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Pink Salmon, *Oncorhynchus gorbuscha*, Tagging Experiments in Southeastern Alaska, 1938-42 and 1945

ROY E. NAKATANI, GERALD J. PAULIK, and RICHARD VAN CLEVE

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CONTENTS

Figures

Tables

Pink Salmon, *Oncorhynchus gorbuscha*, Tagging Experiments in Southeastern Alaska, 1938-42 and 1945[1]

ROY E. NAKATANI,[2] GERALD J. PAULIK,[3] and RICHARD VAN CLEVE[4]

ABSTRACT

A total of 20,532 pink salmon (*Oncorhynchus gorbuscha*) were tagged and released in southeastern Alaska north of Sumner Strait during the years of 1938 to 1942 inclusive, and in 1945. The recovery of 7,027 of these tags in the fish traps confirmed the findings of other investigators that the pink salmon stocks of the northern part of southeast Alaska are separate from those in the southern part. They also show that pink salmon enter the northern part of southeast Alaska through two paths: (1) through Icy Strait, and (2) through the lower end of Chatham Strait. No evidence was found of movement through Peril Strait from Salisbury Sound into Chatham Strait. The centers of density of each group of tags appeared to move in a consistent manner, but a smaller number of tags from each release were dispersed throughout the northern part of southeastern Alaska. Differences were noted between the movements of fish in odd and even years. Also a larger proportion of earlier tagged fish moved to recovery locations father inland. In all areas and in all years the fishing season closed about the time of the greatest abundance of fish in the fishery, therefore the later parts of the runs were not studied. Apparently the 1941 run was the largest and that in 1945 the smallest. Migration rates were studied by plotting the catch per trap as well as by the recovery of tags. The latter showed movements of 9.05 to 33.37 miles per day. Survival rates computed for thirty releases with total tag recovery periods of two or more weeks averaged 0.384. Weekly exploitation rates varied from 0.142 to 0.452 averaging 0.250. The weekly *F* exponential rate of fishing averaged 0.514. Recoveries of tags from seines were not used since their proportion of tags recovered was less than one-half their proportion of the catch. Recommendations are made for future tagging experiments based upon the results of this analysis.

INTRODUCTION

From about 1920 to 1950 the U.S. Fish and Wildlife Service (FWS) collected considerable data on Alaska fisheries. An inventory of these data, made under a contract between the University of Washington College of Fisheries and the FWS, disclosed records of pink salmon, *Oncorhynchus gorbuscha*, tagged in the northern part of southeastern Alaska (Fig. 1) in 1938-42 and 1945. A total of 20,532 tagged fish were released in 55 tagging experiments during the 6 yr; 7,027 of the tags were recovered. In this report the tagging and recovery data are analyzed; supplemented by records of the daily catches of pink salmon from about 100 traps that operated in the area in the years covered by the experiments.

All recovery and catch data were transferred to punch cards and processed through an electronic digital computer at the Research Computer Laboratory, University of Washington. Details of programming for the different analyses, including tables of the data used in the computations, are on file at the National Marine Fisheries Service Auke Bay Fisheries Laboratory at Auke Bay, Alaska, and at the College of Fisheries.[5] Past reports on salmon tagging experiments in Alaska include those by Rich (1927), Rich and Suomela (1929), and Rich and Morton (1930).

The tagging experiments covered in this report must be evaluated with a full understanding of the restrictions imposed on the staff originally responsible for them. The difficulties involved in executing a tagging and recovery program covering an area the size of the northern half of southeastern Alaska and involving a fishery as complex as the pink salmon

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[5]Nakatani, R. E., G. J. Paulik, and R. Van Cleve. 1963. Analysis of past Alaskan pink salmon tagging experiments, 1938-1945. Unpublished manuscript, 163 p. Fisheries Research Institute, University of Washington, Seattle, WA 98195.

