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FISHERIES COMMISSION**

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BETWEEN CANADA AND THE UNITED STATES FOR THE
PROTECTION, PRESERVATION AND EXTENSION OF
THE SOCKEYE SALMON FISHERIES IN
THE FRASER RIVER SYSTEM

BULLETIN XIII

**MARINE TAGGING
OF FRASER RIVER SOCKEYE SALMON**

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ABSTRACT

The tagging of sockeye by the International Pacific Salmon Fisheries Commission while the sockeye were en route to spawn in the Fraser River system during the years 1938 to 1948 is reported. The tagging and recovery methods together with the recovery problems are described. Principal and alternate routes of migration are determined but not their precise importance. Retrograde migration is negligible except for the blowback phenomenon involving late-season sockeye delaying entry into the river. Problems related to the determination of rates of migration are discussed and rates are expressed in terms of modal-migration times. Times of passage of races of sockeye are estimated and factors affecting the accuracy of the times are discussed. Deficiencies in the experiments and inherent difficulties made the estimation of annual populations impractical and the estimation of fishing intensities inaccurate and inconsistent.

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MARINE TAGGING OF FRASER RIVER SOCKEYE SALMON¹

INTRODUCTION

The Fraser River is one of the greatest sockeye salmon (*Oncorhynchus nerka*) rivers in the world. However a disastrous decline in production led to the ratification of a Convention between Canada and the United States which provided for the creation in 1937 of the International Pacific Salmon Fisheries Commission, whose prescribed duties were to protect, preserve and extend the sockeye salmon fishery of the Fraser River. The Salmon Commission's regulatory powers were withheld until it had completed eight years of intensive scientific research for purposes of isolating the reasons for the continuing decline of the fishery and the measures necessary for the restoration of the fishery to its former magnitude. Upon the completion of the eight years of research the Salmon Commission began in 1946 to regulate the fishery in Convention waters (FIGURE 1) and to permit the fishermen of the two contracting countries to take each year as equal portions of the allowable catch as was practical.

A careful examination by the Salmon Commission of historical records of commercial landings and spawning ground escapements revealed that sockeye runs to various tributaries of the Fraser River were unevenly depleted: some runs appeared relatively unaffected, some greatly reduced, while others had disappeared completely. Each run evidently represented an individual spawning stock, population or race, and each would require separate management consideration (Thompson, 1940). The term "race" as used here is defined by Royal (1953) and assumes that homogeneity exists in each population spawning in a particular area which is subject to the same general reproductive environment. All available knowledge indicated that special fishing regulations would be required to allow for varying protection, if possible, to the individual runs depending on the degree of depletion of each. Special regulations could not be formulated without knowing the routes of migration and dates of passage of each run through the commercial fishery. Knowledge would also be required of commercial fishing efficiency if the desired escapement of spawners was to be obtained for each run and if the allowable catch was to be divided equally between the fishermen of each of the two nations. Further, it would be necessary to determine the rate of migration for each run of sockeye salmon through the commercial fishery and to study the effect of closed periods to secure an adequate escapement from each run.

The solution to these problems was sought primarily through a program of saltwater tagging which would supply a positive means of identifying individual sockeye as they migrated through the fishery en route to their spawning grounds in the Fraser River watershed. A series of

¹This investigation was originally outlined and inaugurated by Dr. W. F. Thompson, now Professor Emeritus, University of Washington, and Dr. J. L. Kask, now Chairman of the Fisheries Research Board of Canada.

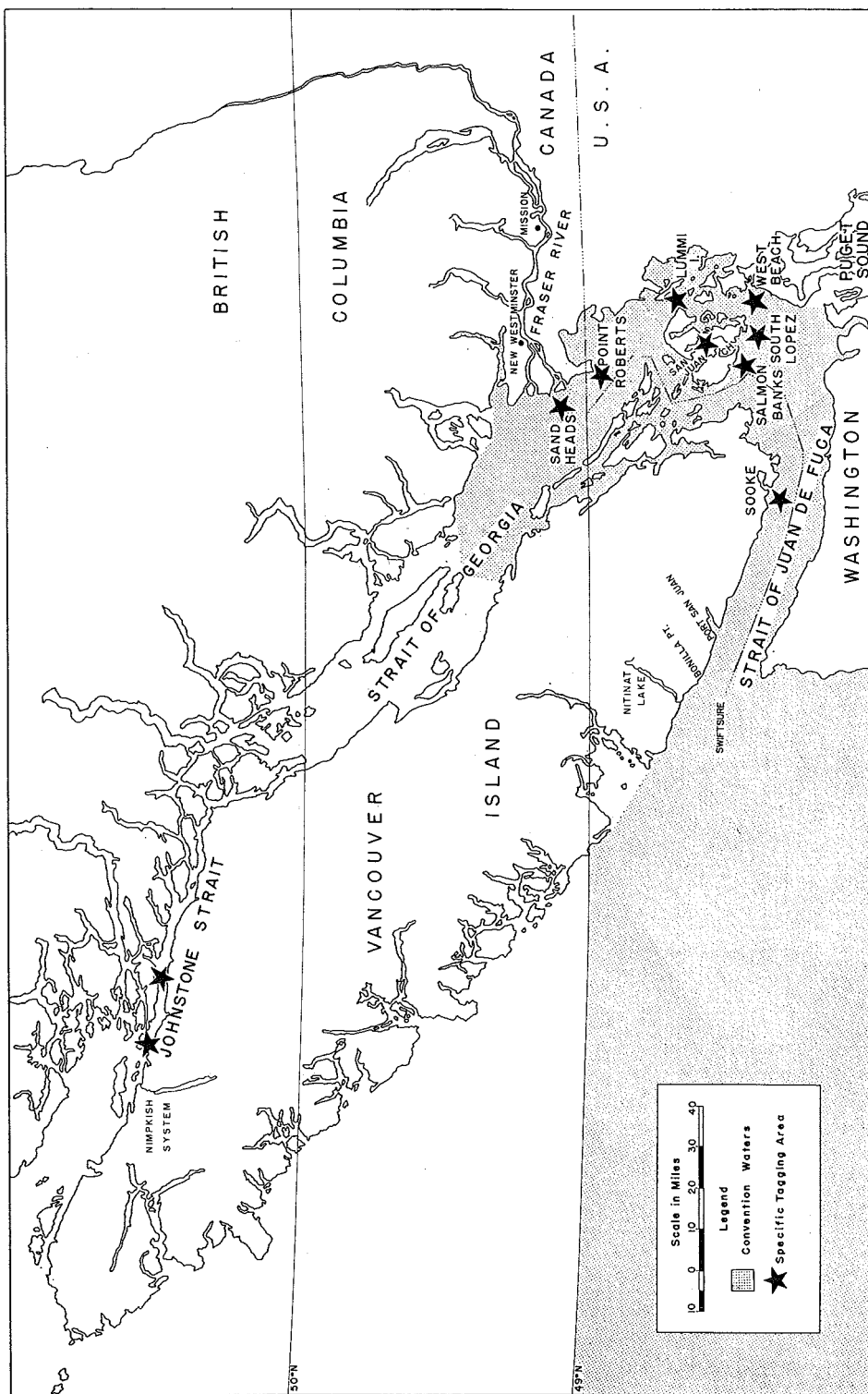


FIGURE 1—Convention waters and tagging areas.

tagging experiments was begun in 1938 at Sooke near the southern end of Vancouver Island (FIGURE 1) and was carried on annually until 1948 in which year the tagging was terminated before the start of the sockeye

TABLE 1—Period and number of occasions of tagging and per cent recovered by year and tagging area. (Occasions when oval tags were used instead of, or in addition to disk tags are indicated.)

Year	Tagging Area	First Date	Last Date	Number of Occasions	Number Tagged	Number Recovered	Per cent Recovered
1938	Sooke	June 11	Sept. 3	13	980	438	44.7
	Sand Heads	Aug. 27	Sept. 15	13	2,587	1,269	49.1
1939	Sooke	May 25	Sept. 7	14	960	546	56.9
	Salmon Banks	July 28	Sept. 4	20	1,355	947	69.9
	San Juan Channel	Aug. 25	Aug. 29	4	220	158	71.8
	South Lopez	July 20	Sept. 5	16	1,011	634	62.7
	West Beach	July 19	Aug. 15	7	63	41	65.1
	Lummi Island	July 24	Aug. 23	12	1,144	603	52.7
	Point Roberts	Aug. 8	Sept. 1	3	31	21	67.7
	Sand Heads	Aug. 13	Sept. 29	24	2,325	1,751	75.3
	Sooke	June 13	Sept. 5	13	930	444	47.7
	Salmon Banks	July 29	Aug. 18	7	869	482	55.5
1940	South Lopez	Aug. 15	Aug. 16	2	60	31	51.7
	Lummi Island	July 29	Aug. 16	14	706	328	46.5
	(Oval tags)	Aug. 1	-----	1	10	4	40.0
	Sand Heads	July 27	Sept. 13	6	16	7	43.8
	(Oval tags)	Aug. 20	Sept. 11	5	63	38	60.3
	Johnstone Strait	July 16	Aug. 12	15	1,555	770	49.5
	Sooke	June 12	Sept. 4	13	849	501	59.0
	Salmon Banks	July 16	Aug. 27	13	332	195	58.7
	San Juan Channel	July 8	Aug. 24	4	72	46	63.9
	South Lopez	July 25	Aug. 12	8	270	188	69.6
1941	West Beach	July 17	July 18	2	94	63	67.0
	Lummi Island	July 8	Aug. 23	10	690	402	58.3
	Point Roberts	July 11	July 24	4	179	120	67.0
	Sand Heads	July 24	Sept. 18	37	1,614	1,005	62.3
	(Oval tags)	Aug. 6	Sept. 20	10	296	132	44.6
	Johnstone Strait	July 21	Aug. 7	14	1,191	784	65.8
	Sooke	July 2	Sept. 8	17	1,744	824	47.2
	Sooke	July 8	Sept. 2	16	1,001	506	50.5
	Sooke	July 3	Sept. 7	20	537	246	45.8
	(Oval tags)	July 3	Sept. 5	19	526	235	44.7
1945	Sooke	May 10	Sept. 13	33	882	326	37.0
	(Oval tags)	May 10	Aug. 2	21	543	238	43.8
1946	Sooke	June 6	Sept. 23	35	3,902	1,484	38.0
1947	Sooke	July 10	Sept. 15	25	3,294	1,256	38.1
1948	Sooke	June 30	July 6	3	433	156	36.0
Total					33,334	17,219	51.7

TABLE 2—Percentage distribution of recovered tags by recovery area for each tagging area, all years combined.

RECOVERY AREA	TAGGING AREA								
	Sooke	Salmon Banks	San Juan Channel	South Lopez	West Beach	Lummi Island	Point Roberts	Sand Heads	Johnstone Strait
United States									
Salmon Banks	5.7	9.5	7.4	5.0	1.9	1.7	---	*	*
South Lopez	1.5	1.8	2.9	2.1	5.8	1.0	---	---	---
West Beach	2.2	3.0	2.9	2.7	---	1.0	---	---	---
Rosario Strait	1.5	0.7	---	1.9	---	0.4	---	---	---
Lummi Island	2.4	3.6	2.5	2.7	1.9	3.0	---	*	*
San Juan Channel-Haro Strait	0.8	3.3	5.9	1.6	1.0	0.6	---	---	---
Point Roberts	10.6	12.3	23.0	14.5	10.6	16.1	7.1	2.2	0.5
Miscellaneous Washington	5.0	0.3	---	---	1.0	0.1	---	---	---
Unknown United States	2.3	3.0	2.9	1.8	1.9	1.9	---	0.1	*
All United States Areas	32.1	37.6	47.5	32.4	24.0	25.9	7.1	2.4	0.6
Canada									
West of Sooke	2.1	---	---	---	---	---	---	---	---
Sooke	2.3	0.2	---	0.2	---	0.1	---	---	---
Convention Waters of Georgia Strait	6.6	10.2	11.8	12.7	3.8	10.8	9.2	13.7	5.4
Fraser Estuary and River									
Canoe Pass	4.8	6.3	2.9	6.6	11.5	7.9	5.0	5.7	2.4
Main Arm	13.1	12.6	11.3	14.2	20.2	19.7	27.0	19.7	16.0
Middle Arm	1.4	3.3	2.5	3.5	2.9	4.1	7.8	2.6	6.9
Point Grey	1.8	5.7	5.9	6.8	1.9	5.8	9.9	3.1	9.7
North Arm	1.2	1.8	0.5	1.4	1.9	2.7	4.3	1.4	4.0
New Westminster	8.7	5.2	5.4	5.6	11.5	7.0	7.8	8.9	5.3
Above Bridge	7.5	8.6	8.3	7.7	13.5	7.2	15.6	12.7	5.8
Above Commercial Fishery	10.8	3.8	2.0	5.9	6.7	6.0	4.3	14.6	3.9
Spawning Grounds	5.1	3.5	0.5	2.6	1.0	2.2	0.7	14.0	1.5
Pt. Young-Johnstone Strait	0.7	0.2	---	---	---	---	---	---	**37.9
Unknown Canada	1.9	1.1	1.5	0.5	1.0	0.1	1.4	1.1	0.5
All Canadian Areas	67.9	62.4	52.5	67.6	76.0	74.1	92.9	97.6	99.4

*Indicates area in which 1 or 2 tags were recovered and were too small a percentage of the total recoveries to list in the table.

**The 37.9 per cent were distributed as follows in the subdivisions of the Point Young-Johnstone Strait area: Upper Johnstone Strait 25.4%, Lower Johnstone Strait 11.5%, Non-Convention Waters of Georgia Strait 1.0%.

fishing season. Additional marine tagging was conducted intermittently from 1938 to 1941 at Salmon Banks, San Juan Channel, South Lopez, West Beach, Lummi Island, Point Roberts, Johnstone Strait, and Sand Heads off the mouth of the Fraser River. A total of 33,334 sockeye were tagged and 17,219 tags or 51.7 per cent were recovered (TABLE 1). TABLE 2 lists for each tagging area during the combined years the percentage distribution of the tag recoveries according to the recovery areas shown

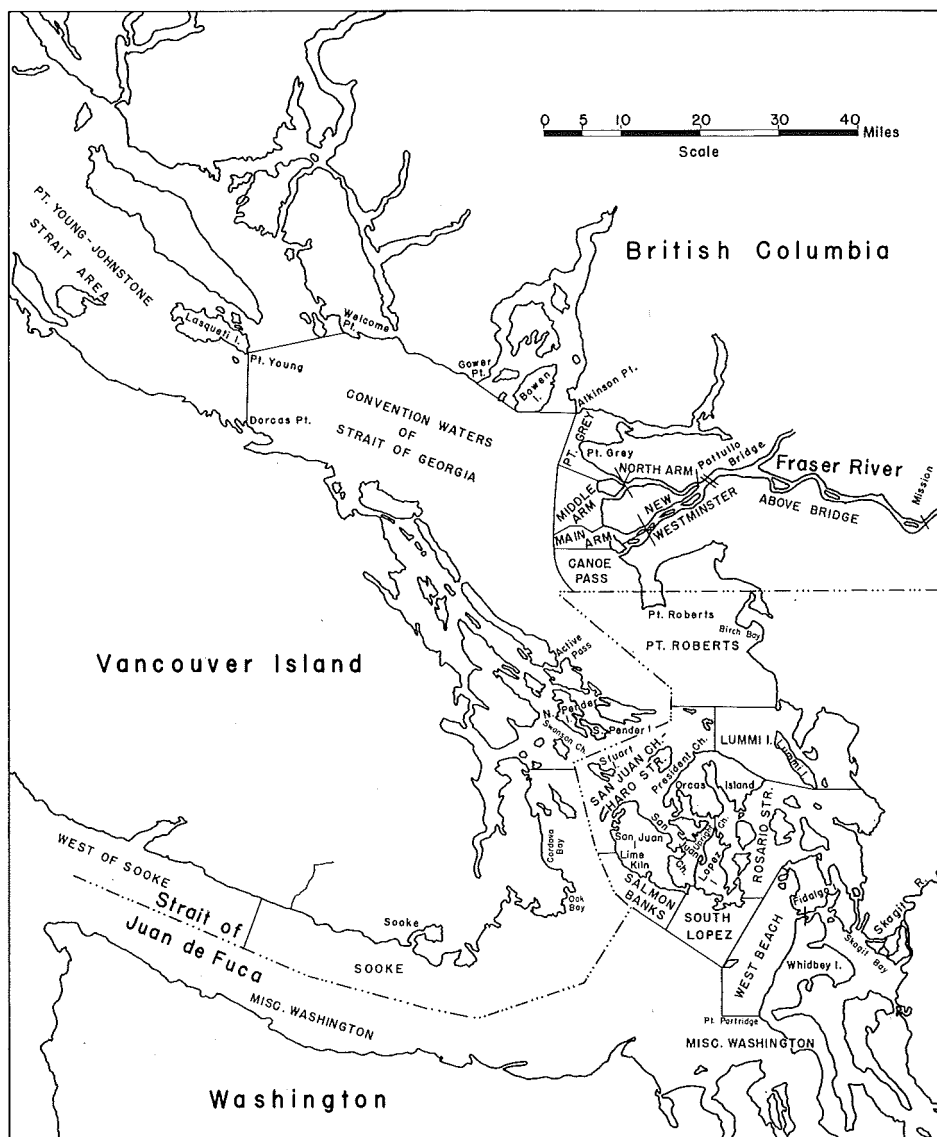


FIGURE 2—Recovery areas. Miscellaneous Washington area includes: off west coast of Washington, Swiftsure Bank, Strait of Juan de Fuca, Hoods Canal, inner Puget Sound, and Washington streams. See FIGURE 5 for detailed map of Point Young-Johnstone Strait area.

in FIGURE 2. Preliminary analyses of the data from some of the experiments have been presented by MacKay, Howard and Killick (1944, 1945) and Idyll (1951).

The purpose of this report is to make a complete and critical analysis of all the saltwater tagging data obtained from the Salmon Commission's experiments and to summarize information from previous tagging and fin-marking experiments to assess (1) routes of migration, (2) speed of migration, (3) time of passage of individual races, and (4) commercial fishing mortality.

It will be shown that saltwater tagging was successful in fulfilling some of the objectives, but that it was of little or no value in solving others. Each of the objectives will be treated separately, although they may be inter-related.

TAGGING AND RECOVERY METHODS

Tagging Methods

The sockeye tagged at Sooke were obtained from pile-driven traps which were usually lifted and emptied of the accumulated catch every Monday and Thursday. However when catches were large the traps were sometimes emptied daily. The tagging crew accompanied the fishing company boat to the traps. The trap spiller was elevated until the salmon were forced close to the surface. The salmon were thus confined in a small area from which the sockeye were caught, in dip-nets as they presented themselves without regard to size, and transferred to a floating live-box. After the tagging sample had been obtained, the live-box was towed some distance offshore from the traps to prevent immediate recapture of fish after tagging.

Sockeye tagged in other areas were caught either by purse seines or by reef nets. At Salmon Banks, San Juan Channel, South Lopez, West Beach and Johnstone Strait² the sockeye were purchased directly from the captains of purse seine vessels. The sockeye were transferred by dip-net from the pursed seine to a floating live-box just before the remaining fish were brailled aboard the fishing vessel. The live-box was then towed clear of the fishing vessel before tagging was begun so that the fishermen could resume fishing with a minimum of delay.

At Sand Heads and Point Roberts the Salmon Commission chartered a purse seine vessel and conducted its own fishing. In the Point Roberts area a few sockeye were also bought from regular purse seine vessels. In the case of the chartered vessel the sockeye were tagged directly from the pursed seine in most instances and the other species of salmon were released untagged.

²At Johnstone Strait a purse seine vessel and its crew were sometimes engaged to fish for the Salmon Commission during week-end closures. In these instances the sockeye were tagged directly from the pursed seine.

At Lummi Island the majority of the sockeye tagged were obtained from reef nets. At the start of a day's tagging live-boxes were left at the reef nets so that the live sockeye could be transferred from the nets to the live-boxes. Near the end of the day's fishing the tagging crew returned and towed the live-boxes clear of the reef nets and proceeded to tag the imprisoned sockeye.

In the actual tagging operation a sockeye was dipped out of the live-box and transferred to a tagging box. One man held the fish securely while a second man inserted a 3-inch nickel pin bearing a white celluloid disk, 0.531-inch diameter with a red spot in its center, through the body of the fish just below the center of the dorsal fin. A second similar disk bearing a serial number, the Salmon Commission's address, and an offer of reward on one side and a red spot on the other side, was placed with the red spot visible on the free end of the pin. The protruding pin was then cut to the proper length and knotted so the disks were held secure and flush against the salmon. Following this, the fork length of each fish was measured and a scale sample was taken immediately posterior to the

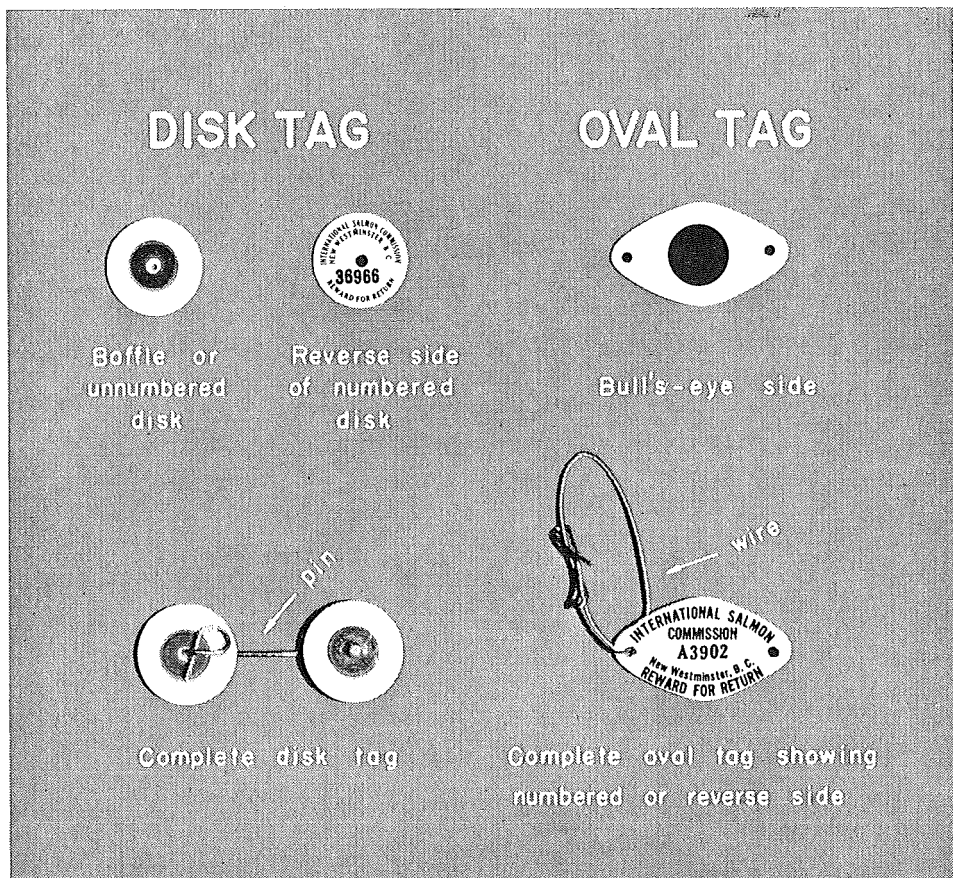


FIGURE 3—Photographs of disk and oval tags.

dorsal fin and one inch above the lateral line. Scars or abnormalities were recorded before the fish was released. Speed was of utmost importance during this operation to prevent injury to the salmon. The individual fish was seldom out of the water more than 35 to 40 seconds.

In 1940, 1941, 1944 and 1945 some (1,438) sockeye were tagged with oval tags. The oval or football-shaped tag was a white, thin, plastic plate with a red spot in its center on one side; and the tag number, the Salmon Commission's address and offer of reward printed on the opposite side. The tag was 1-inch long and 0.58-inch wide with a small hole through each end. It was secured to the fish under the dorsal fin by a fine braided monel wire, initially about 9-10 inches long, which was thrust through the tissue with a needle and through one hole in the tag. The ends of the wire were then tied in a reef knot so that the tag dangled closely behind the fin. It took approximately twice as long to apply the oval tag as it did the disk tag.

FIGURE 3 contains photographs of disk and oval tags. The disk tag is commonly referred to as the Petersen tag and the oval tag is frequently called the Atkins tag.

Recovery Methods

To encourage the capture and reporting of tags a reward of 50 cents was offered for the return of each tag accompanied with the following information: tag number, place, date and method of capture, and name of person or vessel making the recovery.

Cannery officials were personally notified about the tagging program and their aid enlisted. Posters were placed by Salmon Commission personnel in each cannery and at wharves wherever Fraser River sockeye might be landed by the commercial fishery. Tag return books were left with the cannery bookkeepers who were personally instructed to ask both fishermen and cannery employees for tags and to record the tag recovery data in the tag return books. In a number of cases tag return books were also given to fish buyers. In addition notices of the experiments were posted on or near spawning grounds and at local stores and post offices. Notices of the experiment together with posters, return forms and instructions were sent to the Washington State and Canadian Departments of Fisheries for distribution among their personnel. Notices were also posted in other areas where sockeye might be caught and in offices where fishing licences were sold or permits were granted to Indian fishermen.

During the sockeye fishing season men were stationed by the Salmon Commission at the principal fishing ports to collect statistics on commercial landings. In addition to these duties they were instructed to recover tags from fishermen and cannery workers. These men distributed to purse seine fishermen maps showing the different fishing areas, and log books for recording fishing information. These books contained special pages for recording the capture of tagged fish to facilitate accurate reporting

of tags recovered. The fishermen were canvassed at least weekly and the recovered tags were collected along with the fishing information.

In the Canadian gill net fishery it was impractical to distribute log books to every fisherman. However during the years 1940 to 1947 the Salmon Commission had one to three small boats on the Fraser River to contact the fishermen on the fishing grounds for purposes of obtaining catch-per-unit-of-effort information. Recovered tags were collected at the same time that the fishing information was obtained.

During the period of saltwater tagging the Salmon Commission also conducted a number of tagging experiments in fresh water at points within the Fraser drainage while the sockeye were en route to the spawning grounds. Hell's Gate and Bridge River Rapids on the Fraser River were two of the most important points. Marine-tagged fish recaptured or intercepted during the experiments within the Fraser drainage were released alive and records were kept of these incidents for inclusion in the tag recovery data. It was anticipated that the racial identity of some of these fish would be disclosed by their subsequent recovery on the spawning grounds and information would be gained on the rates of migration of these fish from points in salt water to various points en route to the spawning grounds. A number of the marine-tagged sockeye that had been intercepted and released at Hell's Gate or Bridge River Rapids were subsequently recovered but only two of these recoveries occurred on spawning grounds (see TABLE 27, Nechako District). Many of the remaining unrecovered fish may have failed to reach the spawning grounds because of variable block conditions at Hell's Gate and Bridge River Rapids before construction of fishways. But it is also believed that the placement of the tag number on the inner side of the disk, the side next to the fish's body, reduced the chances of final recovery on the spawning grounds. The number on the disk could not be read easily while the tag was on a live fish, consequently, live recaptured fish were held out of water before release longer than would have been necessary had the number been on the outer side of the disk. It was apparent in some instances that the numbers were actually misread.

Considerable numbers of tags were recovered by Indians while fishing for subsistence. Salmon Commission observers on their weekly visits to the Indian fishing stations collected and redeemed recovered tags. Frequent canvass was necessary to insure accurate recovery information as some Indians were reluctant to return tags. The Indian agents also assisted in the collection of recovered tags.

The last and one of the most important points at which tagged salmon were recovered was on the spawning grounds. Every sockeye stream was visited at least once each spawning season by a member of the Salmon Commission's staff. An attempt was made to recover all tagged sockeye seen whether alive or dead. In some areas tagged fish were examined at

counting fences. On major spawning streams periodic patrols were made, live tagged fish were captured by spear whenever possible, and all available dead fish were examined for tags.

Recovery Problems

In tagging experiments it is impossible to recover every tagged fish for the following important reasons:

1. Mortality due to the tagging operation,
2. Mechanical failure of tag,
3. Natural mortality,
4. Failure to detect all tagged fish in the commercial catch,
5. Failure to return all recovered tags,
6. Impossibility of examining every fish on the spawning grounds.

Reasons 1, 2, and 3 occur to a variable extent in most tagging experiments. Since it is usually impossible to determine separately the number of tags lost due to fish injured at time of tagging, or to mechanical failure of the tag, or to natural mortality, the three factors are usually referred to collectively as tag mortality. Every effort should be made to keep tag mortality to a minimum.

When planning a tagging experiment, particularly one in which a large number of spawning ground recoveries is desired, it should be borne in mind that the number of available tagged fish will be reduced by recoveries in the commercial fishery and at other points and also by mortality while en route to the spawning grounds. Schaefer (1951a) observed during a tagging and enumeration study of sockeye in the Harrison system that a loss of tagged fish occurred and that this loss increased as the distance between the tagging point and the spawning grounds increased. He believed that this loss was the combined result of natural mortality during migration and of mortality caused by tagging. But he could not determine the relative importance of the two causes. It logically follows that the loss of tags also increases as the time between tagging and recovery increases. Bevan (1959) on the basis of a small number of sockeye that were tagged twice with disk tags estimated that about 10 per cent of the sockeye lost one of the tags.

Reasons 4 and 5: failure to observe tags and to get prompt returns can be minimized by use of conspicuous tags and vigorous publicity. Frequent canvass emphasizes the importance of the tagging program while the ease with which the returns can be made reduces the number of unreported tags and increases the accuracy of the recovery information. Experience has shown that the use of logbooks containing pages for reporting tags recovered and frequent canvassing of the fishermen brought about good tag recovery in the United States purse seine fishery. In the Canadian gill net fishery the most effective method of obtaining recovered

tags was by contacting the fishermen on the fishing grounds by means of the Salmon Commission's vessels.

Reason 6: only a small percentage of the tagged fish that escape the commercial and Indian fisheries are recovered on the spawning grounds.³ Counting fences near the spawning grounds make possible the examination of all fish ascending past the fences. But it is usually impractical to maintain fences on more than a few streams which are usually small ones. It is therefore necessary to patrol the remainder or majority of the spawning areas by boat and by foot, first to recapture as many live tagged fish and secondly to examine as many dead fish for tags as possible. The following factors tend to limit the number of spawning ground recoveries:

- a. Observations of the fish are affected by the degree of turbidity, the size of the stream, and the length of the spawning area. Under the best of conditions only a fraction of the spawning population is visible or available to the observer.
- b. Fluctuations in water level flush spent and dead fish into deep water, or into lakes where they are inaccessible. In addition carcasses are buried in mud, lost in log jams or are removed by predators or scavengers.

ROUTES OF MIGRATION

Previous Investigations

The most extensive tagging experiment on Fraser River sockeye prior to the work of the International Pacific Salmon Fisheries Commission was reported by O'Malley and Rich (1919). In 1918 a total of 4,494 adult sockeye salmon were tagged at the following five areas: Sooke, Salmon Banks, Whidbey Island, Lummi Island and Point Roberts during the period July 14 to August 21. The tags, which were attached at the base of the caudal fin, consisted of serially-numbered silver or aluminum bachelor-button tags similar to those used for marking cattle.

O'Malley and Rich concluded on the basis of the 1,199 tags returned (26.7%) that the great majority of sockeye salmon entering the Strait of Juan de Fuca and migrating to the Fraser River took the following route: "Across Washington Sound to the 'Banks' south of the San Juan Islands and to the western shore of Whidbey Island; from there northward through Rosario Strait and the southern part of the Strait of Georgia, past Point Roberts to the mouth of the Fraser River" (p. 29). They also concluded that there was no evidence to indicate that this route was varied in different parts of the season.

³As recently as June 1958, a tag that had been put on a sockeye at Sooke on June 24, 1946 was returned by a lady who found it on the banks of the Cedar River near Renton, Washington (a densely populated area). The tag, both disks and the pin, after being out 12 years was still intact and the printing was still legible.

A few sockeye were found to have migrated to Point Roberts by way of Haro Strait, but the authors warned that the apparent proportions might be modified by the fact that there were 26 traps in Rosario Strait and only 11 in Haro Strait. Nevertheless the 831 sockeye tagged at Sooke during the period July 14 to August 6, 1918 resulted in 23 recoveries in Rosario Strait and only 1 in Haro Strait. A similar preference for Rosario Strait was also indicated by the tagging at Salmon Banks. O'Malley and Rich found, "Little if any correlation between the number of traps and the number of marked fish taken in any particular region . . ." (p. 30). However they felt that although correlation was not apparent it could be expected to appear if sufficient data were available.

A few instances were found where a retrograde migration had apparently taken place and tagged sockeye had traveled away from rather than toward the Fraser River. The authors stated that it was possible that faulty data may have accounted for this, especially in such extreme cases as fish tagged at Lummi Island and reported recaptured at Salmon Banks and West Beach; or that the retrograde sockeye may have been bound for some stream other than the Fraser.

Re-examination of O'Malley and Rich's data indicates that, even when the possibility of error is ignored, the instances of retrograde migration were indeed very few. Of the 1,199 tags returned, only 84 were reported from locations which would indicate that some sockeye did not proceed directly toward the Fraser River after tagging. These can be reduced to seven by making allowances for fish which may have drifted for short distances in a direction away from the Fraser River because of tidal action or the possible effects of tagging or which may have proceeded toward the river in an indirect manner. Some interchange of fish between the Salmon Banks and West Beach (Point Partridge) areas was apparent.

Williamson (1927) tagged 519 sockeye salmon with strap or cattle tags affixed to the caudal fin at Deepwater Bay, Seymour Narrows in the southern portion of Johnstone Strait during August 7-14, 1925. The returns numbered 107 or 20 per cent of the total tags applied. Of these, 7 were taken at Point Grey near the Fraser River and 75 were taken in the river. The remaining 25 recovered tags were distributed as follows: 17 in the tagging area, 7 in nearby inlets of lower Johnstone and upper Georgia Straits, and 1 at Whidbey Island. Clemens (1932) during a discussion of spring salmon (*O. tshawytscha*) tagging mentioned the tagging of nine sockeye at Robson Bight, Johnstone Strait on August 23, 1928. Four of these sockeye were recovered in the Fraser River.

Foerster (1934, 1936a) marked downstream-migrant sockeye at Cultus Lake and published data on their return as adults in the commercial fishery. Recaptures indicated that Cultus Lake sockeye were distributed throughout the commercial fishery from Juan de Fuca and Johnstone Straits to the Fraser River and that fish of even one race did not necessarily travel in a compact school nor follow the same route on their passage from the ocean

to the spawning grounds. The sockeye approached the river principally by way of the Strait of Juan de Fuca and in general only very small numbers approached by way of Johnstone Strait. However, in some years such as 1936 (Foerster, 1936b) and 1958 (Gilhousen, 1960) the numbers migrating through Johnstone Strait can be significant.

Salmon Commission Investigations

It should be pointed out, before proceeding with a discussion of the Salmon Commission's experiments, that the validity of describing the movements of Fraser River sockeye through the fishing areas by means of tagging is based on a number of assumptions:

1. Tagged fish are representative of normal untagged fish.
2. Fishing gear at the tagging point intercept Fraser River sockeye.
3. Fishing gear are deployed according to the approximate abundance of sockeye in the various areas and sample all the areas through which sockeye move.

Acceptance of the assumption that the tagged sockeye were representative of normal untagged sockeye in their routes of migration appears to have been justified. The tagged sockeye were recovered in all the areas where sockeye are normally caught and they were not recovered in any unusual concentrations in these or other areas. The assumption that the fishing gear at the tagging point intercepted Fraser River sockeye was in reality a fact that was proven by the tagging in 1918 (O'Malley and Rich, 1919), and subsequently reaffirmed by the Salmon Commission's experiments. The assumption that the fishing gear were deployed according to the approximate abundance of Fraser River sockeye in the various areas and that the gear sampled all the areas through which the sockeye moved could not be substantiated. The inability to substantiate this assumption does not prevent the use of the tag recoveries to deduce the routes of migration. But it may prevent the detection of all the routes and also the determination of the precise relative importance of each route. The degree to which this assumption could not be substantiated will therefore be discussed in detail.

There was circumstantial evidence which indicated that the fishing gears were deployed in some measure according to the abundance or availability of sockeye in the various areas. The general pattern of migration deduced by O'Malley and Rich (1919) from tagging at Sooke and at other points in 1918 was similar to that which was indicated by the Salmon Commission's tagging (FIGURE 4), even though considerable changes had occurred in fishing during the years intervening between the two series of experiments. In 1918 the dominant gears in the United States fishery were stationary traps but with their abolition from waters of the State of Washington after 1934 the highly mobile purse seines

became the dominant gears. It should be pointed out, however, that during the trap fishery in the United States waters there also existed a considerable purse seine fishery which should have been encouraged or obliged because of competition to seek out every possible place where the seines might catch salmon without competition from the traps. Yet in general the two gears fished the same areas. Fishermen are persistent in their attempts to ferret out valuable stocks of fish and to exploit them by one

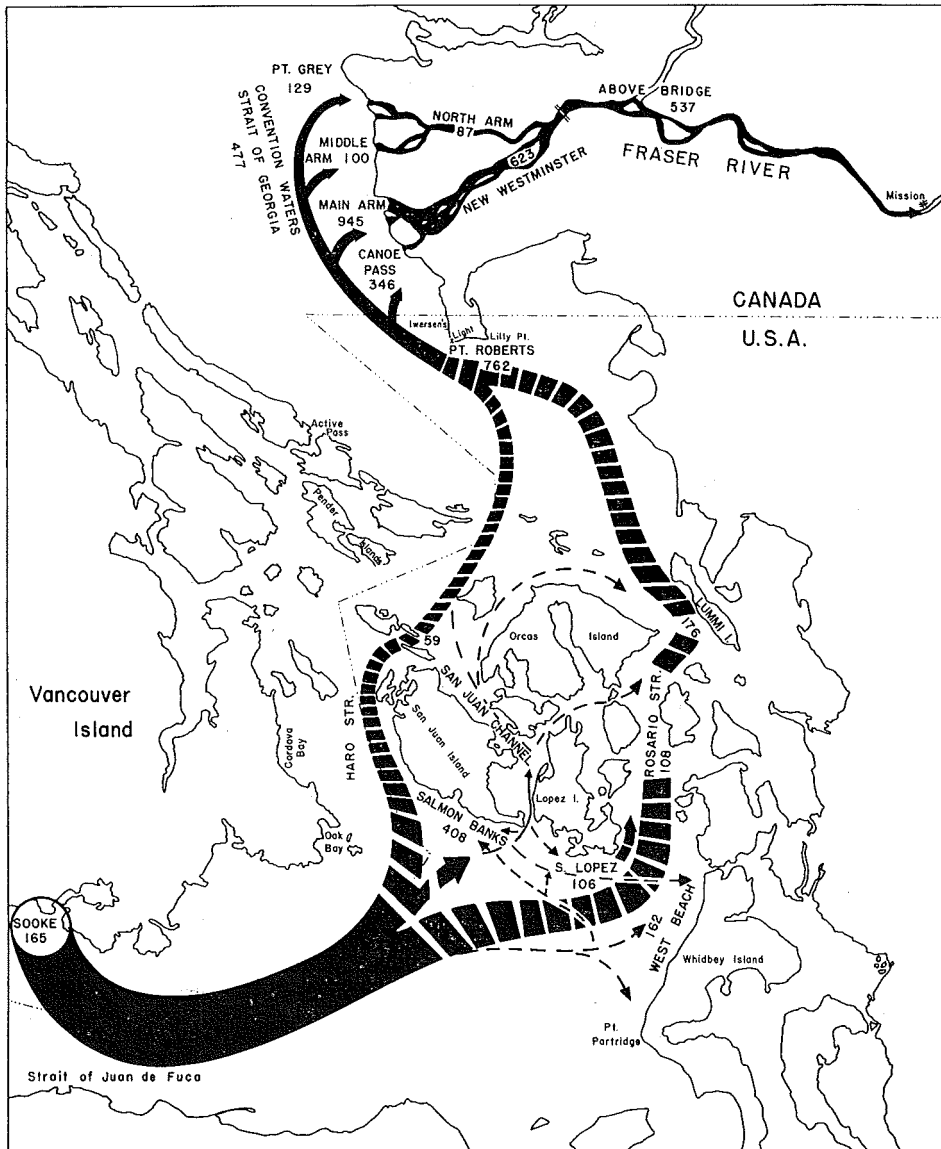


FIGURE 4—Routes of migration of Fraser River sockeye as indicated by tagging at Sooke, 1938-1948, and by information from tagging in other areas. The number of Sooke tags recovered in each area are shown. Broken portions indicate that the relative importance of the routes could not be determined precisely.

means or another. The probability was very unlikely that substantial numbers of sockeye consistently moved unnoticed and unfished through particular parts of the Convention waters en route to the Fraser. In spite of changing and fiercely competitive fisheries the general concept of the routes of migration did not change during the years that intervened between the 1918 tagging and the Salmon Commission's tagging. This leads to the conclusion that the tagging experiments indicated the routes of migration quite accurately but not necessarily their precise relative importance.

