and subsequent tag recovery on the spawning grounds showed that segregation of individual spawning populations by time of occurrence in the Naknek run is limited. There was a more or less complete intermingling of most spawning groups throughout the run; consequently, most spawning grounds derive their fish from all parts of the run and, generally, in proportion to the size of the daily escapement.

Daily escapement age analysis indicated the lack of marked segregation by age in the Naknek run. No seasonal trend in age was apparent in the 1962 Naknek run.

Differences in age characteristics of major spawning ground populations indicated segregation by age on the spawning grounds of the Naknek River system.

It is generally accepted that sockeye salmon (*Oncorhynchus nerka*), when mature, return to the river system of their origin to spawn. This homing tendency was recognized as early as 1738 (Krasheninnkov, 1754) and given formal expression as the "home-stream" theory in the early 1900's (Chamberlain, 1907). Over a period of many years, evidence in support of this theory was obtained from marking experiments in various river systems from Oregon to Alaska.

The applicability of the "home-stream" theory to individual spawning areas within a river system was first suggested by Gilbert (1914–16, 1918–20) in his investigation of the sockeye salmon of the Fraser River in British Columbia. He found widely differing scale types on fish from different parts of the Fraser River system. Several areas were characterized by spawning populations having scale types so radically different as to permit conclusive segregation of one spawning population from another. Gilbert concluded that the appearance in the fishery of fish with the different scale types could be used to ascertain changes in the racial composition of the catch. Since Gilbert's early work, timing and duration of abundance of various spawning groups have been established by tagging experiments (Thompson, 1945; Killick, 1955), and racial identification has been determined by scale studies (Clutter and Whitesel, 1956; Henry, 1961).

Studies on the Fraser River and several other major sockeye salmon systems in North America have shown that individual spawning populations tend to be segregated in their time of occurrence in the run. Each population appears to have its own specific requirements for survival that govern the time at which it migrates from the sea. For a number of river systems this time seems to

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[1] Based in part on a thesis submitted to the graduate school of the University of Hawaii, Honolulu, in partial fulfillment of the requirements for the degree of Master of Science in Zoology, June 1963.

be related to the distance fish must travel to reach the spawning ground and to the type of spawning area they use. In general, it seems that sockeye salmon with the greatest distances to travel occur in the early part of the run, while those with the shortest distances occur in the late part. This is quite evident on the Fraser River and is reported to occur also on the Copper River in central Alaska.[2]

Segregation of spawning groups in time by the type of spawning area utilized has been reported in some systems.

Barnaby (1944) found that fish occurring early in the run populate all the spawning streams entering Karluk Lake on Kodiak Island, whereas most of those appearing late in the run use only the larger streams and lake beaches. Tagging studies on the Skeena River in British Columbia (Fisheries Research Board of Canada, 1957) indicate that sockeye salmon bound for the smaller tributary streams of Babine Lake pass through the fishery earlier than those bound for the outlet spawning grounds.

Seasonal timing may also be related to the age of fish. Rounsefell (1958) presents evidence that "the age of downstream migration has a negative effect on the season of return. The 2-year migrants run first, followed by the 3-, 4-, and finally the 5-year migrants.[3] The ocean age, on the contrary, has a positive effect. The 4-ocean fish run earliest, followed in succession by the 3-, 1-, and 0-ocean fish groups."[4] Similar changes in age composition during the run were reported for the Copper River by Thompson.

Segregation of age groups of sockeye salmon by lake system and by spawning grounds within a lake system has also been reported in the literature. Although the 4_2 age group[5] dominates the Fraser River run annually, three races—the Chilko, Taseko, and Birkenhead—are characterized by a consistent contribution of the 5_3 age group or "2-year-in-the-lake" fish (Henry, 1961). Koo and Smith (1960) noted that various localities in the Iliamna-Clark system of the Kvichak River drainage in Bristol Bay (fig. 1) showed different age compositions. They stated that this was clear evidence of the segregation of subpopulations. Segregation of spawning groups in time and by age might also occur in the commercially important sockeye salmon runs of other river systems of Bristol Bay.

Knowledge of segregation is basic to understanding the dynamics of sockeye salmon stocks. Further, it would provide information essential in designing studies to identify and determine the abundance of populations in the fishery or in the trunk stream before they disperse to the spawning grounds. Finally, such knowledge would have application in showing whether, and to what extent, individual spawning populations could be managed independently in the fishery and what effect present and contemplated regulatory policies could have on these populations.

The purposes of this study were: (1) To determine the extent that major spawning populations of Naknek sockeye salmon may be segregated by time of occurrence in the run, (2) to determine by age study the seasonal pattern of age distribution, and (3) to determine age segregation on the spawning grounds.

The Naknek River system is one of the major producers of sockeye salmon in Bristol Bay (fig. 1). In some years the sockeye salmon run to the Naknek system has exceeded that to the Kvichak River system, which is generally the most pro-

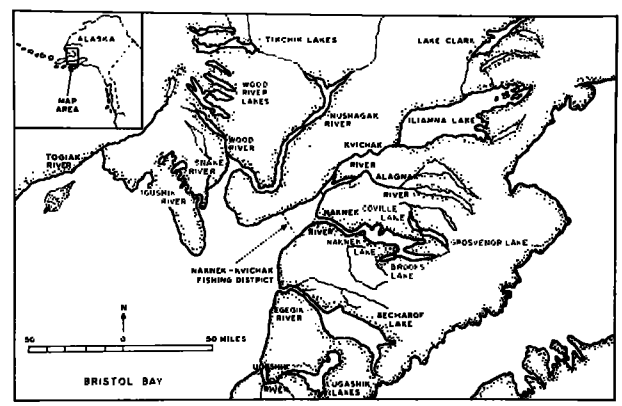

FIGURE 1.—Bristol Bay, showing locations of principal river systems and the Naknek-Kvichak fishing district.

[2] Thompson, Seton H. The red salmon (*Oncorhynchus nerka*) of Copper River, Alaska. Bureau of Commercial Fisheries Biological Laboratory, Auke Bay, Alaska. . (Manuscript).

[3] Refers to the age (figured from time of deposition of the egg) at which the juvenile salmon migrates from fresh water to the sea. Thus, a 2-year migrant is a fish that migrates to sea in its second year of life, a 3-year migrant in its third year.

[4] Refers to the number of winters spent in the ocean before the fish returns to fresh water to spawn.

[5] This method of designating the age of Pacific salmon was first introduced by Gilbert and Rich (1927). The first number denotes the total age of the fish (figured from time of egg deposition), and the subscript represents the year of life that it migrated from fresh water to the sea. Thus, a 4_2 salmon, called "four-two," refers to a fish that migrated to sea in its second year and returned as an adult in its fourth year of life.

ductive, and has made up most of the Naknek-Kvichak commercial catch. The true size of the Naknek run in any one year is difficult to assess because that portion of the run taken in the commercial fishery intermingles in the Naknek-Kvichak fishing district (fig. 1) with sockeye salmon bound for several of the other rivers entering Bristol Bay. In most years the total catch of sockeye salmon in this district has equaled or exceeded the total spawning escapement to these rivers. Spawning escapements in excess of 2 million have been estimated for the Naknek in recent years, giving some indication of the productivity of this system.

Commercial fishing for sockeye salmon in Bristol Bay is done almost entirely by a gill net fishery which is intense and efficient and capable of taking most of the fish in a district during an open fishing period, essentially eliminating spawning escapement. In the present management of the Naknek stocks the entire run is treated as a homogeneous mixture; therefore, to allow spawning escapement from all parts of the run, the fishery is regulated by periodically opening and closing the Naknek-Kvichak district to fishing.

The spawning grounds of the Naknek River system include a complex of four lakes, Naknek, Brooks, Grosvenor, and Coville, and interconnecting and tributary streams (fig. 2). The annual sockeye salmon migration to the Naknek includes fish destined for interconnecting streams, the tributary stream, and beach spawning areas of all four lakes. Before this study, it was not known if spawning groups could be identified by time of migration.

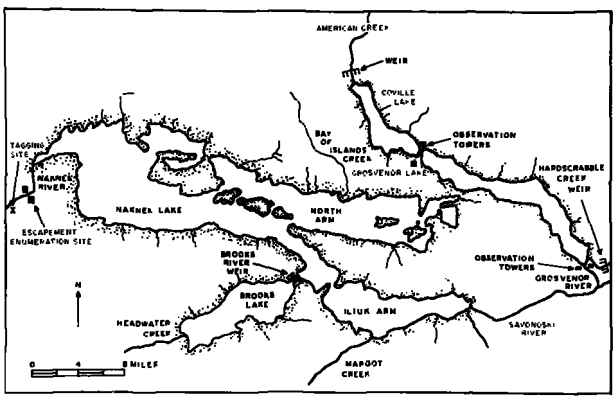

FIGURE 2.—Naknek River system, showing the location of tagging site, weirs, and observation towers.