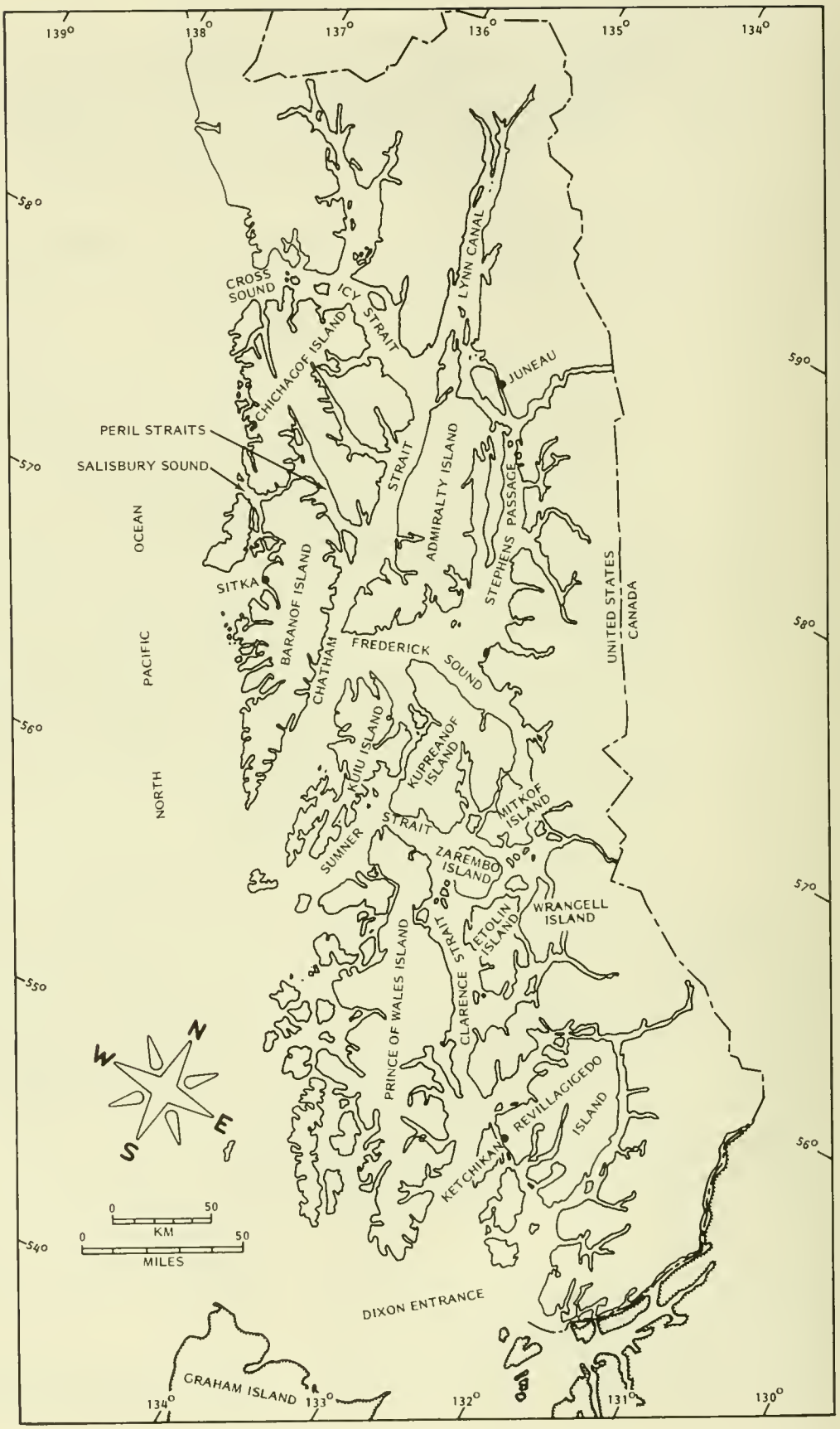


Figure 1. — Southeastern Alaska, area of pink salmon tagging experiments in 1938-42 and 1945.

fishery in this area can be appreciated by those who have attempted such work. Our evaluation has been possible only because of the efforts of the early biologists who collected and preserved the data under difficult conditions. Any criticisms of the techniques or any deficiencies noted in the programs are presented only to facilitate the design of future experiments.