There are four possible avenues of approach for the large numbers of sockeye that migrate through Juan de Fuca Strait to either Point Roberts or to the Strait of Georgia and the Fraser River: 1. The western portion of Haro Strait and its lesser tributary channels which are entirely within Canadian waters; 2. The eastern portion of Haro Strait that is within United States waters; 3. San Juan Channel from which fish must eventually exit into either Haro Strait or Rosario Strait; and 4. Rosario Strait.

One question arises immediately. How important is the migration of sockeye through the portion of Haro Strait and its lesser tributary channels which are entirely in Canada? Fishing information indicates that sockeye are seldom ever abundant, or at least are seldom ever available to fishing gear, in these Canadian waters. An exception to this is recorded for the Adams River race in 1954, "... for a time the migration departed from the usual channels and passed up the west side of the San Juan Island, remaining almost exclusively in Canadian water." (Internat. Pacific Salmon Fish. Comm., 1955, p. 22). This was accompanied by unusually good fishing in waters which the Department of Fisheries of Canada defines as Area 18. This area includes roughly the channels between the numerous islands extending from Haro Strait and Pender Islands to Active Pass and the southern portion of the Strait of Georgia lying between Active Pass and the International Boundary Line. According to Pacific Fisherman (Oct., 1954) exceptionally large catches of sockeye were made at Active Pass. Presumably these catches were the result of the unusual migration of sockeye through the Canadian waters of Haro Strait but these catches may not have been entirely due to the use of that approach; sockeye delaying entry into the Fraser River and milling about in the Strait of Georgia may have been partly responsible. Of the 165 tag recoveries credited to the Sooke area from the Sooke tagging only 2 were recovered at places (Oak and Cordova Bays) adjacent to Haro Strait; of the 477 recoveries credited to the Convention Waters of Strait of Georgia area only 12 were recovered at places within the area extending from Haro Strait to Active Pass (1 - Swanson Channel, 6 - Pender Islands, 5 - Active Pass). Eleven of these latter twelve were from tagging in 1942 and 1946, years in which the Adams River sockeye dominated the runs.

It appears, on the basis of fishing information for Area 18 and the small numbers of tagged sockeye recovered in the area extending from

Oak or Cordova Bays to Active Pass, that the Canadian portion of Haro Strait and its tributary channels were relatively unimportant for sockeye fishing except possibly during some of the cycle years (1942, 1946, etc.) of the Adams River race. However several factors make it unwise to conclude positively that the unimportance is due to the lack of migration of sockeye through Haro Strait rather than to the unavailability of the sockeye to fishing gear. 1. Fishing regulations in some years did not permit fishing in Area 18. 2. Very little fishing is done in the Canadian portion of Haro Strait south of Area 18. This may be partly due to the violent and variable tidal conditions and rough bottom which characterize these waters.

The relative importance of the three avenues of approach (eastern Haro Strait, San Juan Channel, and Rosario Strait) that lie entirely in United States waters is the next question that arises. A review of detailed statistics (Wash. Dept. Fish., unpub.) that were immediately available for the months of July, August and September during the years 1938, 1939 and 1940 (TABLE 3) showed that large percentages of the total catch in the areas extending from Salmon Banks to Point Roberts, inclusive, were made in the Salmon Banks and Point Roberts statistical areas but that only small percentages of the total catch were made in the Rosario and Haro Strait areas which lie between those two. This immediately suggests that availability rather than potential abundance may govern the amounts of gear and the catch of sockeye in each area. For convenience, only the statistics for purse seines have been considered in TABLE 3. This appeared to be permissible since in 1938, 1939 and 1940 the purse seines caught approximately 93, 86, and 79 per cent respectively of all the sockeye caught in the 5 areas.

The importance of San Juan Channel as a fishing area cannot be determined from the statistics for 1938, 1939 and 1940; as the catches in that area after it was opened to fishing in 1939 were included in the Salmon Banks catches. However an examination of statistics (Wash. Dept. Fish., unpub.) for 4 recent years showed that the annual catch in San Juan Channel for the period July through September in the years 1955-1958 amounted to 0.62, 0.50, 0.83, and 0.21 per cent respectively of the total catch by all forms of gear in United States waters extending from Salmon Banks to Point Roberts inclusive. It appears that San Juan Channel can be regarded as an unimportant avenue of approach, first because the catches in its waters are consistently insignificant, and second because whatever sockeye pass through its waters must also emerge into and pass through portions of Haro Strait or Rosario Strait. This logically leaves as the most important avenues of approach the two last mentioned areas.

Comparisons between Haro and Rosario Strait on the basis of the total monthly catches or the ratios of the monthly catches to the monthly landings (TABLE 3) indicated that either the availability or the abundance

TABLE 3—Monthly sockeye catch data for five statistical areas in the United States fishery in 1938, 1939 and 1940.

YEAR AND ITEM	STATISTICAL AREA					TOTAL
	Salmon Banks ¹	West Beach	Rosario Strait ²	Haro Strait	Point Roberts	
1938						
July Catch	10,705	1,099	2,169	401	14,225	28,599
% Catch	37.4	3.8	7.6	1.4	49.7	99.9
Landings	298	32	42	16	290	678
C/L	35.9	34.3	51.6	25.1	49.1	42.2
August Catch	728,789	4,901	68,255	35,400	317,139	1,154,484
% Catch	63.1	0.4	5.9	3.1	27.5	100.0
Landings	2,045	33	254	92	1,695	4,119
C/L	356.4	148.5	268.7	384.8	187.1	280.3
September Catch	6,262	312	43	46	115,036	121,699
% Catch	5.1	0.3	0.0	0.0	94.5	99.9
Landings	177	16	6	2	1,059	1,260
C/L	35.4	19.5	7.2	23.0	108.6	96.6
Total Catch	745,756	6,312	70,467	35,847	464,400	1,304,782
% Catch	57.2	0.5	5.4	2.7	34.2	100.0
Landings	2,520	81	302	110	3,044	6,057
C/L	295.9	77.9	233.3	325.9	146.6	213.7
1939						
July Catch	12,429	1,207	5,460	788	15,385	35,269
% Catch	35.2	3.4	15.5	2.2	43.6	99.9
Landings	295	33	100	20	340	788
C/L	42.1	36.6	54.6	39.4	45.3	44.8
August Catch	202,881	28,484	8,047	21,169	109,542	370,123
% Catch	54.8	7.7	2.2	5.7	29.6	100.0
Landings	1,593	457	115	200	1,049	3,414
C/L	127.4	62.3	70.0	105.8	104.4	108.4
September Catch	23,219	1,150	479	3,797	36,338	64,983
% Catch	35.7	1.8	0.7	5.8	55.9	99.9
Landings	740	133	90	123	830	1,916
C/L	31.4	8.7	5.3	30.9	43.8	33.9
Total Catch	238,529	30,841	13,986	25,754	161,265	470,375
% Catch	50.7	6.6	3.0	5.5	34.3	100.1
Landings	2,628	623	305	343	2,219	6,118
C/L	90.8	49.5	45.9	75.1	72.7	76.9
1940						
July Catch	152,465	4,766	32,731	-----	58,273	248,235
% Catch	61.4	1.9	13.2	-----	23.5	100.0
Landings	607	20	119	-----	395	1,141
C/L	251.2	238.3	275.1	-----	147.5	217.6
August Catch	89,985	14,374	31,403	631	121,254	257,647
% Catch	34.9	5.6	12.2	0.2	47.1	100.0
Landings	509	61	139	3	673	1,385
C/L	176.8	235.6	225.9	210.3	180.2	186.0
September Catch	385	120	4	54	4,152	4,715
% Catch	8.2	2.5	0.1	1.1	88.1	100.0
Landings	85	59	2	7	364	517
C/L	4.5	2.0	2.0	7.7	11.4	9.1
Total Catch	242,835	19,260	64,138	685	183,679	510,597
% Catch	47.6	3.8	12.6	0.1	36.0	100.1
Landings	1,201	140	260	10	1,432	3,043
C/L	202.2	137.6	246.7	68.5	128.3	167.8

¹Includes the Salmon Banks and South Lopez recovery areas and also San Juan Channel after it was opened to fishing in 1939.

²Includes Rosario Strait and Lummi Island recovery areas.

of sockeye had varied between the two areas both seasonally and annually in 1938, 1939 and 1940. On the basis of the percentages that the Rosario Strait and Haro Strait catches were of the total catches in all five areas during July and also on the basis of the ratios of catch per landing it appeared that sockeye were relatively abundant or available in Rosario Strait in July of the three years but were very scarce or unavailable in Haro Strait. A similar comparison of August catches indicated August was the best month for catching sockeye in Haro Strait in 1938 and 1939 when the latter Strait exceeded Rosario Strait in catch per landing in both years, but only exceeded Rosario Strait in catch in 1939. In 1940 fishing in August was very poor in Haro Strait but it was very good in Rosario Strait. It appeared that fishing in September was poor in both areas during all the years except 1939. In that year slightly better than average September catches in Haro Strait indicated that during September sockeye were slightly more available or abundant there than they were in Rosario Strait. In 1939 the indication of greater abundance in Haro Strait may have been partly due to the biennial abundance of pink salmon (*O. gorbuscha*) which occurs on odd-numbered years. However examination of the catches of sockeye per landing indicated that sockeye were actually more abundant in Haro Strait than they were in Rosario Strait during August and September of 1939.

It is indicated that the relative importance of the various routes of migration varied from season to season and from year to year. It is also indicated that although availability may have been a tremendous factor in determining the relative importance of a specific area it does not eliminate abundance as a factor; but it does make untenable the assumption that the fishing gear were deployed according to the abundance of sockeye. A more thorough study of the fishery was not within the scope of this report.

SOOKE

The Salmon Commission tagged 16,581 sockeye from traps near Sooke during the years 1938 to 1948 and 43.4 per cent of the tags were recovered. The annual number tagged varied from 433 in 1948 to 3,902 in 1946 and the annual percentage recovered varied from 36.0 in 1948 to 59.0 in 1941 (TABLE 1). The percentage distribution of the combined recoveries, for the 11 years of tagging, are listed in TABLE 2 by recovery area.

The distribution of the recovered tags indicated conclusively that the great majority of sockeye in the Strait of Juan de Fuca at the times of tagging were migrating to the Fraser River. Of the 7,200 tagged sockeye recovered from the Sooke experiments: 3,910 were recovered either off the mouth or in the Fraser River system. An additional 2,258 were recovered in the areas extending from Salmon Banks and West Beach to the northern limits of the Canadian Convention waters in Georgia Strait. Three hundred were reported without definite information regarding the places

of capture, but it is very likely that most if not all of these were captured in areas en route to Fraser River spawning grounds. One hundred and sixty-five were recovered in the tagging area. Most of the remaining 567 recoveries were from areas frequented by non-Fraser races of sockeye which are relatively unimportant compared to the Fraser races but are nevertheless relatively abundant in the Strait of Juan de Fuca prior to the first part of July. A more detailed discussion of non-Fraser races is contained in the TIME OF PASSAGE section. The principal route of migration from Sooke appears to have been through the following fishing areas in United States Convention waters: Salmon Banks, South Lopez, West Beach, Rosario Strait, Lummi Island, and Point Roberts. This does not mean that all the sockeye that used the principal route passed through each area listed. In fact some fish may have passed directly from Sooke to the South Lopez or West Beach areas. It is also apparent that all the fish that passed through the Salmon Banks and South Lopez areas may not have passed through the West Beach area en route to Rosario Strait, and all the fish that passed through the Salmon Banks or South Lopez areas may not have used the Rosario Strait route in preference to the Haro Strait or San Juan Channel routes. Near Point Roberts the sockeye re-entered Canadian Convention waters. Some sockeye that may have proceeded via Haro Strait or the less frequently used San Juan Channel may have then continued directly to the Fraser River instead of to Point Roberts. It appears possible that at times some sockeye may have migrated through the Strait of Juan de Fuca and may have arrived at the Fraser River without leaving Canadian waters. It is also possible that some sockeye do not enter the Sooke area or other Canadian waters in the Strait of Juan de Fuca but instead pass through United States Convention waters and enter Canadian Convention waters for the first time in the Strait of Georgia.

Entry of sockeye into the Fraser River on the basis of the distribution of recoveries was primarily via the Main Arm (945 recoveries). The other three entrances were frequented in the following order: Canoe Pass, 346 recoveries; Point Grey, 129 recoveries; and Middle Arm, 100 recoveries. Above Mission the sockeye proceeded unmolested to the spawning grounds except for the occasional Indian fishery.

Returning now to the problems of diagramming the routes of migration, the inadequacy of the tagging data is strongly indicated by TABLE 4. The table lists, by year and area, the numbers of recoveries within that portion of United States Convention waters which extend from Salmon Banks to Canadian Convention waters within the Strait of Georgia, plus the percentage distribution of those recoveries within those United States waters. The recoveries in San Juan Channel and in Haro Strait have been listed separately instead of in the combined San Juan Channel-Haro Strait area for purposes of permitting inferences regarding the relative importance of each of these two areas and of Rosario Strait as avenues of migra-

tion. In addition the data for even and odd-numbered years have been arranged separately to facilitate possible inferences regarding the effects of the presence of large numbers of pink salmon in odd-numbered years on the distribution of the recovered sockeye.

Inspection of TABLE 4 indicated that the small numbers of recoveries in some areas plus the considerable degree of variability between areas from year to year made it virtually impossible to determine the precise relative importance of Rosario Strait, Haro Strait, and San Juan Channel routes for a number of reasons. 1. It was necessary to bear in mind that some inaccurate reporting of places of recovery was almost certain to have occurred and that the errors were most likely to be in favor of the most popular fishing areas. 2. It also appeared that the occurrence

TABLE 4—Sooke tagging, 1938 through 1947. Number of recoveries and percentage distributions of the recoveries by area in the major portion of the United States fishery. (Percentages are in parentheses).

YEAR	RECOVERY AREA								TOTAL
	San Juan Islands Areas							Point Roberts	
	Salmon Banks	South Lopez	West Beach	Rosario Strait	Lummi Island	Haro Strait	San Juan Channel		
Even									
1938	33 (33.7)	— —	3 (3.1)	3 (3.1)	5 (5.1)	4 (4.1)	— —	50 (51.0)	98 (100.1)
1940	16 (19.5)	10 (12.2)	3 (3.7)	3 (3.7)	9 (11.0)	— —	2 (2.4)	39 (47.6)	82 (100.1)
1942	32 (15.8)	9 (4.4)	14 (6.9)	27 (13.3)	23 (11.3)	— —	3 (1.5)	95 (46.8)	203 (100.0)
1944	13 (15.3)	11 (12.9)	4 (4.7)	10 (11.8)	3 (3.5)	1 (1.2)	— —	43 (50.6)	85 (100.0)
1946	93 (23.8)	34 (8.7)	15 (3.8)	36 (9.2)	25 (6.4)	5 (1.3)	1 (0.3)	182 (46.5)	391 (100.0)
Subtotal Average	187 (21.6)	64 (7.6)	39 (4.4)	79 (8.2)	65 (7.5)	10 (1.3)	6 (0.8)	409 (48.5)	859
Odd									
1939	35 (22.0)	8 (5.0)	14 (8.8)	1 (0.6)	22 (13.8)	7 (4.4)	2 (1.3)	70 (44.0)	159 (99.9)
1941	35 (20.5)	14 (8.2)	11 (6.4)	11 (6.4)	16 (9.4)	5 (2.9)	5 (2.9)	74 (43.3)	171 (100.0)
1943	45 (23.4)	5 (2.6)	48 (25.0)	7 (3.6)	29 (15.1)	1 (0.5)	4 (2.1)	53 (27.6)	192 (99.9)
1945	44 (26.8)	14 (8.5)	16 (9.8)	7 (4.3)	10 (6.1)	— —	— —	73 (44.5)	164 (100.0)
1947	62 (26.4)	1 (0.4)	34 (14.5)	3 (1.3)	34 (14.5)	16 (6.8)	3 (1.3)	82 (34.9)	235 (100.1)
Subtotal Average	221 (23.8)	42 (4.9)	123 (12.9)	29 (3.2)	111 (11.7)	29 (2.9)	14 (1.5)	352 (38.9)	921
Grand Total Average	408 (22.7)	106 (6.3)	162 (8.7)	108 (5.7)	176 (9.6)	39 (2.1)	20 (1.2)	761 (43.7)	1780

of pink salmon on odd-numbered years affected the deployment of fishing gear. For example, the abundance of pink salmon in the West Beach area on odd-numbered years appears to have increased the relative number of tagged sockeye recovered in that area in those years. This could have been the result of differences between sockeye and pink salmon in regard to both timing and distribution: for although the runs of these two salmon overlap one another, the sockeye tend to appear and peak in the subject fishing areas earlier than the pinks do; also, important spawning grounds for pinks exist in a number of nearby river systems in addition to the most important Fraser system. These differences in timing and distribution probably resulted in the shifting of fishing effort from sockeye to pinks as the respective runs waned and waxed. 3. Fishing regulations also added to the difficulties in determining the importance of the routes of migration. Some of the waters lying between San Juan, Orcas and Lopez Islands including parts of San Juan Channel have for many years been included in an area closed to commercial salmon fishing termed the San Juan Preserve. This preserve automatically prevented the recovery by commercial fishing of tagged fish which might have migrated from San Juan Channel to Rosario Strait via Upright Channel, but it did not prevent the recovery of tagged fish that migrated from San Juan Channel to the Haro Strait area. Also because of the biennial abundance of pink salmon, the fishing regulations on odd-numbered years have tended to differ from those on even-numbered years. The differing regulations plus the occurrence of the dominant late-running Adams sockeye during three of the even-numbered years (1938, 1942 and 1946) may have accounted for the greater relative recovery of tagged sockeye in the Point Roberts area during even-numbered years than in odd-numbered years.

It will be recalled that O'Malley and Rich (1919) stated on the basis of the tagging in 1918 that there was no evidence that the principal route of migration was varied in different parts of the season. However consideration of information derived from the Salmon Commission's experiments plus the short period of tagging at Sooke in 1918, July 14 to August 6, and also the periods of tagging at other points indicates that neither the 1918 experiments nor the Salmon Commission's experiments were adequate to illustrate possible variations. But rather than dismiss the question of variability too hastily a determined effort has been made to glean from the Salmon Commission's experiments whatever information they might contain on seasonal variability.

The recoveries represented by the data listed in TABLE 4 for the eight United States areas were retabulated by year and by seven-day tagging periods. Then the annual recoveries in each area for each tagging period were weighted in terms of per cent according to the numbers of sockeye that had been tagged during the respective period. The weighted recoveries for even-numbered years (1938, 1940, 1942 and 1944) were then totalled for each tagging period by area of recovery. Finally the

weighted recovery totals for each area were divided by the number of years represented by tagging in each period, regardless of whether or not all the areas were represented by recoveries, to give an average weighted recovery figure for each area according to period of tagging. The last two steps were also applied to the data for the odd-numbered years (1939, 1941, 1943 and 1945). Data for 1946 and 1947 were not treated in this manner because as a result of the Salmon Commission's regulations sockeye fishing was prohibited until July 25 and August 18 respectively in the subject areas. TABLE 5 is a tabulation of the average weighted recovery data.

Inspection of the table indicates the following patterns of tag recovery for the various areas:

Salmon Banks—Recovery was high from July 14 to August 10 during the even-numbered years and reached a peak value of 4.19 during the period July 28 to August 3 after which time it declined gradually. The

TABLE 5—Sooke tagging, 1938 through 1945. Average weighted recovery data by area and period of tagging.

AREA AND EVEN OR ODD YEARS	PERIOD TAGGED									
	July 1-6	July 7-13	July 14-20	July 21-27	Jul.28 -Aug.3	Aug. 4-10	Aug. 11-17	Aug. 18-24	Aug. 25-31	Sept. 1-7
Salmon Banks										
Even	-----	0.99	3.72	4.04	4.19	3.17	1.37	1.67	1.62	0.44
Odd	0.96	1.28	3.02	5.08	5.90	4.24	4.46	5.77	7.69	5.27
South Lopez										
Even	-----	0.53	1.18	2.12	0.68	0.25	0.70	0.19	0.43	1.25
Odd	0.96	1.60	2.30	1.40	1.68	1.00	0.55	0.72	0.78	-----
West Beach										
Even	-----	0.15	1.15	0.45	0.92	0.45	0.42	0.24	0.85	-----
Odd	0.96	1.06	1.65	1.62	2.97	3.66	2.78	2.87	1.65	1.60
Rosario Strait										
Even	-----	0.23	0.85	1.60	1.47	1.60	0.94	0.81	0.09	-----
Odd	-----	0.22	0.63	1.74	1.78	2.12	0.14	0.46	-----	-----
Lummi Island										
Even	0.65	0.15	-----	0.23	1.78	1.58	0.55	0.91	0.41	1.34
Odd	1.84	1.06	2.02	1.78	1.09	4.57	2.47	3.03	0.44	-----
San Juan Channel										
Even	-----	-----	-----	0.33	0.30	0.16	-----	0.25	0.12	-----
Odd	-----	-----	-----	0.11	-----	0.50	0.38	0.85	0.54	1.47
Haro Strait										
Even	-----	-----	-----	-----	-----	0.21	0.24	0.48	0.22	-----
Odd	-----	-----	0.24	0.42	0.69	0.50	0.24	0.39	0.22	-----
Point Roberts										
Even	0.30	5.12	6.08	4.82	4.14	5.46	4.97	4.82	4.41	5.32
Odd	8.18	6.23	6.40	8.58	8.72	5.54	7.76	9.07	6.50	2.69
Number Years Represented										
Even	3	4	4	4	3	4	4	4	4	4
Odd	2	3	4	4	4	3	4	4	4	4

recovery during the odd-numbered years was consistently greater than that of even-numbered years with a high value of 5.90 for the period July 28 to August 3 and a still higher or peak value of 7.69 during the period August 25 to 31.

South Lopez—The recovery was never very high in either even-numbered or odd-numbered years but in general the values for the odd-numbered years were slightly higher. The peak values of 2.30 and 2.12 occurred during the periods July 14 to 20 and 21 to 27 of odd and even-numbered respectively. The value of 1.25 for the last tagging period during the even-numbered years should be disregarded as it is the result of 1 recovery, the only recovery in all the areas, from 20 tagged fish. From these data it appears that sockeye are most available at South Lopez during the last half of July.

West Beach—The recoveries in this area on the average were never very great, but they had a definite pattern of biennial variation. The recoveries in this area on even-numbered years were generally less than those in the South Lopez area but on odd-numbered years they exceeded those in the South Lopez area. The pattern of recovery for the odd-numbered years was one of gradual rise in recovery from a value of 0.96 for the first period in July to a peak value of 3.66 for the period August 4 to 10 and a slow decline to a value of 1.60 for the last period, September 1 to 7.

Rosario Strait—The patterns of recoveries for the even and odd-numbered years were quite similar. The recoveries during both series of years were greater than the even-year recoveries at West Beach but less than the odd-year recoveries in that area. In general the recoveries seemed restricted to a slightly shorter portion of the season than did those in the areas already discussed, there being no recoveries during the first and last periods. The period of greatest recovery regardless of even or odd-numbered years was July 21 to August 10 when the values ranged between 1.47 and 2.12.

Lummi Island—During the even-numbered years the pattern of recoveries in this area was somewhat similar to that of the Rosario Strait area in amplitude but in other respects the pattern was considerably more variable. The peak value of 1.78 occurred during July 28 to August 3. The pattern for the odd-numbered years indicated a decidedly greater recovery than during even-numbered years. A fair number of recoveries (value 1.84) occurred during the first period, July 1 to 6. The recovery value reached 2.02 during July 14 to 20 then dropped to 1.09 during July 28 to August 3 and then rose to a peak value of 4.57 during August 4 to 10 and continued at a high level until August 24 before dropping to 0.44 during August 25 to 31.

San Juan Channel and Haro Strait—The recoveries in these two areas were so meager that they preclude a discussion of a pattern for either area except for the comments that recoveries were never made

from early season tagging and recoveries were more numerous during odd-numbered years than on even-numbered years. The average values for San Juan Channel in the even-numbered years were based on one year less than the number of years shown in TABLE 5 because the area was closed during 1938.

Point Roberts—The recoveries in this area with the exception of those during August 25 to 31 and September 1 to 7 in odd-numbered years, when the Salmon Banks recoveries attained values of 7.69 and 5.27 respectively, were in general consistently greater than those of any other area. In addition the recovery was at a high level from the first to the last tagging period. The recovery in odd-numbered years was considerably better than that of the even-numbered years. During even years a peak (6.08) was suggested during the period July 14 to 20 but on odd years two peaks were evident, July 21 to August 3 (8.58 to 8.72), and August 18 to 24 (9.07). During the odd years a low value of 5.54 was indicated for the period of August 4 to 10 which was the period of peak but much smaller recovery values at West Beach, Rosario Strait and Lummi Island. The dip in the Point Roberts pattern may have been a reflection of the increased recovery in the other areas mentioned and these increased recoveries may have been due to movements of fishing gear from one area to another. However, no attempt has been made to estimate the numbers of tags available for recovery in each area by the subtraction of prior recoveries in more seaward areas from the numbers of sockeye initially tagged. Such a procedure does not appear justified in view of the complexity of the factors affecting the experiments. One immediate objection to the procedure is that the route of migration which the analysis of the tagging data seeks to establish would have to be assumed to be known before the corrections could be made.

Before summarizing this discussion which is based on small amounts of quite variable data it should be re-emphasized that a number of factors may have been affecting the patterns of tag recovery and means for correcting or eliminating those effects were not at hand. Some of these factors were: 1. Small numbers of fish tagged in some periods and inconsistent tagging effort (effort refers to numbers tagged), 2. No corrections for recoveries that occurred in other areas, 3. Fishermen returning from Alaska plus immigration by Alaskan fishermen after the start of the sockeye season, 4. The possible improvement of reporting recovered tags as the season progresses, 5. The effect of tagging consistently on one of two specific days of the week instead of every day or at random, 6. The different times of passage of different races that dominated the annual runs, 7. The biennial abundance of pink salmon and fluctuations in that abundance, 8. Tides and weather, 9. Variable fishing regulations, and 10. Strikes and also quotas.

In general the detailed examination of the recovery data (TABLES 4 and 5) indicated that the Salmon Commission's tagging experiments

were not adequate to establish the precise relative importance of the Rosario Strait, Haro Strait and San Juan Channel routes of migration. Consequently the data were not adequate to determine differences between years or parts of a season in regard to the use of the various routes, but we feel quite strongly that such differences do occur. It was shown that the distribution of the recoveries was quite sensitive to fishing regulations and to the presence of sizeable numbers of pink salmon on odd-numbered years. There were slight suggestions: that the periods of peak recovery occurred slightly earlier at South Lopez, West Beach and Rosario Strait than at Salmon Banks; that recoveries were not made in the Haro Strait and San Juan Channel areas early in the season: and that on odd-numbered years the recoveries were more numerous and the peak periods of recovery were later than on even-numbered years.

SALMON BANKS

The Salmon Commission tagged 2,556 sockeye from purse seines in the Salmon Banks area in 1939, 1940 and 1941 (TABLE 1). A total of 1,624 or 63.5 per cent of the tagged fish were recovered. TABLE 6 lists the numbers of Salmon Banks tags recovered and their percentage distribution in the San Juan Islands and Point Roberts areas of the United States fishery. The table also lists comparable information for sockeye tagged at Sooke during similar periods of the years represented by tagging at Salmon Banks. The fact that tagging at Sooke was done almost entirely on Thursdays while the tagging at Salmon Banks was done on various days of the week interfered with a strict comparison of the data derived from the two series of experiments. The tagging at Salmon Banks always resulted in a greater percentage of the tags recovered in the combined San Juan Islands and Point Roberts areas being recovered in the Salmon Banks area than did the tagging at Sooke. Consequently there were relatively fewer Salmon Banks tags available for recovery in the remaining seven areas of the combined San Juan Islands and Point Roberts area than there were of the Sooke tags. Nevertheless the relative as well as the actual recovery in Haro Strait of Salmon Banks tags was greater than it was for Sooke tags in all three years and especially in 1939 and 1941.

The Salmon Banks tagging data (TABLES 2 and 6) indicated that the routes of migration from Salmon Banks to the Fraser River were similar to those taken by sockeye en route from Sooke (FIGURE 4) except that sockeye tagged at Salmon Banks seemed to have used Haro Strait more frequently than sockeye tagged at Sooke. This suggests that a greater portion of the sockeye passing Sooke migrate directly to the areas (South Lopez, West Beach, Rosario Strait and Lummi Island) associated with Rosario Strait, the most easterly approach to the Point Roberts and Fraser River areas; and that a lesser portion of the sockeye that arrive in the Salmon Banks area migrate via these easterly areas; and that instead more of these latter fish use Haro Strait, the more westerly

approach. However the meager amount of data available and the fact that the tagging at Sooke and at Salmon Banks was not done at random nor on similar days of the week detracts from the acceptability of this hypothesis.

TABLE 6—Comparison between Salmon Banks and Sooke tagging; 1939, 1940 and 1941. Number of recoveries and percentage distributions of the recoveries by area. (Percentages are in parentheses.)

TAGGING AREA AND YEAR	RECOVERY AREA								TOTAL
	San Juan Islands							Point Roberts	
	Salmon Banks	South Lopez	West Beach	Rosario Strait	Lummi Island	Haro Strait	SanJuan Channel		
Salmon Banks									
1939	101 (30.3)	15 (4.5)	39 (11.7)	1 (0.3)	33 (9.9)	37 (11.1)	3 (0.9)	104 (31.2)	333 (99.9)
1940	36 (22.1)	13 (8.0)	6 (3.7)	7 (4.3)	20 (12.3)	3 (1.8)	4 (2.5)	74 (45.4)	163 (100.1)
1941	18 (29.5)	2 (3.3)	4 (6.6)	4 (6.6)	5 (8.2)	4 (6.6)	2 (3.3)	22 (36.1)	61 (100.2)
Total	155	30	49	12	58	44	9	200	557
Average %	(27.3)	(5.3)	(7.3)	(3.7)	(10.1)	(6.5)	(2.2)	(37.6)	
Sooke									
1939	24 (22.9)	6 (5.7)	8 (7.6)	1 (1.0)	13 (12.4)	2 (1.9)	2 (1.9)	49 (46.7)	105 (100.1)
1940	12 (20.7)	7 (12.1)	2 (3.4)	3 (5.2)	6 (10.3)	---- (3.4)	2 (3.4)	26 (44.8)	58 (99.9)
1941	25 (18.7)	11 (8.2)	5 (3.7)	11 (8.2)	14 (10.4)	5 (3.7)	4 (3.0)	59 (44.0)	134 (99.9)
Total	61	24	15	15	33	7	8	134	297
Average %	(20.8)	(8.7)	(4.9)	(4.8)	(11.0)	(1.9)	(2.8)	(45.2)	

SAN JUAN CHANNEL AND SOUTH LOPEZ

During 1939 and 1941 the Salmon Commission tagged 292 sockeye in the southern portion of San Juan Channel and 1,281 off the southern tip of Lopez Island. An additional 60 sockeye were tagged in the South Lopez area during 1940. Nearly 70 per cent of the San Juan Channel tags were recovered and approximately 64 per cent of the South Lopez tags were recovered. Data regarding the tagging in these two areas are shown by TABLES 1, 2 and 7.

The small amount of tagging in San Juan Channel yielded very little information on the routes of migration of sockeye found in the area. It appeared that some sockeye retrograded or dropped back from the Channel to the Salmon Banks, South Lopez and West Beach areas. However erroneous reporting may have been partly responsible for that indication. Many of the San Juan Channel sockeye migrated to the Point Roberts area and some were taken in the Lummi Island area. Detailed examina-

TABLE 7—San Juan Channel and South Lopez tagging, 1939 and 1941. Number of recoveries and percentage distributions of the recoveries by area. (Percentages are in parentheses.)

TAGGING AREA AND YEAR	RECOVERY AREA								TOTAL
	San Juan Islands Areas							Point Roberts	
	Salmon Banks	South Lopez	West Beach	Rosario Strait	Lummi Island	Haro Strait	San Juan Channel		
San Juan Channel									
1939	10 (12.8)	4 (5.1)	6 (7.7)	---- ----	5 (6.4)	4 (5.1)	8 (10.3)	41 (52.6)	78 (100.0)
1941	5 (38.4)	2 (15.4)	---- ----	---- ----	---- ----	---- ----	---- ----	6 (46.2)	13 (100.0)
Total Average %	15 (25.6)	6 (10.2)	6 (3.8)	---- ----	5 (3.2)	4 (2.6)	8 (5.2)	47 (49.4)	91
South Lopez									
1939	36 (18.6)	16 (8.2)	20 (10.3)	1 (0.5)	18 (9.3)	7 (3.6)	6 (3.1)	90 (46.4)	194 (100.0)
1941	6 (9.2)	2 (3.1)	3 (4.6)	15 (23.1)	5 (7.7)	---- ----	1 (1.5)	33 (50.8)	65 (100.0)
Total Average %	42 (13.9)	18 (5.6)	23 (7.5)	16 (11.8)	23 (8.5)	7 (1.8)	7 (2.3)	123 (48.6)	259

tion of the tag recoveries did not indicate whether some of these fish passed through Upright Channel to Lummi Island and Point Roberts or whether some of the fish passed from San Juan Channel to Point Roberts and Lummi Island via President Channel instead of Haro Strait proper. It was indicated that Haro Strait was used by at least some of the fish. The San Juan Preserve could have hindered the detection of fish moving through Upright Channel and thence to Rosario Strait and Lummi Island.

The fish tagged in the South Lopez area tended to follow the same migratory routes that were indicated by the Sooke and Salmon Banks experiments, with the majority of the fish being recovered in the Strait of Georgia and the Fraser River drainage. A number of fish, as in the San Juan Channel experiments, were retaken in adjacent areas (Salmon Banks, West Beach and San Juan Channel-Haro Strait) which were not on the direct route to the Fraser River. Mackay *et al.* (1945) in an earlier report on the Salmon Commission's tagging remarked that there appeared to be some to and fro movement of individual sockeye but that the numbers moving in directions opposite to that of the Fraser River were insignificant. O'Malley and Rich (1919) found that there was apparently interchange of sockeye between the Salmon Banks and West Beach areas.

WEST BEACH

During 1939 and 1941 the Salmon Commission tagged 157 sockeye in the West Beach area. Approximately 66 per cent of the tags were

recovered. The number of fish tagged is too small to warrant much discussion of the results listed in TABLE 2. Most of the recoveries were made in areas coincident with what is considered to be the normal or most important migration route but some recoveries were made in the South Lopez, Salmon Banks, and San Juan Channel-Haro Strait areas.

LUMMI ISLAND

The Salmon Commission tagged 2,550 sockeye in the Lummi Island area during the years 1939, 1940 and 1941. Approximately 52 per cent of the tags were recovered. TABLES 1, 2 and 8 list information concerning these experiments. The distribution of the tag recoveries was in accordance with what might be reasonably expected on the basis of information derived from tagging experiments conducted further to seaward (Salmon Banks, Sooke, etc.). One facet of the Lummi Island tagging which perhaps should be mentioned is that in 1941 a very large proportion of the fish tagged were tagged on Saturdays during the week-end closures. Such a factor certainly influences the distribution of the tag recoveries and limits the rigorous comparisons of year against year and tagging area against tagging area. The Saturday tagging may explain why the percentages of the tags recovered in United States waters tended to be less in the San Juan Islands areas and greater in the Point Roberts area in 1941 than they were in the other years (TABLE 8). The effects of the tagging during the week-end closures in 1941 on the recoveries in Canadian waters were less clearly indicated. This will be discussed in detail under Bias by Day of the Week in the section on FISHING INTENSITY.

TABLE 8—Lummi Island tagging; 1939, 1940 and 1941. Number of recoveries and percentage distributions of the recoveries by area. (Percentages are in parentheses.)

YEAR	RECOVERY AREA								TOTAL
	San Juan Islands Areas							Point Roberts	
	Salmon Banks	South Lopez	West Beach	Rosario Strait	Lummi Island	Haro Strait	SanJuan Channel		
1939	13 (10.2)	4 (3.1)	14 (11.0)	— —	16 (12.6)	6 (4.7)	— —	74 (58.2)	127 (99.8)
1940	6 (6.7)	5 (5.6)	— —	1 (1.1)	15 (16.7)	2 (2.2)	— —	61 (67.8)	90 (100.1)
1941	4 (3.9)	5 (4.9)	— —	4 (3.9)	9 (8.8)	— —	— —	80 (78.4)	102 (99.9)
Total	23	14	14	5	40	8	—	215	319
Average %	(6.9)	(4.5)	(3.7)	(1.7)	(12.7)	(2.3)	—	(68.1)	

POINT ROBERTS

During 1939 and 1941 the Salmon Commission occasionally tagged a few sockeye in the Point Roberts area. The recoveries numbered 141 or approximately 67 per cent of the 210 fish tagged. Except for the tags recovered in the tagging area (approximately 7 per cent) the remainder

of the recoveries (approximately 93 per cent) were made in Canadian waters.