The Naknek run is of relatively short duration, normally occurring between mid-June and late July, however, spawning takes place over a considerably longer period of time. Depending on the area utilized, spawning may begin as early as late July or as late as early October. The peaks of spawning activity occur about mid-August on the lake tributary streams and during the latter part of September on the interconnecting streams and lake beaches.

Segregation of populations by age groups by time of occurrence in the run and on the spawning grounds has been reported to occur in other river systems, but before this study, little was known of the extent to which this occurred in the Naknek River system.

MATERIALS AND METHODS

Of the various methods now used to identify races of salmon, the tag and recovery technique supplemented by age analysis was considered to be the most direct means for accomplishing the purposes of this study.

TAGGING OPERATIONS

Salmon were captured and tagged daily in 1962 by Bureau of Commercial Fisheries personnel at a site on the south bank of the Naknek River 24 miles above the mouth (fig. 2). Most of the upstream migration in the vicinity of the tagging site occurs along the south bank of the river.

Sockeye salmon ascending the trunk streams characteristically migrate in a narrow band close to shore. Specimens for tagging were caught in a "seine trap" (fig. 3), consisting of a 400- by 12-foot beach seine having 3-inch mesh (stretch measure). The seine was set by boat from shore and attached to a steel stake driven into the river bottom 150 feet offshore. The remaining 250 feet of seine was allowed to trail downstream with the current, forming a partial rectangular enclosure of about 38,000 square feet open on the downstream side. The free end of the net was attached to shore by a rope. The upstream portion of the seine attached to the stake was fitted with a trip lever that could be released by a rope leading to shore. When an observer located in a tower on the river bank saw fish entering the enclosure, the lever was tripped, releasing the net from the stake and allowing it to be carried downstream around the fish. Meanwhile, the free downstream

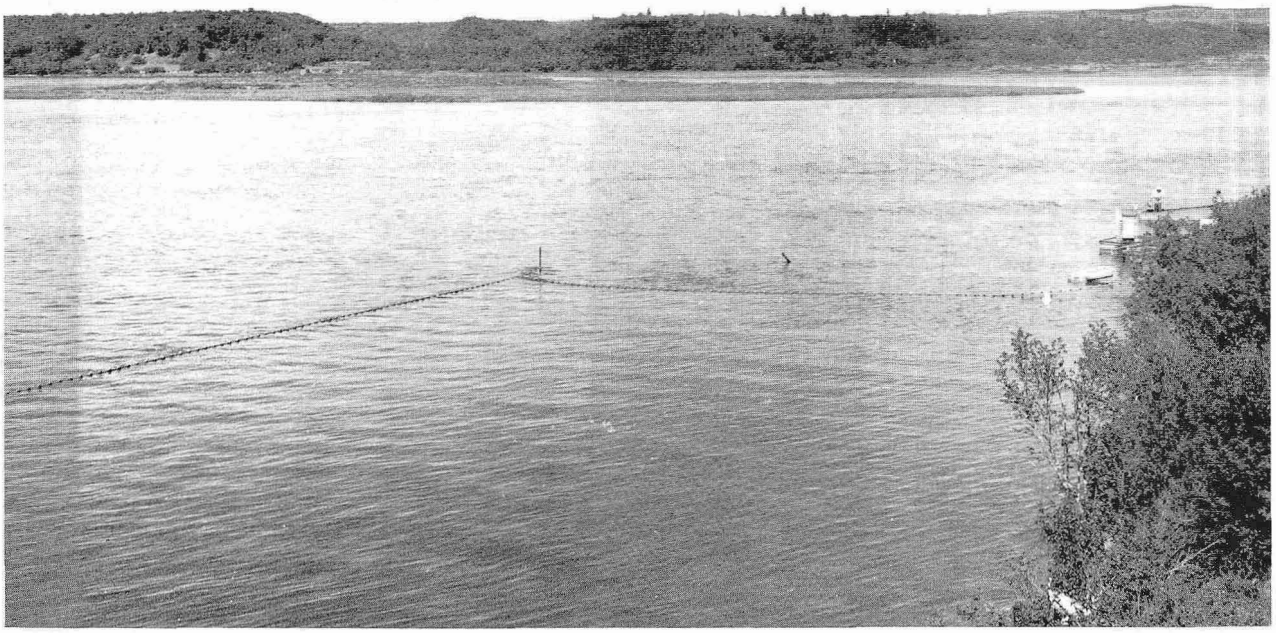

FIGURE 3.—Beach seine trap used to capture sockeye salmon for tagging, Naknek River, 1962. Dock is at right.

end of the net was pulled to shore, completely enclosing the fish.

Three men tagged the fish. The first dipped fish from the holding pen and transferred them to tubs containing an anesthetic; the second transferred the anesthetized fish to the tagging cradle and held it; and the third attached the tag and released the fish.

Two anesthetics were used. From June 24 to 30, tricaine methanesulfonate (MS 222) was used; from July 1 to 18, the remaining period of the experiment, quinaldine was used because of its more rapid action in producing anesthesia.

A pair of 1-inch plastic disk tags was attached to the fish (one on each side) with a nickel pin that was inserted through the fleshy part of the back about 1 inch below the base of the posterior to the insertion of the dorsal fin. A different color combination of tags was used each day (table 1), making it possible to determine the date of tagging through visual observation of tagged fish on the spawning grounds. The tags applied to the left side of the fish were serially numbered.

Between June 24 and July 18, 1962, 6,822 sockeye salmon were tagged (table 1), accounting for 0.94 percent of the estimated total run and giving an estimated tagged to untagged ratio of 1:106.

TAG RECOVERY

Tagged fish recoveries were in the form of both visual observations and actual recaptures. Observations provided information only on the date of tagging. Recaptures yielded additional information on age, length, and sex.

SAMPLING FOR AGE, SIZE, AND SEX

A portion of the fish captured and tagged each day was sampled to determine the age, size, and sex composition of the Naknek spawning escapement. Some fish from every seine haul were sampled, the exact number depending on the size

TABLE 1.—*Sockeye salmon in daily escapements and number and percent tagged, Naknek River, June 24 to July 21, 1962*

Date	Fish in daily escapement [1]	Tag color combination [2]	Fish tagged in daily escapement	
	Number		*Number*	*Percent*
June 24	0	B-G	2	[3]
25	6	W-Y	85	[3]
26	7,122	R-B	31	0.44
27	1,578	G-W	113	7.16
28	1,434	Y-R	6	0.42
29	10,974	B-W	324	2.95
30	74,286	R-G	726	0.98
July 1	20,214	Y-B	109	.54
2	10,956	W-R	144	1.31
3	20,112	G-Y	588	2.92
4	21,666	B-B	525	2.42
5	293,712	R-R	1,704	0.58
6	128,514	Y-W	713	.55
7	115,938	G-G	660	.57
8	6,024	B-Y	178	2.95
9	2,412	W-G	314	13.02
10	1,116	Y-Y	204	18.28
11	1,182	B-R	213	18.02
12	1,194	G-B	106	8.88
13	2,142	R-W	31	1.45
14	954	W-B	25	2.62
15	666	Y-G	11	1.65
16	792		0	
17	372		0	
18 [4]	216	R-Y	10	4.63
19	18			
20	42			
21	24			
Total	723,666		6,822	0.94

[1] Escapement estimates provided by Alaska Department of Fish and Game. Margin of error determined from previous studies is 3 percent of estimated total run.
[2] Colors used were blue (B), green (G), red (R), white (W), and yellow (Y). The first letter of a color combination designates the left side tag color.
[3] Percent of daily escapement tagged was not completed for the first 2 days. The earliest fish to arrive commonly held up between the tagging and tower sites below the rapids for a day or two until the schools build up in size.
[4] Tagging ended on this date.

of the catch and the magnitude of the daily escapement. If the escapement and seine catch were small, every fish was sampled; if they were large, every second, third, or fourth fish was sampled. A total of 3,094 fish, or about 45 percent of the total number tagged, were sampled.

Samples were also taken from individual spawning grounds during the period of spawning activity and from the weirs on Brooks River and American and Hardscrabble Creeks almost daily. In addition, fish obtained during beach seining for tag recovery records were sampled for age, size, and sex. Survey crews covering the smaller tributary streams for tags sampled the spawners in these areas.

Tagged fish were seen near the outlets of all lakes and on some spawning grounds. Observers in towers located on each bank of the river at the outlet of Grosvenor and Coville Lakes (fig. 2) recorded the number of fish and the color combination of all tags seen entering these lakes. At Brooks Lake observers recorded tagged fish as they passed through counting gates of the Brooks River weir (fig. 2). On certain spawning grounds it was necessary to rely largely on observations of tagged fish, because sometimes the fish could not be recaptured. This was particularly true for salmon spawning on Grosvenor Lake beaches and deep swift portions of Grosvenor River and Naknek Lake outlet areas. Here observers counted tagged fish from towers located on boats.