HISTORICAL REVIEW

The first major tagging experiments on pink salmon in southeastern Alaska were conducted in 1924 and 1925 by the Bureau of Fisheries under the direction of Willis H. Rich (Rich 1927) " . . . to discover the main routes of the salmon migrating through the maze of channels of the Alexander Archipelago and the distribution of the fish following these routes to the various spawning grounds." This work was continued by Rich and Suomela (1929) and Rich and Morton (1930).

One of the most significant findings of these early workers was the virtual separation of the southeastern Alaska fishery into two distinct areas—one to the north of Kuiu, Kupreanof, and Mitkof islands, and the other to the south. The interchange of tagged pink salmon between these areas was so small that for all practical purposes the areas could be considered separate. The northern area included Icy Strait, Lynn Canal, Chatham Strait, Frederick Sound, and Stephens Passage; the southern area included Sumner Strait, Clarence Strait, and the south and west coasts of Prince of Wales Island.

Tagged pink salmon released in Icy Strait moved eastward and then southward in Chatham Strait to Frederick Sound. In Frederick Sound they traveled eastward and then northward. Most of the pink salmon released in lower Chatham Strait during mid-July moved into Frederick Sound, and those released in early August moved north into upper Chatham Strait and south into Sumner Strait. Fish released in Frederick Sound in early August distributed themselves throughout Frederick Sound and along Stephens Passage.

An extensive series of experiments in the southern area and some tagging experiments in the northern portion of southeastern Alaska were reported by Verhoeven.[6] Verhoeven concluded that the pink salmon spawning migration is a "random to-and-fro" wandering through the fishery. He maintained that the apparent directional tendencies found by other investigators resulted from random movement combined with the location of the fishery in relation to the location of the tagging stations. The validity of Verhoeven's hypothesis of random to-and-fro movement is of critical importance to the formulation of an acceptable policy for regulating the fishery. If pink salmon move randomly within an area, any geographical variation in fishing intensity in the area would not differentially affect the population. Only the total fishing pressure would determine the escapement of any particular stream and would affect all races in the same manner. The primary function of management would then be to define each of these homogeneous areas and to regulate each area as one unit.

The independence of salmon stocks in the southern and northern portions of southeastern Alaska was also shown by Verhoeven (citation in footnote 6, Figs. 25, 26).

During 1950, 17,400 pink salmon were tagged in Icy Strait and upper Chatham Strait by the FWS (Elling and Macy 1955). Tagged fish were released daily from tagging stations in Icy Strait from 25 July through 14 August, ending the day before the opening of the commercial fishing season. Generally speaking, the results of the 1950 tagging experiments agreed with the results of Rich and his colleagues in the twenties. Stream surveys, combined with a daily schedule of tagging, enabled Elling and Macy (1955) to determine when pink salmon destined for a particular spawning stream passed the various tagging sites. However, the limited period during which daily releases were made restricted the utility of the experiments. Different races of pink salmon passing the Icy Strait tagging stations were not separated in time into clear-cut groups. Elling and Macy (1955) found that fish bound for streams in Stephens Passage, Chatham Strait, and Icy Strait passed through Icy Strait about the same time.

EXPERIMENTAL AND ANALYTIC METHODS

Tags and Tagging

The method used in tagging during the 1938-42 and 1945 experiments was described to us by S. J. Hutchinson in a personal interview. S. J. Hutchinson participated in the experiments. Fish were captured in salmon traps and were tagged with a metal strap tag clipped to the dorsal margin of the caudal fin. The method of handling during tagging was similar to that described by Davidson and Christey (1938).

In 1938-41, tags were serially numbered so that each fish could be identified on recovery. In 1942 and 1945, a single number was used to identify all fish tagged in an experiment, and in some cases the same identification number was used for more than one experiment. Problems arising from the confusion between tags recovered from two experiments in 1945 will be discussed in the section on migration through Peril Strait.

[6]Verhoeven, L. A. 1952. A report to the salmon fishing industry of Alaska on the results of the 1947 tagging experiments. Unpublished manuscript, 21 p. Fisheries Research Institute, University of Washington, Seattle, WA 98195.