SAND HEADS

The Salmon Commission tagged 6,901 sockeye caught by purse seines in the vicinity of the Sand Heads off the mouth of the Fraser River during the four years 1938 to 1941. The recoveries numbered 4,202 or approximately 61 per cent of the total tagged and attained a maximum value of 75.3 per cent in 1939. The high percentages recovered reflect the intensity of the fishery in confined waters plus the selectivity of gill nets (the only commercial fishing gear in the river and in the area immediately adjacent to its mouth) for disk tags. The oval tag was introduced in 1940 and 1941 in an attempt to eliminate selectivity and to obtain an estimate of the amount of selectivity for disk tags. Selectivity will be discussed in detail in the section on FISHING INTENSITY.

Tagging indicated that sockeye at Sand Heads were destined for spawning grounds in the Fraser River watershed. Two per cent of the recoveries were from United States waters (primarily from the Point Roberts area) and one per cent were from unknown Canadian areas.

JOHNSTONE STRAIT

During 1940 and 1941 the Salmon Commission tagged 2,746 sockeye from purse seines in that portion of upper Johnstone Strait extending from Plumper Islands to Forward Bay (FIGURE 5). The per cent recovery from the 1940 tagging was 49.5 while that from 1941 was 65.8. Probable reasons for the increased recovery during the odd-numbered year will be given in the section on FISHING INTENSITY. There is little that can be said regarding the routes of migration of the sockeye tagged in Johnstone Strait as the sockeye present there during the periods of tagging (July 16 to August 12, 1940 and July 21 to August 7, 1941) appear to have been bound primarily for the Fraser River and to have moved rather directly through the constricted waters of Johnstone Strait and Discovery Passage and thence through the Strait of Georgia to the Fraser River. Of the 1,554 Johnstone Strait tags recovered from the 2 years of tagging there were 394 and 179 recovered in upper and lower Johnstone Strait, respectively. Of those credited to upper Johnstone Strait there were 11 recoveries reported from Knight Inlet which has a native sockeye run and 1 recovery reported from Fitzhugh Sound which is northwest of the areas shown by FIGURE 5 and is en route to the Rivers Inlet spawning grounds. There were 10 recoveries reported by the United States fishery (7-Point Roberts, 1-Salmon Banks, 1-Lummi Island, and 1-unknown). Comparison of the distribution of recoveries at the mouth of the Fraser River of Johnstone Strait tags with that of Sooke tags of nearly equivalent tagging dates indicated that sockeye from Johnstone Strait were decidedly more available at the more northerly entrances to the river than were sockeye from Sooke. Chi-square comparisons of the

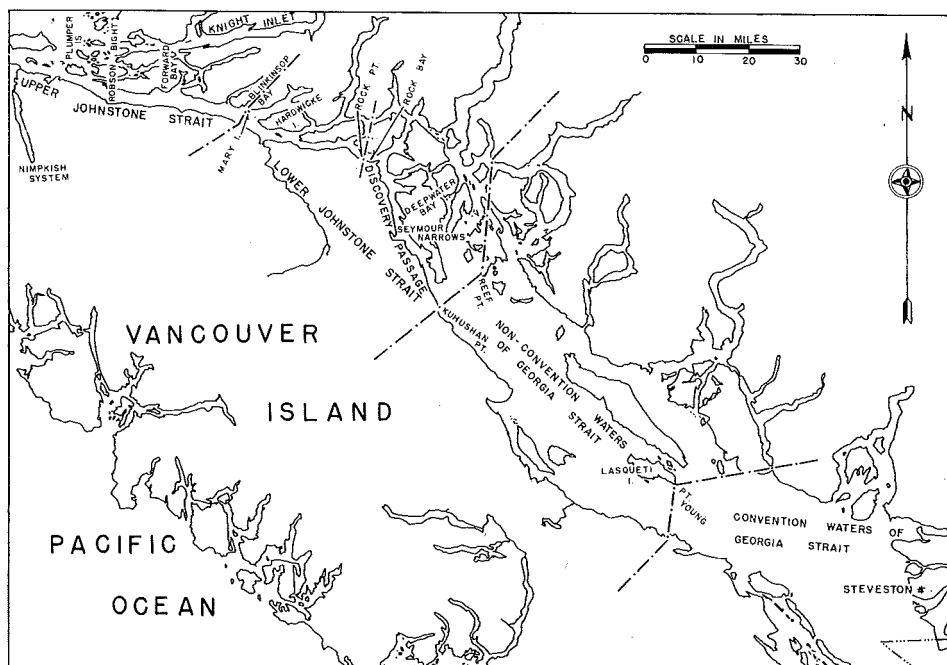


FIGURE 5—Johnstone Strait tagging area (Plumper Islands to Forward Bay) and subdivisions of Point Young-Johnstone Strait recovery area.

distributions represented by TABLE 9 indicated that the differences were very significant ($p < 0.001$).

Comparison of Sooke tagging of equivalent date with that of Johnstone Strait, on the basis of spawning ground recoveries, indicated in general that identical races were sampled at the two tagging locations. In 1940 Johnstone Strait tagged sockeye were recovered in six specific Fraser River spawning areas, while sockeye tagged at Sooke were recovered in five of these same areas. The 1941 spawning ground recoveries were too few to permit a similar comparison.

TABLE 9—Comparison of the distribution of Johnstone Strait tags with Sooke tags recovered in the Mouth of Fraser area in 1940 and 1941. (Percentages in parentheses.)

TAGGED AT	1940					1941				
	Mouth of Fraser				TOTAL	Mouth of Fraser				TOTAL
	Canoe Pass	Main Arm	Middle Arm	Point Grey		Canoe Pass	Main Arm	Middle Arm	Point Grey	
Sooke	17 (26.6)	37 (57.8)	4 (6.2)	6 (9.4)	64 (100.0)	14 (22.6)	39 (62.9)	3 (4.8)	6 (9.7)	62 (100.0)
Johnstone Strait	19 (7.5)	101 (40.1)	57 (22.6)	75 (29.8)	252 (100.0)	19 (6.5)	147 (50.3)	51 (17.5)	75 (25.7)	292 (100.0)
Total	36	138	61	81	316	33	186	54	81	354

Chi-square=35.5

df 3

$p < 0.001$

Chi-square=26.9

df 3

$p < 0.001$

Retrograde Migration

The tag returns from the various experiments indicated that instances of retrograde movement, herein defined as any movement away from the Fraser River regardless of whether or not the sockeye was indigenous to the river, were few. Only 853 of the 17,219 recovered tags were reported from places not directly en route to the Fraser River, and these can be reduced to 152 or less than 0.9 per cent of the total recoveries by judicious omissions.

There were 498 recoveries credited to the West of Sooke and Miscellaneous Washington areas. These were fish either apparently en route to or in non-Fraser areas such as Nitinat Lake, Barkley Sound (Somass River), Skagit Bay (Skagit and Baker Rivers), and the Lake Washington drainage. Most of these recoveries resulted from fish tagged at Sooke during May, June and the first week of July.

There were 12 recoveries credited to the Upper Johnstone Strait area which may have been en route to spawning streams in Knight Inlet and Rivers Inlet. These were fish tagged in Upper Johnstone Strait.

There were 99 recoveries of fish tagged in various areas and recovered elsewhere which may have drifted for short distances in a direction away from the Fraser River because of tidal action or the possible adverse effects of tagging, or which may have proceeded toward the river in an indirect manner, or which may have been erroneously reported from areas adjacent to the tagging area. Erroneous reporting of the recovery of tags from areas adjacent to the actual area of recovery is a distinct probability especially in a mobile fishery. Examples of recoveries included in these 99 omissions are: 43 South Lopez tags reported from Salmon Banks; 27 San Juan Channel tags reported from Salmon Banks (15), South Lopez (6), and West Beach (6); and 9 West Beach tags reported from Salmon Banks (2), South Lopez (6), and San Juan Channel-Haro Strait (1).

There were 92 fish tagged at Sand Heads and recovered at Point Roberts. These will be discussed subsequently under the heading Blowbacks.

Many of the remaining 152 recoveries cannot be reasonably considered to be indications of retrograde migration of Fraser River sockeye. For example, 13 recoveries in the West of Sooke area, 8 recoveries in the Miscellaneous Washington area, and 50 recoveries in the Point Young-Johnstone Strait area of sockeye tagged at Sooke can be so considered only because of the previous definition of retrograde. Many of these sockeye were obviously not Fraser River sockeye. In addition some of these aberrant recoveries may have been the result of erroneous reporting. When all things are considered, retrograde migration of Fraser River sockeye except for blowbacks from the mouth of the river to the Point Roberts area is nonexistent for practical purposes.

Blowbacks

Fishermen have long believed that sockeye milling about while delaying off the mouth of the Fraser River, particularly after the first of September, are prone to drift into the Point Roberts area during or after periods of strong northwest wind. This phenomenon frequently results in increased daily catches in the Point Roberts area and has been termed "blowback" or "driftback". To prevent the catching of excessive numbers of delaying sockeye and pink salmon, should this retrograde movement occur, parts of the area in many years at least as far back as 1930 have been closed to fishing for varying periods in September and occasionally extending into October.

The tagging at Sand Heads resulted in 92 recoveries in the Point Roberts area: 61 in 1938, 29 in 1939 and 2 in 1941. This definitely confirmed the observations of fishermen that fish milling about off the mouth of the river do drift back into the Point Roberts area on occasion. The recoveries represented sockeye which had been tagged several days previous to the day of recapture and it was therefore improbable that they had drifted into the Point Roberts area immediately after tagging due either to tidal action or the handling associated with tagging. They also represented the movements of fish from Canadian to United States waters rather than the movements of fishermen as the International Boundary restricts movements of the latter.

The dates on which the sockeye had been tagged at Sand Heads and the dates on which they had been recovered at Point Roberts provided a

TABLE 10—Blowbacks in September, 1938: Number of sockeye caught and number of Sand Heads tags recovered at Point Roberts.

Date Recovered At Point Roberts	Date Tagged at Sand Heads							Total Re-covered	Catch	North-west Wind ¹	Tide ²
	August			September							
	29	30	31	3	4	5	8				
Sept. 1	---	---	---	---	---	---	---	---	7,350	20	Flood
" 2	---	---	---	---	---	---	---	---	2,052	---	---
" 3	Closure							---	---	---	---
" 4	---	---	---	---	---	---	---	---	1,939	---	---
" 5	---	---	---	2	---	---	---	2	4,651	---	---
" 6	---	---	---	---	---	---	---	---	1,800	---	---
" 7	---	---	2	---	---	---	---	2	7,086	151	Flood-Ebb
" 8	---	---	1	5	2	2	---	10	*25,594	---	---
" 9	---	---	---	1	1	1	---	3	10,780	---	---
" 10	Closure							---	---	108	Ebb
" 11	1	2	4	1	1	11	8	28	*38,227	19	Flood
" 12	---	---	1	---	---	3	1	5	15,670	---	---
" 13	---	1	1	1	---	1	1	5	5,189	134	Ebb
" 14	Closure—Sept. 14 through Oct. 2							---	---	---	---

¹Refers to total miles of northwest wind during 24 hours. Measured by the Department of Transport's Meteorological Station, at the Vancouver International Airport on Sea Island in the Fraser Delta about 16 miles northwesterly from Point Roberts.

²Refers to phase of tide during period of northwest wind.

*Indicates increased catch which was attributed to blowback.

basis for relating the drifting back of sockeye to sudden increased catches and to the occurrence of certain environmental conditions such as wind and tide. TABLES 10 and 11 respectively present for 1938 and 1939, the dates the sockeye were tagged, the dates the sockeye were recovered, the daily catches, the amounts of northwest wind, and the tidal conditions. In September, 1938 sudden increased catches at Point Roberts on the 8th and 11th were associated with increased recoveries of Sand Heads tags and in each instance more than the usual amount of northwest wind had prevailed the day before (TABLE 10). During the 10-hour period of northwest wind on the 7th the tide was flooding during the first 7 hours and ebbing during the last 3 hours. During the 8-hour period of northwest wind on the 10th the tide was ebbing during the last 5 hours. In 1939 sockeye were less abundant than in 1938 and the catches on September 6, 25 and 26 which have been designated as blowbacks were smaller than those of 1938. Sand Heads-tagged sockeye were recovered in the catches of each of these dates and each date was preceded by strong northwest winds (TABLE 11). How-

TABLE 11—Blowbacks in September and October, 1939: Number of sockeye caught and number of Sand Heads tags recovered at Point Roberts.

Date Recovered At Point Roberts	Date Tagged at Sand Heads									Total Recov- ered	Catch	North- west Wind ¹	Tide ²
	September Only												
	1	3	6	9	14	16	22	23	25				
Sept. 1	---	---	---	---	---	---	---	---	---	---	4,765	63	Ebb
" 2	Closure									---	---	---	---
" 3	---	---	---	---	---	---	---	---	---	---	4,384	10	Flood
" 4	---	---	---	---	---	---	---	---	---	---	4,200	73	Ebb
" 5	---	---	---	---	---	---	---	---	---	---	3,891	141	Flood
" 6	1	3	---	---	---	---	---	---	---	4	*9,183	38	Ebb
" 7	---	---	---	---	---	---	---	---	---	---	3,361	19	Ebb-Flood
" 8	---	---	---	---	---	---	---	---	---	---	2,932	159	Ebb-Flood
" 9	---	---	---	---	---	---	---	---	---	---	1,354	236	Ebb-Flood
" 10	---	---	---	---	---	---	---	---	---	---	211	115	Ebb
" 11	Closure									---	---	---	---
" 22	Sept. 11 through 24									---	---	62	Ebb
" 23										---	---	163	Ebb-Flood
" 24										---	---	454	Ebb-Flood
" 25	---	---	---	1	---	1	---	1	---	3	*2,405	315	Ebb-Flood
" 26	1	---	---	1	1	---	---	1	1	5	*1,158	113	Flood
" 27	---	---	---	---	---	---	---	---	---	---	11	41	Flood
" 28	---	---	---	1	---	---	1	---	2	**4	18	67	Ebb-Flood
" 29	---	---	---	---	---	---	---	---	---	---	39	80	Ebb-Flood
" 30	Closure									---	---	---	---
Oct. 1	---	---	---	---	---	---	---	---	---	---	223	187	Ebb-Flood
" 2	---	---	1	---	---	---	---	1	---	2	95	266	Flood
" 3	---	---	---	---	---	---	---	---	---	---	75	---	---
" 4	---	---	---	---	---	---	---	1	---	1	13	71	Ebb

¹Refers to total miles of northwest wind during 24 hours.

²Refers to phase of tide during period of northwest wind.

*Indicates increased catch which was attributed to blowback.

**The recovery date may be in error as the total catch was only 18 sockeye.

ever the catches on September 25 and 26 may not have been due to a single retrograde movement into the area. They may have been due to an accumulation of fish as the result of several such movements during the 14 days of no fishing that preceded the catches. The blowback of September 6 was preceded the day before by 9 hours of northwest wind which commenced on the last of the ebb but prevailed mainly during the flood tide. The blowbacks of the 25th and 26th were preceded by almost 60 hours of continuous northwest wind during which time the tides ebbed and flooded several times. The catches in the San Juan Islands were compared with those in the Point Roberts area to ensure that the catches designated as blowbacks were not due to waves of newly arriving fish. The comparisons indicated that the increased catches at Point Roberts in the instances listed in TABLES 10 and 11 were not the result of fish arriving in the area by way of the normal migratory routes.

Strong northwest winds preceded the blowbacks in 1938 and 1939 but the variations in the times and numbers of fish tagged, in the fishing regulations, and in the annual abundance of sockeye late in the season made unwarranted the acceptance of a relationship between northwest wind and blowbacks (increased catches). The data for the two other years of tagging at Sand Heads (1940 and 1941) were too meager to warrant analysis. One would suspect that the concurrence of ebb tides with northwest winds might also contribute to blowbacks. Waldichuck (1957) stated that water currents at Sand Heads are due south on the ebb tide and due north on the flood tide. The Canadian Hydrographic Service (1957) indicated that northerly gales further affect tidal conditions by making the slack earlier at high water and by making the ebb stronger. However much more detailed observations of wind and tidal conditions and more precise times of the catches than were available for this analysis would appear to be necessary before the effects of wind and tide on the delaying sockeye can be correctly evaluated.

A study was made of daily catches at Point Roberts and wind conditions during September of 1942, 1946, 1954 and 1958; years when sockeye from the Adams River race were abundant. The study was complicated by fishing regulations which closed large portions of the Point Roberts area to prevent the catching of drifting sockeye and as a consequence also limited the recorded instances of blowbacks (increased catches). However the limited data available indicated that the relationship between wind and blowbacks was poor. In 1958 the Salmon Commission observed that large numbers of sockeye had drifted into the Point Roberts area on several occasions and spectacular catches were made in spite of the fishing restrictions (Internat. Pacific Salmon Fish. Comm., 1959). TABLE 12 lists the daily catches in the Point Roberts area and also in the San Juan Islands area together with the amounts of northwest wind during the period September 19 through October 2, 1958. The catches in the San Juan Islands during this period were extremely small and indicated that most of the sockeye run had already passed through

the area, but large catches in the Point Roberts area of 276,963 and 145,470 sockeye respectively on September 23 and 30 indicated that driftbacks or blowbacks had occurred. The catch on the 23rd was not preceded or accompanied by northwest wind but the catch on September 30 was. Thus it was indicated that blowbacks can occur, regardless of wind conditions, whenever delaying sockeye are abundant.

The assumption that northwest wind and/or ebb tides cause blowbacks restricts the delaying sockeye to milling about between the mouth of the Fraser River and Point Roberts. Examination of the tags recovered within the Strait of Georgia indicated that this restriction was not so and that the sockeye ranged widely within the Strait of Georgia. This may explain why sockeye tagged at Sand Heads prior to a blowback were not consistently represented in the recoveries at Point Roberts. For example, 5 sockeye tagged on September 3, 1938 were recovered at Point Roberts during a blowback on September 8 but only 3 sockeye tagged on August 31 and September 5 were recovered at that time. But 3 days later, during the September 11 blowback when only 1 sockeye tagged on September 3 was recovered there were 4 recoveries from sockeye tagged on August 31 and 11 recoveries from sockeye tagged on September 5. Apparently the position of the various groups of delaying sockeye was also a factor in determining whether they would drift into the Point Roberts area.

In summary it may be stated that abundance and position of delaying sockeye are important factors contributing to regression to the Point Roberts area and that northwest winds and strong ebb tides may expedite this regression.

TABLE 12—Comparison between daily catches in Point Roberts area and Northwest Wind in 1958.

DATE	CATCHES		NORTHWEST WIND		CHANGES IN CLOSED PORTION OF POINT ROBERTS AREA
	Pt. Roberts	San Juan Is.	Total Miles	Duration in Hours	
Sept. 19	3,827	738	22	2	Enlarged to include all area W of a line extending true S from Point Roberts light.
20	week-end	week-end	---	---	
21	closure	closure	7	1	
22	21,438	812	3	1	
23	276,963	440	6	2	
24	6,599	170	---	---	Enlarged to include all area W of a line extending true S from Lilly Point.
25	16,461	1,354	13	2	
26	week-	week-	---	---	
27	end	end	---	---	
28	closure	closure	43	8	
29	42,513	51	112	8	Entire area open.
30	145,470	29	74	10	
Oct. 1	42,121	640	43	7	All area W'ly of a line from Iwersen's Dock toward Active Pass light closed.
2	14,154	188	7	2	
3	week-end closure	week-end closure	30	6	

RATE OF MIGRATION

Previous Investigations

O'Malley and Rich (1919) estimated the migration rate of Fraser River sockeye by analyzing the returns from tagging at various sites in the commercial fishery. They first calculated the arithmetic mean migration time or days-out from each tagging site to specific recovery areas. Their results for fish tagged at Sooke were as follows: 2.8 days to Salmon Banks, 4.1 days to West Beach, 5.7 days to Rosario Strait, 5.8 days to Lummi Island, 7.2 days to Point Roberts and 10.5 days to the Fraser River. They listed similar data for tagging at Salmon Banks, Partridge Point (West Beach area), Village Point (Lummi Island area), and Point Roberts. The mean migration times were subsequently used to calculate mean rates of migration in terms of miles per day. O'Malley and Rich felt that the calculated rates of migration were undoubtedly too low since the tagged fish were recovered primarily in traps, which were seldom lifted daily. Frequently three to four days elapsed between successive lifts for an individual trap. Considering the relatively short distances between the tagging site and the recovery sites in contrast to the times the fish were free, an error of even one day let alone three or four days would make the calculated rates of migration extremely biased and too slow.

Williamson (1927) mentioned the rapid rate of migration of sockeye tagged during August 7-14, 1925 at Deepwater Bay, north of Seymour Narrows. One fish was recovered 110 miles away in the Fraser River, 3 days after it was tagged. Two others were recovered at the mouth of the river a distance of about 100 miles after 4 days. The first fish traveled at the rate of about 36.7 miles per day while the second and third traveled at the rate of 25 miles per day. If the average number of days-out is calculated, from the data presented by Williamson for all but 2 of the 70 fish recovered in the Fraser River fishery from Point Grey to Mission, an average of between 10 and 11 days is obtained. The 2 fish omitted were out an unusually long time; 36 and 48 days respectively.

Salmon Commission Investigations

PROBLEMS

Several problems which are inherent in estimating rates of migration have arisen during analyses of the Salmon Commission's tagging experiments. These problems will be discussed in some detail before proceeding with additional analyses since the problems influence certain decisions which must be made regarding the number of usable experiments and the most useful statistics, (mean, median, mode, etc.).

Effects of Tagging

MacKay *et al.* (1945) in an analysis of the Salmon Commission's experiments stated that a definite delay occurs at all points of tagging but

that they were unable to conclude whether this was a natural phenomenon or the result of tagging. Parker and Black (1959) in a discussion of tagging troll-caught chinook or spring salmon pointed out that the effects of fatigue upon survival are important in tagging. In a subsequent study Parker, Black and Larkin (1959) after exercising coho in fresh water with no ill effects, hypothesized that Pacific salmon become more resistant to the effects of exertion as they cease feeding during the spawning migration. The circumstances surrounding the tagging of troll-caught chinook and coho salmon (*O. kisutch*) are quite different from those surrounding the tagging of sockeye from traps, purse seines or reef nets. The sockeye in the trap and net fishing areas are not feeding as actively and are more urgently committed to their spawning migration than are chinook or coho in trolling areas. In fact many of the troll-caught chinook are not destined to spawn in the same year in which they are tagged. Jensen and Jewell (1958) observed while tagging seine-caught coho in the Strait of Juan de Fuca that the relative numbers that were subsequently recovered decreased when the hauls for tagging exceeded 50 fish. This was especially noticeable when heavy swells were running. They concluded, "Some handling mortality must have occurred when large numbers of fish were caught by the tagging boat in rough weather." (p. 62).

In view of the lack of quantitative data regarding the injurious or adverse effects of tagging mature migrating salmon in salt water, it was apparent that the Salmon Commission's marine experiments should be carefully examined before concluding that the migration rates derived from them were representative of untagged fish. During the experiments at Sooke there were five instances when brown-water conditions prevailed and fish were dying in the traps. There were two instances when the fish tagged were in poor condition due to holding the fish in the live-box; in one instance the fish while in the live-box were retained in the trap for approximately half a day before they were tagged, in the other instance very rough weather broke the live-box. The tagging crews realized that the fish were apparently in poor condition and made notes to that effect in the log. The subsequent recaptures from these experiments were few and confirmed the observations of the tagging crews. There was one other instance when the crew recorded that some of the fish in the trap were scarred apparently from the effects of a previous lift when the trap may not have been entirely emptied of fish. However the proportion of tags recovered from this experiment did not appear to be abnormal and the experiment was not omitted. This made 8 experiments that apparently contained fish in poor physical condition out of a total of 209 experiments at Sooke. Seven of the eight were omitted from the analyses. There was no direct mention of fish being in poor condition at any of the other tagging sites, but it may be suspected that at times fish in poor condition were also tagged at those sites. The logs occasionally contained comments that dead salmon were found in the purse seine or live-box at the completion of tagging, or that dense concentrations of jellyfishes or large num-

bers of pink salmon in the purse seine interfered with the selection of sockeye for tagging, or that stormy weather prolonged the tagging. Examination of the recovery data from the groups of fish to which these comments pertained did not appear to justify the omission of those groups from subsequent analyses.

Evidence of the effects of tagging in addition to unusually low percentages of recovery from individual experiments may also be indicated by unexpected differences between tagging areas in regard to percentages of recovery. It was anticipated, provided there were no extenuating circumstances, that tagging experiments performed in a distant area like Sooke would result in the largest percentages of recovery in the commercial fishery. Fish tagged in such an area would have to migrate through a greater number of fishing areas and would be migrating for a longer period of time than fish tagged in areas like Sand Heads, near the river and the upstream limits of commercial fishing. It was similarly anticipated that intermediate percentages of recovery would occur from tagging experiments in areas between Sooke and Sand Heads.

Because the tagging in the different areas was not done at similar times and therefore sockeye of the same races were not necessarily tagged, the data were tabulated according to weekly periods of tagging after elimination of those experiments in an area for which there was no tagging in at least one other area during the respective weekly period. The occasional experiment using oval tags was omitted. Also eliminated were combined experiments in an area when the total number of fish tagged was less than 20 during a week. The resultant TABLE 13 contained eight weekly periods of tagging, extending from about mid-July to the second week of September, in four areas during the years 1939, 1940 and 1941. The initial data appeared quite copious but were wanting when broken down into weekly periods. As a result all four areas were not represented during all three years nor were they represented in all the weekly periods. Comparisons between different weeks of tagging in the same area or between different tagging areas in the same week revealed large variations in percentages of recovery. There appeared to be no consistent increase or decrease in the percentages when the tagging in a distant area like Sooke was compared with tagging in areas progressively closer to the Fraser River like Salmon Banks, Lummi Island and Sand Heads. It was impossible to evaluate the role of the effects of tagging in these variations because of a number of factors, aside from chance, such as: tagging on different days of the week, varying fishing regulations, and tagging in areas where fish do not delay and in an area (Sand Heads) where certain fish do delay.

During the Salmon Commission's experiments there were 33 occasions when the percentages of tags recovered exceeded 70 per cent; on 4 occasions the recovery exceeded 80 per cent, the highest 2 being 82 per cent for a group of 50 sockeye tagged August 3 and 4, 1941 off the Sand

TABLE 13—Comparison between tagging areas, by weekly periods of tagging, on the basis of percentages of tags recovered by commercial fishery in 1939, 1940 and 1941.

YEAR AND TAGGING AREA													
	1939				1940				1941				
	Sooke	Salmon Banks	Lummi Island	Sand Heads	Sooke	Salmon Banks	Lummi Island		Sooke	Salmon Banks	Lummi Island	Sand Heads	
	July 17 - 23				July 15 - 21				July 14 - 20				
No. Tagged % Recovered	242 55.0	32 43.8			74 35.1				118 52.5		56 45.2		
No. Tagged % Recovered	99 53.5		181 61.3		102 54.9				39 64.1	158 57.6	145 62.1	51 37.3	
No. Tagged % Recovered	96 45.8	455 54.5	184 41.3			499 50.9	237 52.7		108 74.1	131 67.2	173 65.9	319 62.7	
No. Tagged % Recovered		686 54.2	257 49.8		212 41.0	107 57.9	271 39.1		66 74.2	69 59.4	52 61.5	102 64.7	
No. Tagged % Recovered	209 55.0	436 64.9			73 49.3	323 48.6	198 33.3		130 59.2	160 57.5	125 48.0	149 66.4	
No. Tagged % Recovered	122 39.3	536 71.5	522 41.4		104 51.9				64 46.9	73 57.5	28 35.7	112 70.5	
No. Tagged % Recovered	32 71.9	429 67.6		145 57.9	57 57.9				46 60.9	38 65.8		90 55.6	
No. Tagged % Recovered	23 56.5			449 51.2					29 44.8	Sept. 1 - 7			27 44.4

Salmon Banks area was enlarged to include tagging in South Lopez and San Juan Channel areas during the 3 years.

Heads and 82.4 per cent for a group of 51 sockeye tagged August 13 and 14, 1939 at Salmon Banks. Although such high percentages of recovery do not have a direct bearing on the question of the effects of tagging on rate of migration they are remarkable since most of the recoveries were made by the commercial fishery. The high recovery indicates that in at least the majority of the experiments the effects of tagging could not have been serious. Further, it will be pointed out subsequently that the use of the modal time out for estimating the rate of migration tends to eliminate data derived from abnormal or injured fish.

Selection of Best Statistic

In the subsequent analyses the speed of migration is expressed in terms of the time (days-out) required for fish to migrate from an area of tagging to specific areas of recovery. This appeared to be the practical thing to do because it will be shown that neither the distances migrated nor the times elapsed between tagging and recovery were precisely known. In addition, for purposes of managing the fishery, it is most convenient to refer to the time necessary for the fish to migrate from one point to another, especially in view of the fact that the rate of migration may not be constant between different points.

The modal days-out was used as the best estimate of migration time rather than the arithmetic mean or the median days-out. The arithmetic mean since it is the sum of the values of all the items divided by the number of items is severely affected by the extreme values. The median is not distorted by the values of the extremes, but it may not be the most common value. The mode is the most typical or descriptive measure of common tendency provided the items are sufficiently numerous to form a reasonably smooth distribution. In this analysis the mode has the property of limiting the estimated migration times to those based on fish which were apparently least affected by tagging. It also has the property of eliminating errors due to erroneous reporting. As a consequence of these attributes and the tendency for the frequency distribution of the recovery data to be skewed in the direction of tardiness the mode indicates a more rapid rate of migration than either the median or the mean. The following is an example of the migration times in days-out obtained by the use of each of the three statistics for sockeye tagged, in July and those tagged in August, at Sooke and recovered in the Point Roberts area during 1938 through 1945:

Month Tagged	Mode	Median	Mean
July	3	5	7.2
August	4	6	8.7

Mixture of Differently Behaving Races

Wandering and differential rates of migration are factors that may contribute to the apparent slow migration of some fish. Early races of sockeye such as the Stuart, Bowron and Chilko races pass through the

fishery during relatively short periods of time; but late races such as the Birkenhead, Adams, Weaver, Harrison and Cultus sockeye pass through the fishery during relatively long periods and frequently delay for extended periods off the mouth of the Fraser River. Since the sockeye tagged in an area during a day's tagging are probably from a mixture of races it is not at all unlikely that some fish from delaying races may be tagged along with those from non-delaying races and that some fish from the delaying races may start to delay as they approach the mouth of the river. The subsequent recoveries from such a day's tagging may present a skewed frequency distribution of days-out because of these delaying fish.

Time Errors

It is easy to make errors when recording or recalling dates. If a fisherman erroneously states a date of recovery which preceded the actual date of tagging, the investigator is aware of the error and excludes the recovery before estimating the migration times or rates of migration. However if the stated date is later than the actual date of recovery, the investigator will probably be unaware of the error and will include the erroneous recovery. The net result of this sort of error is that the number of days-out to a specific area will be too great and the estimated rate of migration will be too slow.

A second type of time error occurs when a recovered tagged fish is not discovered until after it has been delivered to a tender or cannery and the day of capture is reported as the day on which the tag is found. The net result of this error is to increase the length of time the tagged fish was out and to decrease the estimated rate of migration.

A third time error which detracts from the accuracy of the estimated rate of migration is the lack of information regarding the exact time of day when each tagged fish was recovered. This error tends to be self compensating since some of the fish recovered may have been out a fraction of a day less and others may have been out a fraction of a day more than the whole-number of days reported. However when fishing is being done from sunset to dawn, as is the case in some segments of the gill net fishery, the fishermen may fail to associate accurately the passage of one day into the next when reporting recovered tags. In fact the tags in some instances may not be discovered until daylight. These instances of error are not self compensating. The errors in estimating rates of migration caused by reckoning time on a day basis are accepted as inconsequential. In general it is not practical to attempt to obtain the exact times when tagged fish were recovered, but it must be admitted that, for short distances or small numbers of days-out, the error in the estimates of the rate of migration per day or per hour can be significant.

Time errors may be partially responsible for the frequent observation that fish which migrate short distances appear to do so at a slower rate than do fish which migrate long distances (O'Malley and Rich, 1919;

Gilbert and Rich, 1927). Here again, the use of the mode will eliminate many of the errors.

Distance Errors

Estimated migration rates are also affected by distance errors. For practical purposes the distances migrated are accepted as the distances represented by the most direct routes between the tagging site and recovery locations. It is also assumed that each fish migrated in a constant direction. It is obvious that these assumptions result in minimum estimates of the distances migrated, since some fish may choose longer alternate routes or may move in a wandering manner.

In addition to the above basic assumptions the migration distance is frequently not a precise measurement from the point of tagging to the point of recovery, because practical considerations may dictate that tagging points or recovery points be grouped, or because some recoveries may be reported from a large general area rather than from precise points. These happenings can lead to errors in the distances migrated and consequently in the estimates of the rates of migration. The range of possible error increases as the size of the area of tagging or of recovery increases, but the relative importance of the error tends to decrease as the distance between the tagging and recovery area increases.

The occasional incorrect reporting of the place of recovery introduces an unknown amount of error. Selection of the mode as the statistic that best represents the speed of migration of a group of fish tends to eliminate such error.

Errors Due to Variable Fishing Intensity

It is readily apparent that fishing regulations, strikes, bad weather, or other factors that affect fishing intensity may also affect the temporal distribution of the recoveries. If fishing is delayed in an area until after the faster migrating fish of a tagged group have passed, then only the slower migrating fish will be available for recovery and the estimated rate of migration to that area for the group will be too slow. Conversely, if fishing is in progress when the fastest migrating fish are passing through the area but is terminated before the remainder of the group of tagged fish have passed, the estimated rate of migration will be too fast to represent the speed of the entire group. Intermittent stoppages such as those caused by week-end closures can bias the estimated rates of migration in either direction depending on when the tagging is done in relation to the time required for the fish to reach pertinent recovery areas. The effects of tagging on different days of the week are discussed in regard to the rate of migration for sockeye tagged at Sooke, and also under Bias by Day of the Week in the section on FISHING INTENSITY.

METHOD OF ANALYSIS

Before proceeding with an analysis of the migration time of sockeye salmon in the commercial fishery it was deemed advisable to group certain

recovery areas so they would correspond more closely with the major concentrations of fishing gear. For this reason the Salmon Banks and South Lopez areas were combined. The consolidation of the two areas was desirable in order to base conclusions on as large a number of events as possible and appeared permissible since the two areas adjoin one another and occupy a combined area of about 16 miles in greatest extent. The Canoe Pass, Main Arm, Middle Arm and Point Grey areas were combined to form a new area henceforth known as the Mouth of Fraser, because they adjoin one another and are contiguous with the channels leading into the Fraser. In addition the North Arm and New Westminster areas were combined as they are arms of the river occupying approximately equivalent positions, immediately upstream from the Mouth of Fraser area.

Tag returns from the commercial fishery were grouped according to recovery areas. The recovery date of each tag return was checked by comparison with the tagging date and dates of closure in the pertinent recovery area. Erroneous recovery dates became readily apparent whenever the recapture dates were recorded prior to the date of tagging or were reported during a closure. The number of tags discarded for these reasons was negligible. The recoveries in each area were then tabulated by date of tagging and number of days-out. Sockeye recovered the same day they were tagged were recorded as zero days-out.

SOOKE

The recoveries in each area from the small number of sockeye tagged on any given day at Sooke were widely distributed in regard to date of recovery and number of days-out. It was therefore deemed desirable to combine the recoveries from as many days and from as many years of tagging as possible. But before attempting to combine the data for the 11 years of tagging (1938 to 1948) at Sooke it was necessary to perform some preliminary analyses to determine the amount of variability between different parts of a season or annual migration and between different years. Three sources of possible variation were immediately apparent: 1. Alternate use of oval and disk tags during 1944 and 1945; 2. Differential seasonal behavior of sockeye; 3. Fishing regulations and strikes.

Preliminary Analyses

It was important to know whether the greater length of time (almost twice as long) required to attach the oval tag would cause the estimated migration time for oval-tagged fish to be different from that of disk-tagged fish. To test the hypothesis that fish tagged with either tag migrated at the same rate, the recoveries in the Mouth of Fraser area were selected. The choice of recoveries in this area appeared reasonable since the greatest number of recoveries occurred there and nearly equal numbers of each tag were recovered. The recoveries for each tag type were grouped into periods of days-out (0-7, 8-14, 15-21, 22-28 and 29 plus) from Sooke to the Mouth

of Fraser and the grouped data were compared by the chi-square method. The migration times for oval-tagged fish were not significantly different from those of disk-tagged fish in either 1944 ($p < 0.98$) or 1945 ($p > 0.30$). The hypothesis was therefore accepted and the days-out data for the two types of tags were combined.

Seasonal differences in behavior or rate of migration could cause estimated migration times to be erroneous if the recovery data were indiscriminately combined. O'Malley and Rich (1919) concluded that sockeye tagged late in the season, in 1918, migrated more quickly than those tagged early in the season. But MacKay *et al.* (1944) and Idyll (1951) on the basis of the Salmon Commission's experiments concluded the converse. It was therefore desirable to re-examine the recovery data, to determine whether seasonal and/or annual changes had occurred, before combining data for different parts of a season and for different years. Each year's tagging data were divided into two periods, data from sockeye tagged during July and data from those tagged in August. Data from sockeye tagged prior to July and after August were omitted because strikes and fishing regulations severely affected the days-out pattern of recoveries from fish tagged in June and September. For a similar reason only the data from the eight years, 1938 through 1945, were included in the examination of seasonal behavior. The late opening of the sockeye fishing season in 1946, 1947 and 1948 made it impossible for the commercial fishery to recover the fastest migrating fish of those groups which were tagged before fishing was permitted. In addition the 1948 tagging was terminated on July 6. The recoveries of Sooke-tagged fish in the combined Salmon Banks and South Lopez areas, in the Point Roberts area, and in the Mouth of Fraser area were used to compare July-tagged fish with August-tagged fish in regard to days-out. Point Roberts and the Salmon Banks-South Lopez areas were major fishing areas in the United States fishery and the Mouth of Fraser area was the most important area in the Canadian fishery. It was considered impractical to make comparisons for the recoveries in the minor United States fishing areas (West Beach, Rosario Strait, Lummi Island and San Juan Channel-Haro Strait) as the numbers of recoveries in each area were few.

TABLE 14 summarizes the results in regard to sockeye recovered in the Salmon Banks-South Lopez areas. There were no significant differences between years for fish tagged in July or in August. There were also no significant differences between July and August fish in the combined years. It was therefore concluded that there were no seasonal or annual differences in rate of migration of sockeye from Sooke to Salmon Banks and South Lopez.

Comparisons of days-out data for Sooke-tagged sockeye recovered in the Point Roberts area during the years 1938-1945 inclusive indicated that there was a significant difference ($p < 0.01$) between years for fish tagged

in July but that there was none ($p < 0.20$) between years for fish tagged in August. In spite of this suggested difference between years for fish tagged in July the data for that month for all the years were combined and compared with the combined August data. The chi-square value had a probability of less than 0.5 thereby indicating that there was a significant difference between July and August fish in rate of migration from Sooke to Point Roberts. It was suggested that differences in behavior between early and late-migrating races at Point Roberts might have caused the differences between the July and August data and variations in behavior also may have caused the difference between the years when only the July data were compared; since the relative strength of early and late races in each year's mixture of races had varied from year to year.