Actual recaptures of tagged fish were obtained from several sources. On Brooks River and American and Hardscrabble Creeks (fig. 2), tagged fish were obtained at weir traps. Tributary and interconnecting streams that were not checked by means of weirs were surveyed for tagged fish on foot or by boat several times during the spawning period. In some of the larger and deeper streams, tagged fish were recaptured by beach seining or by spearing with the use of skin diving and scuba diving techniques.

Total spawning ground recoveries amounted to 1,202 fish, or about 18 percent of those tagged (table 2). An additional 82 tagged fish were sighted, but the color combinations could not be positively identified.

Scales taken from sockeye salmon at the time of spawning have margins that are absorbed to such an extent that only fresh-water age is discernible on a projector. It was necessary to resort to length-frequency distributions of 2- and 3-ocean sockeye salmon derived from fish sampled at the tagging site (1,428 males and 1,621 females) for the assignment of ocean age to each fish sampled on the spawning ground. Approximately 98 percent of the fish in the 1962 escapement spent 2 or 3 years in the ocean. For assignment of ocean age, the dividing line used between fish of 2-ocean and 3-ocean age was 540 mm. for females and 553 mm. for males. Fish shorter than those lengths were considered as 2-ocean, and those longer as 3-ocean. I found no discrepancies between ages assigned to tagged salmon sampled twice—in the trunk stream and on the spawning grounds.

Fish were measured to the nearest millimeter from the center of the eye to the fork of the tail.

The sex of each fish was determined from external characteristics.

METHODS OF ANALYSIS

Seasonal Timing of Spawning Populations

The extent of segregation of individual spawning populations by time of occurrence in the run may

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TABLE 2.—*Numbers of tags recovered on spawning grounds—by color combination, date of tagging, and location—Naknek River system, 1962*

Location	Tag color combination [1] and number of salmon tagged (in parentheses)																								Total
	B–G (2)	W–Y (85)	R–B (31)	G–W (113)	Y–R (6)	B–W (324)	R–G (726)	Y–B (109)	W–R (144)	G–Y (588)	B–B (525)	R–R (1,704)	Y–W (713)	G–G (660)	B–Y (178)	W–G (314)	Y–Y (204)	B–R (213)	G–B (106)	R–W (31)	W–B (25)	Y–G (11)	R–Y (10)	
	June							July																	
	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18		
Naknek Lake:																									
Naknek River lake outlet		2	1			6			3		7	18	7	2	2		3		2		3	2		58
Bay of Islands Creek						1			3	1	3	17	4	1	2	1	5	1	1					40
Margot Creek						4	2	1	1	7	5	22	3	6		2	2	3	1				2	61
Brooks River		1		3		12	8	5	12	21	30	59	29	17	8	5	11	13	11	4	1			250
Grouped lateral streams		2	1				3		2	5	7	12	6	1		1	3	4		1				48
Iliuk Arm Beach												1	1											2
Miscellaneous [2]		1										1	1	1	1									5
Brooks Lake:																									
Grouped lateral streams [3]			[1]		[1]	[3]	[2]		[2]	[2]		[5]	[6]		[1]		[3]							[26]
Headwater Creek [3]									[2]			[1]	[2]			[1]						[1]		[7]
Weir count [4]		1	4	4	1	13	20	2	4	12	9	33	25	9	4	4	3	2			2	1	1	154
Savonoski River:																									
Dick's Creek							1		1	6		5	1		1									15
Grosvenor Lake:																									
Grosvenor-Coville connecting stream				1															1					2
Grouped lateral streams				1		1	1	2	1	3	4	6	5	4	1	3	1	1	1					35
Hardscrabble Creek		2		2		2	8		10	10	20	29	16	7	1	4	5	5	2	1				124
Grosvenor River										2	4	9	7	3		1	1	2	1	1			1	32
Beach spawning area											2	6	2				2							12
Coville Lake:																									
American Creek			1	4		11	14	3	10	34	47	94	57	24	5	18	16	12	3	1	2		4	360
Grouped lateral streams												2	2											4
Total		9	7	15	1	50	57	13	47	101	138	314	166	75	25	39	52	43	23	8	8	3	8	1,202

[1] Colors used were blue (B), green (G), red (R), white (W), and yellow (Y). The first letter of a color combination designates the left side tag color.
[2] Location of recovery unknown.
[3] The figures in this entry are placed in brackets because they are included in the Brooks Lake weir counts and have therefore been excluded from the total at the bottom of the column.
[4] Corrected upstream count taken as lake total.

be shown by the number and distribution of color combinations of tagged fish on the spawning grounds. Theoretically, with no segregation the frequency distributions of color combinations occurring on particular spawning grounds should be similar to those of the overall tagged population.

Because of the size and depth of many spawning areas we could not recapture or see all tagged fish present. If the likelihood of recapture or observation were equal for all tag color combinations, spawning ground recoveries should have reflected the relative proportion of tags from each day of tagging. Minor disagreement between actual and expected tag recovery proportions could have occurred as a result of sampling variation and would not necessarily indicate segregation. On the other hand, any substantial disagreement could be taken as a sign of segregation.

Actual tag recoveries were compared with the expected recoveries for major spawning grounds of the Naknek system in two ways: (1) By graphical comparison of the pattern of weighted spawning ground recoveries by day of tagging with the pattern of the daily escapement passing the tagging site, and (2) by statistical comparison using contingency χ^2 analysis (Snedecor, 1956) to test the hypothesis of like tag recovery distributions between spawning areas.

It would have been desirable to tag a given proportion of the run each day so that individual spawning populations would have been tagged in proportion to their daily abundance. This would have made it possible to compare directly the spawning ground recoveries for each day of tagging with the appropriate daily escapement size. This could not be done, however, because the size of the daily escapement, which was counted upstream from the tagging site, was unknown before each day's tagging.[6] Salmon in the escapement were counted daily from observation towers located on each bank of the river 1½ miles upstream from the tagging site (fig. 2). Counting migrating sockeye salmon from towers has been proved a reliable method of assessing the size of daily escapements in Bristol Bay [7] (Becker, 1962).

The number of recoveries was dependent on the number of fish tagged ($r=0.949$, d.f.$=21$, $P(0.001)$), but because a different proportion of the run was tagged each day, recoveries were weighted to make them directly comparable to the daily escapement size. Weighting was accomplished by adjusting the number of fish tagged each day to a standard proportion of the daily escapement. The standard selected was the proportion tagged (0.58 percent) on July 5, the day when the greatest number of fish were tagged (table 1). Weighted spawning ground recoveries for each day's tagging were obtained as follows:

$$W=\frac{0.58A}{X}$$

Where:

W = Weighted recoveries
A = Actual recoveries
0.58 = Proportion of the escapement tagged on day of greatest tagging
X = Proportion of the run tagged on day in question

For any spawning area, the proportion of adjusted recoveries for each day of tagging is thus directly comparable to the daily escapement. I obtained the graphical pattern of tag recoveries for selected spawning areas by plotting the percentage of the total adjusted recoveries by day of tagging and compared this pattern with that of the daily escapement, which was obtained by plotting the percentage of the total escapement on each day of tagging. The amount of disagreement or similarity between the two graphs indicated the extent of segregation.

We recovered adequate tags to make this comparison for most of the known major spawning grounds of the Naknek system; however, for some areas the difficulty encountered in sampling the spawning populations resulted in insufficient recoveries to make comparisons. These included the beach spawning areas of Grosvenor Lake, the tributary streams of the Savonoski River, and a "suspected" beach spawning area in Iliuk Arm of Naknek Lake (fig. 2). For most of the small lateral tributary streams with small spawning escapements, tag recoveries were so few that streams had to be grouped to provide sufficient recoveries for comparison.

Some problems were encountered in identifying tag color combinations. In shallow-water streams

[6] Estimates of the daily escapement size were provided by the Alaska Department of Fish and Game (table 1).

[7] Staff of the Administration of Alaska Commercial Fisheries. 1956. Progress report and recommendations for 1957. 34 pp. [Processed.]

(less than 5 feet deep), most tag color combinations were easily identified, but in deep-water spawning areas (more than 5 feet deep), most observers reported some difficulty in positively identifying green tags and in distinguishing light blue and yellow tags from white. Red tags were identified the most easily in deep water. Thus, the assumption of equal likelihood of observation for all tag color combinations would not hold true for fish in deep water. The degree of efficiency of observing tagged fish in deep water depends on the depth of the water and the tag color combination. Fortunately, most known spawning in the Naknek system takes place in water that is less than 5 feet deep.