To test this suggestion the runs for each of the eight years under study were classified, on the basis of the numerical importance of the early and late races composing the spawning ground escapements, into the following two categories: those supported primarily by early races; and those supported primarily by late races. The Salmon Commission's Annual Reports disclosed that the four years 1938, 1939, 1942 and 1943 were supported primarily by late-running sockeye such as the Adams, Birkenhead

TABLE 14—Comparison of July with August Sooke-tagged sockeye recovered in the Salmon Banks-South Lopez area, 1938-1945.

DAYS-OUT	TAGGED IN JULY OF YEAR								TOTAL
	1938	1939	1940	1941	1942	1943	1944	1945	
0 - 7	5	13	17	27	15	7	14	25	123
8 +	4	1	4	2	3	3	3	5	25
Total	9	14	21	29	18	10	17	30	148

Chi-square=6.106

df 7

$p > 0.50$

DAYS-OUT	TAGGED IN AUGUST OF YEAR								TOTAL
	1938	1939	1940	1941	1942	1943	1944	1945	
0 - 7	14	19	3	11	15	23	4	13	102
8 +	8	6	2	4	2	3	1	4	30
Total	22	25	5	15	17	26	5	17	132

Chi-square=6.368

df 7

$p < 0.50$

DAYS-OUT	MONTH TAGGED		TOTAL
	July	August	
0 - 7	123	102	225
8 - 14	17	25	42
15 - 21	6	4	10
22 +	2	1	3
Total	148	132	280

Chi-square=3.306

df 3

$p > 0.30$

and Cultus races; while the four years 1940, 1941, 1944 and 1945 were supported primarily by early-running sockeye which were predominantly of the Chilko race (Internat. Pacific Salmon Fish. Comm., 1954, 1955, 1956). A chi-square comparison between these two series of years after the data for each were grouped into periods of days-out (0-7, 8-14, 15-21, and 22 plus) indicated that the two series were significantly different ($p < 0.02$) in regard to migration time from Sooke to Point Roberts.

Comparison of the days-out data for July-tagged fish during only the late-run years 1938, 1939 and 1942 (TABLE 15) indicated that there were significant differences ($p < 0.05$) between the years. The July 1943 data had to be omitted from this comparison as in that year there were only six recoveries in the Point Roberts area of July-tagged fish and all were out less than seven days. An additional or separate comparison was made of the July data for 1938 and 1942 only as these were years of the dominant cycle of the Adams River race. There was no significant difference be-

TABLE 15—Comparison of July with August Sooke-tagged sockeye recovered at Point Roberts; 1938, 1939, 1942 and 1943.

DAYS-OUT	TAGGED IN JULY OF YEAR			TOTAL
	1938	1939	1942	
0 - 7	3	18	22	43
8 - 14	4	1	9	14
15 +	3	4	3	10
Total	10	23	34	67

Chi-square=10.263 df 4 $p < 0.05$
1938 vs. 1942

Chi-square=4.656 df 2 $p = 0.10$

DAYS-OUT	TAGGED IN AUGUST OF YEAR				TOTAL
	1938	1939	1942	1943	
0 - 7	10	22	34	25	91
8 - 14	10	10	7	12	39
15 +	2	7	9	3	21
Total	22	39	50	40	151

Chi-square=10.300 df 6 $p > 0.10$

DAYS-OUT	MONTH TAGGED		TOTAL
	July	August	
0 - 7	49	91	140
8 - 14	14	39	53
15 - 21	2	10	12
22 - 28	2	6	8
29 +	6	5	11
Total	73	151	224

Chi-square=5.308 df 4 $p > 0.30$

tween the two cycle years. The comparison of the days-out data for August-tagged fish during the late-run years indicated that there were no significant differences ($p > 0.10$) between years. There was also no significant difference between the combined July data and the combined August data for this series of years ($p > 0.30$).

Similar comparisons for the early-run series of years 1940, 1941, 1944 and 1945 (TABLE 16) indicated no significant differences between the years in regard to fish tagged in July ($p < 0.50$) or in regard to fish tagged in August ($p = 0.10$). There was also no significant difference between the combined July data and the combined August data ($p > 0.10$).

It was concluded from these tests that there were significant differences, in rate of migration from Sooke to Point Roberts, between sockeye tagged in July and those tagged in August during the combined years 1938 through 1945; and also that there were significant differences between the years for fish tagged in July but that there was none for fish tagged in August. However when the annual data were classified according to whether early or late races predominated there were significant differences between the two classes of years but there were no significant differences between July and August fish within each class of years.

TABLE 16—Comparison of July with August Sooke-tagged sockeye recovered at Point Roberts; 1940, 1941, 1944 and 1945.

DAYS-OUT	TAGGED IN JULY OF YEAR				TOTAL
	1940	1941	1944	1945	
0 - 7	5	40	17	44	106
8 - 14	3	6	5	6	20
15+	1	1	2	2	6
Total	9	47	24	52	132

Chi-square=5.578 df 6 $p < 0.50$

DAYS-OUT	TAGGED IN AUGUST OF YEAR				TOTAL
	1940	1941	1944	1945	
0 - 7	17	14	13	4	48
8+	7	6	5	8	26
Total	24	20	18	12	74

Chi-square=6.254 df 3 $p = 0.10$

DAYS-OUT	MONTH TAGGED		TOTAL
	July	August	
0 - 7	106	48	154
8 - 14	20	20	40
15 - 21	3	3	6
22+	3	3	6
Total	132	74	206

Chi-square=5.975 df 3 $p > 0.10$

Comparisons were next made of the days-out data for sockeye tagged in July and for those tagged in August at Sooke and recovered at the Mouth of Fraser during the years 1938 through 1945. There were significant differences between years for fish tagged in July ($p < 0.05$) and even more significant differences between years for fish tagged in August ($p < 0.001$). The July and August data were therefore separated, according to the years in which early races were predominant and years in which late races were predominant.

There were significant differences ($p > 0.01$) between the late-run years for July-tagged fish but none ($p < 0.50$) between the late-run years for

TABLE 17—Comparison of July with August Sooke-tagged sockeye recovered in the Mouth of Fraser area; 1938, 1939, 1942 and 1943.

DAYS-OUT	TAGGED IN JULY OF YEAR				TOTAL
	1938	1939	1942	1943	
0 - 7	16	38	49	19	122
8 - 14	19	11	17	18	65
15 - 21	5	2	5	5	17
22 - 28	5	1	6	4	16
29+	9	5	3	6	23
Total	54	57	80	52	243

Chi-square=26.984 df 12 $p > 0.01$
1938 vs. 1942

Chi-square=15.493 df 4 $p < 0.01$

DAYS-OUT	TAGGED IN AUGUST OF YEAR				TOTAL
	1938	1939	1942	1943	
0 - 7	5	11	11	12	39
8 - 14	11	11	17	9	48
15 - 21	2	4	11	3	20
22 - 28	4	3	15	6	28
29+	12	22	44	16	94
Total	34	51	98	46	229

Chi-square=12.630 df 12 $p < 0.50$
1938 vs. 1942

Chi-square=4.437 df 4 $p > 0.30$

DAYS-OUT	MONTH TAGGED		TOTAL
	July	August	
0 - 7	122	39	161
8 - 14	65	48	113
15 - 21	17	20	37
22 - 28	16	28	44
29+	23	94	117
Total	243	229	472

Chi-square=91.591 df 4 $p < 0.001$

August-tagged fish (TABLE 17). Similar results were obtained when only the two cycle years (1938 and 1942) of the Adams River sockeye were compared. When the data from the July-tagged fish for the four years were combined and compared with the similarly combined data for the August-tagged fish there was a very significant difference ($p < 0.001$). Sockeye tagged at Sooke in August were recovered more slowly in the Mouth of Fraser area than were those tagged in July. This is readily apparent by visual inspection of the portion of TABLE 17 which compares the migration times of fish tagged during the two months. The large numbers of late recoveries of August-tagged sockeye occurred despite the fact that fishing in the Fraser River area was generally curtailed during the latter part of September during this series of years. This would have tended to limit the numbers of late recoveries.

Similar comparisons were made of the sockeye tagged at Sooke and recovered in the Mouth of Fraser area during the early-run years 1940, 1941, 1944 and 1945 (TABLE 18). The differences between years for fish tagged in July were not significant ($p > 0.50$) but for fish tagged in August the differences between years were significant ($p > 0.001$). When the July data were compared with the August data for the combined four years the fish tagged in July were out significantly fewer days before recovery in the Mouth of Fraser area than were those tagged in August ($p < 0.001$). As in the case of sockeye tagged in July and August during the years 1938, 1939, 1942 and 1943 this difference in migration time between July and August sockeye in 1940, 1941, 1944 and 1945 was also very apparent from a cursory inspection of the data (TABLE 18).

The preliminary analyses of migration times of sockeye tagged at Sooke in July and August during the years 1938 through 1945 indicated the following:

1. There were no annual or seasonal variations in the migration time from Sooke to the Salmon Banks-South Lopez areas.
2. Significant annual and possibly significant seasonal variations occurred in the migration time from Sooke to Point Roberts. However when the data for the eight years were segregated according to whether the years were characterized by late-season or early-season races there were no significant annual or seasonal variations within each category of years; but there were significant differences between the two categories.
3. Significant annual and seasonal variations occurred in the migration time from Sooke to the Mouth of Fraser area. These differences were caused by differential behavior of early and late-run sockeye.
4. Sockeye tagged during July as a group appeared to migrate more quickly to distant areas than did those tagged in August. This difference in rate of migration occurred primarily as the result of delay behavior in the vicinity of the mouth of the Fraser River. MacKay *et al.* (1944) and Idyll (1951) concluded essentially the same.

TABLE 18—Comparison of July with August Sooke-tagged sockeye recovered in the Mouth of Fraser area; 1940, 1941, 1944 and 1945.

DAYS-OUT	TAGGED IN JULY OF YEAR				TOTAL
	1940	1941	1944	1945	
0 - 7	18	31	30	30	109
8 - 14	13	23	19	16	71
15 - 21	3	5	8	4	20
22 - 28	6	4	4	3	17
29+	5	2	1	6	14
Total	45	65	62	59	231

Chi-square=10.845

df 12

p>0.50

DAYS-OUT	TAGGED IN AUGUST OF YEAR				TOTAL
	1940	1941	1944	1945	
0 - 7	22	24	31	8	85
8 - 14	22	17	16	2	57
15 - 21	9	3	11	9	32
22 - 28	1	4	6	2	13
29+	36	11	20	8	75
Total	90	59	84	29	262

Chi-square=30.256

df 12

p>0.001

DAYS-OUT	MONTH TAGGED		TOTAL
	July	August	
0 - 7	109	85	194
8 - 14	71	57	128
15 - 21	20	32	52
22 - 28	17	13	30
29+	14	75	89
Total	231	262	493

Chi-square =47.846

df 4

p<0.001

Migration Times

The following is a discussion of the actual migration times in terms of the modal numbers of days-out of sockeye tagged at Sooke and recovered in various areas of the commercial fishery. The data from the years 1938 through 1945 will be presented first followed by individual presentations for the years 1946 and 1947. The commencement of regulation of the sockeye fishery by the International Pacific Salmon Fisheries Commission in 1946 and the resultant late starting of sockeye fishing in 1946 and 1947 made individual presentations desirable.

FIGURE 6 presents graphs of the percentage frequency distributions of the migration times from Sooke to specific areas for sockeye tagged in July and for those tagged in August. The data for the years dominated by the late races have been graphed separately from those for the years

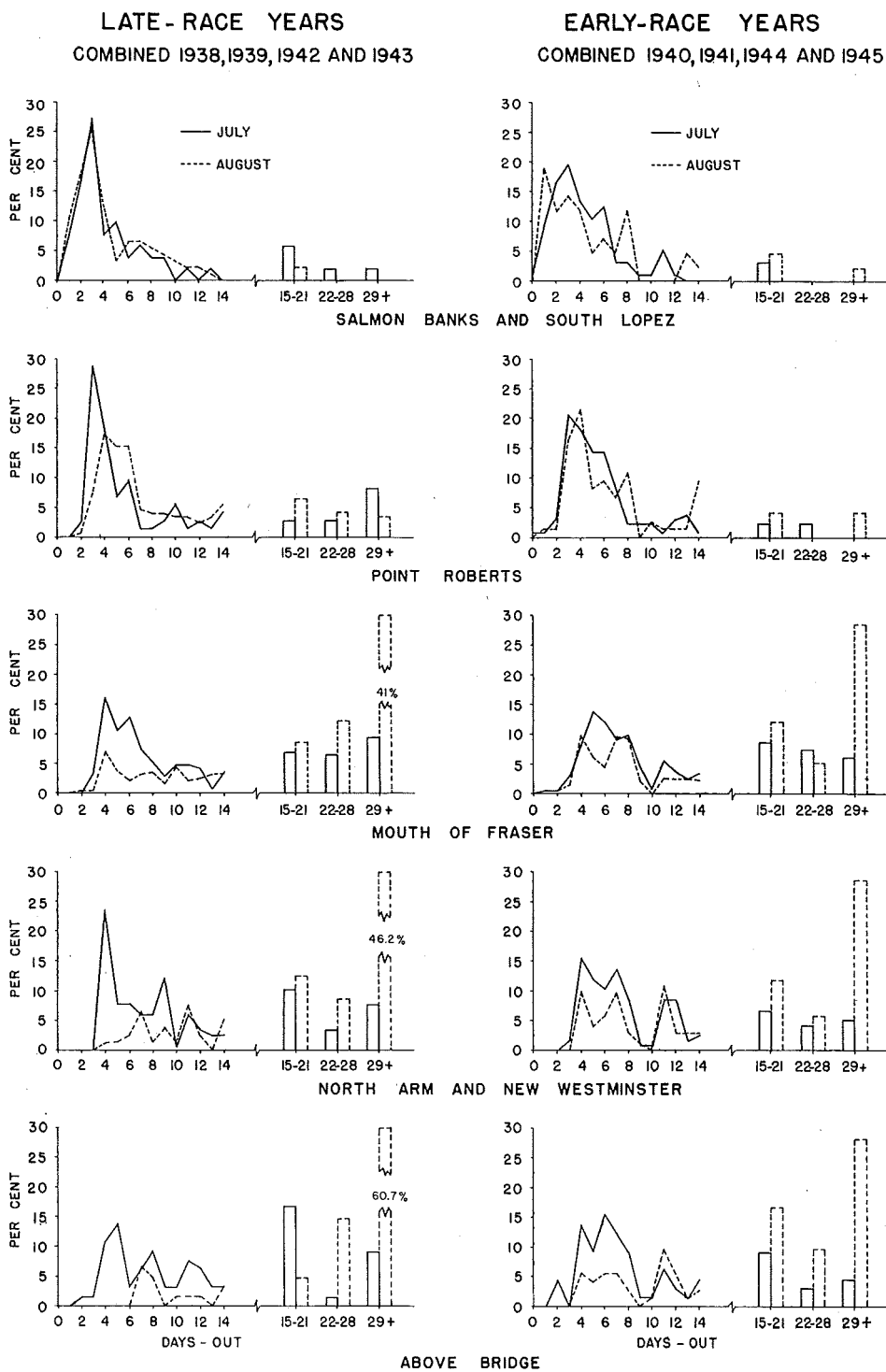


FIGURE 6—Sooke tagged sockeye. Percentage frequency distribution by days-out of July and of August tagged sockeye recovered in specific areas during 1938, 1939, 1942 and 1943 combined and 1940, 1941, 1944 and 1945 combined.

dominated by early races. The data for 0-14 days-out are represented by polygons but data for 15 or more days-out have been grouped (15-21, 22-28 and 29 plus) and are represented by bars. Reasons have already been given for the omission of data for recoveries in some of the United States areas. Data from recoveries in the Convention Waters of the Strait of Georgia area in the Canadian fishery have also been omitted because the recoveries were few in number, widespread in range of days-out, and greatly affected by fishing regulations. The modal-migration times indicated by the graphs were as follows.

Sooke to Salmon Banks and South Lopez — the modes at 1 and 3 days-out indicated by FIGURE 6 should be ignored and in their stead a migration time of 2 days should be accepted. The mode at 1 day-out for the August-tagged fish during the early-race years was the result of 8 recoveries 1 day-out among a total of 42. Furthermore the mode of 1 day-out was not consistent with the mode of 4 days-out to Point Roberts indicated by the same group of tagged fish and was not consistent with the previous conclusion that there was no seasonal difference in rate of migration from Sooke to Salmon Banks and South Lopez. The modes at 3 days-out for the other groups of fish were also biased estimates of the migration time because of the relationship between the particular days of the week on which sockeye were tagged at Sooke and the week-end closures which prevented the recovery of tagged fish in United States waters on Saturdays. The three days on which tagging was done most frequently at Sooke were Thursday, Monday and Saturday in decreasing order of importance. The week-end closures prevented the recovery of Thursday-tagged fish 2 days-out, of Monday-tagged fish 5 days-out, and of Saturday-tagged fish 7 days-out. The effects of the closures are apparent from TABLE 19 which lists the frequency distributions by days-out, for the first 7 days according to the day of the week on which the fish were tagged, for those fish recovered in the Salmon Banks-South Lopez areas and also for those recovered in the Point Roberts area. Many of the fish tagged at Sooke on Mondays and Saturdays arrived in the Salmon Banks-South Lopez areas within 1 day and the largest numbers arrived within 2 days. Some Thursday-tagged fish also arrived in the areas within 1 day but the Saturday closure prevented recovery 2 days-out and as a result the greatest number of recoveries occurred 3 days-out. When these facts are considered it appears that the modal-migration time from Sooke to the Salmon Banks-South Lopez areas should be 2 days. The recovery within 7 days of over 78 and 74 per cent respectively of all the July-tagged and August-tagged fish recovered in the Salmon Banks-South Lopez areas indicated that the sockeye delayed little if at all in those areas.

Sooke to Point Roberts — the modal-migration time was 3 days for fish tagged in July and 4 days for those tagged in August. In addition to the slower rate of migration indicated by the mode in August there was

an indication that considerable numbers of August-tagged fish required 5 or 6 days to reach Point Roberts, particularly during years when late races dominated the runs (1938, 1939, 1942 and 1943). Some fish arrived in the Point Roberts area within 2 days. The indication of a slower rate of migration in August than in July may have been due to the commencement of delay by some late-run fish at Point Roberts or to the re-entry into the area of fish delaying off the mouth of the Fraser River and milling about. The tagged fish passed through the Point Roberts area during a relatively short but somewhat longer period of time than they required to pass through the Salmon Banks-South Lopez areas. The percentages recovered during the first week after tagging of the total tags recovered in the Point Roberts area were about 67 and 80 per cent respectively during the late and early-race years for July-tagged fish and 60 and 65 per cent respectively for August-tagged fish.

There was a possibility, depending upon the day of the week on which the fish were tagged, that the week-end closures and the recovery of tagged fish before they reached Point Roberts could have caused biased estimates of the migration times. Inspection of TABLE 19 indicated that there were relatively fewer Monday and Saturday-tagged fish and more Thursday-tagged fish recovered in the Point Roberts area than in the Salmon Banks-South Lopez areas. Recovery of Monday and Saturday-tagged Sooke fish in the Point Roberts area was limited by the prior removal of tagged fish by the San Juan Islands fishery; which included the West-Beach, Rosario Strait, Lummi Island and San Juan Channel-Haro Strait areas in addition to the Salmon Banks-South Lopez areas; and the fact that 3 to 4 days were required for many of the fish to arrive in the Point Roberts area. Monday-tagged fish arrived on Thursday or Friday with only 1 or 2 days of the fishing week remaining. Saturday-tagged fish arrived with 3 or 4 days of

TABLE 19—Comparison between Monday, Thursday and Saturday tagging at Sooke on basis of the numbers of recoveries in the Salmon Banks-South Lopez and Point Roberts areas within 7 days. July and August tags for combined years 1938-1945.

NUMBER OF RECOVERIES IN SALMON BANKS-SOUTH LOPEZ AREAS									
Day Tagged	Days-Out								Total
	0	1	2	3	4	5	6	7	
Monday	—	17	30	22	7	Sat.	1	1	78
Thursday	1	10	*2	34	22	15	18	12	114
Saturday	—	2	11	5	4	4	3	Sat.	29
Total	1	29	43	61	33	19	22	13	221
NUMBER OF RECOVERIES IN POINT ROBERTS AREA									
Monday	—	1	7	12	15	Sat.	17	9	61
Thursday	1	1	Sat.	55	57	47	32	14	207
Saturday	—	—	1	4	7	5	3	Sat.	20
Total	1	2	8	71	79	52	52	23	288

*Fishing was permitted on Saturday, July 27, 1940.

fishing remaining. But many of the Thursday-tagged Sooke fish passed through the San Juan Islands during the week-end closure and arrived in the Point Roberts area on Sunday or Monday at the start of the fishing week. It therefore appears from TABLE 19 that a migration time of 3 to 4 days from Sooke to Point Roberts is a reasonable estimate.

Sooke to Mouth of Fraser — the modal-migration time based on the combined July and August data was 4 days but almost as many fish were recovered 5 days-out. The week-end closures primarily on Saturdays and Sundays prevented the recovery 5 or 6 days-out of fish tagged at Sooke on Mondays. It is therefore probable that the migration time should be 4 or 5 days instead of only 4. It appears that the modal-migration times for fish tagged in July and August were nearly equal but that the August-tagged fish as a group were either much slower in passing through the area or they were much slower in becoming available to the fishing gear than were the July-tagged fish. During the early and late-run years approximately 47 and 50 per cent of the July fish recovered in the area were out 7 days or less and only about 6 and 10 per cent respectively were out over 28 days; but only about 32 and 17 per cent of the August fish were recovered within 7 days and about 29 and 41 per cent respectively were out over 28 days. This delay in August was most pronounced during the late-run years (1938, 1939, 1942 and 1943) (FIGURE 6).

Sooke to North Arm and New Westminster areas — the modal-migration time to these areas was 4 days for fish tagged at Sooke in July but was very poorly indicated to be 11 days for fish tagged in August. Nearly as large a number of August fish were recovered 4 and 7 days-out as were recovered 11 days-out. The recovery of the first August-tagged fish in the areas only 4 days-out followed by generally greater numbers of recoveries 7 days later may have been more than coincidence. The week-end closures plus prior removal of tagged fish in areas en route to the North Arm-New Westminster areas may have caused this pattern of recovery.

The tendency of fish tagged in August to delay off the mouth of the Fraser River is also evident from the recoveries in these areas, particularly in those years when the late races were dominant. Approximately 52 and 45 per cent respectively during the early and late-race years of the July-tagged fish were caught within 7 days but only 30 and 11 per cent respectively during the two series of years of the August-tagged fish were caught within 7 days. Conversely only about 5 and 8 per cent of the July-fish were out over 28 days but 29 and 46 per cent of the August fish were out over 28 days.

Sooke to Above Bridge — the modal migration time appeared to be 4 to 6 days for fish tagged in July, but for fish tagged in August the data were too few to warrant acceptance of the poorly defined modes at either 7 or 11 days-out. It was apparent that in years when early races were predominant (1940, 1941, 1944 and 1945) that some fish tagged at Sooke

in August were recovered in the Above Bridge area 4 days-out but that similar or larger numbers were recovered 7 and 11 days-out. As in the case of the recoveries in the North Arm-New Westminster areas the pattern of recoveries in this area were modified by the recoveries in more seaward areas and by the week-end closures. The differences between the two series of years and between July and August fish in the proportions of each month's tagged fish that entered the river within specific time intervals were again apparent from FIGURE 6.

The year 1946 marked the first year of regulation by the Salmon Commission of the commercial fishery for sockeye salmon. Sockeye fishing in the San Juan Islands and Point Roberts areas of the United States fishery was prohibited until July 25; but purse seine fishing did not start until July 31 because of a strike (Pacific Fisherman, September, 1946). The Point Roberts area was closed September 26 and no sockeye were landed by the United States fishery after September 25. A total of 30 recoveries from fish tagged prior to July 31 and after September 9 were therefore excluded from the days-out data presented for the Salmon Banks-South Lopez and Point Roberts areas in FIGURE 7. The figure indicates that the modal-migration time in 1946 from Sooke to the Salmon Banks-South Lopez areas was 2 days and that it was 4 days to the Point Roberts area. These times which were primarily for August or late-season fish were consistent with those suggested by the tagging during the years 1938 through 1945. Fishing in 1946 with sockeye gill nets was permitted in the Fraser River and the Convention waters of the Strait of Georgia areas of the Canadian fishery from August 8 to September 25 and it was permitted again commencing October 14. Fishing with spring salmon gill nets (minimum mesh size of 8 inches) was permitted beginning June 1. Intermittent purse seining was permitted in the Strait of Georgia area from September 2 through 13.

The days-out data for 1946 shown in FIGURE 7 for the recoveries in the Mouth of Fraser, North Arm-New Westminster and Above Bridge areas of the Canadian fishery include only data for sockeye tagged from August 5 through September 9 and recovered in sockeye gill nets. The migration times indicated are therefore primarily those of late-season or delaying fish. In this regard it should be pointed out that the Adams River sockeye which are known to delay off the river for a considerable time was the dominant race in 1946. No mention will be made of the few sockeye, primarily early-season fish, recovered in spring nets except in those instances where they contributed pertinent information. The omission of data from recoveries of fish tagged after September 9 appeared warranted since it was impossible for fish tagged after that date to be out more than 15 days if they were to be recovered before the September 25 - October 13 closure. Moreover September 9 was the latest date that fish could be tagged at Sooke and still be potentially recoverable by purse seines in the Convention Waters Strait of Georgia area before the termination of that fishery on September 13.

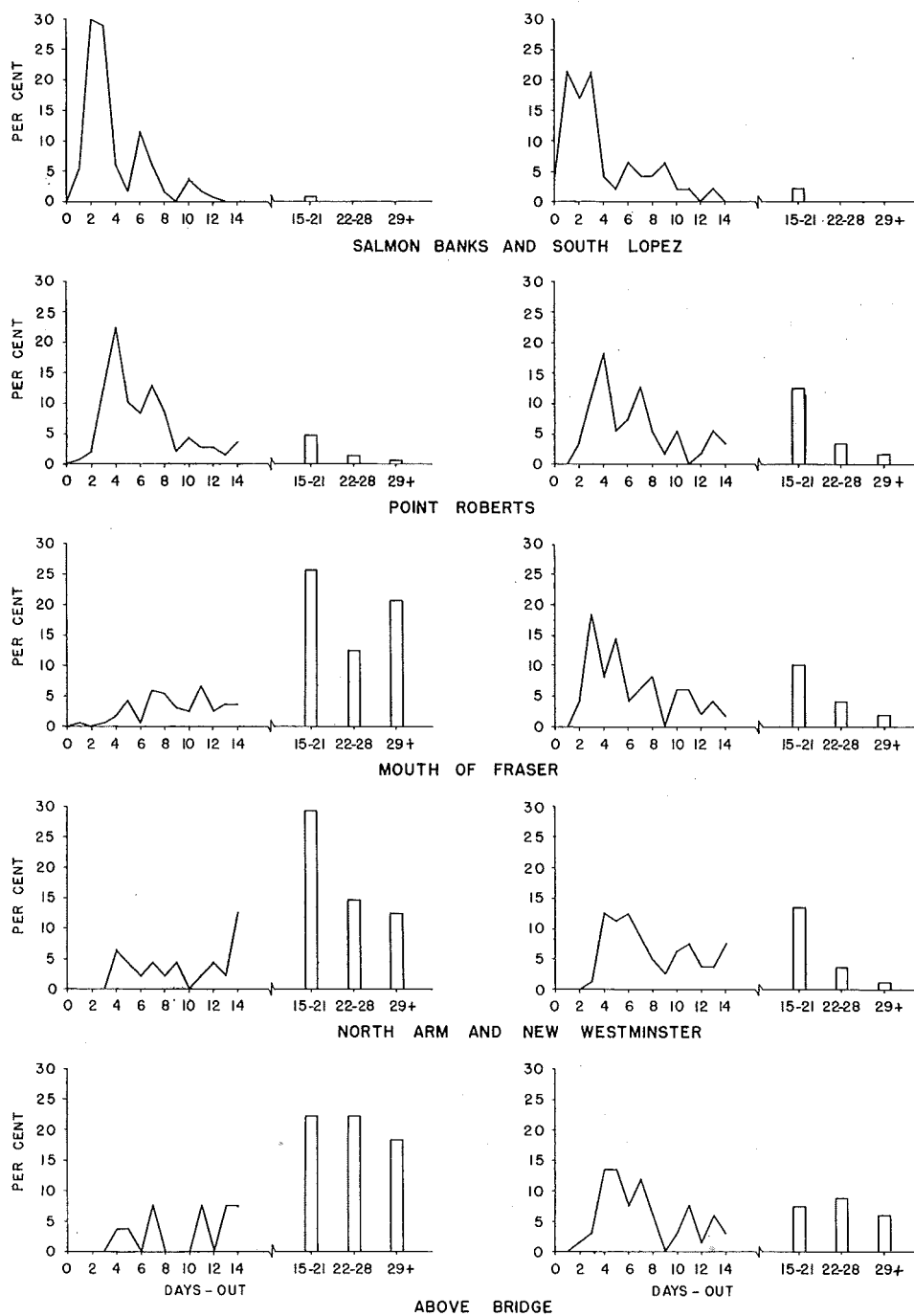
19461947

FIGURE 7—Sooke tagged sockeye, 1946 and 1947. Percentage frequency distribution by days-out of recoveries in specific areas.

Sooke to the Convention Waters of the Strait of Georgia area — the recoveries were greatly affected by purse seining in this area from September 2 through 6, and particularly on the 11th and 13th when a special area adjacent to the mouth of the Fraser River was also included in the area open to seining. The purse seines caught 750,561 sockeye on those 2 days (Internat. Pacific Salmon Fish. Comm., 1947) or about 74 per cent of the total 1,115,735 sockeye caught by purse seines in the Strait of Georgia during the period September 2-13. The seiners did not fish on the 12th because of the glut of fish at the canneries. The migration times to this area based on recoveries by sockeye nets and purse seines are shown by the following tabulation instead of by FIGURE 7.

Days-Out	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22-28	29+
No. Recovered	3	3	3	6	4	8	5	2	6	5	7	8	8	2	3	3	6	1	14	20

It is apparent that some sockeye in 1946 reached the Strait of Georgia area within 4 to 5 days and that they continued to be available there for a long time. No distinct modal-migration times were indicated although the maximum numbers of recoveries occurred on the 9th, 15th and 16th days-out.

Sooke to the Mouth of Fraser, North Arm and New Westminster, and Above Bridge areas — no definite modal-migration times to these areas in 1946 are indicated by FIGURE 7. It is evident from the recoveries, even though they were primarily from late-season fish (those tagged from August 5 through September 9), that a few fish reached and entered the river within 4 to 5 days after they had been tagged at Sooke. However the majority of the late-season fish were not recovered in the river areas until they had been out 15 days or more. Recoveries from the primarily early-season fish (those tagged prior to August 5 and recovered in spring nets) which were excluded from FIGURE 7 were greatest in each of the areas on the 5th day-out and no fish was recovered in a spring net more than 15 days-out. This indicated that the early-season fish entered the river more promptly than the late-season fish. The 1946 data for recoveries in these areas were consistent with the data for 1938 through 1945.

In 1947, sockeye fishing in the San Juan Islands and Point Roberts areas was not permitted until August 18. The data illustrated in FIGURE 7 for recoveries in these areas in 1947 were therefore limited to sockeye tagged on or after August 18. The figure indicates that the recoveries in the Salmon Banks and South Lopez areas occurred in greatest numbers from 1 to 3 days-out. It is quite possible that the largest numbers of sockeye actually arrived in the areas within 2 days; for many of the sockeye had been tagged on Thursdays and any arrivals on Saturdays would have been protected by the week-end closures. The modal-migration time to Point Roberts was 4 days.

Fishing in 1947 with sockeye gill nets was not permitted in the Fraser River and Strait of Georgia areas of the Canadian fishery until September

8 and purse seining was only permitted in the Strait of Georgia area from September 15 to 24 inclusive. Considerable numbers of sockeye that had been tagged at Sooke from July 10 to September 8 were recovered in purse seines and sockeye gill nets in the Canadian waters just mentioned, but probably because of the late start of fishing none of these tagged fish was recovered less than 15 days-out. These recoveries were therefore of no value in estimating migration times. Only three recoveries were made in the subject waters from the very few sockeye tagged on or after September 8. It was therefore necessary to omit all the recoveries by purse seines or sockeye gill nets from the 1947-data shown in FIGURE 7 for the Canadian areas and to use instead only data from recoveries in spring salmon nets.

Fishing for spring salmon with gill nets having a large mesh size of 8 inches or more was permitted from July 1 through September 7 and about 15,000 sockeye were landed by the Fraser River gill net fishery during that period. These fish were caught primarily in large-mesh nets made of light twine or "hung in" (by hanging two or three times more web than is normally woven onto a given length of cork line). The sockeye fishing efficiency of the large-mesh nets was thus greatly increased. In addition many of the nets that were hung normally were fished in such a manner as to entangle rather than gill fish (Internat. Pacific Salmon Fish. Comm., 1948). As tagging had commenced at Sooke on July 10 some tagged sockeye representing both early and late races were among those caught in the spring nets. On the basis of these recoveries the migration times in 1947 from Sooke to the following areas were indicated by FIGURE 7 to be: Mouth of Fraser—3 days, North Arm and New Westminster—4 to 6 days, and Above Bridge—4 to 7 days. No migration time from Sooke to Convention Waters of the Strait of Georgia area is available as no recoveries by spring nets were made in that area.

Summary of Migration Times from Sooke

The most likely migration times in days-out from Sooke to certain recovery areas for sockeye tagged primarily in July and August during the years 1938 through 1947 were as follows: Salmon Banks and South Lopez—2, Point Roberts—3 to 4, Mouth of Fraser—4 to 5, North Arm and New Westminster—4 to 7, and Above Bridge—4 to 11. It would have been desirable to have presented separate summaries for July and for August fish but a review of the data and FIGURES 6 and 7 indicated that separation was not warranted. The migration times were biased by the mixture of races, the effects of fishing regulations and closed periods, and changes in fishing intensity. The late-season fish as a group after arriving in the Point Roberts area were definitely slower in passing through the fishing areas than were the early-season fish. This was especially true of the length of time required for late-season fish to pass through the Canadian fishing areas adjacent to or in the Fraser River and was caused by the tendency of races of sockeye arriving off the mouth of the river beginning in August to delay

entry into the river. Any apparent difference between early and late-season fish in rate of migration was probably due to this delay behavior and to the commencement of delay on the part of some fish before they reached the mouth of the river. The tagging indicated that some sockeye, particularly early-season fish, migrated from Sooke to the Fraser River in a remarkably short time; while other sockeye, particularly late-season sockeye, were out a great many days before their capture in or near the river. It is impossible to vouch for the accuracy of all the data upon which this statement is based, but confirmation of both the rapidity and variability of the rate of migration was obtained in 1947 when eight Sooke-tagged sockeye were recovered 105 miles away in the mouth of the Fraser River by Salmon Commission personnel while test fishing. Five of the sockeye had been tagged during the period July 17 to 24 and had been out 2 to 5 days before recovery. Three sockeye had been tagged during the period August 8 to 27 and had been out 4 to 38 days before recovery.

SALMON BANKS

The data from sockeye tagged at Salmon Banks, South Lopez and San Juan Channel have been combined. They are referred to as the Salmon Banks' data for purposes of determining migration times. The consolidation was desirable in order to base the conclusions on as large a number of events as possible. This appeared permissible since the majority of the tagging experiments in the combined areas were performed at tagging sites within a 2-mile radius of one another. Inspection of the recovery data indicated that the pattern in regard to days-out in 1939 was quite different from the patterns in 1940 and 1941 which were quite similar. The percentage frequency distributions by day-out of Salmon Banks-tagged sockeye recovered in certain areas during 1939 are compared by FIGURE 8 with those recovered during 1940 and 1941 combined.

The modal numbers of days-out to certain fishing areas were as follows: Lummi Island—2 days in 1939 with almost as many recoveries 3 days-out, and 2 days in 1940-1941; Point Roberts—3 days in 1939 and in 1940-1941; Convention Waters of the Strait of Georgia—8 days in 1939 and 3 to 4 days in 1940-1941; Mouth of Fraser—7 days in 1939 but 3 days in 1940-1941; North Arm and New Westminster—10 days in 1931 but 6 days in 1940-41; Above Bridge—7 days in 1940-1941 but in 1939 the mode was ill defined. The mode in the Above Bridge area in 1939 was indicated at 55 days-out by 6 recoveries but 5 recoveries were recovered on each of the following numbers of days-out: 6, 48, and 50.

It appears that many of the sockeye tagged in 1939 delayed a considerable period of time in the area lying between Point Roberts and the Fraser River, whereas in 1940 and 1941 many sockeye upon arrival in the Canadian fishing areas proceeded up river without pronounced delay. Additional evidence of these differences is presented in TABLE 20 which lists the recovery data in terms of the percentage of the annual recoveries

in each of the Point Roberts, Mouth of Fraser, North Arm-New Westminster, and Above Bridge areas that occurred within specific intervals of days-out (0-7, 8-14, etc.). Inspection of the table shows that in 1939 about 70 per cent of the recoveries in the Point Roberts area occurred within 7 days after the fish were tagged at Salmon Banks and that about 6 per cent were out over 28 days; but that in 1940 and 1941 the respective approximate percentages were 88 and 2. In 1939 in the Mouth of Fraser area about 18 per cent of the recoveries were out 7 days or less and about 46 per cent were out over 28 days; but in 1940 and 1941 the respective approximate percentages were 44 and 22. The recoveries in the North Arm-New Westminster and Above Bridge areas also indicated that relatively fewer sockeye entered the river within 7 days and more entered after 28 days in 1939 than in 1940 and 1941.

A special purse seine season was permitted in that portion of the Convention waters of the Strait of Georgia adjacent to the mouth of the Fraser River for a period of approximately 11 fishing days from Friday, August 25 to Monday, September 9, 1939. During this period the purse

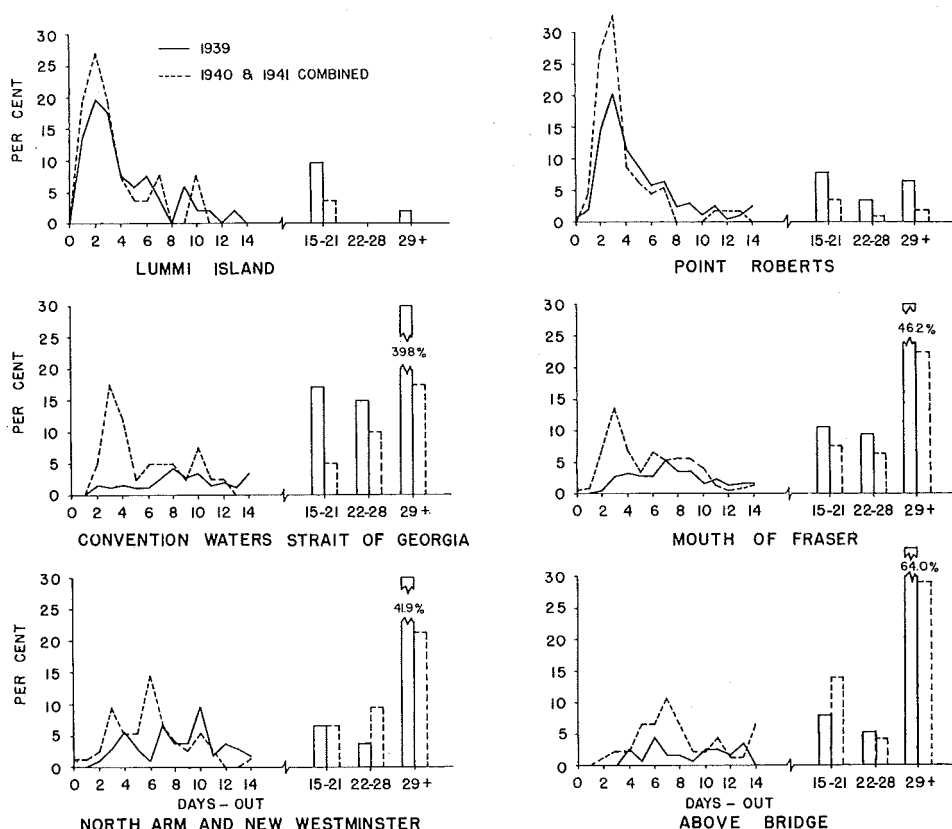


FIGURE 8—Salmon Banks tagged sockeye. Percentage frequency distribution by days-out of recoveries in specific areas. 1939 vs. 1940 and 1941 combined.

TABLE 20—Salmon Banks tagging; 1939 vs. 1940 and 1941 combined. Percentages of the recoveries in each area that occurred during specific intervals of days-out.

DAYS-OUT	RECOVERY AREA							
	Point Roberts		Mouth of Fraser		North Arm-New Westminster		Above Bridge	
	1939	1940-41	1939	1940-41	1939	1940-41	1939	1940-41
0 - 7	69.5	88.5	17.6	44.2	20.0	46.6	9.6	29.0
8 - 14	12.8	5.3	16.0	19.6	27.6	16.0	13.2	23.7
15 - 21	7.9	3.5	10.7	7.5	6.7	6.7	7.9	14.0
22 - 28	3.4	0.9	9.5	6.3	3.8	9.3	5.3	4.3
Over 28	6.4	1.8	46.2	22.3	41.9	21.3	64.0	29.0

seine fleet caught 93,301 sockeye including 100 that had been tagged at Salmon Banks. These 100 tagged sockeye represented about 41 per cent of the total number of Salmon Banks tags recovered in the Convention Waters of the Strait of Georgia area in 1939. No purse seining was permitted in this area during 1940 and 1941.

On Wednesday, September 6, 1939 when the maximum catch occurred, there were 37 tag recoveries. These recoveries were from fish tagged at Salmon Banks as early as July 28 and as late as August 29, which were out 8 to 40 days before they were recovered adjacent to the Fraser River. They indicated that some fish which were present in the Salmon Banks area in late July and early August contributed to the catches made off the mouth of the river in early September.

On the basis of knowledge of the fishery plus information from fin-marked fish and scale analysis a period of delay off the mouth of the river especially late in the season has generally been accepted but only tagging has been able to demonstrate this with positively identifiable fish. The number of fish delaying in 1939 may have been greater than was indicated by the tag returns, as many of the fish that had been delaying may have escaped upriver during a 9-day extended closure of the fishery that was in effect from Saturday, September 16 to Monday, September 25. No extended closures of the Fraser River fishery occurred in 1940 and 1941. As a result of this closure the differences between the recoveries in Canadian fishing areas in 1939 and the combined years 1940 and 1941 are not indicative of the actual greater number of sockeye delaying off the mouth of the Fraser River during 1939.

LUMMI ISLAND

The percentage frequency distributions by days-out to specific recovery areas are shown by FIGURE 9 for sockeye tagged at Lummi Island during 1939 and the combined years 1940 and 1941. Inspection of the raw data indicated that the data for 1939 were quite unlike those for 1940 and 1941 which were quite similar.

The modal numbers of days-out to certain United States and Canadian areas were as follows: Point Roberts—2 days in 1940 and 1941, but 2 or

5 days in 1939 with fair numbers of recoveries occurring from 1 to 8 days-out in that year; Mouth of Fraser—6 days in 1940-1941, but only 3 days in 1939 when contrary to the rapid migration indicated by the mode, relatively more sockeye took longer to enter the river mouth than in 1940 and 1941; North Arm-New Westminster—3 or 6 days in 1940-1941 combined, but 6 days in 1939 when over 41 per cent of the recoveries were out over 28 days even though recoveries occurred consistently from the 2nd through the 7th day-out; Above Bridge—6 or 13 days in 1940-1941, but 7 days in 1939 with the recoveries in that year occurring over a more protracted range of days-out than in 1940 and 1941. The data for the recoveries in the Convention Waters of the Strait of Georgia area were omitted from FIGURE 9. They are presented in tabular form instead, because of the amorphous nature of the 1939 data and the paucity of the combined 1940 and 1941 data.

Days-out.....	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22-28	29+
No. Recovered																						
1939.....	2	2			2	2	2	3	3	1	1	3	6	4	6	3	1	2	1	2	13	34
1940-1941.....	2	4	8	9	4	4			1		1	2		1		2			1		5	4

The tabulation shows that in 1939 the migration time of sockeye tagged at Lummi Island and recovered in the Strait of Georgia area was indefinite

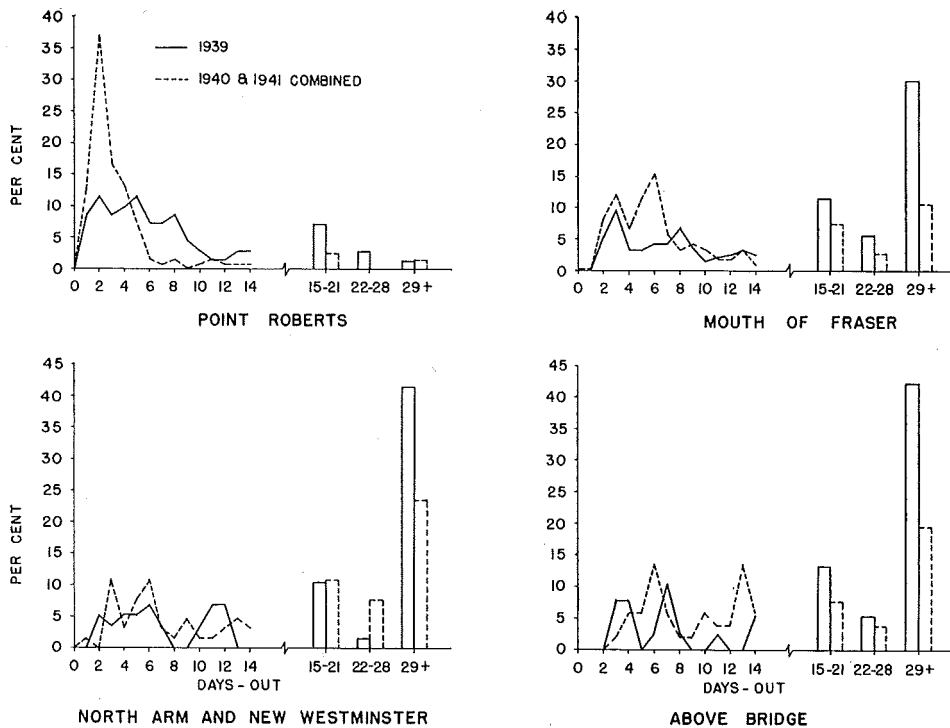


FIGURE 9—Lummi Island tagged sockeye. Percentage frequency distribution by days-out of recoveries in specific areas. 1939 vs. 1940 and 1941 combined.

and that the tagged sockeye were available in the Strait of Georgia for many days. In 1940 and 1941 the modal-migration time was 4 or 5 days and fewer sockeye were recovered a long time after tagging than were recovered in 1939.

The foregoing estimated migration times are at best only very rough approximations because the recoveries in most instances were too few to indicate well defined modes. It is very apparent that many more sockeye tagged in 1939 at Lummi Island were prone to delay after passing Point Roberts than were those tagged in 1940 and 1941. This is true in spite of the 9-day closure of the Fraser River gill net fishery in 1939 which commenced on September 16. Actually the proportion of the fish delaying was probably greater than that indicated by the recoveries because fish escaping upstream during the closure could not be recovered.

POINT ROBERTS

Too few sockeye were tagged at Point Roberts (31 in 1939 and 179 in 1941) to warrant a detailed discussion of the results. The tagging in 1941 was done during the period July 11 to 24, and the recovered sockeye indicated a rate of migration and entry into the Fraser River which was consistent with the rates indicated by sockeye tagged early in the season at Sooke, Salmon Banks and Lummi Island.

SAND HEADS

Information regarding the speed of migration of sockeye tagged off the mouth of the Fraser River during the years 1938 to 1941 was presented by MacKay *et al.* (1945). However the report was intended to be preliminary and did not discuss the effects of fishing regulations on the tagging data. The data, with the exception of those for 1940 which were too few, have been reexamined for presentation in more detail.

The tagging at Sand Heads resulted in the following recoveries in the Point Roberts area of the United States fishery which were discussed previously: 61 in 1938, 29 in 1939, and 2 in 1941. Tagging in 1941 started at Sand Heads on July 24 almost a month earlier than in 1938 and 1939. This should have afforded an opportunity for some fish tagged in July and August to be recovered in the Point Roberts area if they were milling about off the mouth of the Fraser River. The almost complete lack of recoveries at Point Roberts in 1941, therefore, lends credence to the concept that the dropping back of fish occurs primarily in September when late-running races are delaying entry into the river. It will be demonstrated subsequently that some fish did delay off the river in 1941 and that these were fish tagged in September.

Inspection of the data available in regard to Sand Heads tags recovered in the Canadian fishing areas indicated that the tags had not been applied in similar numbers throughout the seasons and that the fishing regulations during the years 1938, 1939 and 1941 had been quite

different. A table for each of the respective years (TABLES 21, 22 and 23) was therefore prepared listing the dates and numbers of fish tagged and the dates and numbers of fish recovered in each of the following areas: Convention Waters of the Strait of Georgia; Mouth of Fraser (includes Canoe Pass, Main Arm, Middle Arm and Point Grey areas); North Arm and New Westminster; and Above Bridge. The closed periods and gear restrictions were also indicated on the tables. It will be noted from the tables that the week-end closures for the Above Bridge area were usually four to six hours longer than they were for the other areas of the Fraser River fishery. To limit the tables to a reasonable size commensurate with the amount of data contained, it was decided to omit from all areas data from experiments that yielded less than 10 recoveries in the Mouth of Fraser area. Data from the few oval tags which were used in some of the 1941 experiments were also omitted.

Convention Waters Strait of Georgia

Much of the Sand Heads tagging occurred adjacent to the common boundary between the Convention Waters Strait of Georgia area and the Mouth of Fraser area. Many of the tagged sockeye delayed in these areas, consequently, the days-out before recovery were more indicative of the period of delay than they were of the actual speed of migration.

In 1938 the area open to purse seining in the Strait of Georgia area was extended to include the waters immediately adjacent to the Fraser River during the period September 1 through 9. All fishing in the Fraser River area was suspended from September 10 through October 2 with gill netting being resumed on October 3. From the tagged fish recovered by purse seines on September 8 and 9 it was evident that some sockeye had delayed a minimum of 10 to 12 days. The 10-day figure was derived from sockeye tagged on August 30 while the 12-day figure was derived from data from two small experiments on August 27 and 29 which were omitted from TABLE 21. From the recoveries that occurred when gill netting was resumed on October 3 it was evident that some fish tagged on September 5, 8 and 14 were still in the Strait of Georgia area 19 to 29 days later.

In 1939 purse seining was permitted in the area including the waters adjacent to the river from August 25 through September 8. However, very little information was obtained from the few fish recovered by purse seines as most of the tagging was done after the termination of seining. Gill netting in the Fraser River fishery was suspended from September 16 to 25. On September 25 it was resumed with the following restrictions. The week-end closures were increased from 48 hours to 72 hours beginning Friday, September 29. Following this date the mesh size of gill nets was restricted to a minimum of 6½ inches. This latter restriction would have made the recovery of tagged fish less efficient than it was prior to September 29.

TABLE 22—1939 Sand Heads tagging. Numbers and dates of recoveries in Fraser River fishery.

DATE TAGGED		DATE RECOVERED																				TOTAL	
		September										October											After 10/20
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	10/20			
Sept. 3 6	3 6	CONVENTION WATERS OF THE STRAIT OF GEORGIA—PURSE SEINE RECOVERIES																				5 3	
		(Minimum Mesh Size for Gill Nets: 6½ Inches Effective October 1 in All Areas)																					
		CONVENTION WATERS OF THE STRAIT OF GEORGIA—GILL NET RECOVERIES																					
		No Purse Seining After 0800 September 9.																					
Sept. 3 6 9 10 11 13 16 18 22 23 25	3 6 9 10 11 13 16 18 22 23 25	CONVENTION WATERS OF THE STRAIT OF GEORGIA—GILL NET RECOVERIES																				10 5 26 15 16 8 13 5 8 38 48 11 13 57 29 44 12 29 11 21 147 156	
		MOUTH OF FRASER																					
		Sept. 29-Oct. 2																					
		72-hour Closure																					
Sept. 3 6 9 10 11 13 16 18 22 23 25	3 6 9 10 11 13 16 18 22 23 25	NORTH ARM AND NEW WESTMINSTER																				4 1 20 7 13 2 9 1 7 66 66 5 5 23 12 16 7 24 6 7 53 54	
		Sept. 29-Oct. 2																					
		72-hour Closure																					
		76-hour Closure																					

¹Numbers tagged each date: 9/3 - 72; 9/6 - 57; 9/9 - 251; 9/10 - 133; 9/11 - 177; 9/13 - 50; 9/16 - 155; 9/18 - 51; 9/22 - 80; 9/23 - 573; and 9/25 - 561.

The gill net recoveries in the Strait of Georgia indicated, oddly enough, that the fish in general were not recovered soon after tagging even though there was much fishing in the vicinity of the Sand Heads. From TABLE 22 it can be deduced that only about 26 per cent of the 80 recoveries by gill net from the fish tagged during the period September 3 to 13 inclusive were made prior to the 9-day suspension of fishing on September 16. This is in keeping with the experience of fishermen who state that late-season fish which delay in the Strait of Georgia are not readily available to gill nets when the fish first arrive in the area and that they do not become so until they begin to enter the river. The following recapitulation of the gill net recovery data from the Convention Waters of the Strait of Georgia area shows for each tagging day during the period September 3 to 13 the number and percentage of the recoveries that occurred after the September 16 to 25 closure.

DATE TAGGED IN 1939	GILL NET RECOVERIES AFTER RESUMPTION OF FISHING		RANGE OF DAYS-OUT TO RECOVERY
	Number	Approx. %	
Sept. 3	4	40	24-32
6	3	60	20-27
9	22	85	17-41+
10	12	80	16-33
11	11	69	14-30
13	7	88	14-37+

In 1941 purse seining was not permitted in the Strait of Georgia area and there was no extended closure in September. The usual 48-hour week-end closures prevailed until September 26 when they were increased to 72 hours. Gill nets with less than 6½-inch mesh were prohibited effective October 1. Tagging was begun July 24, nearly a month earlier than in 1938 and 1939, and fair numbers of sockeye were tagged at frequent intervals until August 20. Only small numbers of sockeye were tagged from then until September 9 when 494 were tagged with disk tags and fair numbers were tagged on several subsequent dates. Because of the differences between the period of tagging in 1941 and those of 1938 and 1939, the recovery data for 1941 were divided into two groups (TABLE 23): data from tags applied during the period July 29 to August 19; and data from those applied September 9 to 17. This permitted a comparison of the early-season tagging with the late-season tagging in 1941 and a comparison between the three years for late-season tagging.

Inspection of the small number of recoveries in the Convention Waters of the Strait of Georgia area listed in TABLE 23 for the various tagging experiments indicated that they were too few in that area in 1941 to permit inferences regarding differences between the fish tagged early and those tagged late in regard to the number of days that they were out. Comparison, by inspection, of the recoveries from the fish tagged late in the season in 1941 with the recoveries from the fish tagged in 1938 and 1939

TABLE 23 (Continued)—1941 Sand Heads tagging. Numbers and dates of recoveries in Fraser River fishery.

DATE TAGGED	DATE RECOVERED																														TOTAL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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The numbers tagged each date were as follows: 7/29 - 25; 8/2 - 146; 8/3 - 36; 8/10 - 47; 8/11 - 44; 8/12 - 46; 8/14 - 39; 8/18 - 29; 8/19 - 51; 9/9 - 494; 9/12 - 47; 9/14 - 60; and 9/17 - 74.

*There were no recoveries in the Above Bridge area from the July 29 experiment.

(TABLES 21 and 22) although far from precise indicated that relatively fewer fish in 1941 delayed in the Strait of Georgia than in 1938 or 1939.

Mouth of Fraser

It was mentioned previously that the numbers of days that sockeye tagged in or immediately adjacent to the Mouth of Fraser area were out before recovery in that area provided estimates of the period of delay off the river. These estimates were a minimum as the sockeye were not necessarily tagged upon their arrival in the area.

In 1938 the maximum number of recoveries in the Mouth of Fraser area from the experiments listed in TABLE 21 were made on September 8 and 9 after the fish had been out from 1 to 10 days. These dates of maximum recovery were the same as those for recoveries by gill nets and purse seines in the Convention Waters of the Strait of Georgia area. The 23-day suspension of fishing from September 10 to October 3 automatically prevented recoveries from the last group of fish listed (those tagged September 14) before they were out at least 19 days. Nevertheless, fish from this last group were consistently recovered each fishing day during the first 2 weeks after the resumption of fishing. The 42 recoveries from the September 14 tagging during this 2-week period indicated that some fish delayed in the vicinity of the Sand Heads from 19 to 31 days. Reference to the recoveries of fish tagged prior to September 14 showed that some fish delayed even longer.

In 1939 the recoveries prior to the 9-day suspension of fishing in September were few and seldom occurred before the fish were out at least 4 days (TABLE 22). Reference to the following recapitulation of the recoveries in the Mouth of Fraser area showed that relatively many of the fish that were recovered after the resumption of fishing from the tagging experiments of September 3 to 13 had been out a minimum of 14 to 25 days.

DATE TAGGED IN 1939	RECOVERIES AFTER RESUMPTION OF FISHING		RANGE OF DAYS OUT TO RECOVERY
	Number	Approx. %	
Sept. 3	3	27	25-38
6	6	46	22-37
9	47	82	17-41+
10	21	72	15-40+
11	34	77	15-39+
13	9	75	14-37+

Recoveries from the experiments listed in TABLE 22 were made quite consistently each fishing day during the 2-week period of October 2 to 16 in spite of the 6½-inch mesh restriction which commenced October 1. Reference to the experiment of September 9 showed that 36 of the 57 recoveries were made during the period October 2 to 13. This indicated that many of the fish tagged on September 9 delayed from 23 to 34 days. Reference to the recoveries from the fish tagged on September 23 and 25

disclosed that they were made in greatest number on October 4 and 5 when those two groups of fish had been out a minimum of 11 to 9 days respectively. Further reference to TABLE 22 showed that fish from these same groups seemed to have been most available in the areas further upriver (North Arm-New Westminster and Above Bridge) on October 2 and 3. While this may appear to be unusual it probably can be explained by the effects of fishing on stocks of fish delaying off the mouth of the river and on those stocks of fish which entered the river during the preceding 72-hour week-end closure. An examination of the gill net catches indicated that they decreased rapidly after the first day (October 2) of the fishing week. The catch on October 2 was over twice that of October 3.

It appears that the fishery quickly decimated the numbers of fish in the North Arm-New Westminster and Above Bridge areas and consequently the numbers of tagged fish recovered in those areas also decreased. But the fishery in the Mouth of Fraser area continued to catch fish as they entered the river, consequently, the recoveries in that area did not decrease. The tag recoveries and the catches during the succeeding fishing week (October 9-13) seemed to indicate that this pattern of events was a weekly occurrence.

In 1941 the tagging was begun early. In addition the fishing restrictions, when compared to those of 1938 and 1939, should have had a minimum effect on the recovery of tagged fish. The lengths of the week-end closures were increased by 24 hours effective September 26 and the 6½-inch minimum mesh size for gill nets became effective October 1. The last tagging experiment listed in TABLE 23 was dated September 17. There was therefore a period of 13 days before the fish from this experiment could have been affected by the mesh regulation which would have tended to reduce the possibilities of recovering those fish after 13 days-out. The increased length of the week-end closures would have also tended to decrease the number of recoveries. The net effect of these restrictions when comparing the days-out for fish tagged early in the season with those for fish tagged late in the season would have been to limit or reduce the number of days-out for the late-tagged fish. Nevertheless when the recoveries in the Mouth of Fraser area of fish tagged from July 29 to August 19 were compared with the recoveries from the fish tagged in September less than 18 per cent of the early-tagged fish were out over 13 days while in the case of the late-tagged fish the percentage exceeded 50.

The modal number of days-out in 1941 of the Sand Heads sockeye tagged early in the season and recovered in the Mouth of Fraser area was 2 days but for fish tagged in September it was 3 days. In addition the September fish continued to be recovered in fair numbers after being out considerably greater numbers of days than were the fish tagged earlier. The modal numbers of days-out determined from tagging in a region where delay occurs may not be acceptable indices of the actual speeds of

migration. In the case of the recoveries of Sand Heads-tagged sockeye in the Mouth of Fraser area in 1941 the modal numbers of days-out are perhaps estimates of the numbers of days that elapsed before the tagged fish attempted to enter the river or began to and fro sorties into the river mouth and thus became available to the gill net fishery in the Mouth of Fraser area.

North Arm-New Westminster and Above Bridge

The numbers of recoveries of Sand Heads tags in the North Arm-New Westminster and Above Bridge areas were rather few, especially in 1938. The recoveries and migration times in these areas will therefore be discussed simultaneously.

In 1938 the almost complete lack of recoveries by the commercial fishery within the river prior to the resumption of fishing following the September 10 to October 3 closure even though fish had been tagged at Sand Heads in sizeable numbers on five occasions from August 30 to September 8 (TABLE 21) indicated that either the fish were delaying off the river or they were being caught as they attempted entry into the river. The patterns of recovery in the Convention Waters of the Strait of Georgia and the Mouth of Fraser areas confirmed the existence of delay outside the river but they did not necessarily indicate that the fish were being caught with such rapidity that none remained to enter the river. However comparison of the recoveries in those areas with the recoveries in the North Arm-New Westminster and Above Bridge areas, especially in the Above Bridge area immediately after the resumption of fishing on October 3, indicated that once the fish attempted to or entered the river they were either rapidly caught or they escaped upriver past the limits of commercial fishing. Large numbers of recoveries in the Above Bridge area on October 3 and 4 followed subsequently by very few recoveries plus large numbers of spawning ground recoveries imply that many fish escaped upriver during the September 10 to October 3 closure. The delay factor plus the suspension of fishing prevented the estimation of the rate of migration from Sand Heads to the North Arm-New Westminster or the Above Bridge areas in 1938.

In 1939 the recovery patterns (TABLE 22) in the subject areas were quite similar to those of 1938 even though fishing was suspended for only 9 days commencing September 16. It appears that a number of fish that had been delaying off the mouth of the river during the first part of September (those sockeye tagged before or on September 16) escaped upstream during the 9-day closure and that additional numbers of this same group of fish continued to escape upstream during the next two week-end closures. These assertions were supported by the following evidence: 1. The recoveries in the Above Bridge area when fishing was resumed on September 25 were greater than they were in either the Convention Waters of the Strait of Georgia or the Mouth of Fraser or the North Arm-New

Westminster areas. This indicated that an upstream movement of fish had been in progress during the 9-day closure. 2. The recoveries in the North Arm-New Westminster and Above Bridge areas during the first week of the resumption of fishing decreased to almost zero after the second day but they did not in the more downstream areas.

The pattern of a large number of recoveries in the upstream areas during the first two days of the fishing week followed by small numbers during the remainder of the week was repeated during the second and third succeeding week. This indicated that with the resumption of fishing after each closure a body of sockeye moving upstream was present in the North Arm-New Westminster and Above Bridge areas and that this body of sockeye was quickly depleted by fishing and by emigration, and also that the intense fishery in the Convention Waters of the Strait of Georgia and Mouth of Fraser areas removed most of the potential recruitment as the sockeye approached the river during the fishing week. It also appears, on the basis of the recoveries on September 25 (5 in North Arm-New Westminster and 2 in Above Bridge areas) of sockeye tagged on September 23, that once the sockeye enter the river some of them may ascend to the North Arm-New Westminster area or even the Above Bridge area within 2 days.

In 1941 the recoveries (TABLE 23) in the North Arm-New Westminster and Above Bridge areas reflected a seasonal variation similar to that mentioned for the recoveries in the Mouth of Fraser area. For example, over 85 per cent of the fish tagged in July and August and recovered in the North Arm-New Westminster area were out only 13 days or less; but less than 25 per cent of the recoveries of fish tagged in September were made in the same length of time. In the Above Bridge area over 57 per cent of the recoveries from the July and August experiments were out only 13 days or less; but in the case of the September experiments the percentage of the recoveries occurring within the same length of time was less than 51. The seasonal difference in this latter area is greater than the comparison indicates for if the comparison is made on the basis of the tags recovered within 10 days the percentage remains at 57 for the July-August tags but falls to less than 40 for the September tags. In addition consideration should be given to the previously mentioned mesh restriction effective October 1. This would have had the effect of decreasing the possibility of late recoveries and consequently causing the fish tagged in September to appear to be out lesser lengths of time before recovery than were fish tagged in July and August.

An estimate of the number of days required for the sockeye tagged in 1941 to move from the Sand Heads to the North Arm-New Westminster and Above Bridge areas is rather difficult in view of the limited data available and the number of variables involved. The data from experiments in July and August were dominated by the large experiment of August 2. These data indicated that some sockeye migrated from the Sand

Heads to the North Arm-New Westminster area in 1 or 2 days. The mode was 2 days-out. It took 2 to 3 days for the early-tagged fish to arrive in the Above Bridge area. The recoveries from the large number of sockeye tagged (494 with disk tags) on September 9 dominated the days-out distribution of the recoveries from all the experiments. The September 9 tagging indicated that some sockeye migrated from the Sand Heads to the North Arm-New Westminster area and also to the Above Bridge area within 7 days. The mode in both areas occurred on the seventh day.

Summary of Migration Times from Sand Heads

Before summarizing this discussion of the rates of migration of sockeye tagged at Sand Heads the following problems or variables are recalled. 1. The tagging was done in an area where delay occurs and was usually done late in the fishing season when many of the fish had been present prior to tagging for unknown lengths of time. 2. The tagging was done on various days of the week but not with sufficient frequency on similar days of the week. Reasonably consistent numbers of sockeye were not tagged each day nor were they tagged necessarily in relation to abundance. As a result, the data for each of the years were dominated by the data from the occasional days when large numbers of sockeye were tagged. 3. The fishing regulations during the three years were dissimilar but in each year they tended to become more restrictive as the fishing season progressed. 4. The proximity of much of the tagging in 1938 and 1939 to the midseason closures that occurred in those years biased the frequency distribution of the days-out data, but as will be shown later the spawning ground recoveries did afford means of deducing which races of sockeye were involved in delay and which races benefited from the closures.

During the discussion of the tagging in some areas other than at Sand Heads the effects of tagging on different days of the week on the estimates of migration times to various areas were examined. This was not done in the case of the tagging at Sand Heads because of the problems just listed. Only in 1941 did it appear that the Sand Heads data might be amenable to such an examination. However it appears in this instance that consideration of the days of the week on which the tagging was done would not have resulted in more accurately estimated migration times. Nevertheless the weekly pattern of tag recovery or of fishing that was described in connection with the recoveries in the North Arm-New Westminster and Above Bridge areas certainly indicates the effect that tagging on different days of the week can have on the estimation of migration times.

The following summarizes the inferences obtained regarding the rates of migration of sockeye tagged at Sand Heads. Delay off the mouth of the river or in the Strait of Georgia was shown to have occurred in 1938, 1939 and 1941 and to have occurred principally among fish present in September. Relatively fewer fish delayed in 1941 than in 1938 or 1939. Many fish delayed a minimum of 19 to 34 days. Because of delaying behavior, modal-

migration times were not acceptable estimates of the rates of migration and no migration times were given for recoveries in the Point Roberts and Convention Waters Strait of Georgia areas. Modal times in 1941 of 2 days for fish tagged early in the season and 3 days for fish tagged late in the season before recovery in the Mouth of Fraser area were accepted as better measures of the time elapsing between tagging and availability of the sockeye to gill nets in the Mouth of Fraser area than they were of migration times to that area.

In 1939 some Sand Heads-tagged sockeye reached the North Arm-New Westminster area in 2 days. In 1941 those tagged early in the season also reached the area in maximum numbers in 2 days but those tagged late in the season did not reach the area in maximum numbers until they were out 7 days. Similar numbers of days were also required for sockeye to reach the Above Bridge area in 1939 and 1941 except that the numbers of days required by the early-season fish in 1941 were 2 to 3. The 7-day estimated migration time from Sand Heads to the North Arm-New Westminster and Above Bridge areas for late-season fish is a biased estimate and therefore the difference between it and the 2 or 3-day migration times obtained for the early-season fish is not a valid difference. The biased estimate was the result of a combination of tagging delaying fish, tagging extremely unequal numbers on different days of the week, and depleting by fishing the stocks of fish in the North Arm-New Westminster and Above Bridge areas that had entered the river during the week-end closures. Once the sockeye entered the river they passed upstream rapidly; some fish in 1939 reached the Above Bridge area within 2 days.

JOHNSTONE STRAIT

A preliminary examination of the Johnstone Strait tags recovered in each area within the commercial fishery indicated that the rates of progression from one area to the next were quite similar for both 1940 and 1941 and that the data for the two years could be combined. FIGURE 10 illustrates the percentage frequency distribution of the recovered tags in each area in terms of days-out. The modal-migration times or days-out were: Upper Johnstone Strait—1; Lower Johnstone Strait—4; Convention Waters of Strait of Georgia—7; Mouth of Fraser—8; North Arm and New Westminster—9, a second mode of equal amplitude occurred 17 days-out but it was masked by grouping the data after the 14th day; Above Bridge—12.

The proportion of the recoveries in each area that were out over 14 days increased rather consistently as the recovery areas were further and further from the tagging area. In the Upper Johnstone Strait area only 17 of the 308 recoveries in that area or less than 6 per cent were out over 14 days. At least part of these can be assumed to have been sockeye native to the Johnstone Strait area and not to the Fraser River since 6 of the 17 were recovered in Knight Inlet which receives streams that support sock-

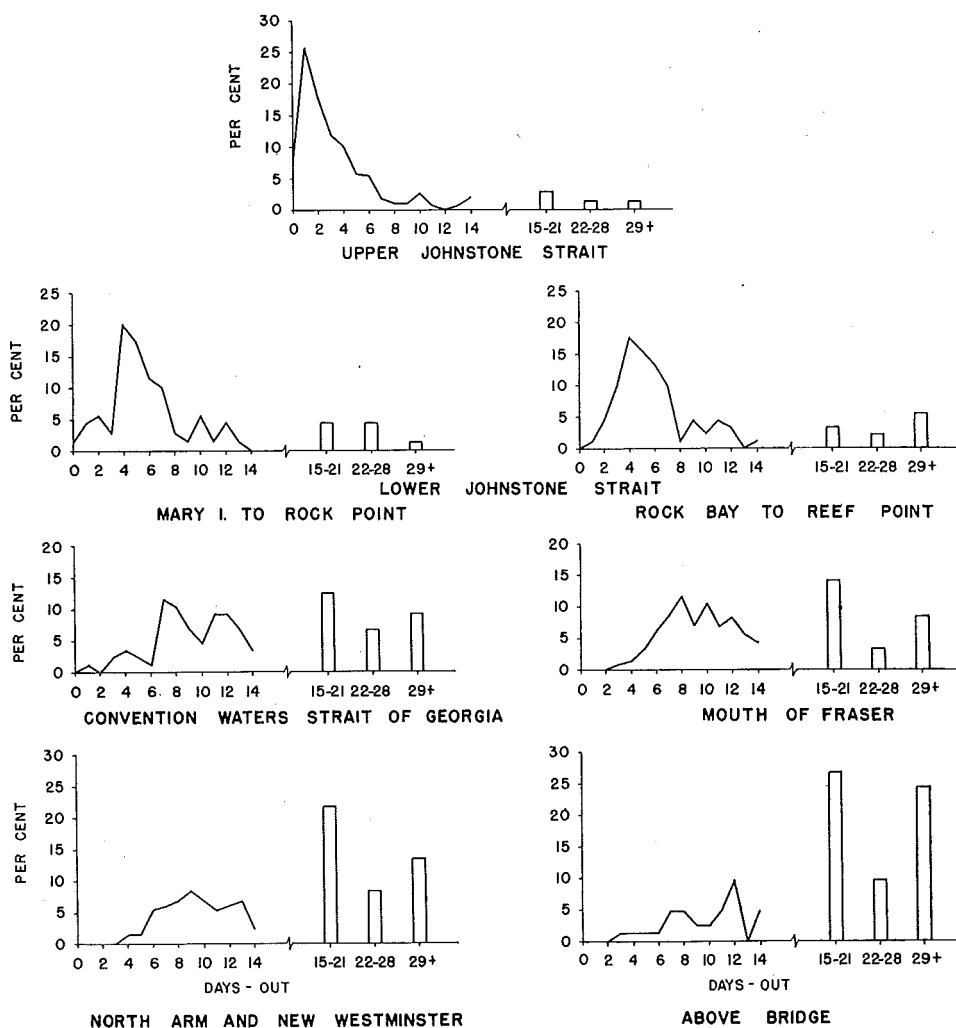


FIGURE 10—Johnstone Strait tagged sockeye. Percentage frequency distribution by days-out of recoveries in specific areas. 1940 and 1941 combined.

eye runs. In the Above Bridge area of the Fraser River nearly 61 per cent of the 82 fish that were recovered were out over 14 days. However some Johnstone Strait-tagged sockeye appeared in the catches of the Fraser River gill net fishery within 3 days and some were reported from the North Arm-New Westminster and Above Bridge areas of the fishery within 4 days. The modal-migration times may have been too great as the result of the effects of fishing or of the relationship between the week-end closures and the days of the week on which the fish were tagged.

The recoveries in each area from each day's tagging were examined to ascertain the effects of week-end closures on the recoveries and the estimated migration times. During the Johnstone Strait experiments the

numbers of times that tagging was done on each day of the week during 1940 and 1941 were as follows:

1940—Monday 2, Tuesday 2, Wednesday 3, Thursday 4, Friday 1, Saturday 1, and Sunday 1;

1941—Monday 3, Tuesday 3, Wednesday 3, Thursday 2, Friday 1, Saturday 1, and Sunday 1. The numbers of tags recovered in each area were in general too few and were usually spread over too long a time interval to provide for a conclusive analysis. Therefore only the effects of the week-end closures on the recoveries in the Upper Johnstone Strait area (includes the tagging area) and in the Mouth of Fraser area will be discussed.

Upper Johnstone Strait—The week-end closures in Johnstone Strait commenced at 1800 on Fridays and ended at 1800 on Sundays. Sockeye tagged on Sunday, Monday, Tuesday, and Wednesday were recovered in the Upper Johnstone Strait area in greatest number 1 day-out. Those tagged on Saturday were not recovered in maximum number until the 2nd day-out which was Monday, the first full day of fishing after the week-end closure. Sockeye tagged on Thursday and Friday were not recovered in maximum number until Monday which was 4 and 3 days-out respectively for fish tagged on those two days, except that for some unknown reason an equally large number of Thursday-tagged fish were recovered on the day they were tagged. Perhaps these fish were tagged in the midst of a concentration of fishing gear. Regardless of the day of the week on which the fish were tagged they became relatively scarce or unavailable in the area within 5 or 6 days. Saturday and Sunday tags were recovered in the Upper Johnstone Strait area in the largest relative numbers and Thursday and Friday tags were recovered in the smallest relative numbers.

Mouth of Fraser—Sockeye tagged in Johnstone Strait began to appear in the catches in the Mouth of Fraser area within 3 to 4 days and the frequency of their occurrence increased steadily to a maximum or mode on the 8th day. However the recovery of many tagged fish before they reached the Mouth of Fraser area and also the week-end closures may have been partially responsible for the modal-migration time of 8 days. The week-end closures in the Mouth of Fraser area varied during the 1940 and 1941 seasons, being either 48 or 72 hours in duration beginning either Saturday or Friday morning, respectively. Monday-tagged fish began to be recovered in the Mouth of Fraser area on the following Thursday or Friday (3 to 4 days-out, respectively). Their continued recovery on Saturday and Sunday was prevented by the week-end closure but was resumed with increasing frequency on Monday (7 days-out), the start of the second fishing week. The maximum recovery occurred on the second Thursday (10 days-out). Tuesday-tagged fish did not begin to be recovered until Monday (6 days-out) after the week-end closure. The frequency of recovery increased from Monday to Friday (10 days-out) when the peak

recovery occurred. Wednesday-tagged fish began to be recovered on Monday (5 days-out) and they were recovered in maximum number on Thursday (8 days-out). Thursday-tagged fish also began to be recovered on Monday (4 days-out) and they were recovered in maximum numbers on both Thursday and Friday (7 and 8 days-out, respectively). Friday-tagged fish began to be recovered on Monday (3 days-out) but the peak recovery did not occur until the Monday (10 days-out) of the second fishing week. Many Thursday and Friday-tagged fish may have been in the area before Monday of the second week but the week-end closure may have prevented their earlier recovery. The frequency of recovery for both Thursday and Friday-tagged fish remained quite high throughout the second week of fishing (11 to 16 and 10 to 15 days-out, respectively). Saturday and Sunday-tagged fish were reported in the Mouth of Fraser area on Tuesday and Wednesday, respectively (3 days-out) and fair numbers were being recovered by Friday (6 and 5 days-out, respectively) of the first week of fishing. However the maximum numbers of recoveries did not occur until near the end of the second fishing week, when the maximum number of Saturday tags was recovered on Thursday (12 days-out) and the maximum numbers of Sunday tags were recovered on Wednesday (10 days-out) and Friday (12 days-out).

TABLE 24 lists the numbers and percentages of the recovered Johnstone Strait-tagged sockeye which were recovered in each area en route from the tagging area to the limits of commercial fishing in the Fraser River according to the day of the week on which the fish had been tagged. Fish tagged on Thursdays were recovered in the smallest relative number in the tagging area and in the largest relative number in the Mouth of Fraser area. The small recovery in the tagging area was probably the result of the week-end closure which began in Johnstone Strait at 1800 on Friday. As a consequence of this protection the fish arrived in the Mouth of Fraser area in relatively maximum numbers and also in the shortest modal-migration time, 7 or 8 days. The migration time of 8 days, based on the combined recoveries regardless of the day of the week on which the fish were tagged, may be too great.