In analyzing recoveries for the experiment, I compared the following spawning areas and the escapement in the manner described above.

1. Individual lakes, i.e., Naknek, Brooks, Grosvenor, and Coville. In this comparison the corrected upstream Brooks River weir count of tagged fish was used as the total recoveries for the lake. This was done because few tags were returned from the Brooks Lake tributary streams. The upstream tag count was corrected by deducting tagged fish that moved back downstream through the weir to spawn in Brooks River. For the other lakes, tag recaptures and sightings obtained by all methods (i.e., during stream surveys, at spawning stream weirs, by beach seining, and by skin diving) were totaled for all streams draining into each lake.

2. Individual, large major valley or terminal streams with similar physical characteristics and periods of spawning activity and with recorded escapements in excess of 10,000 fish. These include American, Hardscrabble, Margot, and Bay of Islands Creeks which drain into Coville, Grosvenor, and Naknek Lakes respectively (fig. 2). Headwater Creek, major tributary of Brooks Lake, had too few recoveries for comparison (table 2).

3. Interconnecting streams (Brooks and Grosvenor Rivers).

4. Grouped small lateral tributary streams of all four lakes combined.

5. Naknek River area at the outlet of Naknek Lake.

Recoveries for days or periods of tagging were arranged in contingency tables for comparisons between selected spawning areas, and the proportion of tags in each period was tested for independence by chi-square. Spawning areas compared in this manner were essentially those listed above. In addition, tag recoveries from the small lateral streams of each lake were grouped to provide adequate numbers for testing and were treated as a single spawning unit. Tag recovery proportions for lateral streams of each lake were compared and tested. Comparisons and tests were also made between spawning areas of unlike physical characteristics, escapement records, and spawning periods (i.e., between the large major valley streams, small lateral streams, and interconnecting streams).

For most of the areas compared, tag recoveries from single days of tagging were too few to permit tests of independence on a day-to-day basis, and sufficient recoveries were obtained by combining the recoveries from several continuous days of tagging into a number of periods that included all 23 days of tagging. Tests of independence were thus made on a period-to-period basis.

Tests for segregation were grouped into tagging periods based on the area of spawning. In the lakes, the 23-day tagging experiment was divided into seven tagging periods with 3 days in each period, except the first and last periods, which had 4 days. In the other spawning areas, it was necessary to group the taggings into three periods. These periods were unequal in length because they were based on the daily escapement pattern of the run (table 1). The first period, representing early-run salmon, included recoveries from taggings between June 24 and July 2. This period contained an early peak of abundance, which is usually characteristic of the Naknek sockeye salmon run. This early peak may represent spawning groups that are segregated in time of occurrence and destined for particular spawning areas. The second period representing middle-run fish, which compose most of the escapement, extended from July 3 to 8, inclusive. The third period, representing "tail-of-the-run" fish, included recoveries from July 9 to 18 taggings.

Age Segregation by Time of Occurrence on the Run and on the Spawning Grounds

Segregation of population by age groups by time of occurrence in the run was studied as follows. The percentages of the various age groups in the daily

escapement were determined from scale readings. Percentages for the four dominant age groups (4_2, 5_2, 5_3, and 6_3), which made up 98 percent of the 1962 escapement, were plotted graphically for each day of sampling. This was done for males and females, both separated and combined. The graphs were examined to determine if particular age groups tended to be segregated in certain portions of the run. Similar graphs were prepared for the percentage of salmon that had spent 2 and 3 years in fresh water and 2 and 3 years in the ocean. The 1962 escapement was composed almost entirely (99.8 percent) of fish of 2- and 3-fresh-water age, and 98 percent of 2- and 3-ocean age. These graphs were examined for the extent of segregation by both fresh-water and ocean ages.

Age segregation on the spawning grounds was studied by comparing the age composition of individual spawning ground samples with each other and with age composition of the total escapement. The age composition of the total escapement was derived from the daily percentage age composition, weighted according to the size of the daily escapement. The escapement and spawning ground age compositions were compared on the basis of age group and of fresh-water and ocean ages. Theoretically, with representative sampling of all spawning areas, a lack of segregation by age categories would be shown by close agreement between the total escapement and the individual spawning ground age compositions. Substantial disagreement would indicate segregation.

The frequencies of occurrence of the four age groups (i.e., 4_2, 5_2, 5_3, 6_3) in most of the run were arranged in a contingency table to compare the age compositions of the individual major spawning grounds of the Naknek system. The proportion of fish in each age group was then tested for independence by chi-square. A probability value of less than $P=0.01$ was considered to indicate unlike age compositions between the areas tested and, therefore, segregation by age on the spawning grounds.

RESULTS AND DISCUSSION

Extent of Segregation by Time of Occurrence in the Run

Graphical comparisons of the pattern of weighted recoveries by day of tagging with the pattern of the daily escapement are a somewhat subjective approach to studying the extent of segregation. On the other hand, statistical tests of like tag recovery distributions between spawning areas are objective in nature. Results obtained by both methods were similar.

Results of Graphical Comparisons

Graphical comparisons of the pattern of weighted tag recoveries for individual spawning areas by days of tagging with the pattern of daily escapement to the entire system are presented in figures 4–7.

It is obvious from these comparisons that most of the spawning areas derive their escapement from all portions of the run. In most areas the proportion of tag recoveries appears, in general, to be related to the size of the escapement on the date of tagging. Greater variability between the tag recovery and escapement pattern is apparent for such areas as Bay of Islands and Margot Creeks, Grosvenor River, and Naknek River at

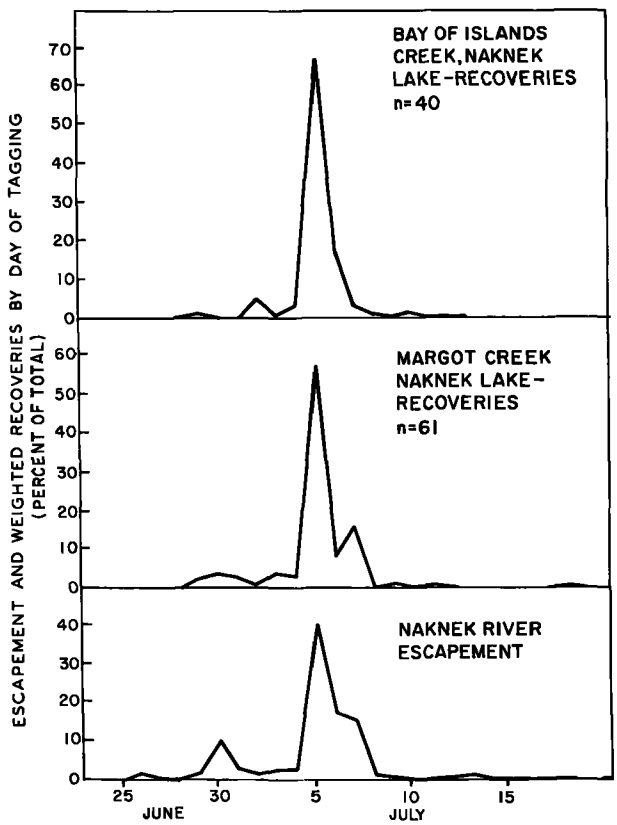

FIGURE 4.—Naknek River escapement and weighted spawning ground tag recovery distributions by day of tagging, 1962 (Margot and Bay of Islands Creeks).

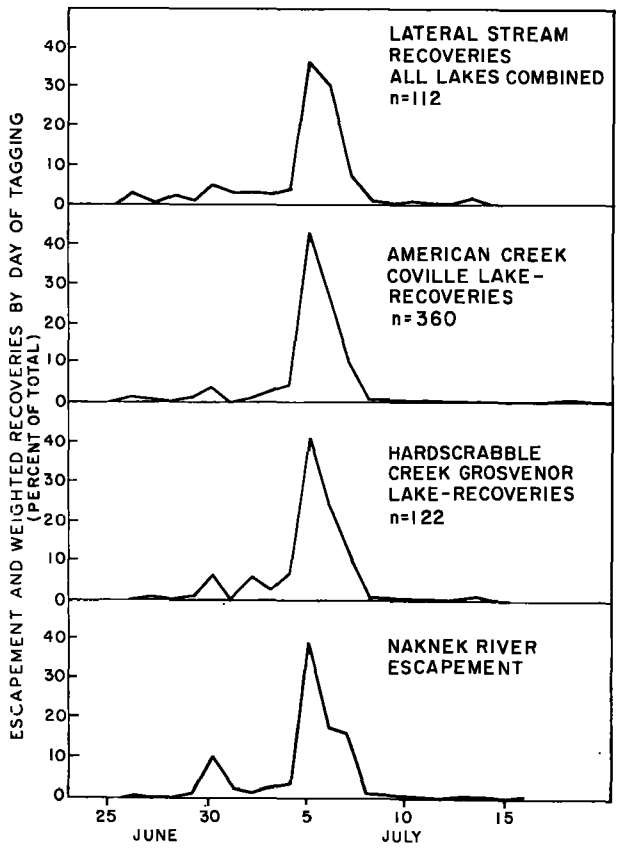

FIGURE 5.—Naknek River escapement and weighted spawning ground tag recovery distributions by day of tagging, 1962 (lateral streams, American Creek, and Hardscrabble Creek).