MacKay *et al.* (1944) from consideration of median times of migration concluded that sockeye tagged at Sooke or at Johnstone Strait on similar dates arrived at the mouth of the Fraser River after approximately the same number of days had elapsed. This was rather surprising since the Johnstone Strait and Sooke tagging areas were respectively about 186 and 104 miles away from the mouth of the river. A strict comparison of modal-migration times is rather difficult because of the different circumstances surrounding the tagging in each area. The tagging in Johnstone Strait was done on every day of the week, but only for very short periods: July 16 to August 12, 1940 and July 21 to August 7, 1941. The tagging at Sooke in 1940 and 1941 was done almost exclusively on Thursdays, but for long

TABLE 24—Distribution between areas of tags recovered from each day-of-the-week's tags; Johnstone Strait, 1940 and 1941 combined. (Figures in parentheses are percentages.)

RECOVERY AREA	TAGGED ON							TOTAL RECOVERIES
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.	
Upper Johnstone Strait	38 (26.2)	35 (23.5)	44 (26.2)	40 (13.9)	26 (15.3)	53 (27.3)	72 (35.1)	308 (23.3)
Lower Johnstone Strait (Mary I. to Reef Pt.)	8 (5.5)	20 (13.4)	23 (13.7)	39 (13.5)	29 (17.1)	23 (11.9)	18 (8.8)	160 (12.1)
Strait of Georgia (Non-Convention and Convention waters)	11 (7.6)	9 (6.0)	16 (9.5)	29 (10.0)	5 (2.9)	16 (8.2)	11 (5.4)	97 (7.4)
Mouth of Fraser (Canoe Pass, Main Arm, Point Grey, and Middle Arm)	61 (42.1)	56 (37.6)	63 (37.5)	132 (45.8)	69 (40.6)	76 (39.2)	82 (40.0)	539 (40.9)
North Arm-New Westminster	16 (11.0)	19 (12.8)	14 (8.3)	27 (9.4)	27 (15.9)	16 (8.2)	14 (6.8)	133 (10.1)
Above Bridge	11 (7.6)	10 (6.7)	8 (4.8)	21 (7.3)	14 (8.2)	10 (5.2)	8 (3.9)	82 (6.2)
Total	145 (100.0)	149 (100.0)	168 (100.0)	288 (99.9)	170 (100.0)	194 (100.0)	205 (100.0)	1319 (100.0)

periods: June 13 to September 5 and June 12 to September 4, respectively. It was therefore decided to compare only fish tagged on Thursdays and to limit and to segregate the Sooke data according to those from fish tagged in July and to those from fish tagged in August. TABLE 25 lists the data compared.

Sockeye tagged on Thursdays at Johnstone Strait required a modal-migration time of 7 days in 1940 and 8 days in 1941 to reach the Mouth of Fraser area. Sockeye tagged on Thursdays at Sooke in July required 5 or 6 days in 1940 and 6 days in 1941 while those tagged in August required 13 days in 1940 and 8 days in 1941. For the 1940 and 1941 data combined, the modal days-out for the Johnstone Strait fish was 7 or 8, for the July-Sooke fish it was 6, and for the August-Sooke fish it was 8. It thus appears that the modal-migration time to the Mouth of Fraser was 1 to 2 days more for Johnstone Strait sockeye than it was for Sooke sockeye tagged in July but that it was about the same as that for Sooke sockeye tagged in August. It should be pointed out that the migration time of Sooke fish to the Mouth of Fraser in the combined years 1940 and 1941 was slower than the migration time for the combined years 1938 through 1947. However, whatever contributed to this slower migration time for Sooke fish in 1940 and 1941 might also be presumed to have similarly influenced the time for Johnstone Strait fish.

MacKay *et al.* (1944) were unable to determine whether the rate of migration from Johnstone Strait changed during the season. This is understandable since it has already been shown by tagging in other areas that delay behavior off the mouth of the Fraser River on the part of late-season sockeye was responsible for the apparent difference in rate of migration between early and late-season fish. Unless it were possible to recover tagged fish immediately upon arrival in the delay area it would be impossible to accurately compare the speed of migration of early-season fish with that of late-season fish. In addition, the periods of tagging in Johnstone Strait were so short (24 days in 1940, excluding 8 sockeye tagged on August 12, and 18 days in 1941) that they precluded the detection of a difference in behavior (delay) between early and late-season sockeye.

SUMMARY OF MIGRATION TIMES IN THE COMMERCIAL FISHERY

TABLE 26 is a summary of the most likely migration times of marine-tagged sockeye to certain recovery areas in the commercial fishery. The distances from Sooke or Johnstone Strait to each of the pertinent recovery areas are also listed. It was apparent from the preceding discussion that the data did not warrant the estimation of separate migration times for early-season and late-season sockeye. However, in general, in each instance where two migration times are listed in TABLE 26 the fastest time can be assumed to apply to early-season sockeye and also to late-season sockeye.

TABLE 25—Johnstone Strait vs. Sooke: days-out to Mouth of Fraser for sockeye tagged on Thursday only, 1940 and 1941.

DAYS- OUT	JOHNSTONE STRAIT						Sooke					
				July						August		
	1940	1941	Total	%	1940	1941	Total	%	1940	1941	Total	%
0	---	---	---	---	---	---	---	---	---	---	---	---
1	---	---	---	---	---	---	---	---	---	1	1	0.7
2	---	---	---	---	---	---	---	---	1	---	1	0.7
3	---	---	---	---	---	---	---	---	---	---	---	---
4	2	1	3	2.3	3	3	6	5.5	5	4	9	6.6
5	3	2	5	3.8	6	6	12	10.9	5	3	8	5.8
6	11	4	15	11.4	6	14	20	18.2	4	5	9	6.6
7	20	4	24	18.2	3	8	11	10.0	3	11	14	10.2
8	14	10	24	18.2	3	12	15	13.6	3	12	15	10.9
9	1	---	1	0.8	---	1	1	0.9	2	2	4	2.9
10	---	---	---	---	---	---	---	---	---	---	---	---
11	7	2	9	6.8	4	5	9	8.2	1	---	1	0.7
12	5	4	9	6.8	---	3	3	2.7	4	1	5	3.6
13	5	2	7	5.3	2	---	2	1.8	6	---	6	4.4
14	3	1	4	3.0	4	2	6	5.5	2	2	4	2.9
15-21	12	7	19	14.4	3	5	8	7.3	6	3	9	6.6
22-28	3	---	3	2.3	6	4	10	9.1	1	4	5	3.6
Over 28	7	2	9	6.8	5	2	7	6.4	35	11	46	33.6
Total	93	39	132	100.1	45	65	110	100.1	78	59	137	99.8

The slowest time applies to late-season sockeye that during the course of delaying off the mouth of the Fraser River mill about in the Strait of Georgia and occasionally re-enter the Point Roberts area. These late-season fish upon arrival in the delay area are not immediately available to the fishing gear, consequently, migration times based on their capture include unknown amounts of delay time. Tagging at Sand Heads indicated that some sockeye delayed as long as 19 to 34 days.

The differences between sockeye tagged at Sooke, Salmon Banks, Lummi Island, and Sand Heads in migration times to identical areas are not necessarily equivalent to the migration times between tagging areas because of the following:

1. The temporary effect of tagging, whatever it may be on the rate of migration, can be reasonably assumed to be greatest for short distances and least for long distances.

2. The errors, whatever they may be aside from the effects of tagging, involved in estimating the migration rates for short distances or small numbers of days-out will tend to be proportionately larger than those for long distances or large numbers of days-out.

3. The various races of Fraser River sockeye differ from one another in delay behavior.

4. Closures of the fishery may prevent the consistent recovery of tagged fish and this may affect the temporal and spacial distribution of the recoveries.

Henry (1961) by analysis of the racial composition of catches in recent years derived speeds of migration which agree in general with those listed in TABLE 26. His reference to a speed of 3 days from Juan de Fuca Strait to San Juan Islands concerns areas which respectively overlap and extend further to the west and north than the Sooke and Salmon Banks areas. His Lower Fraser River area includes the Mouth of Fraser and North Arm-New Westminster areas referred to in this report.

MIGRATION TIMES TO POINTS ABOVE THE COMMERCIAL FISHERY

TABLE 26 listed only the migration times from marine-tagging locations to recovery areas in the commercial fishery without regard to racial origin of the Fraser River sockeye involved. The recoveries of tagged sockeye near or on specific spawning grounds disclosed the racial origin of the sockeye involved and made available a means of estimating rates of migration of individual races. Killick (1955) pointed out that the numbers of recovered tags that could be used to establish accurate rates of travel of individual sockeye were relatively few. A gross estimate of the numbers of marine tags recovered above the commercial fishery can be obtained from TABLE 2. During the 4 years of tagging at Sand Heads less than 29 per cent

TABLE 26—Summary of the most likely migration times of marine-tagged sockeye in terms of days-out to certain recovery areas in the commercial fisheries.

RECOVERY AREA	DISTANCE IN STATUTE LAND MILES FROM		TAGGING AREA AND YEAR				
	Sooke ¹ to	Johnstone ² Strait to	Sooke	Salmon Banks	Lummi Island	Sand Heads	Johnstone Strait
			1938-1947	1939-1941	1939-1941	1938, 1939, 1941	1940-1941
Salmon Banks and South Lopez	38.0	-----	2	---	---	---	---
Point Roberts	87.5	-----	3-4	2-3	2	---	---
Mouth of Fraser	104.1	186.1	4-5	3-7	3-6	2-3	8
North Arm and New Westminster	119.7	201.7	4-7	6-10	3-6	2-7	9
Above Bridge	138.2	220.2	4-11	7+	6-13	3-7	12

¹Measured from Sooke Inlet to: Salmon Banks (Cattle Point), Point Roberts (Point Roberts Light), Mouth of Fraser (2½ miles upstream from Steveston Jetty Light), North Arm-New Westminster (St. Mungo Cannery), and Above Bridge (Port Haney).

²Measured from Robson Bight.

of the tags returned were recovered above the limits of commercial fishing in the Fraser River and of these the returns that could be assigned or related to specific spawning grounds amounted to only 14 per cent. The proportion of the recoveries that occurred upstream from the commercial fishery from the 11 years of tagging at Sooke amounted to nearly 16 per cent but the proportion that could be assigned to spawning grounds was only 5 per cent. The relative numbers of spawning ground recoveries from tagging at other marine locations were even less. Killick (1955) pointed out some of the problems, which prevented the use of a large proportion of the recovered tags, such as: suitability of tagging locations, physical effects of tagging, delays along the path of migration, differences between the sexes, and accuracy of recovery dates. Additional reasons for the omission of many tags recovered above the limits of commercial fishing are given in the TIME OF PASSAGE section of this report.

Since data on the rate of migration of specific races of sockeye are also available from tagging done at places within the Fraser River drainage as well as at places within the commercial fishery, it was thought appropriate to include, in one table (TABLE 27), a summary of racial-migration times from both marine and certain freshwater tagging locations. The names of the districts referred to are those used in the Salmon Commission's annual reports (Internat. Pacific Salmon Fish. Comm., 1960). The freshwater tagging locations in the table were limited to Hell's Gate and Bridge River Rapids on the main Fraser River, and to the Harrison River at Harrison Bay. Only data from sockeye recovered alive were used. Data from recoveries made near the spawning grounds while the sockeye were still actively migrating were preferred to data from recoveries on the actual spawning grounds because the time elapsing between arrival and recovery on the grounds was quite variable and was usually unknown. Indian recoveries were only included from those fisheries which intercepted migrating fish at well defined points and which were canvassed frequently by Salmon Commission personnel. Recoveries at weirs and traps are treated as if the fish were captured at these devices immediately upon arrival. The tagging at Hell's Gate and Bridge River Rapids prior to 1945 was omitted as fishways at Hell's Gate were not available until 1945 and they were not available at Bridge River Rapids until 1946. The principal sources of the data used in the table are given in the remarks column. No remarks indicate that the data were from recoveries made mainly by Salmon Commission personnel.

Two sockeye belonging to the Nechako races were tagged at Sooke in 1946 and intercepted at Hell's Gate 21 and 25 days-out (TABLE 27). These same fish were released alive at Hell's Gate and were subsequently recovered dead on the Stellako River spawning grounds. These were the only instances in which the migration times from Sooke to Hell's Gate were obtained for members of a race which were positively identified by tagging.

TABLE 27.—Summary of migration times to points near or on Fraser River spawning grounds of sockeye tagged at various locations and recovered alive.

DISTRICT AND PLACE OF RECOVERY	TAGGING AREA	DISTANCE IN MILES	YEARS	NUMBER RECOVERED	DAYS-OUT			REMARKS
					Range	Mean	Mode	
STUART Forfar Cr.	Sooke Hell's Gate Bridge R. Rapids	788 541 466	1946 1945 & 46 1945 & 46	4 100 68	28-34 16-34 13-34	31 22 18	---	Weir Weir Weir
Kynoch Cr.	Sooke Bridge R. Rapids	774 462	1946 1946	4 15	28-33 13-18	29 15	---	Weir Weir
Outlet Stuart Lake	Sooke Hell's Gate Bridge R. Rapids	714 477 402	1945-47 1945-47 1945 & 46	11 147 91	25-36 11-32 10-27	29 18 14	---	Indian fishery Indian fishery Indian fishery
NORTHEAST Bowron R.	Sooke Hell's Gate Bridge R. Rapids	768 531 456	1946 & 47 1945-48 1945 & 46	30 311 141	23-35 14-28 12-30	28 20 17	---	Weir Weir Weir
NECHAKO Hell's Gate Outlet Fraser Lake	Sooke Sooke Hell's Gate Bridge R. Rapids Sooke Bridge R. Rapids	237 707 470 395 718 406	1946 1946 & 47 1945-47 1945 & 46 1946 & 47 1945 & 46	2 7 170 69 5 46	21-25 21-61 12-40 9-32 21-61 12-38	23 41 24 19 42 22	---	See text Indian fishery Indian fishery Indian fishery Indian fishery Indian fishery
CHILCOTIN Farwell Canyon	Sooke Salmon Banks Hell's Gate Bridge R. Rapids Hell's Gate	406 368 170 95 215	1944-46 1940 1945-48 1945 1945-48	5 2 93 37 24	20-32 19-21 3-30 3-28 11-34	26 20 13 8 24	---	Indian fishery Indian fishery & Comm. staff Indian fishery Indian fishery Indian fishery
NORTH THOMPSON Raft R.	Sooke Hell's Gate Hell's Gate	391 154 217	1946 1946 1946	2 145 8	42-53 7-37 20-26	49 16 23	---	Pritchard trap Pritchard trap
SOUTH THOMPSON South Thompson R.	Sooke Hell's Gate Hell's Gate	243 205 67	1944 1940 & 41 1941	2 3 2	21-25 26-27 23	23 26 ---	---	Indian fishery Indian fishery Schaefer (1951)
LILLOOET Skookumchuck, on Lillooet R.	Sooke Salmon Banks Harrison R. Sooke Sand Heads Sooke Salmon Banks Sand Heads Harrison R.	263 161 278 240 176 102	1938 & 45 1939 1938-47 1939-41 1938-41 1939 & 41	2 13 14 9 48 2	33-37 4-33 31-59 28-55 18-59 18-37	35 19 43 46 35 28	---	Indian fishery Indian fishery Indian fishery Indian fishery Indian fishery Schaefer (1951)
HARRISON Weaver Cr.	Sooke Sand Heads Harrison R.	184 82 8	1941-47 1938-41 1940 & 41	8 5 103	36-79 24-61 2-23	62 38 9	---	Schaefer (1951)
LOWER FRASER Cultus Lake	Sooke Salmon Banks Sand Heads Sooke	175 137 73 167	1939-47 1939 & 40 1939-41 1940-47	9 12 21 5	49-103 54-120 25-82 11-53	81 97 56 30	---	Schaefer (1951) Sweltzer Cr. weir Sweltzer Cr. weir Sweltzer Cr. weir
Upper Pitt R.	Sooke							

TIME OF PASSAGE

Fraser River Races of Sockeye

Two sources of information have been used to estimate the times when specific races of sockeye were present in the different fishing areas or at certain points in fresh water. The principal source has been the recoveries of marine-tagged sockeye near the spawning grounds by Indians and other persons plus recoveries on the actual spawning beds. This has been supplemented by data from tagging within the Fraser River drainage (FIGURE 11) at Harrison Bay, Hell's Gate and Bridge River Rapids while the sockeye were en route to the spawning grounds. In some instances these sources have been supplemented further by information from fin-marked fish and published data.

TABLE 28 lists the estimated times of passage of certain races of Fraser River sockeye through specific tagging areas, as derived from the tagging dates of sockeye recovered on or near the spawning grounds during the 11 years (1938-1948) of tagging by the Salmon Commission. The range represents the earliest and latest dates on which the recovered sockeye of the race specified had been tagged in the area designated during the combined years. The times when the first, peak and last sockeye of the major portion of each race may be expected to be passing through a specific area are designated by the quartile dates on which 25, 50 and 75 per cent, respectively, of the recovered sockeye had been tagged in that area. Some errors undoubtedly accrued in the derivation of these quartile dates without weighting the tag recoveries before the data for the various years were combined. However weighting in order to compensate for annual variations in the numbers of sockeye tagged and recovered did not seem feasible. Where it was obvious that the quartile dates were inaccurate, the dates have been qualified during the discussion of the pertinent race. The choice of the first and third quartile dates to describe the expected duration of passage of a race severely underestimates the extreme or actual duration of passage but it focuses attention on the interval when sockeye of a particular race can be confidently expected to be passing. The tagging at Bridge River Rapids in 1943 was done only from September 18 to 25. It was obvious that the spawning ground recoveries (19 Stellako and 1 Chilko) which resulted from the 169 sockeye tagged at that time should not be used in the derivation of the quartile dates and should not be included in TABLE 28. Also omitted from the table were the data previously discussed by Schaefer (1951) regarding the times of passage of sockeye tagged in the Harrison River plus data in those instances where the spawning ground recoveries for a specific race were few. However these omitted data plus information from other sources are included in the discussion of the individual races. In some years, tagging started too late or terminated too early to intercept all the races. It was sometimes done only once a week and then not in relation to the abundance of sockeye.

Fishing was not consistent from year to year or throughout an individual season and the escapements did not necessarily represent the peaks of the runs. These and other factors which contributed to the lack of precision in the times of passage and the chronological order of races are discussed more fully under "Value of Tagging and Factors Affecting Time of Passage Data" at the end of this section.

Henry (1961, p. 53, TABLE 17) listed the normal times of passage at the San Juan Islands of various races of sockeye, based on scale analyses.

TABLE 28—Estimated times of passage of races of Fraser River sockeye based on tags recovered on or near specific spawning grounds, 1938-1948 inclusive.

RACE OR GROUP OF RACES	TAGGING AREA	YEARS OF DATA	NUMBER RECOVERED	TIME OF PASSAGE				
				Range		25%	50%	75%
Early Stuart	Sooke	4	48	6/18	7/18	7/5	7/10	7/14
	Hell's Gate	10	944	6/28	8/6	7/6	7/11	7/17
	Bridge R. Rapids	3	441	7/7	8/3	7/13	7/17	7/23
Bowron River	Sooke	2	36	7/10	8/4	7/15	7/18	7/21
	Hell's Gate	9	463	7/6	8/26	7/22	7/27	8/1
	Bridge R. Rapids	4	175	7/14	8/26	7/27	8/2	8/7
Upper Pitt River	Sooke	3	17	7/18	8/8	7/21	7/28	8/4
Horsefly River	Hell's Gate	1	8	7/25	8/3	8/1	8/2	8/3
	Bridge R. Rapids	1	10	7/27	8/12	7/31	8/1	8/4
Raft River	Hell's Gate	10	145	7/23	9/4	8/2	8/6	8/18
Seymour River	Hell's Gate	6	49	7/26	9/4	8/3	8/15	8/29
Chilko River	Sooke	5	14	7/18	8/14	7/26	8/2	8/7
	Salmon Banks	1	12	7/29	7/31	7/29	7/29	7/31
	Johnstone Strait	2	16	7/20	8/8	7/24	7/31	8/2
	Hell's Gate	11	1919	7/13	9/24	8/10	8/20	8/25
	Bridge R. Rapids	4	858	7/17	9/19	8/15	8/23	8/30
Late Stuart	Hell's Gate	4	84	7/28	9/4	8/3	8/9	8/17
	Bridge R. Rapids	3	58	7/30	9/2	8/3	8/11	8/19
Stellako River	Sooke	2	27	7/15	8/22	7/25	8/4	8/12
	Hell's Gate	11	1823	7/26	10/10	8/20	8/29	9/5
	Bridge R. Rapids	4	624	7/13	10/9	8/24	9/3	9/9
Birkenhead River	Sooke	9	31	7/31	9/4	8/13	8/21	8/24
	Salmon Banks	3	18	7/29	8/30	8/9	8/15	8/21
	Lummi Island	3	11	7/24	8/23	8/6	8/13	8/22
	Sand Heads	4	77	8/11	9/22	9/2	9/5	9/11
Lower Adams	Sooke	5	155	7/23	9/23	8/17	8/27	9/3
	Salmon Banks	1	20	8/2	9/1	8/7	8/9	8/18
	Lummi Island	2	11	7/28	8/23	8/5	8/21	8/23
	Sand Heads	3	442	8/24	9/25	9/5	9/8	9/13
	Hell's Gate	10	3949	8/9	11/2	9/28	10/4	10/9
Weaver Creek	Sooke	6	20	8/5	9/23	8/10	8/22	8/28
	Sand Heads	3	20	9/5	9/17	9/9	9/9	9/12
Cultus Lake	Sooke	3	9	8/22	8/29	8/24	8/25	8/27
	Salmon Banks	2	13	8/9	9/1	8/13	8/15	8/27
	Sand Heads	3	21	9/1	9/25	9/11	9/16	9/25

In the following discussion of individual races of Fraser River sockeye, each race is generally mentioned according to the chronological order of its passage through the fishing areas.

EARLY AND LATE STUART

The Stuart River or Lake district provides spawning areas for a number of races which can be divided into two groups, early races and late races, on the basis of the times that the groups pass through the fisheries and arrive on the spawning grounds. The Early Stuart sockeye are the first of the Fraser River sockeye to pass through the fisheries and to arrive at their natal streams approximately 800 miles distant from Sooke. Killick (1955) lists the peak date of passage of these races at New Westminster as July 3-5 in 1953. The Late Stuart sockeye migrate nearly one month later than the Early Stuart sockeye and according to Killick (1955) pass through the commercial fisheries during the last of July and the first of August. The times of peak spawning in such early-race streams as Forfar, Gluske, Kynoch and Rossette Creeks were July 31 to August 4. In the late-race streams such as Middle and Tachie Rivers the times of peak spawning were September 11 to 18 in 1953 (Internat. Pacific Salmon Fish. Comm., 1954).

Since the spawning grounds as well as the times of spawning of the early races were distinct from those of the late races, the times of passage of these two groups could be traced through the Indian fishery. However there were at least two factors that could have detracted from the precision of the identification of early and late races among the tagged sockeye recovered in the Indian fishery and on the spawning grounds. 1. There were unquestionably some errors in the reported dates of recovery. 2. There were instances when it was not clear whether the fish were recovered dead or alive or whether the fish were unspawned or spawned. Early-race fish could have been recovered on late-race spawning grounds as they were passing through to their own grounds, or early-race fish after spawning could have been recovered on late-race grounds in a spent or dead condition because of drifting or flushing from the small early-race spawning streams. The number of instances when it was obvious that these factors could have affected the data were few and since the factors were kept constantly in mind during the analysis the inferred times of passage were probably reasonably accurate. The use of the first and third quartile dates in describing the times of passage, and the use of the second quartile or median dates in inferring the peak times has a tempering or moderating effect on the unknown errors.

Early Stuart

Reference to TABLE 28 indicates that the main body of the Early Stuart races can be expected at Sooke between July 5 and 14 with July 10 being the approximate date of greatest abundance. These dates when

allowance is made for 2 days migration time from Sooke to the Salmon Banks area of the San Juan Islands are tardy in relation to the expected peak date of July 6 given by Henry (1961) for the occurrence of the Early Stuart races at the San Juan Islands. However the dates given in TABLE 28 for the range are in reasonable agreement with the dates given by Henry for the duration of the run. No information from tagging is available regarding the times of passage of the Early Stuart fish through other saltwater areas.

The Early Stuart races were present at Hell's Gate, approximately 81 miles or 4 to 5 days migration upstream from the limits of commercial fishing at Mission, between July 6 and 17 and were most abundant at the Gate about July 11. The time of their occurrence at Bridge River Rapids on the Fraser, about 75 miles or 3 to 4 days migration upstream from Hell's Gate, was July 13 to 23 and the time of greatest abundance was July 17. The distances and migration times to Hell's Gate and Bridge River Rapids are from Killick (1955).

Late Stuart

No known recoveries of Late Stuart sockeye tagged in salt water were ever reported from the spawning grounds. But it would appear on the basis of the times that Late Stuart sockeye were present at Hell's Gate (August 3 to 17 with August 9 as the peak date) that they would be present in the saltwater areas at about the same time as the Raft and Seymour sockeye. This inference agrees with findings of Henry (1961) who lists August 3 as the expected peak date of the Late Stuart races at the San Juan Islands.

BOWRON RIVER

The recoveries of Sooke tags at the Bowron weir indicated that the Bowron sockeye follow closely after the Early Stuart sockeye in order of passage to the spawning grounds. The dates of passage of the majority of this race were July 15 to 21 with July 18 being the approximate peak date. Tagging at other points in salt water was usually begun too late to intercept fish bound for the Bowron area but scale analysis (Henry, 1961) has provided a peak expected date at the San Juan Islands of July 20. Recoveries from fish tagged at Hell's Gate and Bridge River Rapids indicated that Bowron fish may be expected at the Gate between July 22 and August 1 with July 27 being the date of greatest abundance, and at the Rapids between July 27 and August 7 with August 2 being the peak date.

UPPER PITT RIVER

The Pitt River is the first major tributary upstream from the mouth of the Fraser. Its sockeye are included in the so-called group of "lower river" sockeye which do not ascend to Hell's Gate. The tagging at Sooke resulted in a total of 17 recoveries on the spawning grounds of the Upper Pitt River and its tributaries: 1 in each of the years 1940 and 1943, and

15 in 1947. The recoveries indicated that Upper Pitt River sockeye were present at Sooke during the period July 21 to August 4 and that they were probably present in greatest number about July 28. Data on sockeye tagged in the Salmon Banks and Lummi Island areas which were recovered on the Pitt spawning grounds include 6 tagged in 1918 (O'Malley and Rich, 1919) and 12 tagged in 1939. The combined data indicate that Upper Pitt River sockeye were passing through the fisheries from Salmon Banks to Lummi Island from July 24 to August 10 and that their time of maximum abundance was about August 2. One sockeye tagged off the Sand Heads in 1941 and recovered in the Upper Pitt area indicated that some Pitt River sockeye were present off the mouth of the Fraser on August 6. Four sockeye tagged in Johnstone Strait on August 10, 1925 (Williamson, 1927) were recovered in the Upper Pitt area. These times of passage do not reflect the correct timing of the Upper Pitt River race as it is known to enter the Fraser River early in the season. Test gill netting in the Pitt River a short distance below Pitt Lake during the period July 22 to 25, 1952 indicated that a substantial number of fish were ascending the Pitt River at that time. In addition scale analysis has indicated an expected peak of July 22 in the San Juan Islands area which includes Salmon Banks and Lummi Island areas (Henry, 1961).

QUESNEL LAKE OR HORSEFLY RIVER

The once very abundant Quesnel races were nearly exterminated by the effects of a mining dam on the Quesnel River and of Hell's Gate. The dam was removed in 1921 (Thompson, 1945) and the first or right-bank fishway at Hell's Gate was completed in the spring of 1945 (Talbot, 1950). Perhaps because of the very low abundance of these races during the period of tagging (1938-1948) no Quesnel sockeye tagged in salt water were recovered on the spawning grounds. Hence the times of passage of the Quesnel races at various points have had to be estimated by other means. The race which spawns in the upper Horsefly River has increased substantially in recent years.

Killick (1955) by relating the times of fishing closures in the Fraser River gill net fishery to the pattern of arrival of the sockeye at the Horsefly spawning grounds in 1953 estimated that the peak of the present Quesnel run occurred in the New Westminster area on or about July 25 and that the run was present in that area from about July 15 to August 10. Reference to his FIGURE 14 indicates that the peak at Hell's Gate probably occurred about July 30 and that the run was probably passing there during the period July 22 to August 15. Information regarding the time of passage at Hell's Gate in 1945 is available from eight sockeye tagged at the Gate between July 25 and August 3 and recovered at the Horsefly River spawning grounds. In that same year there were recovered on those grounds 10 sockeye tagged at Bridge River Rapids during the period July 27 to August 12 (TABLE 28).

Twenty-six sockeye that had been fin-marked as yearlings at the Quesnel Field Station were recovered in the commercial fisheries as returning adults in 1953 and over 200 were recovered at the field station or in its immediate vicinity (Internat. Pacific Salmon Fish. Comm., 1954). The number and times when the marked fish were recovered in various fishing areas in 1953 were as follows:

Area	Number	Time
San Juan Islands	17	July 21 - 30
Point Roberts	3	July 23 - August 6
Fraser River	6	July 21 - August 6

It is concluded from the information presented that sockeye en route to the Quesnel area are present in the Sooke area about the third week of July and are following closely behind the Early Stuart and Bowron races as they migrate toward their respective spawning grounds. There is some statistical evidence that the Fraser River races in both 1945 and 1953 were earlier than usual, especially in 1953 (Gilhousen, 1960). Henry (1961) lists July 28 as the expected peak date of the Horsefly race at the San Juan Islands.

RAFT RIVER

Only four sockeye tagged in salt water were recovered on the Raft River spawning grounds, all in 1940. They indicated that members of this race were present in 1940 at Sooke and in Johnstone Strait on July 25 and 24 respectively and at Salmon Banks on July 29. Scale analysis indicates that the expected peak date at the San Juan Islands is August 2 (Henry, 1961). The tagging at Hell's Gate resulted in recoveries at Raft River for every year of tagging (1938-1948 incl.) except 1941 and indicated that this race can be expected at the Gate between August 2 and 18 and to be most abundant about August 6.

SEYMOUR RIVER

One sockeye tagged at Sooke on August 4, 1947 was the only recovery of a saltwater tag on the Seymour River spawning grounds. The recoveries made on the spawning ground during 6 of the 11 years of tagging at Hell's Gate are the only other tagging data available to indicate the approximate time of passage of this race through the commercial fisheries. These data indicate that Seymour sockeye might reasonably be expected to be passing through the saltwater fishing areas during the period July 25 to August 20. Henry (1961) listed the following expected times of passage of Seymour sockeye at the San Juan Islands: duration of run—July 21 to August 18, peak day—August 3. The first quartile date from fish tagged at Hell's Gate and recovered at Seymour River was August 3 and the third quartile date was August 29. August 15 appears to be the date when Seymour sockeye were most abundant at Hell's Gate.

SCOTCH CREEK

The early history of Scotch Creek indicated that this race was once abundant one year out of every four. The dominant or "big" years occurred on the 1913 quadrennial cycle. The sockeye began to arrive at the Creek about August 15. They were present in greatest number about August 31 and they ceased arriving about September 15. These early runs were frequently followed by a second run of late fish (Killick; MS.). The early-run sockeye practically disappeared from Scotch Creek during the 1930's and early 1940's. In 1945 the occurrence of an early run was again noted and three sockeye which had been tagged at Hell's Gate during the period July 26 to August 19 were recovered in Scotch Creek. Since 1945 the early Scotch Creek race has been slowly increasing in number on those years which are related to the original 1913 cycle and the time of their occurrence on the spawning grounds has been similar to that of the original run. Some sockeye which had been tagged late in the season at both saltwater and freshwater locations were recovered in Scotch Creek. However those recoveries have been ignored as they indicated times of passage similar to those of the late-running Lower Adams and Little River sockeye which appear to be "sustaining" the late run to Scotch Creek as the result of crowding on the spawning grounds during the "big" years. The Lower Adams and Little Rivers are less than 2½ miles distant from the mouth of Scotch Creek and their sockeye are dominant on the 1914 rather than the 1913 cycle years.

CHILKO RIVER

Currently the Chilko sockeye are the second most abundant race of sockeye in the Fraser system and in one year out of each four they contribute 70-75 per cent of the entire catch of Fraser River sockeye.

The spawning ground recoveries credited to the Chilko race included recoveries from Chilko Lake and River and also from the Indian fishery that occurs at various points extending upstream from Farwell Canyon on the Chilcotin River to the Chilko River spawning grounds. On the basis of these recoveries the estimates of the times when Chilko sockeye may be expected to be passing through various areas are as follows:

- Sooke, July 26 to August 7, peak August 2;
- Salmon Banks to Lummi Island, July 29 to 31;
- Point Roberts, July 30 (O'Malley and Rich, 1919);
- Johnstone Strait, July 24 to August 2, peak July 31;
- Sand Heads, August 9 to 13, peak August 12;
- Hell's Gate, August 10 to 25, peak August 20;
- Bridge River Rapids, August 15 to 30, peak August 23.

On the basis of scale analysis, Henry (1961) has listed the duration of the Chilko run and its normally expected peak at the San Juan Islands (includes Salmon Banks and Lummi Island) as July 10 to August 31 and

August 2, respectively. In 1952, Killick (1955) deduced that the peak of the Chilko run entered the Fraser River on August 3, however, this date may have been unusually early for in this same year the run peaked in United States waters earlier than in any year since the beginning of daily catch records in 1935 (Internat. Pacific Salmon Fish. Comm., 1953). In some years the progress of the run may be bimodal as it was in 1948 when the first peak in the United States fishery occurred between July 31 and August 3 and was followed by a second peak on August 8 and 9 (Internat. Pacific Salmon Fish. Comm., 1949).

BIG SILVER CREEK

This stream flows into Harrison Lake about midway along its east shore. It supports small runs of sockeye which were once described by Gilbert (1919) as being practically extinct. Subsequent to 1940 this race has recuperated to a point where the escapements, in years related to the 1940 quadrennial cycle, have ranged from 4,500 to 12,000. The escapements on the other three cycles have continued to be quite small, frequently numbering only a few fish (Internat. Pacific Salmon Fish. Comm., 1955-61).

In 1940, three sockeye tagged at Salmon Banks and one at Lummi Island were recovered in Big Silver Creek. Their time of passage through the San Juan Islands area was thus indicated to be July 29 to August 6. In the same year, two sockeye tagged at Harrison Bay in the Harrison River during the week ending August 24 were subsequently recovered in Big Silver Creek (Schaefer, 1951). This indicated that some sockeye of this race had passed about 20 miles upstream beyond the limits of commercial fishing at Mission by August 24.

STELLAKO RIVER

The Salmon Commission's annual reports for the years 1938 to 1960 list five streams in the Nechako District in which sockeye usually spawn each year: Endako, Nadina, Nithi, and Stellako Rivers and Ormonde Creek. Of these the Stellako River was the only stream in which sockeye spawned in significant numbers during the period of tagging (1938-1948) and it is still the most important stream. The times of passage given here are therefore only for Stellako River sockeye. No problem existed in the identification and omission of data from the odd spawning ground recovery of a non-Stellako sockeye as the spawning grounds of the five streams are discretely separated from one another. In addition the spawning of the non-Stellako sockeye occurred almost one month earlier than that of the Stellako sockeye. It was therefore possible to include data from tagged sockeye recovered in the Indian fishery in the vicinity of Fraser Lake even though sockeye bound for all five streams might be intercepted in that vicinity. The time of tagging plus the time of recovery in the Indian fishery when compared with the respective times for sockeye recovered on the spawning grounds made obvious the occasional recovered

fish that had been tagged too early and recovered too early to be a Stellako sockeye. Data from such obvious non-Stellako sockeye were omitted.

It appears that Stellako sockeye on the basis of tag recoveries can be expected to be present at various points along their migration route as follows: in the Sooke area from July 25 to August 12 (peak August 4); at Hell's Gate from August 20 to September 5 (peak August 29); and at Bridge River Rapids from August 24 to September 9 (peak September 3). No estimate of the time of passage of Stellako sockeye at the San Juan Islands is available from tagging, but scale analysis (Henry, 1961) indicates July 18 to August 31 and August 4 to be the respective expected dates for the duration and peak passage of the Stellako race. Likewise tagging does not permit an estimate of the time of passage of this race at the mouth of the Fraser River because three sockeye tagged during the period August 2 to September 3 of the combined years 1938, 1939 and 1941 were the only Sand Heads-tagged sockeye recovered on the Stellako spawning grounds. However Killick (1955) compared the fishing closures in the New Westminster area of the Fraser River with the daily counts of sockeye ascending past the outlet of Fraser Lake. His FIGURES 16 and 17 indicate the time of passage of the Stellako race through the New Westminster fishery, in 1952 and 1953, to have been approximately July 25 to August 30 with the peak occurring during the first week of August. Henry (1961) mentions that this race, in some years at least, delays in the Gulf of Georgia.

BIRKENHEAD RIVER

Sockeye reach the Birkenhead spawning grounds after migrating 170 miles from the mouth of the Fraser River via the Harrison and Lillooet Rivers and ascending Skookumchuck Rapids, a point of difficult passage 19 miles above Harrison Lake. For purposes of estimating the times of passage of the Birkenhead race all tagged sockeye which were recovered in either the Lillooet or Birkenhead Rivers were considered as belonging to that race.

Tagging indicated that Birkenhead sockeye may be expected in the Sooke Area from August 13 to 24 (peak August 21) and in the areas from Salmon Banks to Lummi Island from August 9 to 21 (peak August 15). The obvious inconsistency between the time of passage at Sooke and that at the combined Salmon Banks-Lummi Island areas plus the recovery at Skookumchuck Rapids on the Lillooet River of a sockeye tagged at Lummi Island on July 24, 1939, the earliest date of tagging at Lummi Island, indicates that Birkenhead sockeye may be expected in those areas considerably earlier than the quartile dates indicate (TABLE 28). O'Malley and Rich (1919) reported the recovery of four sockeye in the Lillooet and Birkenhead Rivers that had been tagged at Sooke, Salmon Banks and Lummi Island during the period July 27 to August 5, 1918. Henry (1961) lists July 20 to September 4 and August 10 as the respective expected dates of duration of run and peak passage at the San Juan Islands. One

sockeye tagged at Point Roberts on August 29, 1939 and recovered in the Birkenhead area was the only such recovery from tagging by the Salmon Commission at Point Roberts. But there were 16 sockeye recovered in the Birkenhead area from tagging at Point Roberts in 1918 and 1925 (O'Malley and Rich, 1919; and Bolton, 1930), during the period July 30 through August 28 of the combined years. The combined recoveries indicated that August 15 was the peak date of passage at Point Roberts. The quartile dates listed in TABLE 28 are not valid indices of the time of passage of Birkenhead sockeye at the mouth of the Fraser River because in 1938 and 1939 when 61 Sand Heads tags were recovered in the Birkenhead area, the tagging had not started in earnest until August 30. Some Birkenhead sockeye must have been present off the mouth of the river before that date as was indicated by 15 recoveries in the Birkenhead area of sockeye tagged at Sand Heads in 1941 during the period August 11 through September 17. The first, second and third quartile dates indicated by these 15 recoveries were August 19, August 28 and September 11 respectively. These latter dates are more reasonable than those shown in TABLE 28 but even in 1941 the tagging effort was not consistent throughout the period of tagging. Some information on the probable time of passage of this race at Johnstone Strait is available from the recovery of two Birkenhead sockeye that were tagged in that Strait on July 24 and 31, 1941 plus the previously reported (Williamson, 1927; and Clemens, 1932) recovery of four Birkenhead sockeye tagged in Johnstone Strait during the period August 10 through 23 of the combined years 1925 and 1928.

Birkenhead sockeye in addition to being tagged in salt water were also tagged at a number of points in fresh water (Schaefer, 1951). One point in particular was at Harrison Bay in the Harrison River about one mile above its confluence with the Fraser River. The various races that spawn in the Harrison watershed must ascend past this point to reach their spawning grounds. The data from Harrison Bay tags recovered on the spawning grounds are therefore useful in segregating the various runs to the Harrison System on the basis of their times of passage and in relating those times to the times derived from saltwater tagging. The majority of Birkenhead sockeye were indicated to be passing through the Harrison River between the weeks ending August 16 through September 2 (peak, week ending August 24) but it was also indicated that some Birkenhead fish were ascending the Harrison River as early and as late as the weeks ending August 9 to October 7.

During the discussion of the rate of migration of sockeye tagged off the Sand Heads it was stated that some sockeye especially those present in September delayed entry into the Fraser River. Spawning ground recoveries plus consideration of the midseason fishing closures provided a means of deducing which races of sockeye were involved in delay behavior. These means indicated that Birkenhead sockeye belonged to a delaying race.

LOWER ADAMS

The Lower Adams sockeye are the most abundant of the Fraser River races and are referred to in this section as Adams River sockeye. These fish populate the following three spawning grounds in order of increasing importance: 1. South Thompson River (drains from Little Shuswap Lake to Kamloops Lake); 2. Little River (drains from Shuswap Lake to Little Shuswap Lake); and 3. Lower Adams River (that portion of the Adams River which drains from Adams Lake to Shuswap Lake). The Adams River sockeye migrate late in contrast to the already mentioned Seymour and Scotch Creek sockeye which also spawn in the South Thompson district.

More sockeye tagged in salt water or at Hell's Gate were recovered in the Adams River area than in any other portion of the Fraser River drainage. All fish recovered in the South Thompson, Little and Lower Adams Rivers plus those recovered in Shuswap and Little Shuswap Lakes were considered to be Adams River sockeye for purposes of determining the time of passage of this late run. Recoveries in the main Thompson River were omitted for they might have included sockeye from races bound for the North Thompson in addition to those bound for the South Thompson district.

The times of passage of the majority of Adams River sockeye as indicated by tagging were as follows:

Sooke—August 17 to September 3, peak August 27;

Salmon Banks to Lummi Island—August 7 to 22, peak August 15;

Sand Heads—September 5 to 13, peak September 8;

Hell's Gate—September 28 to October 9, peak October 4.

The dates derived from tagging at Sooke and also from tagging within the area extending from Salmon Banks to Lummi Island during the combined years were inconsistent in respect to the tagging areas and also in respect to the normally expected dates of August 5 to September 12 and August 22 listed by Henry (1961) for the duration and peak, respectively, of the Adams run at the San Juan Islands. Probable reasons for these inconsistencies were: variable behavior from year to year, variable tagging effort in relation to abundance, and combined data regardless of the variations between years.

Gilhousen (1960) on the basis of catches and scale analyses plus historical data has stated the following regarding the migratory behavior of Adams River sockeye: They are the latest of the upriver races to migrate and spawn. They are slow in moving from the fishery to the spawning grounds. This is due to a period of delay off the mouth of the Fraser River plus a slow rate of upstream migration. The length of delay may vary from two to six weeks for individual fish, however, the Adams River sockeye suddenly tend to begin entry into the river about mid-September. They require three days to move from Steveston near the mouth of the river to Mission (the upper limits of commercial fishing) and

a total of seven or eight days to reach Hell's Gate. They are highly variable in time of passage, and also in the symmetry and spread of the time-abundance curves representing their annual occurrence. As large a degree of variability from year to year has not been observed to date in other races of Fraser River sockeye. They are usually later in time of peak migration during the years of the larger dominant runs (1942, 1946, 1954, and 1958) and earlier in time of peak migration during years of the sub-dominant runs. At Adams River the sub-dominant run occurs on the year following the dominant run.

The times of peak passage of Adams River sockeye determined from tagging at Sooke and at Sand Heads are compared below with times of peak passage in the San Juan Islands and entry into the Fraser River determined by Gilhousen (1960) during three dominant cycle years.

Year	Sooke (Tagging)	San Juan Is. (Gilhousen, 1960)	Sand Heads (Tagging)	Entry into River (Gilhousen, 1960)
1938	Aug. 20	Aug. 24	Sept. 8	Sept. 13 - Oct. 9
1942	Aug. 27	Aug. 24	-----	Sept. 13 - Oct. 7
1946	Sept. 3	Aug. 28	-----	Sept. 15 - 27

In 1942 and 1946 the peak dates at Sooke indicated by the tagging were three to six days later than the peak dates of fishing in the San Juan Islands. These inconsistencies may have been due to the relative inefficiency of the Sooke traps in catching Adams River sockeye, which is frequently mentioned by trap fishermen, plus the variability of the tagging effort in relation to abundance. The following is a comparison of catches in 1946 in the Sooke area by traps and by other gear during three fishing periods. Also shown are the numbers and percentages of the trap catches of sockeye that were tagged during the same periods.

Fishing Period	Trap Catch	No. Tagged	% Tagged	Other Gear Catch
Aug. 19 - 23	3,654	287	7.9	13,969
Aug. 26 - 30	15,446	492	3.2	*384,645
Sept. 2 - 6	2,185	227	10.4	-----

*On August 26, purse seiners located a large body of sockeye but by August 29 the fishing tapered off (Internat. Pacific Salmon Fish. Comm., 1947).

It is apparent that the trap catches indicated the period of peak passage correctly, but it is also apparent that relatively more sockeye were tagged both before and particularly after the peak than were tagged during the peak period. A detailed examination of the Sooke tagging data during the three periods under discussion showed that the percentages recovered in the commercial fishery of those sockeye tagged each period decreased from August 19 to September 6 and that conversely the percentages recovered on the spawning grounds increased. In addition it was recorded that the escapement was not from the peak of the run (Internat. Pacific Salmon Fish. Comm., 1951). It is therefore concluded that the inaccurate peak date of the Adams run derived from tagging at Sooke in 1946 was due to failure to tag in relation to the abundance of sockeye, and to the com-

bined effects of fishing and regulations which caused the escapement to be unrepresentative of the run. The tagging at Sand Heads indicated that the Adams River sockeye delayed off the mouth of the Fraser River. If consideration is given to the fact that the time of passage derived from tagging does not include the total delay time, then the peak date of September 8 derived from tagging at Sand Heads in 1938 compares favorably with the peak period of entry into the river during the same year, September 13 to October 9, derived by Gilhousen (1960).

WEAVER CREEK

This small stream which joins the Harrison River via a slough approximately 3.5 miles below Harrison Lake has been a consistent producer of sockeye. Twenty recoveries occurred at Weaver Creek during 6 of the 11 years that sockeye were tagged at Sooke. These indicated that the majority of Weaver Creek sockeye were passing Sooke from August 10 to 28, peak August 22. One sockeye tagged in Johnstone Strait on July 21, 1940 was recovered at Weaver Creek. This date of tagging was considerably earlier than the earliest date of any Sooke tag (August 5, 1940) in any year. Five sockeye tagged in the Salmon Banks to Lummi Island areas during the period August 6 through 15 were recovered at Weaver Creek. Scale analysis indicated that normally this run can be expected at the San Juan Islands from July 25 to September 5, with August 16 being the peak date (Henry, 1961). Twenty recoveries at Weaver Creek of sockeye tagged off the Sand Heads in 1938, 1940 and 1941 indicated that this race was present off the mouth of the Fraser River in maximum numbers about September 9 but failed to indicate reasonable dates for the duration of the run (TABLE 28). It is probable that with the exception of tagging at Sooke, the tagging in salt water was never conducted late enough to sample adequately the last of the Weaver Creek sockeye. Schaefer (1951) reported on the results of tagging and of scale analyses from samples of sockeye caught in a trap in the Harrison River at Harrison Bay, about eight miles downstream from Weaver Creek. The tagging indicated that Weaver Creek sockeye were passing Harrison Bay during the weeks ending October 5 to 21 and were most abundant about the week ending October 12. The scale analyses indicated approximately similar dates of passage.

HARRISON RIVER

The Harrison River sockeye spawn in a section of the river known as Harrison Rapids which lies upstream from Harrison Bay and below the mouth of the Weaver Creek drainage. Very few tags were recovered from the Harrison spawning grounds. This was probably due to the river's large size, its frequently discolored water, and to the lack of a determined effort to observe or enumerate this race prior to 1945 (except in 1941) when a system of annual enumeration by tagging near the Harrison spawning grounds was inaugurated.

One sockeye tagged July 28, 1947 was the only recovery from the Sooke tagging. Four sockeye tagged off the Sand Heads between September 8 and 14 in the years 1938 and 1941 were the only other recoveries of salt-water tags. Even the tagging at Harrison Bay, almost on the spawning ground during the years 1939 through 1941, resulted in only 10 recoveries. Nine of these recoveries occurred in 1941 when the Harrison Rapids area was patrolled systematically for the first time (Schaefer, 1951). These recoveries indicated that members of this race were approaching the spawning grounds during the weeks ending September 30 to November 29 and were most abundant about October 25. Similar dates were obtained by analyses of scale samples taken at the Harrison River trap during the three years of tagging at that point. Schaefer also remarked that some of the Harrison Rapids spawners reached the region of the spawning grounds as much as four or six weeks before spawning. The peak of spawning on these grounds usually occurs about the second week in November.

WIDGEON SLOUGH

A small group of sockeye spawn in an area only 34 miles upstream from the mouth of the Fraser. This area, called Widgeon Slough, is a side channel of the Pitt River just below Pitt Lake. The escapements to Widgeon Slough since the commencement in 1942 of efforts to enumerate the annual spawning populations at that place have never exceeded 1,700 sockeye. This plus the fact that the Widgeon race spawns about the first two weeks in November would seem to make the recovery on these spawning grounds of sockeye tagged in salt water extremely unlikely. Nevertheless two sockeye tagged at Sooke were recovered at Widgeon Slough. They indicated surprisingly early dates of passage through the Sooke area: one had been tagged July 31, 1947 and the other had been tagged August 7, 1944.

CULTUS LAKE

Nine recoveries during the years 1939, 1940 and 1947 at the Cultus Lake counting fence of sockeye tagged at Sooke indicated that sockeye of that race were present at Sooke during late August but the recoveries were too few to indicate the duration or peak of the run. Recoveries of fin-marked sockeye showed that members of the Cultus race can be expected in the Sooke area during a prolonged period (TABLE 29). Occasional representatives were present as early as mid-July and as late as the last of September. Their period of maximum abundance at Sooke extended from about August 15 to September 1.

Data indicating the time of passage of Cultus Lake sockeye through Johnstone Strait are sparse. One sockeye tagged August 8, 1940 in Johnstone Strait was recovered at the lake. Six Cultus Lake, fin-marked, sockeye were recovered in the Johnstone Strait fishery in 1929 and 1930 (Foerster, 1934, 1936a). The earliest recovery was July 13 and the latest recovery was September 4.

TABLE 29—Times when fin-marked Cultus Lake sockeye were recovered in various fishing areas in certain years.

RECOVERY AREA	YEAR	NUMBER RECOVERED	PERIOD PRESENT					REMARKS
			Range	Quartile				
				First	Second	Third		
Sooke	1930	9	8/20-27	9/13-20	8/28-9/4	9/5-12	9/5-12	Foerster, 1936a
	1932	229	7/24-30	9/18-24	8/14-20	8/21-27	8/28-9/3	Foerster, 1936b
	1933	1864	7/10-16	9/25-10/1	8/14-20	8/28-9/3	8/28-9/3	Foerster, 1936b
	1938	220	8/15	9/19	8/22	8/26	8/29	Internat. Pacific Salmon Fish. Comm., unpub. No observer at Sooke until 8/15.
Salmon Bks.	1930	23	7/28-31	9/21-29	7/28-31	8/12-19	8/28-9/4	Includes recoveries in West Beach and all San Juan Is. areas except Lummi I.
	1932	365	7/24-30	9/4-10	8/7-13	8/14-20	8/21-27	Includes recoveries in all U.S. areas except Swift- sure and Pt. Roberts
	1933	3817	7/10-16	10/2-8	8/21-27	8/28-9/3	9/4-10	
	1938	763	7/25	9/5	8/17	8/22	8/24	Includes Gulf of Georgia and Cherry Pt.
Lummi I.	1930	225	5/29	10/1-4	7/28-31	8/12-19	8/28-9/4	Includes Birch Bay
	1932	248	7/31-8/6	9/4-10	8/14-20	8/21-27	8/28-9/3	Includes Birch Bay
	1933	620	7/31-8/6	9/4-10	8/14-20	8/21-27	8/28-9/3	Includes Boundary Bay
Pt. Roberts	1930	92	8/4-11	10/14	8/20-27	8/28-9/4	9/21-29	Includes Boundary Bay
	1932	289	7/24-30	9/4-10	8/7-13	8/21-27	8/21-27	Includes Boundary Bay
	1933	972	7/10-16	9/25-10/1	8/21-27	8/21-27	9/4-10	Includes Boundary Bay
	1938	499	7/31	9/9	8/23	8/29	9/3	Includes Boundary Bay
Fraser River and Vicinity	1930	5	8/12-19	11/22	11/13	11/13	11/14	
	1932	819	8/14-20	11/20-26	9/4-10	9/18-24	9/25-10/1	
	1933	1673	7/17-23	11/6-12	9/11-17	9/18-24	10/2-8	
	1938	2037	7/27	11/8	8/30	9/10	10/13	

The period when the majority of the Cultus Lake fish can be expected to be present in the Salmon Banks area was indicated by tagging to be August 13 to 27. The extreme period of their presence was indicated by fin-marked fish to be approximately from July 16 to October 8. The period of greatest abundance based on fin-marked fish extended from about the second week in August to the first week in September. Scale analysis also indicated that the duration of the Cultus Lake run is lengthy and that normally the peak at the San Juan Islands can be expected about August 21 (Henry, 1961).

No sockeye tagged in the Lummi Island area were recovered at Cultus Lake. The recoveries of fin-marked fish indicated that Cultus Lake sockeye were occasionally present in the vicinity of Lummi Island as early as the last of May and as late as mid-October. They were most abundant from approximately August 15 to September 1.

No recoveries were made at Cultus Lake from the few fish tagged at Point Roberts. Recoveries of fin-marked fish indicated that Cultus Lake sockeye were present in the Point Roberts area from mid-July to mid-October and were most abundant from about August 20 to September 10. This latter date may be too early as the occasional restriction of fishing in the Point Roberts area during September would have inhibited the recovery of fish in September.

Tagging at Sand Heads indicated that Cultus Lake sockeye were present off the mouth of the Fraser River from September 1 to 25 and that they were most abundant from September 11 to 25 with the peak day being September 16. The recoveries of fin-marked fish in the river and off its mouth indicated that Cultus Lake fish were present in that area from about the last part of July to the last part of November and were most abundant during the month of September. Perhaps the termination of tagging at the Sand Heads by September 25 and the effects of closures during the latter part of the fishing season tended to cause the indicated termination of the period of abundance to be slightly too early. Foerster and Ricker (1937) remarked that the recoveries of fin-marked Cultus Lake sockeye indicated that a delay of one to two weeks occurred between the time Cultus Lake fish were present at Point Roberts and the time they were present in the lower Fraser River. Tagging also indicated that Cultus Lake sockeye were a delaying race.

SETON-ANDERSON

No spawning ground recoveries for sockeye which spawn in Gates and Portage Creeks of the Seton-Anderson Lakes area have been listed. These races are badly depleted. The few recoveries reported from the area may not have been from bona fide Gates Creek or Portage Creek sockeye since some of the Indian fishermen from the nearby Bridge River Rapids fishery are residents of this area. In addition, in some years before the construction of fishways, large numbers of sockeye that were destined for

areas further up the Fraser were blocked at the Rapids. Many of these dropped downstream and then ascended to the Seton-Anderson spawning grounds.

The Gates Creek sockeye run earlier than the Portage Creek sockeye. In 1956, sockeye were observed to be ascending the Seton Dam fishway en route to Gates Creek between July 20 and August 20 (Andrew and Geen, 1960). The run to Portage Creek is known to pass through the Fraser River fishery in mid-September (Internat. Pacific Salmon Fish. Comm., 1955).

Non-Fraser Races of Sockeye

The Somass River and Nitinat Lake areas on Vancouver Island were the only non-Fraser freshwater areas in British Columbia where tagged sockeye were recovered in number (TABLE 30). The large number of recoveries at Nitinat was largely due to a commercial fishery on the lake. The dates of recapture at Nitinat were usually unknown or indefinite, therefore, no attempt has been made to estimate the days-out between tagging and recovery. The earliest tagging at Sooke of a recovered Nitinat fish was May 25 and the latest was July 11. However since tagging earlier than May 25 was done in only one year it is possible that some Nitinat fish may have been present at Sooke at an earlier date. The majority of the sockeye recovered at Nitinat had been present at Sooke during the first two weeks of June.

The Skagit River and Lake Washington areas were the only freshwater areas in the State of Washington where tagged sockeye were recovered in number (TABLE 30). The Skagit River or Baker River run of sockeye is a natural run that ascends the Skagit River and thence the Baker River to a hydroelectric project near Concrete, Washington. Trapping facilities at this point offered an unusually good opportunity for a thorough recovery of tagged fish. This in part explains the rather large numbers of tags recovered from a relatively small population. The annual escapements since 1925 have never exceeded 7,000 sockeye (Wash. Dept. Fish., 1959 Annual Report). Tagged sockeye recovered by the commercial fishery in Skagit Bay and the mouth of the Skagit River, even though the Bay is saline water, were also listed in TABLE 30 as they were undoubtedly Baker River sockeye. Four recoveries at Grandy Creek (one each during the years 1940, 1942, 1943 and 1946) may have been the result of artificial propagation at the now inactive Birdsvew hatchery which received its original stock of sockeye from the Baker River. All the tagged sockeye that were recovered in Skagit Bay and the Skagit Drainage had been tagged at Sooke except two: one tagged at Salmon Banks on August 6, 1939 and one tagged at West Beach on July 17, 1941.

The Baker River race of sockeye based on the quartile dates of the recovered tagged sockeye can be expected at Sooke from June 21 to July 6 and to be most abundant at Sooke about June 30 to July 2 (TABLE 30).

TABLE 30—Estimated times of passage of non-Fraser River sockeye tagged at Sooke and recovered en route or on specific spawning grounds, 1938-1948 inclusive.

AREA AND RIVER SYSTEM	YEARS OF DATA	NUMBER RE- COVERED	TIME OF PASSAGE AT SOOKE				REMARKS
			Range	25%	50%	75%	
Vancouver Island							
Somass R.	4	8	6/6	7/15	6/14	6/25	Includes 1 recovered at Sproat Falls.
Nitinat L.	7	80	5/25	7/11	6/6	6/8	Includes 7 recovered in Hobiton R.
Skagit Bay & Drainage							
Lower Skagit R. & Bay	10	130	6/11	9/6	6/22	6/30	Mainly in commercial fishery.
Baker River	9	138	6/11	7/21	6/21	7/2	Trap at Concrete, Wash.
Upper Skagit R. & Misc. Tributaries	6	7	7/2	7/11	7/2	7/4	Includes 4 recovered in Grandy Cr.
Lake Wash. Drainage							
Lakes Sammamish and Washington	3	4	6/15	6/24	6/15	6/21	
Cedar River	5	12	6/24	7/15	6/27	7/3	
Issaquah Creek	5	38	6/10	7/17	6/27	7/4	Mainly at hatchery weir.

The modal-migration time of Baker River sockeye from Sooke to Skagit Bay and the lower Skagit River was 5 days, and to the Baker River trap it was 22 days.

The sockeye runs to Cedar River and Issaquah Creek in the Lake Washington watershed are introduced runs from Baker River stock (Royal and Seymour, 1940) and like the donor race they also pass through the fishing areas early in the season. The sockeye tagged at Sooke required a prolonged range of days to arrive at the hatchery weir maintained by the Washington State Department of Fisheries: 25 to 75 per cent of the recovered fish were out 80 to 107 days, the median days-out was 90. This large number of days-out is not an accurate indication of the speed of migration, since Issaquah Creek sockeye require many days to complete the freshwater phase of the spawning migration and the maturation of sex products before they approach the hatchery weir. During 1957 approximately 125 days elapsed between the time (late June) when sockeye were entering fresh water at the Government Locks at Seattle and the time (late October) when sockeye were present at the Issaquah weir, about 40 miles away, in a spawning or spent condition.

Factors Affecting Time of Passage Data and the Value of Tagging

Experience in the management of Fraser River sockeye has led to the adoption of the following concept: only the central part or peak portion of the migration curve of each individual run is composed of sockeye that are properly related to the normal environmental cycle in their reproductive area and the beginning and end of a curve consist of variants whose migrations are not properly timed for maximum reproduction (Royal, 1953). The peak of each run alone is capable of producing the maximum return from a minimum escapement and it is from the peak of each run in an average year that the escapement is desired. However since there are at times several races passing through the fishery simultaneously; but not in perfect synchronization, and since the races are not all of equal numerical importance it will not always be practical to attempt to attain an escapement from the peak of each race. On the other hand, the variants are insurance against unusual conditions. Occasions may arise where the arrival of a race in the fishery may be either unusually early or late due to abnormal marine conditions and where it may be apparent that an escapement from the peak of such a race would arrive at the spawning grounds at a time which was not properly related to the freshwater regime. On such occasions it may be prudent to manage the fishery in such a manner as to obtain the escapement from either the first or last portions of the race, which in this instance may be more properly timed than the peak.

Tagging in salt water has been of value in supplying information regarding the expected time of passage of individual races through the fishery, however, the information lacked precision. On the whole, the

greatest contributions of tagging were the speedy yield of information during the introductory phases of the Salmon Commission's investigations and development of management policies and the supplementation or confirmation of the more precise information subsequently derived from racial analysis by means of scales. The following is a discussion of some of the factors which affected the precision of the time of passage data.

TAGGING PERIOD

The tagging except at Sooke did not begin early enough in the season to adequately sample the early runs and it frequently was terminated before the late-running races had passed. In addition the tagging in any one area was seldom more than once or twice a week. Consequently it was possible to fail to tag fish from numerically small races or to miss their peak abundance. These factors made it impossible to establish the period of passage or the chronological ranking of some of the races with precision. For example: the time of passage through saltwater areas other than Sooke could not be established from tagging for early-running races such as Early Stuart and Bowron; the recovery in the fishery of fin-marked Cultus Lake fish showed that race to be present for much longer periods than were indicated by tagging; nor could a precise chronological ranking be obtained of such races as Chilko, Raft, Seymour, and Upper Pitt or the less important Big Silver race.

TAGGING IN RELATION TO ABUNDANCE

It is desirable to tag the fish of each race in relation to the pattern of their changing abundance throughout the season to insure the maximum likelihood of accurately determining the peak time of passage of each race at the tagging point. No attempt was made to do this during the Salmon Commission's marine tagging nor was tagging accomplished in relation to the abundance of the combined races. However it is doubtful that tagging in relation to the abundance of fish in each race could be accomplished in any program where a number of races of unequal numerical importance are passing during simultaneous or overlapping periods of time without prior knowledge which would obviously make the tagging unnecessary. Further it should be pointed out that tagging in relation to abundance will not insure an accurate estimate of the peak time of passage, unless the escapement is obtained in relation to the pattern of abundance of each race or is obtained from the peak of each race, and unless the recovery effort on the spawning ground is also distributed so as to sample all or the major parts of the escapement with relative uniformity.

An example of an inaccurate peak date due to the combined effects of failure to tag in relation to abundance and the failure to obtain the escapement from the peak of the run was cited during the discussion of the time of passage of the Lower Adams race in 1946 at Sooke. It was also mentioned that in 1942 the peak date of passage of this race at Sooke

of August 27 derived from tagging did not agree with the peak date in the San Juan Islands of August 24 derived from catch information. An examination of tagging and catch data for the Sooke area in 1942 during the period when the Lower Adams sockeye should have been passing in considerable numbers discloses that peak catches were made during the period August 20 through 24 but that 124 sockeye on August 17, 131 on August 24, and 136 on August 31 were the only sockeye tagged during times that bracketed the period of peak catches. The discrepancy in 1942 between the peak date of passage at Sooke indicated by tagging and the peak date in the San Juan Islands indicated by catches therefore seems to have been the result of failure to tag in relation to abundance. It seems almost unnecessary to also point out that failure to tag in relation to abundance during times when populous races such as the Lower Adams race were passing nearly simultaneously with less populous races such as the Weaver Creek race made it quite unlikely that sockeye from the less populous races would be tagged and that their peak time of passage would be detected. Examination of stream recovery data discloses that during the three years 1938, 1942 and 1946 when the Lower Adams sockeye were dominant and 146 Sooke-tagged sockeye were recovered on Lower Adams spawning grounds, that there were only 3 Sooke-tagged sockeye recovered on the Weaver Creek spawning ground.

ESCAPEMENT

The fishing regulations do not affect all the races or all portions of an individual run equally. Since the time of passage is based on the tagged fish recovered on or near the spawning grounds and since the Fraser River gill net fishery is capable of removing 98 per cent of the fish migrating during a given period (Royal, 1953) the recoveries reflect the time of passage for the escapement more accurately than they do for the run (catch plus escapement) as a whole.

Even when the escapement is initially proportional to all parts of the run or is at least from the peak of the run as it passes through the fishery, its timing as indicated by the spawning ground recoveries can be subsequently biased by fluctuating conditions at natural obstructions in the river such as Hell's Gate and Bridge River Rapids in the main Fraser River, Farwell Canyon in the Chilcotin River, Skookumchuck Rapids in the Lillooet River, etc. The fish on the spawning grounds are only those fish which have succeeded in passing the obstructions and such passage may have been possible only at certain times or water levels.

INDIAN FISHERIES

The Indian catches of sockeye for personal use do not necessarily reflect the precise peak time of passage of individual races of sockeye to the spawning grounds for the Indians do not fish all parts of the runs with equal intensity. The Department of Fisheries of Canada regulates the

place, time and numbers of fish that the Indians can take (Howard, 1945). Nevertheless they prefer to concentrate on the early parts of the runs to obtain fish in prime condition. Fishing may cease when sufficient fish are caught even though fish are continuing to migrate past the fishing stations. During the Salmon Commission's experiments there were times when the Indians concentrated on the catching of tagged fish because of the rewards being paid. Since the tags recovered in this manner decreased the numbers that were available for recovery by Salmon Commission personnel on the actual spawning grounds the data derived from the Indian recoveries were included wherever practical in estimating the times of passage of specific races.

MISCELLANEOUS FACTORS

In addition to the factors just mentioned in this section that affected the time of passage data, there were a number of other extenuating circumstances involving the actual mechanics of recovering tagged fish on the spawning grounds. These latter circumstances were previously mentioned in the Recovery Problems section of the INTRODUCTION and will not be recalled here. They directly affect the numbers of recoveries on the spawning grounds and as a result the numbers represent the ease or fortuitous circumstances surrounding the recoveries and not necessarily the numbers of tagged fish on the spawning grounds. Nevertheless, subsequent observation has shown that despite the shortcomings of tagging, the times of passage derived from the Salmon Commission's tagging were useful approximations.

POPULATION SIZE

An annual Fraser River sockeye run is a stratified population composed of a number of races. It was shown in the TIME OF PASSAGE section that the races enter the fishery and proceed to the spawning grounds in a chronological order and at times which are specific for each race. On occasion several races may be migrating simultaneously but not necessarily in perfect synchronization. Killick (1955) has shown, in addition, that chronology is maintained even within a race: the first and last fish of a race that pass through the fishing areas also tend to be the first and last fish, respectively, that arrive at the spawning grounds.

Schaefer (1951b) and Chapman and Junge (1956) have presented mathematical methods for estimating the sizes of stratified populations by tagging. However the Salmon Commission's marine-tagging experiments did not fulfill the basic requirement of the above methods that either the tagging or the sampling, for the recovery of the tagged fish and the determination of the ratios of tagged to untagged fish, must be done in relation to the abundance of the fish at the times of tagging or sampling. The failure to tag at Sooke in proportion to the daily abundance of sockeye was mentioned when discussing the time of passage of the Lower Adams

sockeye. TABLE 31 compares by fishing period the numbers of sockeye caught by the Sooke traps with the numbers and percentages of the sockeye tagged from those catches in 1946. The catches in the Sooke area by other gear are also shown. The numbers of fish caught fluctuated greatly and the relative numbers tagged tended to fluctuate inversely with the catches. The number of sockeye that could be tagged from a particular trap lift was limited by the size of the live-box and the time required to transfer fish to it. The number of trap lifts was limited by the trap operator's schedule and the need for favorable weather and tide during the lifting. It was therefore impractical to attempt to tag in relation to the abundance of fish. In addition the trap catches at Sooke were a varying fraction of the total catches in the Sooke area during August of 1946. On the peak day of August 27, the traps caught only 3 per cent of the day's catch, the remaining 97 per cent of the catch in that area being taken by purse seines and gill nets.

The deficiency in mixing or the failure to tag in proportion to the abundance was not compensated by fishing in each area in relation to the abundance of fish. This was particularly so beginning in 1946 because of the Salmon Commission's responsibility to regulate the fishery and to divide the annual catches equally between the Canadian and United States fisheries. For example, at the start of the 1946 season the catches were small and the amounts of gear in relation to the catches were large. This

TABLE 31—Trap catches of sockeye together with numbers and percentages tagged plus the catches by other gear, by weekly fishing periods in the Sooke area in 1946.

FISHING PERIOD	TRAPS			CATCH BY OTHER GEAR
	Catch	Number Tagged	Per Cent Tagged	
June 3 - 7	41	37	90.2	-----
June 10 - 14	94	46	48.9	-----
June 17 - 21	234	106	45.3	-----
June 24 - 28	226	171	75.7	-----
July 1 - 5	187	157	84.0	-----
July 8 - 12	471	356	75.6	-----
July 15 - 19	901	436	48.4	-----
July 22 - 26	1,489	316	21.2	-----
July 29 - Aug. 2	2,456	187	7.6	-----
Aug. 5 - 9	3,119	333	10.7	159
Aug. 12 - 16	7,335	492	6.7	5,791
Aug. 19 - 23	3,654	287	7.9	13,969
Aug. 26 - 30	15,446	492	3.2	384,645
Sept. 2 - 6	2,185	227	10.4	-----
Sept. 9 - 13	1,776	161	9.1	-----
Sept. 16 - 20	382	65	17.0	-----
Sept. 23 - 27	76	33	43.4	-----

was again true at the finish of the season in the United States fishery and to a lesser extent in the Canadian fishery. This suggests that fishing was most intense when fish were least abundant.

To these major considerations the following factors in regard to the 1946 season should be added:

1. A large proportion (43.6%) of the tagging at Sooke was completed before fishing in the major United States areas began in earnest on July 31 and the peak of the run did not occur at Sooke until the last week of August (TABLE 31). Fifty-five per cent of the total United States catch occurred in the last week of August (Internat. Pacific Salmon Fish. Comm., 1947).

2. The weekly closures in the United States fishery were 36 hours and in the Canadian fishery they were 48 hours except that in the Fraser River gill net fishery (District 1) the closure from September 20 to 23 was 72 hours. These closures certainly permitted escapements of tagged and untagged fish. The escapements were probably in proportion to the intensity (abundance) of the run at the times of the closures but the ratio of tagged to untagged fish in each group of escaping fish was probably far from constant.

3. An extended closure of the Fraser River gill net fishery commencing September 25 was purposely provided to allow a large number of the fish to escape upstream that were delaying off the mouth of the Fraser. A large escapement was realized and when the fishery resumed sockeye fishing on October 14 the large body of fish that had been present before the closure was gone (Internat. Pacific Salmon Fish. Comm., 1947). In addition, the Point Roberts area was closed from September 25 to October 7 (Wash. Dept. Fish., 1946).

4. The efficiency of the gear in relation to the abundance of fish was not constant. For example: the number of fish that a gill net fisherman can catch in a unit of time is limited by the capacity of his net, his ability to remove the fish from the net and the availability of someone to deliver his catch to. Therefore when the abundance of fish exceeds the fishing potential of the fleets the proportion of the run that escapes increases.

It may be argued that 1946 was an atypical year since it was the cycle year of the dominant Lower Adams run. Moreover, the run's behavior in that year was atypical compared with Adams runs in other dominant cycle years. However an examination of information concerning other years will show that many factors, such as: strikes, regulations, division of the catch, behavior of the fish, etc., acted in concert to cause the fishing to be disproportionate to the abundance of fish in the various areas.

For the purpose of population estimation there were several other deficiencies in the tagging experiments.

1. There was no measure of the tagging mortality which may have resulted from the effects of tagging, or the loss of tags, or the failure to

report recovered tags. Tagging mortality, unless corrected for, tends to cause population estimates which are too large.

2. There was no measure of the difference in availability to the commercial fishery of tagged and untagged fish. In this report sampling is synonymous with commercial fishing since sampling by other means was not sufficiently consistent or comprehensive to be considered for purposes of estimating population size. Fish tagged with disk tags are definitely more available to net fisheries, particularly gill net fisheries, than are untagged fish. This selectivity for tagged fish causes the indicated ratio of tagged to untagged fish in the population to be too great and consequently the estimated population to be too small. Selectivity in the Salmon Commission's experiments will be discussed subsequently in greater detail.

3. There was no measure of the recruitment that occurred as the result of some sockeye approaching the Fraser River by way of Johnstone Strait instead of the Strait of Juan de Fuca.

In summary it may be concluded that a practical marine tagging program to estimate the size of an annual Fraser River sockeye run would be extremely difficult to design and execute. It appears that it was never the Salmon Commission's intention to use the experiments for the estimation of annual populations. Far better estimates can be obtained from the available catch and escapement data than can be obtained from the tagging data. In addition, for subsequent years it has been possible to estimate the size of individual races by means of scale analyses as described by Clutter and Whitesel (1956), consequently, these means are currently being used in the management of the Fraser River sockeye (Henry, 1961).

FISHING INTENSITY

The number of tags recovered in the commercial fishery from a known number of tagged fish will yield an estimate of the proportion of the run that was caught by the fishery. However estimation of fishing intensity in this manner is based upon most of the same theoretical assumptions required for population estimates. Any mortality due solely to tagging or failure to report recovered tags would tend to make the estimated intensities lower than the actual intensities. Conversely, any tendency to catch tagged fish more readily than untagged fish would result in intensity estimates that were too high. Finally any failure to tag or to sample in proportion to abundance could also result in incorrect estimates. In essence the assumptions demand that the tagged fish be representative of the untagged fish in all respects. It is apparent from the results of the Salmon Commission's marine tagging program that, in spite of the large numbers of fish tagged during the numerous experiments in the several tagging areas, the program was more successful in pointing out the problems of estimating fishing intensity than it was in obtaining accurate estimates.

If the recoveries from the Salmon Commission's experiments were

accurate indices of fishing intensity, it could be expected that the experiments in areas furthest from the Fraser River would have yielded the largest percentages of recovery. However it was shown in the RATE OF MIGRATION section that the percentages of recovery did not decrease progressively as the tagging was performed closer and closer to the river (see TABLE 13) during 1939, 1940 and 1941, the only years for which comparisons could be made. Only in 1941; during the July 21-27, July 28-August 3 and August 4-10 periods of tagging, were the percentages of recovery from tagging at Salmon Banks, Lummi Island and Sand Heads consistently less than from tagging at Sooke. The percentages of recovery during these periods ranged from 64 to 74 per cent for the Sooke tagging and they were also quite high for the tagging in the other areas except for the tagging at Sand Heads during the period July 21-27 for which the recovery was only 37 per cent. The differences between areas were not consistent during a season or from year to year. Fishing regulations may have contributed to this inconsistency for the regulations varied both annually and geographically. However no attempt was made to interpret the effects of regulations on the data shown in TABLE 13 because they were so meager and were also affected by many other variables.

Bias by Selectivity

The selectivity of net fisheries especially gill net fisheries for fish tagged with disk tags introduces bias which tends to make the estimates of fishing intensity too large. Indications of selectivity by gill nets occurred during the Salmon Commission's experiments. There were several instances in which disk tags but no fish were found in gill nets. Apparently some tagged sockeye were lost from the nets when the fish pulled free from the fouled tags. TABLE 32 is a gross comparison between the United States and Canadian fisheries in respect to the ratio of untagged sockeye to Sooke-tagged sockeye in the catches in Convention waters. The data were refined before tabulation by the omission of catches and recoveries that would have detracted from the comparison, such as catches and recoveries to the west of the tagging area and recoveries beyond the limits of commercial fishing. There were 10 years of data for tagging with disk tags including 2 years in which the disk tags were almost matched by equal numbers of oval tags. Inspection of TABLE 32 shows that the ratios of untagged sockeye to disk-tagged sockeye were greater in the United States catches than they were in the Canadian catches for each of the 10 years except in 1943, 1945 and 1947. These years are odd-numbered years, years in which pink salmon are important. A comparison of the subtotals for even-numbered years shows that over 2,000 more untagged sockeye per tagged sockeye were caught in the United States fishery than were caught in the Canadian fishery. A similar comparison for the odd-numbered years shows the reverse but the difference between the two fisheries was less than 150 untagged sockeye per tagged sockeye. If the data for

1947 are omitted the odd-numbered-year data reflect 4,287 untagged sockeye per recovered tag in the Canadian catch and 4,442 untagged sockeye per recovered tag in the United States catch. In 1947 both the pattern of tagging and the fishing regulations could have accounted for the unusual difference in the recovery data for the two fisheries and it seems reasonable that the data for 1947 should be omitted.

Examination of the data for the two years, 1944 and 1945, during which oval tags as well as disk tags were used at Sooke disclosed that the number of untagged sockeye per oval-tagged sockeye in the United States fishery was much greater than it was in the Canadian fishery (TABLE 32). It also disclosed that in both fisheries the ratio of untagged sockeye to oval-tagged sockeye was greater than it was for disk-tagged sockeye.

A tendency for more untagged fish per Sooke-tagged fish to appear in the United States catches than in the Canadian catches regardless of type of tag used could have been the result of at least three factors exerting their influence individually or in concert.

1. The canvass for recovered tags may have been more effective in the Canadian than in the United States fishery. The only evidence on hand, aside from the tagged to untagged data under discussion, is the difference between the percentages of the recovered tags that were reported from unknown (or indefinite) sources in the United States (2.3%) and in

TABLE 32—Comparison of the number of untagged sockeye per Sooke-tagged sockeye in United States and Canadian catches in Convention waters.

YEAR	UNITED STATES		CANADA		NUMBER UNTAGGED PERTAGGED SOCKEYE	
	Catch	Tags Recovered	Catch	Tags Recovered	United States	Canada
1938	1,405,948	106	1,858,789	224	13,264	8,298
1939	545,801	171	516,248	241	3,192	2,142
1940	649,629	86	1,004,336	238	7,554	4,220
1941	1,546,308	179	1,986,759	249	8,639	7,979
1942	2,922,022	214	4,947,134	486	13,654	10,179
1943	194,549	196	330,988	247	993	1,340
1944	435,330	58	974,529	165	7,506	5,906
		*36		*159	12,093	6,129
1945	703,036	127	939,000	143	5,536	6,566
		*64		*112	10,985	8,384
1946	3,551,059	442	3,666,020	488	8,034	7,512
1947	82,576	265	331,430	323	312	1,026
Subtotal Even Years	8,963,988	906	12,450,808	1,601	9,894	7,777
Subtotal Odd Years	3,072,270	938	4,104,425	1,203	3,275	3,412
Total	12,036,258	1,844	16,555,233	2,804	6,527	5,904

*These were oval tags. They were omitted from the subtotals and totals.