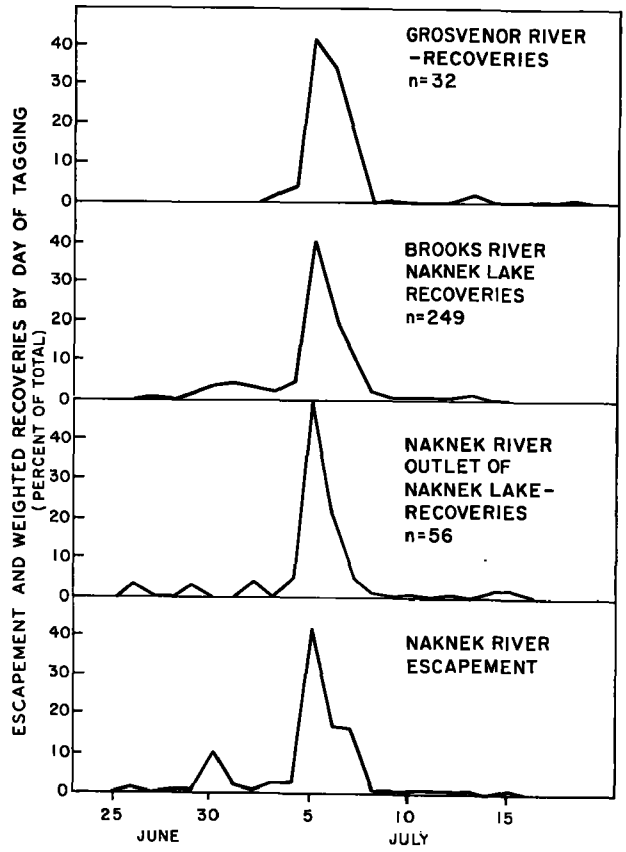

FIGURE 6.—Naknek River escapement and weighted spawning ground tag recovery distributions by day of tagging, 1962 (Naknek River, Brooks River, and Grosvenor River).

the outlet of Naknek Lake (figs. 4 and 6), which had a small number of recoveries (table 2). Spawning areas such as American Creek and Brooks River (figs. 5 and 6), which had a substantial number of recoveries, tend to conform more closely to the daily escapement pattern.

The tag recovery pattern for American Creek (fig. 5) is taken to be representative of the entire escapement into Coville Lake. American Creek, one of the most important spawning areas in the Naknek system, usually receives practically the entire spawning escapement entering Coville Lake. The escapement to the few small lateral streams of Coville Lake in 1962 was only a fraction of that which spawned in American Creek. Only four tags were recovered from these streams (table 2), and they do not change the pattern illustrated by the American Creek recoveries.

The small lateral streams of all lakes had too few tag recoveries for comparison with the escapement on an individual basis; however, the few tags obtained from individual lateral streams were from tags applied throughout the run. When these recoveries are grouped by lakes and weighted in the manner previously described, they provide a pattern quite similar to that of the escapement (fig. 5). The indication is that the escapement to the small lateral streams is also derived from all parts of the run and generally in proportion to the size of the daily escapement.

Two areas, however, seem to show some degree of segregation of their spawning populations. The pattern of recoveries for Brooks Lake shows a greater proportion of tags from the early portion of the run (i.e., before July 2) than the pattern for the other lakes (fig. 7). This is evident not

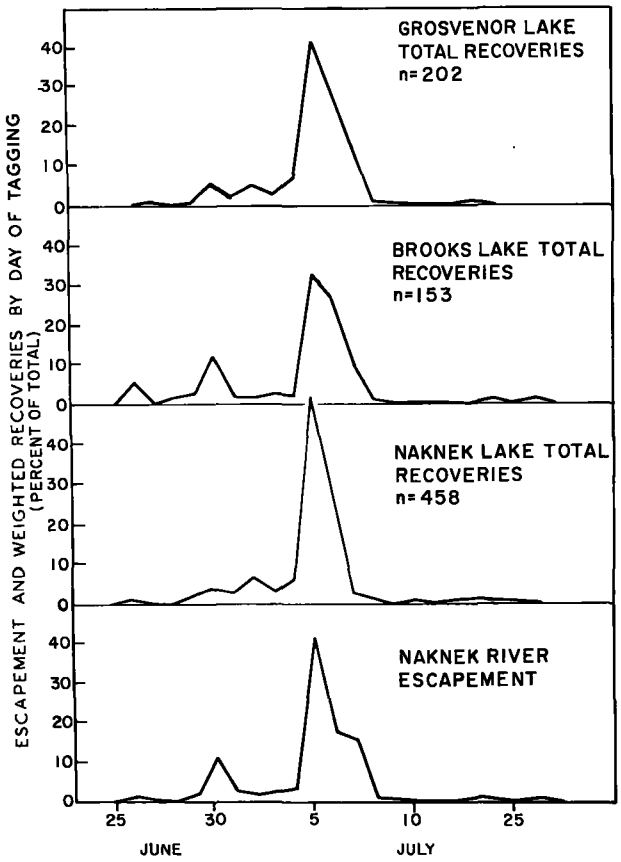

FIGURE 7.—Naknek River escapement and weighted spawning ground tag recovery distributions by day of tagging, 1962 (Grosvenor Lake, Brooks Lake, and Naknek Lake).

only in the Brooks River weir tagged fish count but also in the tag recoveries from the streams tributary to Brooks Lake (table 2).

Grosvenor River had no tagged fish from the early part of the run (fig. 6). Grosvenor River is one of the areas where considerable difficulty was experienced in recapturing tagged fish and in identifying the color combination of those sighted. It is possible, because of the generally smaller numbers of fish tagged in the early part of the run and the few tagged fish recaptured or identified (table 2), that sampling was inadequate and early-run fish were missed as a result of chance. On the other hand, fish from late-run taggings (i.e., after July 2) comparable in size to fish in some early-run taggings were recaptured or sighted in Grosvenor River. This plus the fact that tags were not recovered from the only large tagging day, June 30, in the early part of the run (table 1) strongly suggests segregation of the Grosvenor River population in the latter part of the run. Not enough tags were recovered, however, to formulate a definite conclusion concerning the segregation of the Grosvenor River spawning populations.

Results of Statistical Comparisons

Chi-square tests of the hypothesis of like recovery distributions for comparisons between similar and dissimilar spawning areas yielded results that substantiate those presented above. Probability values less than $P=0.05$ are considered to indicate unlike tag recovery distributions and, therefore, segregation in time of occurrence in the run.

For the comparison between major valley or terminal streams (American, Hardscrabble, Bay of Islands, and Margot Creeks (table 3)), a value of $\chi^2=5.38$, d.f.$=6$, $P=0.50$ was obtained. This high value of P indicates no significant difference between the tag recovery distributions for these streams and, therefore, little segregation of their spawning populations by time of occurrence in the run.

A value of $\chi^2=4.49$, d.f.$=4$, $P=0.37$ was obtained from the comparison of recovery distributions for the grouped lateral streams of Naknek, Brooks, and Grosvenor Lakes (table 4). Coville Lake lateral streams could not be included

TABLE 3.—*Numbers of tags recovered by dates of tagging for major valley streams, Naknek River system, 1962*

Stream	Tags recovered by dates of tagging			Total
	June 24–July 2	July 3–8	July 9–18	
Bay of Islands Creek	4	28	8	40
Margot Creek	8	43	10	61
Hardscrabble Creek	24	83	17	124
American Creek (Coville Lake)	43	261	56	360
Total	79	415	91	585

TABLE 4.—*Numbers of tags recovered by dates of tagging for grouped lateral streams, Naknek River system, 1962*

Lake	Tags recovered by dates of tagging			Total
	June 24–July 2	July 3–8	July 9–18	
Naknek	7	31	9	47
Grosvenor	6	23	6	35
Brooks	9	14	3	26
Total	22	68	18	108

in the comparison because of insufficient tag recoveries. This high value of P indicates a lack of segregation of lateral stream spawning populations by time of occurrence in the run.

The comparison between the total recovery distributions of Naknek, Brooks, Grosvenor, and Coville Lakes (table 5) yielded a P of less than 0.005, suggesting a difference in time occurrence in the run for the populations destined for these lakes. However, almost two-thirds of the chi-square value of 56.57, d.f.=18 is due to the occurrence of a greater than expected proportion of early-run tagged fish in the Brooks Lake escapement (fig. 7). If the Brooks Lake tag recoveries are excluded from consideration and a comparison made only between Naknek, Grosvenor, and Coville Lakes recovery distributions, the resulting $\chi^2=7.43$, d.f.=12, $P=0.82$. Thus, the recovery distributions for these three lakes are not significantly different, and segregation of their spawning populations as a whole is minimal. For Brooks Lake, however, results suggest that it derived a relatively greater proportion of its spawning population from the early part of the run than did the other three lakes.

TABLE 5.—*Numbers of tags recovered by dates of tagging for Naknek, Brooks, Grosvenor, and Coville Lakes, 1962*

Lake	Tags recovered by dates of tagging							Total
	June 24–27	June 28–30	July 1–3	July 4–6	July 7–9	July 10–12	July 13–18	
Naknek	11	36	61	233	50	60	13	464
Brooks	9	34	18	67	17	7	3	155
Grosvenor	5	12	26	110	25	21	3	202
Coville	5	25	47	202	47	35	7	368
Total	30	107	152	612	139	123	26	1,189

Comparison of the tag recovery distributions of unlike spawning grounds, which include the grouped lateral streams of all lakes, Brooks and Grosvenor Rivers (representing interconnecting streams), and American and Hardscrabble Creeks (representing major valley streams) (table 6), yielded a value of $\chi^2=14.87$, d.f.=8, $P=0.06$. This value is essentially at the level of probability ($P=0.05$) below which values of P are considered to indicate unlike tag recovery distributions. The cause of the large χ^2 and resulting low probability level is associated with the absence of early-run (June 24 to July 2) tagged fish in the Grosvenor River recoveries (fig. 6). More than one-third of the χ^2 value of 14.87 is caused by the lack of these early-run tagged fish. Although, statistically, the test does not indicate a tag recovery distribution for Grosvenor River unlike that of the other spawning grounds, the lack of early-run tagged fish in the recoveries and the resulting large chi-square suggest that this area may have derived its escapement primarily from the latter part of the run. If Grosvenor River recoveries are excluded from consideration and a comparison made only between the grouped lateral streams, American Creek, Brooks River, and Hardscrabble Creek, the resulting $\chi^2=8.70$, d.f.=6, $P=0.20$.

TABLE 6.—*Numbers of tags recovered by dates of tagging for unlike spawning grounds, Naknek River system, 1962*

Spawning ground	Tags recovered by dates of tagging			Total
	June 24–July 2	July 3–8	July 9–18	
Grouped lateral streams:				
All lakes	22	68	18	108
Major valley streams:				
American Creek	43	261	56	360
Hardscrabble Creek	24	83	17	124
Interconnecting streams:				
Brooks River	41	164	45	250
Grosvenor River	0	25	7	32
Total	130	601	143	874

Discussion

There is some evidence of heterogeneity between the individual spawning ground tag recovery distributions as compared above. Only Brooks Lake had a tag recovery distribution that differed significantly from those of the other spawning grounds. The distributions for both the lateral streams and the escapement as a whole show that a higher proportion of early-run fish entered Brooks Lake than the other three lakes. Grosvenor River recoveries indicate that it may have received its escapement primarily from the middle and later parts of the run (i.e., after July 2).

Apart from the above situations, however, the evidence presented fails to indicate any clear segregation of most of the known spawning populations composing the Naknek run. It is clear that the recovery distributions for most spawning areas are not significantly different from one another or from the seasonal escapement pattern in the trunk stream. Most areas apparently derive their spawning populations from all parts of the run and, generally, in proportion to the daily escapement.

As mentioned earlier, the Naknek River sockeye salmon run is of relatively short duration when compared with rivers like the Fraser and Karluk. The total spawning escapement enters the Naknek system during a 4- to 6-week period, and normally over half the total escapement occurs in a period of 3 to 5 days (table 1). Spawning activity, however, occurs over a period of 2½ months, although the period and duration of spawning are quite different for the various grounds used. Time of spawning apparently has little effect in producing segregation. Regardless of the characteristics of spawning activity, most grounds seem to receive their escapement proportionately from all parts of the run.

It seems apparent that the short duration of the Naknek run is not an adaptation to a single optimum spawning period for the Naknek system as a whole, and it is probable that the conditions responsible for the compressed nature of the run occur in the ocean before Naknek salmon reach Bristol Bay. Regardless of the cause, it is likely that the short duration of the run is responsible for the significant lack of segregation. The result is, of necessity, a more or less complete intermingling of the spawning populations composing the Naknek sockeye salmon run in the trunk stream and, therefore, in the fishery. In view of this, it seems impossible now to manage in the fishery the individual spawning groups composing the run.

AGE SEGREGATION BY TIME OF OCCURRENCE IN THE RUN

The daily percentages of the four dominant age groups (4_2, 5_2, 5_3, and 6_3) in the 1962 escapement were determined from samples of fish taken at the tagging site. Little difference was noted between the daily age composition of males and females. Both sexes showed similar daily fluctuations in abundance. The age data for males and females were, therefore, combined (fig. 8).

Although daily fluctuations in age composition of the escapement did occur, there were no marked changes in age composition during the run. Only the 5_3 age group appeared to increase in relative abundance toward the end of the run. During the peak escapement period of July 5–7 (table 1), the proportion of the 5_2 age group was somewhat higher and the 5_3 group lower than the overall seasonal average for these groups. Except for daily fluctuations, there appears to be little change

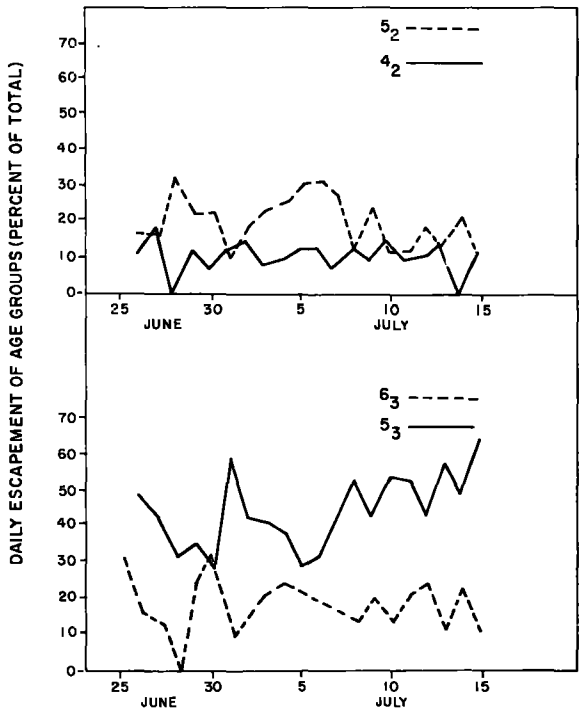

FIGURE 8.—Percent contribution of four dominant age groups of sockeye salmon by day of tagging in Naknek River escapement, 1962.

in the age composition of the escapement with the passage of time. Segregation on the basis of age groups appears to have been minimal in the 1962 Naknek escapement.

In figure 9 the daily age composition of the escapement is replotted by fresh-water and ocean age. When examined from this standpoint, only minor changes in age composition appear to occur during the run. The proportion of 3-fresh-water fish increases, while the 2-fresh-water group decreases slightly after the peak escapement period of July 5–7. Also, the proportion of 3-ocean fish is somewhat higher and that of 2-ocean fish lower during the peak escapement period. There is, however, no marked change in the proportion of any age category during the run. Segregation in time by ocean and fresh-water age appears to have been limited in the 1962 escapement.

To what extent the daily age composition of the Naknek escapement is altered by effects of the fishery is unknown. It is known, however, that the Bristol Bay gill net fishery tends to be selective for the larger or 3-ocean fish (i.e., the 5_2 and 6_3 age groups). It is possible that the fishery could account for the marked day-to-day fluctuations

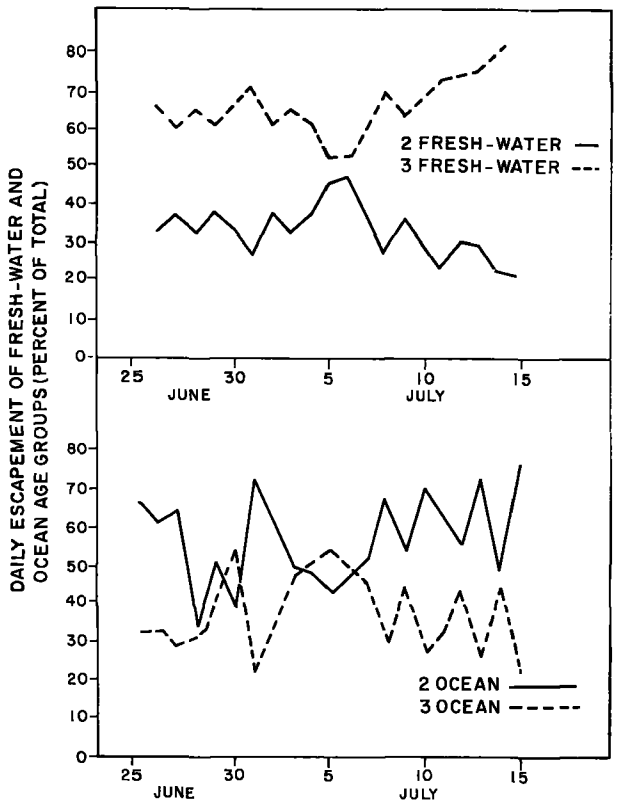

FIGURE 9.—Percent daily age composition of sockeye salmon by fresh-water and ocean age, Naknek River escapement, 1962.