Canada (1.9%) as shown by TABLE 2 for Sooke tags. This difference appears to be negligible. In addition there is a possibility that the detection of recovered tags is better in a gill net fishery, where the fish receive more individual handling, than in a purse seine fishery.

2. The tagging at Sooke may have failed to result in tagged sockeye which were representative of the untagged sockeye in other areas of the commercial fishery. This last supposition is certainly true, for more tagging was done on Thursdays than on any other day of the week. It was not until 1942 that the Salmon Commission began to tag at Sooke on Mondays almost as frequently as on Thursdays. Sockeye tagged at Sooke on Thursdays were less available in the San Juan Islands area and more available in the Fraser River areas than were those tagged on Mondays. The San Juan Islands catch was a major factor in the United States catch and the Fraser River catch was the principal factor in the Canadian catch. The difference in the availability of the tagged sockeye in the various areas could have caused the difference between the United States and Canadian fisheries in the numbers of untagged sockeye per Sooke-tagged sockeye caught. In addition the United States fishery at times receives recruitment in the form of groups or waves of sockeye that are not necessarily intercepted at nor represented by sockeye tagged from the Sooke traps. The Fraser River fishery may also receive some sockeye that pass wide of the Sooke traps but in addition it receives a recruitment of sockeye from Johnstone Strait. These recruitments by non-representative groups of fish plus the failure to properly distribute the tagging effort during the week introduced confusing and conflicting errors.

3. The gill nets which were the mainstay of the Canadian fishery during the years of the Commission's tagging may have been more selective for disk-tagged fish than were purse seines which were the mainstay of the United States fishery. It is felt that selectivity by gill nets was sufficient to cause the numbers of untagged per tagged sockeye in the Canadian catches to be smaller than in the United States catches despite the variable recruitment from Johnstone Strait which would have tended to cause the converse by dilution of the concentration of tagged sockeye in the Canadian areas (Strait of Georgia and Fraser River). The United States areas received only a small and very insignificant recruitment of sockeye from Johnstone Strait. The resultant dilution effect would have been inconsequential.

A comparison between Canadian purse seines and gill nets in regard to the numbers of untagged sockeye per Sooke-tagged sockeye in the catches from within the Strait of Georgia and the Fraser River as far upstream as the Pattullo Bridge was possible for three years (1943, 1946 and 1947) during periods when purse seining was permitted adjacent to the river mouth and adequate catch statistics were available. TABLE 33 presents the comparison and indicates that in each of the three years gill nets were more selective for disk-tagged fish than were purse seines.

TABLE 33—Comparison between purse seines and gill nets in regard to numbers of untagged sockeye per Sooke-tagged sockeye caught in Fraser River fishery.

YEAR	PERIOD	PURSE SEINE		GILL NET		NUMBER UNTAGGED PER TAGGED FISH	
		Catch	Recoveries	Catch	Recoveries	Purse Seines	Gill Nets
1942	Sept. 3-15	1,824,536	36	1,053,991	48	50,681	21,958
1946	Sept. 11 and 13	750,561	36	155,612	8	20,849	19,452
1947	Sept. 15-24	38,890	14	190,016	149	2,778	1,276

OVAL VERSUS DISK TAGS

The selectivity of the gill net fishery for disk-tagged fish led to experiments with oval or Atkins type tags. It was hoped that fish bearing oval tags would not be more available to the commercial fishery than untagged fish. The first oval tags were used in 1940 at Lummi Island and Sand Heads but the numbers of tags were too small to yield usable data. Again in 1941 at Sand Heads some fish were tagged with oval tags while others were tagged with disk tags.

Idyll (1951) compared the recovery in the commercial gill net fishery of the oval tags with that of the disk tags used in 1941. He found that the disk tags were recovered in significantly greater numbers than were the oval tags. However, since the 296 fish tagged with oval tags and the 747 fish tagged with disk tags used in the comparison were not all tagged on the same days it appeared that an additional examination should be made of only the data for the 4 days when both oval and disk tags were used. It subsequently became apparent that the examination should be further limited to only the hauls or sets during which both tags were used. TABLE 34 lists the data used, including the order in which the two types of tags were put on. The recoveries in the commercial gill net fishery indicated that the disk-tagged fish were much more recoverable than were oval-tagged fish. Conversely the oval tags were more recoverable above the limits of commercial fishing than were disk tags. Chi-square tests indicated that the differences in recoverability of the two tags were quite significant, both in the commercial gill net fishery (TABLE 35) and in the Fraser River above the limits of commercial fishing (TABLE 36). Further comparisons of only the September 14 and 17 data were made since on September 9 the number of fish tagged with disks was exceptionally large and the disks were used after the oval tags on September 9 and 12. But even for the September 14 and 17 tagging, the disk tags were significantly more recoverable in the commercial fishery, however, the oval tags were not significantly more recoverable above the limits of commercial fishing.

It appears that the differences in recoverability were actually due to the selectivity of gill nets for disk tags. This inference is based on

TABLE 34—Data from tagging at Sand Heads in 1941 used to compare oval with disk tags.

DATE	SET NUMBER	NUMBER TAGGED	TAG	RECOVERIES			
				Commercial Fishery (Gill Net only)	Above Commercial Fishery	Total	Per Cent
Sept. 9	2	26	Disk	13	3	16	61.5
	2	99	Oval	29	22	51	51.5
	2	403	Disk	195	19	214	53.1
Sept. 12	1	60	Oval	13	12	25	41.7
	1	46	Disk	23	2	25	54.3
Sept. 14	1	60	Disk	37	5	42	70.0
	1	35	Oval	7	10	17	48.6
Sept. 17	2	54	Oval	6	15	21	38.9
	2	74	Disk	44	6	50	67.6
Subtotal	---	248	Oval	55	59	114	46.0
Subtotal	---	609	Disk	312	35	347	57.0
Total	---	857	---	367	94	461	53.8

TABLE 35—Chi-square test of differences between recoveries of oval and disk tags in the Fraser River gill net fishery. 1941-Sand Heads experiments.

TYPE OF TAG	NUMBER TAGGED	NUMBER RECOVERED		NUMBER UNRECOVERED		CHI-SQUARE
		Observed	Expected	Observed	Expected	
Oval	248	55	106.21	193	141.81	43.1709
Disk	609	312	260.79	297	348.19	17.5800
Total	857	367		490		60.7509

Chi-square=60.751

df 1

p is much less than 0.001

TABLE 36—Chi-square test of differences between recoveries of oval and disk tags above the limits of commercial fishing in the Fraser River. 1941-Sand Heads experiments. (Available tags equal number of fish tagged less the number recovered in the commercial fishery.)

TYPE OF TAG	AVAILABLE TAGS	NUMBER RECOVERED		NUMBER UNRECOVERED		CHI-SQUARE
		Observed	Expected	Observed	Expected	
Oval	193	59	37.02	134	155.98	16.1475
Disk	297	35	56.98	262	240.02	10.4916
Total	490	94		396		26.6391

Chi-square=26.639

df 1

p<0.001

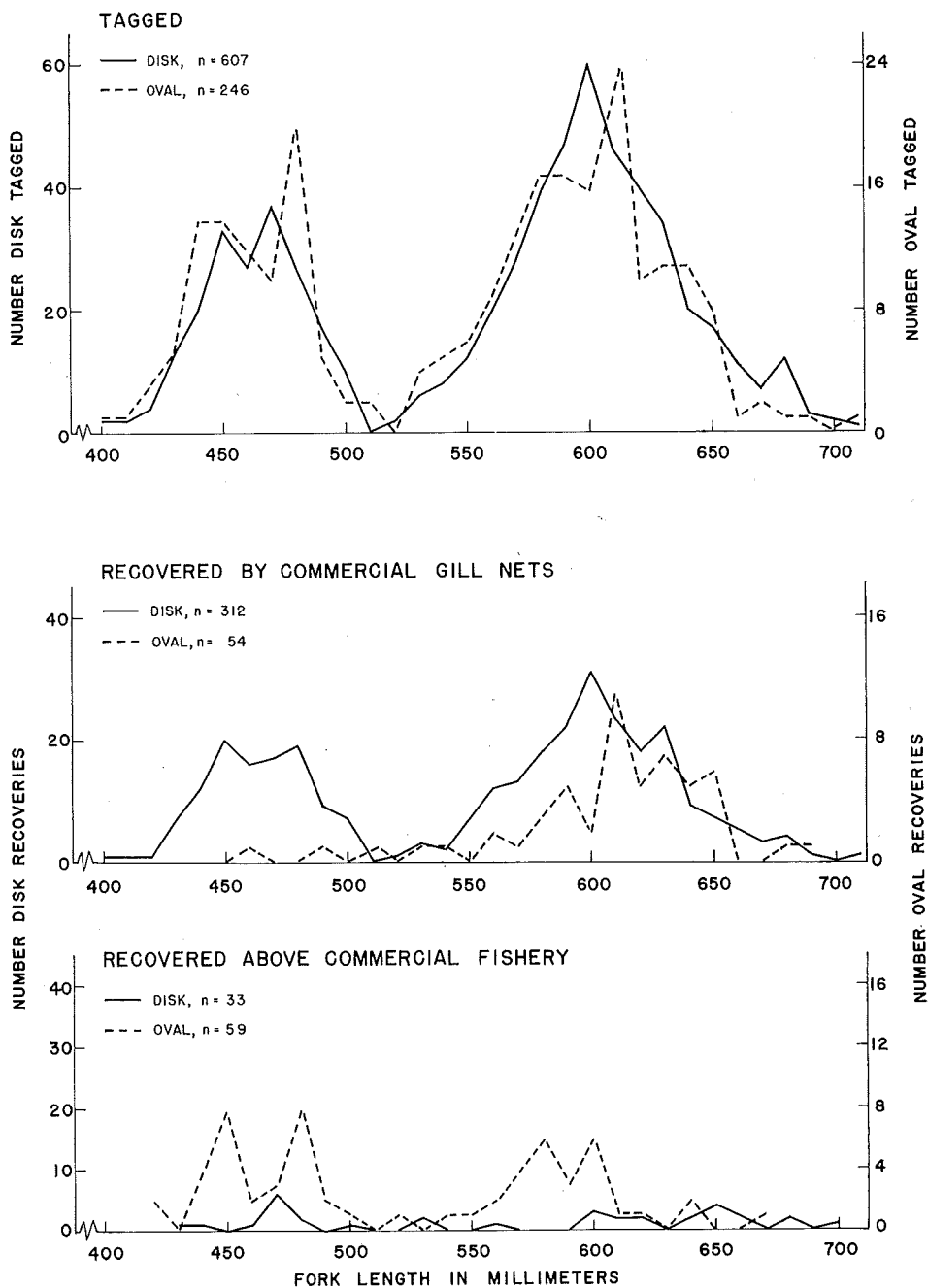


FIGURE 12—Comparison between length frequencies of sockeye tagged with disk and oval tags, at Sand Heads on September 9, 12, 14 and 17, 1941; plus similar comparisons for the subsequent recoveries in the commercial gill net fishery and above the commercial fishery.

a study of the fork lengths of the sockeye at the time of tagging on the four occasions under discussion. FIGURE 12 presents three comparisons of the fork lengths of disk-tagged fish versus those of oval-tagged fish: 1. All the fish tagged; 2. Only those tagged fish recovered in the commercial gill net fishery; and 3. Only those tagged fish recovered in the Fraser drainage above the limits of commercial fishing.

There were no practical differences in fork lengths between the disk-tagged fish and the oval-tagged fish at the time of tagging but there were definite differences between the lengths of the disk-tagged and oval-tagged fish recovered in commercial gill nets and also between those recovered in the Fraser drainage above the limits of commercial fishing. The commercial gill nets caught small fish bearing disk tags more readily than they caught similar-size fish bearing oval tags, especially those fish less than 500 millimeters in fork length. Sockeye of this small size are frequently referred to as jacks and usually escape the gill net fishery (Peterson, 1954). Only 2 of the 87 jack sockeye tagged with oval tags were recovered in commercial gill nets but these same nets recovered 110 of the 192 jacks tagged with disks. This selectivity for small fish tagged with disks was also apparent among the fish with fork lengths over 500 millimeters. The gill nets recovered 202 of the 415 fish over 500 millimeters in fork length that had been tagged with disks but only 52 of the 159 fish of similar lengths that had been tagged with ovals. The 202 recovered disk-tagged fish had a mean fork length of 603.9 millimeters (standard deviation 33.21) while the 52 recovered oval-tagged fish had a mean fork length of 612.5 millimeters (standard deviation 34.30). The difference between the two tags in mean size of fish over 500 millimeters fork length that were recovered was only 8.6 millimeters but it was statistically significant ($t=3.25$ with 252 df, $p<0.01$). Conversely it was noted that above the limits of commercial fishing small-size, oval-tagged sockeye (jacks plus those fish less than about 600 millimeters fork length) were relatively more numerous than were disk-tagged sockeye of similar size. In fact the frequency curves for the recoveries above the commercial fishery appear to be somewhat complimentary to those for the recoveries in the commercial gill net fishery. It was thus indicated that oval-tagged fish were more successful in evading the gill net fishery and consequently they were more numerous above the limits of commercial fishing than were disk-tagged fish. However many of the recoveries above the limits of commercial fishing were made in the Indian fishery with the use of nets, therefore, even above the limits of the commercial fishery it can not be said that there was no selectivity by nets for disk-tagged fish.

Additional comparisons of disk and oval tags were attempted in 1944 and 1945 by tagging sockeye from traps at Sooke. The tagging conditions in these experiments were more carefully controlled than in the Sand Heads experiments. Approximately equal numbers of both tags were used on a given day. It was apparent from the tagging records that the

two types of tags were applied to alternate, small groups of approximately equal numbers of fish; i.e., a group of fish was tagged with oval tags and the next group was tagged with disk tags, etc. The order in which the two tags were used was changed from day to day so that one type of tag was not to be used first oftener than the other. The control of the order of tagging appears to have been less rigorous than might have been desired but it is doubtful that this deficiency biased the data in a constant direction.

Idyll (1951) upon examination of the data from the 1944 and 1945 Sooke experiments was surprised to note that during both years the results indicated that the United States purse seine fishery was significantly more selective for disk-tagged fish than it was for oval-tagged fish and that there was no significant difference between the two tags in regard to the numbers recovered in the Fraser River gill net fishery.

No suitable explanation is at hand as to why the purse seine fishery should have been more effective in recovering disk-tagged fish than it was in recovering oval-tagged fish. Normally one would expect selectivity in the purse seine fishery to be negligible. The Salmon Commission's crews were instructed to tag the sockeye at random regardless of size, consequently, a few jack sockeye were tagged. Some of these jacks might have been small enough to pass through the meshes of a purse seine but might have been unable to do so when encumbered by disk tags. However inspection of the length frequency and recovery data failed to indicate that size of fish was responsible for the apparent selectivity for disk tags by purse seines.

TABLE 37—Chi-square test of differences between recoveries of oval and disk tags in the United States purse seine fishery in Convention waters. 1944-Sooke experiments.

TYPE OF TAG	AVAILABLE TAGS	NUMBER RECOVERED		NUMBER UNRECOVERED		CHI-SQUARE
		Observed	Expected	Observed	Expected	
Oval	498	18	27.94	480	470.06	3.7465
Disk	518	39	29.06	479	488.94	3.6021
Total	1016	57		959		7.3476

Chi-square=7.348

df 1

p<0.01

TABLE 38—Chi-square test of differences between recoveries of oval and disk tags in the United States purse seine fishery in Convention waters. 1945-Sooke experiments.

TYPE OF TAG	AVAILABLE TAGS	NUMBER RECOVERED		NUMBER UNRECOVERED		CHI-SQUARE
		Observed	Expected	Observed	Expected	
Oval	380	40	49.57	340	330.43	2.1248
Disk	379	59	49.43	320	329.57	2.1307
Total	759	99		660		4.2555

Chi-square=4.255

df 1

p<0.05

It was decided to retest the differences in recovery between the two types of tags, but before doing so, some adjustments were made to the numbers of sockeye tagged and recovered. In 1945 all sockeye tagged before July 3 and the related recoveries were omitted as no sockeye were caught by purse seines in United States Convention waters before July 5 or by gill nets in Canadian Convention waters before July 2. In both 1944 and 1945 all sockeye that were not measured at the time of tagging were excluded and the numbers of tagged sockeye that were recovered in the Sooke and West of Sooke areas were also subtracted from the totals tagged. The remainders were accepted as the numbers of each type of tagged sockeye available for recovery by the United States purse seine fishery. TABLES 37 and 38 list the chi-square tests of the differences between oval and disk tags in recoverability in the purse seine fishery. The disk tags were significantly more recoverable than oval tags in both 1944 and 1945 ($p < 0.01$ and < 0.05 respectively).

Before proceeding with chi-square tests of the differences between oval and disk-tagged fish in recoverability by the Fraser River gill net fishery (TABLES 39 and 40) the numbers of available tags listed in TABLES 37 and 38 were adjusted further by subtraction of all recoveries in United States areas. TABLES 39 and 40 indicate that there were no significant differences between the two tags in recoverability by the gill net fishery in either 1944 or 1945. These results are similar to those obtained by Idyll (1951) without the adjustments that have been made in the present analysis.

TABLE 39—Chi-square test of differences between recoveries of oval and disk tags in the Fraser River gill net fishery. 1944-Sooke experiments.

TYPE OF TAG	AVAILABLE TAGS	NUMBER RECOVERED		NUMBER UNRECOVERED		CHI-SQUARE
		Observed	Expected	Observed	Expected	
Oval	460	157	158.03	303	301.97	0.0102
Disk	454	157	155.97	297	298.03	0.0104
Total	914	314		600		0.0206

Chi-square=0.021 df 1 $p < 0.90$

TABLE 40—Chi-square test of differences between recoveries of oval and disk tags in the Fraser River gill net fishery. 1945-Sooke experiments.

TYPE OF TAG	AVAILABLE TAGS	NUMBER RECOVERED		NUMBER UNRECOVERED		CHI-SQUARE
		Observed	Expected	Observed	Expected	
Oval	316	101	93.09	215	222.91	0.9528
Disk	295	79	86.91	216	208.09	1.0206
Total	611	180		431		1.9734

Chi-square=1.973 df 1 $p < 0.20$

In summary, the experiments designed to compare oval with disk tags were unsatisfactory. The results were inconsistent between experiments and were also inconsistent with general knowledge. During the Sand Heads tagging, gill nets were definitely more selective for disk or Petersen tags than they were for oval or Atkins tags. On the other hand during the Sooke tagging, gill nets were not indicated to be more selective for disk tags than for oval tags but purse seines were. It is thought that perhaps the novelty or souvenir value of the less common oval tags may have caused some of the recovered tags to go unreported. A tag with the merits of the disk tag (ease of attachment, easily visible from any quarter, and hard to dislodge) but without its deficiency (easy fouling holds fish captive in nets which might otherwise escape) is a must for experiments in which fishing intensity is to be estimated directly from the percentage recovered of the fish tagged. However to date a satisfactory substitute for the disk tag has not been found. Even if such a substitute were available and the bias due to selectivity were eliminated, it is still possible that the tag recovery in the gill net fishery, where the fish receive more individual handling, would tend to be better than in the purse seine fishery. This latter possibility would prevent direct comparison between areas in regard to estimated fishing intensities, if the areas differed in types of fishing gear.

Bias by Day of Week

The day of the week on which fish are tagged can affect the per cent recovered as well as the place of recovery and the number of days-out before recovery. Therefore the day of the week also affects the pattern of estimated fishing intensities in the fishing areas. Examples of the effects of tagging on different days of the week were sought among the Sooke data as the greatest number of tagging experiments were performed at Sooke. However, even at Sooke, Mondays and Thursdays were the only two days of the week on which tagging was done with sufficient frequency to permit examination and description of the effects.

TABLE 41 was prepared to evaluate the apparent differences between the recovery of Monday and Thursday Sooke-tagged fish. After the omission of some weeks of tagging there remained 25 weeks during which sockeye had been tagged on both Monday and Thursday of each week. The reasons for the omissions were as follows. Too few fish were tagged. Strikes or regulations prohibited fishing at the time or immediately following tagging. Fishing intensity in specific areas or parts of areas was affected by special closures or other special regulations. In a few instances fishing in the San Juan Islands and Point Roberts areas was so poor at the time that very little gear was in operation and the recoveries in those fisheries were zero or nearly so.

The total percentages listed at the bottom of TABLE 41 indicated that more Monday-tagged sockeye than Thursday-tagged sockeye were recov-

TABLE 41—Differences between Monday and Thursday Sooke-tagged sockeye in percentages recovered in certain areas.

DATE	MON. OR THURS.	NUMBER TAGGED	PER CENT RECOVERED				TOTAL PER CENT
			San Juan Islands	Point Roberts	Fraser Fishery	Above Commercial Fishery	
1939							
Aug. 14	M	111	8.1	8.1	32.4	4.5	53.1
Aug. 17	Th	98	13.3	7.1	31.6	3.1	55.1
1940							
Aug. 5	M	105	7.6	10.5	19.0	5.7	42.8
Aug. 8	Th	107	3.7	3.7	34.6	2.8	44.8
1942							
July 13	M	63	7.9	4.8	28.6	12.7	54.0
July 16	Th	45	4.4	11.1	31.1	11.1	57.7
July 20	M	89	11.2	5.6	25.8	3.4	46.0
July 23	Th	108	10.2	3.7	18.5	0.9	33.3
Aug. 3	M	101	14.9	5.9	20.8	4.0	45.6
Aug. 6	Th	103	5.8	11.6	26.2	3.9	47.5
Aug. 10	M	93	9.6	2.1	27.8	3.2	42.7
Aug. 13	Th	116	1.7	6.0	27.6	4.3	39.6
1943							
July 12	M	38	10.5	0.0	15.8	2.6	28.9
July 15	Th	90	3.3	3.3	34.4	0.0	41.0
July 19	M	86	4.6	2.3	22.1	2.3	31.3
July 22	Th	66	9.1	0.0	25.8	6.1	41.0
July 26	M	61	16.4	3.3	19.7	8.2	47.6
July 29	Th	53	17.0	1.9	35.8	0.0	54.7
Aug. 16	M	81	14.8	9.9	16.0	7.4	48.1
Aug. 19	Th	99	28.4	14.8	27.1	1.2	71.5
Aug. 23	M	98	22.4	8.2	18.4	0.0	49.0
Aug. 26	Th	64	14.1	7.8	23.4	6.2	51.5
1944*							
July 17	M	40	20.0	7.5	25.0	2.5	55.0
July 20	Th	40	5.0	7.5	27.5	0.0	35.5
July 24	M	28	10.7	10.7	14.3	3.6	39.3
July 27	Th	33	3.0	9.1	51.5	3.0	66.6
July 31	M	45	13.3	2.2	35.6	2.2	53.3
Aug. 3	Th	27	3.7	7.4	51.8	0.0	62.9
1945*							
July 9	M	37	0.0	13.5	18.9	0.0	32.4
July 12	Th	38	5.3	10.5	10.5	2.6	28.9
July 16	M	30	13.3	3.3	16.7	3.3	36.6
July 19	Th	31	22.6	9.7	32.3	0.0	64.6
July 23	M	47	17.0	10.6	14.9	4.3	46.8
July 26	Th	49	6.1	20.4	30.6	2.0	59.1
July 30	M	26	30.8	0.0	7.7	7.7	46.2
Aug. 2	Th	39	2.6	7.7	12.8	2.6	25.7
Aug. 6	M	61	16.4	3.3	14.8	1.6	36.1
Aug. 9	Th	72	5.6	0.0	16.7	0.0	22.3
1946							
Aug. 5	M	212	13.7	6.1	19.8	1.4	41.0
Aug. 8	Th	121	5.8	9.1	25.6	5.8	46.3
Aug. 12	M	219	9.6	6.8	21.0	4.1	41.5
Aug. 15	Th	154	9.1	14.9	27.3	3.2	54.5
Aug. 19	M	210	18.6	6.7	19.0	2.9	47.2
Aug. 22	Th	77	5.2	15.6	16.9	2.6	40.3
Aug. 26	M	125	14.4	6.4	18.4	3.2	42.4
Aug. 29	Th	130	3.1	4.6	27.7	6.2	41.6
Sept. 3	M	125	12.8	12.8	19.2	10.4	55.2
Sept. 5	Th	102	2.0	8.8	18.6	8.8	38.2
Sept. 9	M	100	2.0	4.0	14.0	7.0	27.0
Sept. 12	Th	61	0.0	6.6	11.5	3.3	21.4
Total	M	2231	12.6	6.1	20.7	4.2	43.5
Total	Th	1923	7.3	8.0	26.1	3.5	44.8

*Oval tags were excluded. Their inclusion would have altered the magnitude but not the direction of the differences between Mondays and Thursdays.

ered in the San Juan Islands but less Monday tags than Thursday tags were recovered in the Point Roberts and Fraser River fisheries. The total percentages also indicated that the escapement was slightly more and that the total fishing mortality was slightly less for fish tagged on Mondays than they were for those tagged on Thursdays.

The percentages for each experiment listed in the table showed:

1. That the recoveries in the San Juan Islands of Monday-tagged sockeye exceeded those of Thursday-tagged sockeye 19 out of 25 times.
2. That the recoveries in the Point Roberts area of Monday's tags exceeded those of Thursday's tags only 11 out of 25 times.
3. That the recoveries in the Fraser River fishery of Monday's tags only exceeded those of Thursday's tags 7 out of 25 times.
4. That the recoveries of Monday's tags above the limits of commercial fishing exceeded those of Thursday's tags 19 out of 25 times.
5. That the total percentages recovered of Monday's tags exceeded those of Thursday's tags 10 out of 25 times.

These data indicated that the differences between Mondays and Thursdays in per cent of tagged fish recovered in the various areas were quite consistent. When commercial fishing was permitted approximately five days per week and was prohibited each week-end throughout the fisheries, which were the approximate circumstances during the years pertaining to these tagging experiments, sockeye that were present in the Sooke area on Mondays were subsequently taken in the San Juan Islands fishery in relatively greater numbers than were those that were present on Thursdays. Those that were present at Sooke on Thursdays were taken in greater numbers in the Point Roberts and Fraser River fisheries and sustained a greater total fishing mortality than did those that were present on Mondays. Thus the escapement past the commercial fisheries was greatest for fish passing the Sooke area on Monday. Great importance cannot be attached to the number of times that the expected result occurred out of the total number of events as the percentages of the tags recovered in each area were not independent of one another. The sockeye in migrating from Sooke to the Fraser River tend to pass through one fishing area at a time in accordance with the positions of the fishing areas along the route of migration. The tags recovered in the first area reduced the number available for recovery in the other areas. However it was this pattern of circumstances and the existence of closed periods at weekly intervals which accounted for the differences in recoverability between sockeye tagged on Monday and those tagged on Thursday. It is surprising that the evidence demonstrating these differences is so apparent in spite of the many variables affecting the tagging, such as: mobile gear, fluctuations in fishing effort, differences in behavior between early and late-running fish, erroneous reporting, etc.

It was mentioned in the ROUTES OF MIGRATION section that the tagging at Lummi Island in 1941 in contrast to that of 1939 and 1940 had been done mostly on Saturdays during the week-end closures. TABLE 8 showed that the recoveries in United States waters in 1941 were relatively less in the San Juan Islands areas and were relatively more in the Point Roberts area than they were in 1939 or 1940. It appears that the week-end closures permitted many of the tagged fish to migrate to the Point Roberts area where they were caught in large numbers. Analysis of the days-out for the fish recovered at Point Roberts in 1941 showed that many of the recoveries occurred on Monday or the second day after they had been tagged at Lummi Island.

TABLE 42 was prepared to determine the effects on the relative recovery by the United States and Canadian commercial fisheries of tagging on different days of the week at Lummi Island. Because the data were insufficient for comparisons between individual days of the week within each year, the data for 1939 and 1940 were restricted to only the tagging on the first four days of each week (Monday through Thursday) and the data from those four tagging days were combined for each year. The data for 1941 were restricted to only the tagging on Fridays and Saturdays and the data from those two tagging days were combined. The combining of Friday's experiments with Saturday's experiments seemed reasonable as it was the practice at Lummi Island to tag late in the day, either shortly before or after the start of the week-end closure in United States waters. No tagging was done on Sundays during the three years. The few recoveries which were reported from unknown United States or Canadian sources were assumed to be from the respective commercial fisheries and were included in the table. The numbers of tags available to the Canadian fishery were assumed to be the numbers of sockeye tagged, less the numbers of tagged sockeye recovered in the United States fishery.

TABLE 42—Effects of tagging on different days of the week at Lummi Island. Tagging on Mondays through Thursdays in 1939 or 1940 vs. tagging on Fridays and Saturdays in 1941.

YEAR AND DAY TAGGED	NUMBER TAGGED	NUMBER AND PER CENT RECOVERED BY				TAGS AVAILABLE TO CANADIAN FISHERY	
		United States Fishery		Canadian Fishery		Number Tags	Per Cent Recovered
1939 Monday-Thursday	990	113	11.4	334	33.7	877	38.1
1940 Monday-Thursday	658	91	13.8	180	27.4	567	31.7
1941 Friday and Saturday	647	101	15.6	261	40.3	546	47.8
Mean difference in per cent recovered, 1941 vs. 1939 and 1940.				3.0	9.8	12.9	

TABLE 42 indicates that the recoveries in the United States and also in the Canadian commercial fisheries were greater in 1941 when the fish were tagged on Fridays and Saturdays and were less in both 1939 and 1940 when the fish were tagged on Mondays through Thursdays. The differences between the years in regard to the recoveries in the Canadian fishery were even more pronounced when allowances were made for the prior recovery of tags in the United States fishery. Many of the sockeye tagged at Lummi Island began to arrive off the Fraser River within 2 or 3 days. This resulted in 1941 in a substantial recovery, on Monday and on the next 4 consecutive days of the fishing week, of fish tagged on Friday and Saturday. In 1939 and 1940 the fish tagged on Monday, Tuesday and Wednesday did not arrive in the Canadian fishery at the start of the fishing week. The fish tagged on Thursdays in those years were available to the Canadian fishery for 5 consecutive fishing days but only after the fish had been out 4 days.

This points out the manner in which tagging on different days of the week at Lummi Island could have caused the recovery from the 1941 tagging to have been greater than it was from the 1939 or 1940 tagging. However it can not be stated that the differences between the years were caused solely by the different tagging days for a number of reasons, such as: 1. The same races of sockeye were not dominant in all three years. 2. The presence of pink salmon in 1939 and 1941 probably caused the fishing effort to be greater in those years than it was in 1940. 3. The fishing regulations were not the same in all three years. The effects of tagging on different days of the week on the numbers of recoveries above the limits of commercial fishing in the Fraser River were not examined because of the annual variations in block conditions at Hell's Gate. The block was so severe in 1941 that very few fish succeeded in escaping to the spawning grounds above the Gate.

A discussion of the Johnstone Strait experiments in the RATE OF MIGRATION section also mentioned differences between fish tagged on different week days in regard to fishing intensity in specific areas as the groups of fish migrated toward the Fraser River. But the total fishing intensity for the tagging experiments on each of the seven days of the week was not listed because the numbers of experiments on each day of the week were too few. However it did appear that the total fishing intensity was greatest for fish tagged on Mondays and least for fish tagged on Fridays.

In summary the marine tagging experiments failed to yield accurate and consistent estimates of fishing intensity for the following reasons.

1. The unknown amounts of natural and tagging mortality minimized the estimates.
2. The selectivity of nets for disk tags maximized the estimates. The experiments to compare the recovery of oval tags with that of disk tags

were inconsistent. It was concluded that the oval tags did not yield more accurate estimates of fishing intensity than did the disk tags and that the results from the oval tags did not offer a valid means for correcting the estimated fishing intensities derived from the disk tags.

3. The fish tagged at Sooke were not truly representative of the untagged fish in the catches in other areas. The percentages of tags recovered did not decrease consistently as the tagging experiments were conducted closer and closer to the Fraser River.

4. Tagging was not done simultaneously and in large enough individual experiments in the various areas with sufficient frequency and consistency to permit estimation of differences in fishing intensities between areas. TABLE 13 contains rough estimates of the total fishing intensities on fish migrating through specific tagging areas during weekly tagging periods.

Daily variations in fishing intensity were indicated by differences between fish tagged on Mondays and those tagged on Thursdays at Sooke in regard to the relative numbers of tags recovered. Variations in fishing intensity were also indicated by the differences between the numbers of recoveries resulting from tagging on different days of the week at Lummi Island and also at Johnstone Strait.

SUMMARY

1. The International Pacific Salmon Fisheries Commission inaugurated a program of tagging sockeye salmon in salt water for purposes of gaining information, which would be useful in the management of the fishery for Fraser River sockeye, such as: routes of migration, rates of migration, times of passage of different races, fishing intensity, and the effects of closed periods and other regulations on fishing intensity.

2. During the years 1938 to 1948, a total of 33,334 sockeye were tagged primarily with disk tags, but 1,438 oval tags were included. Of the number tagged, 17,219 or 51.7 per cent were recovered. Most of the recoveries occurred in the commercial fisheries but substantial numbers of tagged sockeye were also recovered from the Indian fisheries above the limits of commercial fishing and by the Salmon Commission's staff on the spawning grounds. The tagging and recovery methods and also the recovery problems were described.

3. The major tagging effort was in the Sooke area, where sockeye were tagged from traps, primarily on Mondays and Thursdays, during the years 1938 to 1948. Other tagging areas in decreasing order of numbers tagged during various years from 1938 through 1941 were: Sand Heads, Johnstone Strait, Salmon Banks, Lummi Island, South Lopez, San Juan Channel, Point Roberts and West Beach. Tagging in these other areas was done from purse seines except at Lummi Island where most of the fish were tagged from reef nets.

4. The recoveries of sockeye tagged at Sooke indicated that the principal route of migration from Sooke to the Fraser River was through United States Convention waters via Salmon Banks, South Lopez, Rosario Strait, Lummi Island, and Point Roberts. Near Point Roberts in the Strait of Georgia the sockeye re-entered Canadian Convention waters and proceeded to enter the Fraser River, principally via its Main Arm. The routes of lesser importance differed from the principal route in that the sockeye using them approached the Strait of Georgia via Haro Strait or San Juan Channel instead of Rosario Strait. The experiments were not adequate for purposes of establishing the precise relative importance of the various routes or their annual or seasonal variations in importance.

5. The recoveries of sockeye tagged at Salmon Banks, South Lopez, San Juan Channel and Lummi Island indicated a route of migration which was consistent with the principal route used by those tagged at Sooke. However the Salmon Banks tagging indicated that Haro Strait was a slightly more important approach to the Strait of Georgia than was indicated by the Sooke tagging. Catch information indicated that the importance of Haro Strait varied from year to year and also during the season.

6. The recoveries of sockeye tagged in Johnstone Strait indicated a direct movement toward the Fraser River and a greater use of the northern entrances to the river than had been exhibited by the Sooke-tagged sockeye.

7. The Sand Heads tagging confirmed the concept that late-season races of sockeye delay entry into the river and that occasionally large numbers of these sockeye drop back into the Point Roberts area, particularly after September 1. Examination of wind, tide and catch data indicated that abundance and position of delaying sockeye are important factors contributing to dropping back to the Point Roberts area and that northwest winds and strong ebb tides may expedite this regression.

8. In general, regardless of area of tagging, very little retrograde movement or migration in a direction away from the Fraser River was indicated.

9. The rates of migration of Fraser River sockeye obtained from tagging by other investigators and also the effects of tagging and of other problems on the estimation of rates were discussed. The extent of the injurious effects of tagging could not be determined, however, this did not appear to be sufficiently serious during the Salmon Commission's experiments to prevent estimation of rates of migration provided the rates were derived from modal rather than arithmetic mean or median values. The modal values were selected as the best measures of common tendency, since the modes tended to ignore data that might have been derived from injured or unusual fish or that might have been affected by other sources of error. Migration time or days-out between tagging and recovery was selected as a practical means of expressing rate of migration, and modal-migration times from various tagging areas to certain recovery areas were listed.

10. The migration times derived from tagging at Sooke indicated a lack of seasonal or annual variations in migration times from Sooke to Salmon Banks, but the existence of possibly significant seasonal and of significant annual variations in migration times from Sooke to Point Roberts. The variations appeared to be the result of differences in delay behavior between early and late-season races of sockeye. This delay behavior occurred near the mouth of the Fraser River beginning in August and resulted in significant variations in migration times as measured by days-out from Sooke to the Mouth of Fraser area both seasonally and annually.

11. The tagging at Sand Heads indicated: (a) that some sockeye, principally those present in September, delayed a minimum of 19 to 34 days; (b) that the regression of sockeye from the mouth of the river to the Point Roberts area occurred primarily in September; (c) that once the sockeye entered the river they were either rapidly caught or they quickly escaped upstream past the limits of commercial fishing.

12. Sockeye tagged in Johnstone Strait on Thursday appeared to receive more protection from the week-end closure in that area than did those tagged there on other days of the week and they arrived off the Mouth of Fraser area in the shortest modal-migration time, 7 or 8 days-out.

13. Sockeye tagged in Johnstone Strait appeared to require 1 to 2 days more migration time to reach the Mouth of Fraser than did sockeye tagged at Sooke.

14. Times of passage of various races of Fraser River sockeye through the commercial fishery and at certain points within the Fraser River drainage were derived primarily from recoveries of marine-tagged and of freshwater-tagged sockeye, on or near specific spawning grounds. This information plus supplemental information from fin-marked fish and published data were discussed for individual races and groups of races.

15. Estimated times of passage at Sooke were derived for non-Fraser races of sockeye, such as: Somass, Nitinat, Skagit (Baker River) and Lake Washington (Issaquah Creek). These races passed through the fishing areas early in the season, primarily in advance of the Fraser River races.

16. Tagging was of value in supplying expected times of passage of individual races, although the times lacked precision. Factors which affected the precision were discussed.

17. Estimates of the numerical size of annual Fraser River sockeye runs, which are stratified populations, were not obtained by tagging; since neither the tagging nor fishing for purposes of sampling the tagged populations was done in proportion to the abundance of sockeye. In addition there were no measures of tagging mortality, selectivity for tagged fish, or of recruitment by untagged fish via Johnstone Strait. A practical marine tagging program to estimate the annual sockeye populations would be extremely difficult to design and execute. Consequently, in recent years the annual populations and the abundance of individual races have been determined by compilation of catch statistics, enumeration of the spawning escapements, and analyses of scale samples.

18. Accurate and consistent estimates of fishing intensity were not obtained from the marine-tagging experiments because: The amounts of natural and tagging mortality were unknown. The selectivity of nets for tagged fish could not be measured although experiments in which disk-tagged fish were compared with oval-tagged fish showed that selectivity existed. The effects of tagging on different days of the week could not be quantified although their existence was demonstrated.

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