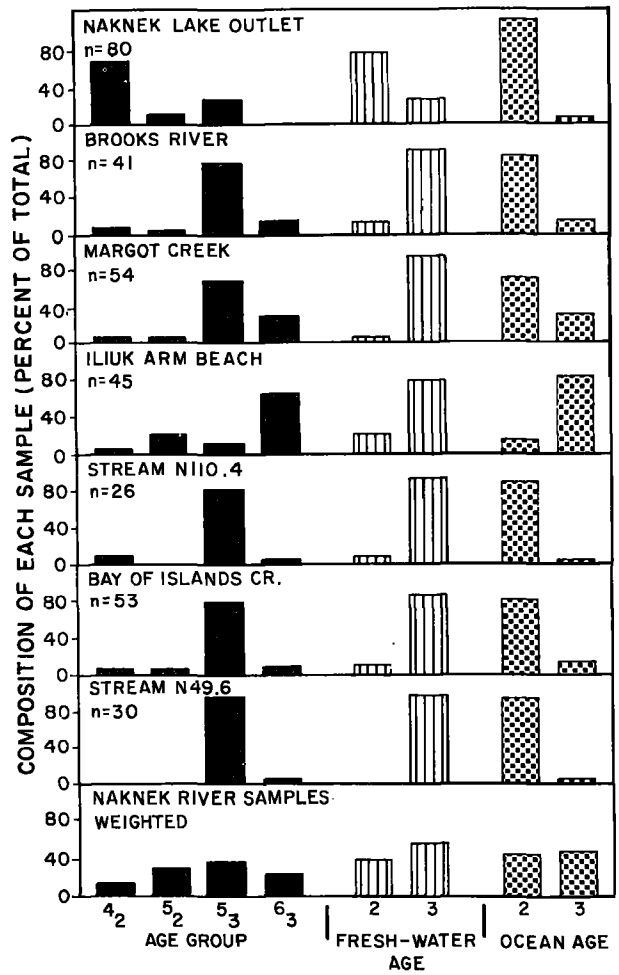

FIGURE 10.—Percent composition of sockeye salmon escapement for major spawning tributaries of Naknek Lake by age group and fresh-water and ocean age, 1962.

that sometimes occur in the age composition and perhaps produce or mask seasonal trends in age.

AGE SEGREGATION ON THE SPAWNING GROUNDS

Results

In figures 10 and 11 and table 7 the age compositions of fish sampled on the spawning grounds are compared with the age compositions of fish sampled at the Naknek River tagging site. In the figures only the individual spawning grounds of each lake with a sample size greater than 25 are compared with the Naknek River samples. Comparisons are made on the basis of dominant age groups (i.e., 4_2, 5_2, 5_3, and 6_3) and fresh-water and ocean age. A complete summary of all age categories present in the samples obtained from all spawning grounds covered in this study is given in table 7.

Figures 10 and 11 and table 7 reveal marked variation in the age composition of the spawning ground samples when compared with each other and with Naknek River samples. This strongly suggests the segregation of populations by age on the spawning grounds of the Naknek River system.

For the major spawning grounds of the Naknek system, the frequencies of occurrence of the four dominant age groups are arranged in a 4–by–9 contingency table (table 8). A chi-square test of the hypothesis of like age compositions for the spawning grounds being compared yielded a value of $\chi^2=549.21$, d.f.$=24$, $P=0.005$. Since the value of P is well below the adopted 0.01 level of significance, it constitutes convincing evidence of unlike age compositions between the areas compared and, therefore, segregation by

TABLE 7.—*Age composition of sockeye salmon on spawning grounds by number and percent, Naknek River system, 1962*

Location	Age group											Fresh-water age			Ocean age			
	3_2	4_2	4_3	5_2	5_3	6_2	6_3	6_4	7_3	7_4	Total	2	3	4	1	2	3	4
Naknek Lake:																		
Stream N 16.1:																		
Number		4	1		3		3				11	4	7		1	7	3	
Percent		36.4	9.1		27.3		27.3					36.4	63.6		9.1	63.6	27.3	
Stream N 18.7:																		
Number		2			3			1			6	2	3	1		6		
Percent		33.3			50.0			16.7				33.3	50.0	16.7		100.0		
Stream N 19.6:																		
Number			1		3			1			5		4	1	1	4		
Percent			20.0		60.0			20.0					80.0	20.0	20.0	80.0		
Stream N 23.4:																		
Number		4			5						9	4	5			9		
Percent		44.4			55.6							44.4	55.6			100.0		
Stream N 49.6:																		
Number					29		1				30		30			29	1	
Percent					96.7		3.3						100.0			96.7	3.3	
Stream N 56.4:																		
Number			1		1						2		2		1	1		
Percent			50.0		50.0								100.0		50.0	50.0		
Bay of Islands Creek:																		
Number		3	1	3	41		5				53	6	47		1	44	8	
Percent		5.7	1.9	5.7	77.4		9.4					11.3	88.7		1.7	83.2	15.1	
Stream N 93.7:																		
Number					20		2				22		22			20	2	
Percent					90.9		9.1						100.0			90.9	9.1	
Stream N 110.4:																		
Number		2	2		21		1				26	2	24		2	23	1	
Percent		7.7	7.7		80.8		3.8					7.7	92.3		7.7	88.5	3.8	
Stream N 111.4:																		
Number				1	6		1				8	1	7			6	2	
Percent				12.5	75.0		12.5					12.5	87.5			75.0	25.0	
Stream N 133.3:																		
Number				1	5		3				9	1	8			5	4	
Percent				16.7	55.6		33.3					11.1	88.9			55.6	44.4	
Iliuk Arm Beach:																		
Number		1		9	6		29				45	10	35			7	38	
Percent		2.3		20.0	13.3		64.4					22.2	77.8			15.6	84.4	
Margot Creek:																		
Number		1		2	36		15				54	3	51			37	17	
Percent		1.9		3.7	66.7		27.8					5.6	94.4			68.5	31.5	
Stream N 142.7:																		
Number		1			5						6	1	5			6		
Percent		16.7			83.3							16.7	83.3			100.0		
Brooks River:																		
Number		3	1	1	30		5	1			41	4	36	1	1	34	6	
Percent		7.3	2.4	2.4	73.2		12.2	2.4				9.8	87.8	2.4	2.5	82.9	14.6	

Location	Age group											Fresh-water age			Ocean age			
	3_1	3_2	4_2	4_3	5_2	5_3	6_2	6_3	6_4	7_3	7_4	Total	2	3	4	1	2	3	4
Naknek Lake:																			
StreamN 156.9:																			
Number			1			2						3	1	2			3		
Percent			33.3			66.7							33.3	66.7			100.0		
Stream N 170.3:																			
Number			1			23						24	1	23			24		
Percent			4.2			95.8							4.2	95.8			100.0		
Lake outlet:																			
Number		1	54		5	20						80	60	20		1	74	5	
Percent		1.3	67.5		6.2	25.0							75.0	25.0		1.3	92.5	6.2	
Brooks Lake:																			
Weir samples:																			
Number	2	4	137	19	183	975	7	107	2	2		1,438	331	1,103	2	23	1,116	290	9
Percent	0.1	0.3	9.5	1.3	12.7	67.8	0.5	7.5	0.1	0.1			23.0	76.7	0.14	1.6	77.6	20.2	0.6
Grosvenor Lake:																			
Lateral streams:																			
Number			4		5	19		8				36	9	27			23	13	
Percent			11.1		13.9	52.8		22.2					25.0	75.0			63.9	36.1	
Lake beaches:																			
Number			6		20	8	1	50				85	27	58			14	70	
Percent			7.1		23.5	9.4	1.2	58.8					31.2	68.2			17.6	82.4	
Hardscrabble Creek:																			
Number			17		19	55		53	1		1	146	36	108	2		73	73	
Percent			11.6		13.0	37.7		36.3	0.7		0.7		24.7	74.0	1.3		50.0	50.0	
Grosvenor River:																			
Number			8		8	30		45	1		2	94	16	75	3		39	55	
Percent			8.5		8.5	31.9		47.9	1.06		2.1		17.0	79.8	3.2		41.5	58.5	
Coville Lake:																			
American River:																			
Number			35	1	193	149	1	295	1	1	1	677	230	446	2	2	185	489	2
Percent			5.2	0.15	28.5	22.0	0.15	43.5	0.15	0.15	0.15		33.9	65.8	0.30	0.30	27.3	72.1	0.3
Naknek River samples weighted: percent		0.1	11.9	0.6	28.7	35.7	1.3	21.4		0.2	0.3		41.9	57.8	0.2	0.7	47.6	50.2	1.5

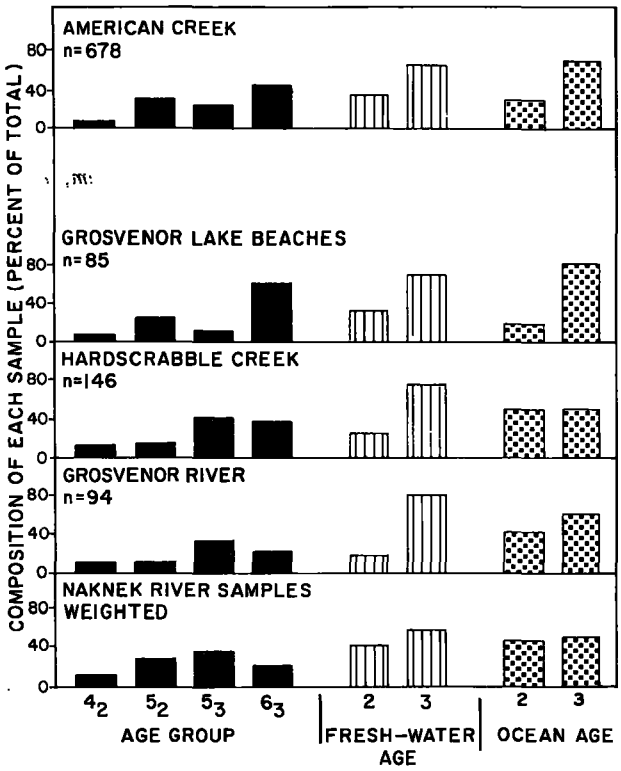

FIGURE 11.—Percent composition of sockeye salmon escapement for American Creek (Coville Lake) and three major spawning areas of Grosvenor Lake compared with overall Naknek system escapement, by age group and fresh-water and ocean age, 1962.

age on the major spawning grounds of the Naknek River system.

Most spawning ground samples contained a considerably higher proportion of the 5_3 age group and a lower proportion of the 5_2 group than did the trunk river samples. Only the Iliuk Arm, Grosvenor Lake beach, and American Creek samples contained a proportion of the 5_2 group approaching that of the river samples. It is notable that the samples from these three areas also contained almost twice the proportion of the 6_3 age group as did the river samples. Ocean-age samples from these three areas were characterized by predominantly 3-ocean fish in 1962. Practically all other spawning ground samples contained predominantly 2-ocean fish, many of them with twice the proportion that occurred in the river samples.

Fresh-water age samples from most areas contained a considerably smaller proportion of 2-fresh-water fish than did the Naknek River samples. Only the samples from stream N23.4 (9 fish) and the sample taken at the outlet of Naknek Lake (80 fish) (table 7) had greater proportions of 2-fresh-water fish. For the Naknek Lake spawning grounds as a whole there was a lack of 2-fresh-water fish, primarily because of the absence of the 5_2 age group.

TABLE 8.—*Numbers of fish in dominant age groups in sockeye salmon samples taken from the major spawning grounds of the Naknek River system, 1962*

Spawning area	Fish in age group—				Total
	4_2	5_2	5_3	6_3	
Bay of Islands Creek	3	3	41	5	52
Iliuk Arm beach	1	9	6	29	45
Margot Creek	1	2	36	15	54
Brooks River	3	1	30	5	39
Naknek Lake outlet	54	5	20	0	79
Grosvenor Lake beach	6	20	8	50	84
Hardscrabble Creek	17	19	55	53	144
Grosvenor River	8	8	30	45	91
American Creek	35	193	149	295	672
Total	128	260	375	497	1,260

Discussion

The absence of the 5_2 age group suggests inadequate sampling of the total Naknek escapement on the spawning grounds. All known spawning grounds were surveyed and sampled in 1962, but only about half of the total escapement counted on the Naknek River could be accounted for on the spawning grounds surveyed. It seems likely that some major spawning areas were not sampled and that these areas could have contained a high proportion of the 5_2 age group that was so prevalent in the river samples.

Until 1962 the Iliuk Arm beach area of Naknek Lake was not regarded as a probable spawning ground. During the 1962 stream surveys in this area, however, survey crews noted large numbers of fish jumping along a 1½- to 2-mile stretch of the southeast shoreline. These fish were present after most of the tributary stream spawning had been completed, but because of the turbid water, we could not definitely establish whether these fish actually spawned in this area nor could we estimate their number. Evidence suggests, however, that they spawned in the beach area. Subsequent sampling of these fish showed that they were composed of a greater proportion of the 5_2 age group than most of the other spawning grounds sampled. It is likely that this population

was sufficiently large to account for a substantial portion of the 5_2 age group represented in the Naknek River samples, but lacking in the samples from the other spawning grounds.

Other probable spawning areas in the Naknek system include the turbid Savonoski River (fig. 2) and most of its clear-water tributary streams and deepwater beach spawning areas as yet unknown. None of these were sampled in 1962.

Regardless of the spawning areas left unsampled, it seems clear from the evidence presented that there is segregation by age on the spawning grounds of the Naknek River system. This agrees with the conclusion reached by Koo and Smith (1960) for various spawning areas of the Kvichak River system in Bristol Bay.

Theoretically this segregation could be of great importance in managing individual spawning populations as they pass through the fishery. If certain spawning grounds are characterized by populations composed predominantly of fish of 2-ocean age and others of 3-ocean age, the effects of the gill net fishery, which is selective for large fish, would be unequal for each group. A knowledge of any consistencies in the age structure of individual spawning populations would, therefore, provide those charged with managing the Naknek sockeye salmon stocks with a means of gaging the possible effects of the fishery on these populations. Many years of data, however, will be required before consistencies in the age structure of individual spawning populations could show up.

The results presented above suggest two important lines of future investigation: (1) A complete survey of all beach and turbid water areas of the Naknek system for spawning areas that were previously undetected, and (2) continued study of segregation by age on the spawning grounds to uncover any consistencies in the age group structure of individual spawning populations.

SUMMARY

1. Tag and recovery techniques were used to determine the extent of segregation by time of occurrence for the individual spawning populations in the sockeye salmon run of Naknek River, Alaska. Salmon were tagged daily on the Naknek River at a site located about 24 miles above the mouth of the river. A different tag color combination was used to identify each day of tagging. Subsequent recovery or observations of tagged fish on the spawning grounds and the relative abundance of each color combination present provided the basis for determining the extent of segregation.

2. Results lead to the following conclusions: (*a*) Segregation of individual Naknek spawning populations by the time of occurrence in the trunk stream was minimal. As a consequence, most spawning grounds derived their fish from all parts of the run and, generally, in proportion to the size of the daily escapement. Exceptions were Brooks River, which received a disproportionate share of early-run spawners, and Grosvenor River, which seemed lacking in early-run fish. (*b*) The short duration of the Naknek run is probably the most reasonable explanation for the intermingling of most spawning groups. (*c*) Because of the lack of segregation in time, it is unlikely that spawning populations can be managed on an individual basis in the fishery. The Naknek sockeye salmon stocks will probably be most effectively managed, as a whole, by securing spawning escapement proportional to the daily abundance of fish in the fishery.

3. No seasonal trends in age composition could be described as characteristic of the Naknek run, probably because of intermingling of most of the spawning populations during the run.

4. Fish from all known spawning grounds of the Naknek system were sampled to determine the age composition of populations associated with the separate spawning areas. Spawning populations have age characteristics that differ significantly from one to another and, therefore, show segregation by age on the spawning grounds of the Naknek River system. Continued study of segregation by age on the spawning grounds is necessary for a number of years to determine if the age structure of specific spawning populations conforms to specific patterns. It is likely that major spawning population's as yet undetected and, therefore, not sampled in this experiment exist in the Naknek system. A thorough survey to locate and determine the magnitude and age characteristics of these populations, if any, is needed for a complete understanding of segregation and the productive importance of individual spawning areas within the Naknek system.

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