Preliminary Processing of Data

The original tagging and recovery data discussed in this report were found in logbooks, original return forms, summary tables, manuscripts, and correspondence. Inasmuch as a large part of the recovery information was taken from summary tables, which were sometimes incorrect or incomplete, considerable effort was expended in comparing these summaries with original records. There was no method by which the date and place of recovery could be absolutely verified, and it was assumed that the summary tables were correct if no evidence to the contrary was found. If information was lacking or if a discrepancy was found which could not be resolved by a search of the records, the recovery was classified as having an unknown date or place of recovery. The changes made as a result of comparison with original records were not many and were usually corrections of obvious errors. In analyses where the recoveries were pooled by geographical areas, recovery reassignments had little effect on the results because the recoveries were usually reassigned to traps near the traps to which they had originally been assigned in the summary tables.

The tag return information was transferred to punch cards and processed through an IBM 650 digital computer to compute such additional information as days out and distance from the tagging station and to punch a final basic card for each return.

There were omissions as well as inaccuracies in the data relating to a number of important factors. Distribution of the seine fleet in time and space, the size of the seine catches and the spawning escapement, and an accurate measure of recovery effort or outline of the program used for recovery were all unknown. Each of these factors will be discussed in more detail in later sections where they are pertinent. Because almost no information was available on the size and distribution of the seine fleet and its catch, this report is restricted to a consideration of trap catch data and trap recoveries of tagged fish, except in the section on mortality rates. Since about 80% of the recoveries were made by traps, this limitation is not severe.

To validate trap catch data, which were submitted by the canneries to the FWS, persons acquainted with trap operations in the areas during the years considered in this report were consulted on methods used to estimate the daily and weekly catches of a salmon trap. No method was found to verify all of the catch data; therefore, no corrections were made in the original cannery records. The fact that catch records kept independently by certain canneries showed excellent agreement with the data submitted to the FWS increased our confidence in the data.

Daily catch data for each trap were transferred from the cannery forms to IBM cards identical to those used by the FWS for recording daily trap catches. When more than one brailing in a day was recorded, the sum of the recorded catches was entered on the IBM card. Records from licensed traps that caught few or no fish were omitted.

The actual daily catch was not always recorded, and the analysis was based on the weekly catch. Traps were frequently fished more than 1 day without being brailed; they were emptied daily only during the last 2 wk of the fishing season. During the latter part of the season when the runs were heavy, some traps were brailed on Saturday and also on Sunday, a closed day, for the usual fishing period of 5½ days a week. Because the operation of traps during the weekend closure is unknown, there is some doubt as to what day those fish recorded as taken on Sunday actually entered the trap. All traps were assumed to have been empty at the beginning of each fishing week and the catches were summed from Monday through Sunday.

Release and Recovery Information

A statistical coding scheme was used to group the waters of the northern part of southeastern Alaska into statistical areas and subareas (Fig. 2) for computer analysis of the tag-recapture and catch data. The closing dates of the fishing season for the years 1938-42 in the major statistical subareas were estimated from data on the daily trap catches (Table 1). A description of the statistical coding system is available in Simpson (1960).

The locations and code numbers of the principal trap sites and the tagging stations are shown in Figure 3. The code numbers used throughout this report are the same as those shown in Figure 3 except for a few minor changes such as those employed in what is known as the Vaughn system (for further information on this system, see the publication cited in footnote 5). The number of traps operating in each major statistical subarea (Fig. 2) each year is given in Table 2.

The numbers of tagging experiments conducted during 1938-42 and 1945 are given in Table 3. Release and recovery data are summarized by year in Table 4. Total recoveries, omitting those from streams, during the period from 1938 to 1945 varied from 28% to 38%. The total, over all years, of 7,027 tags recovered from all sources represents 34.3% of the total releases; 79.8% of the total recoveries were recovered in traps and 16.1% in seines. Because only 30 tagged fish were recovered in streams, stream recoveries were not used in any of the analyses and will not be discussed.

Basic release and recovery information for each experiment is presented in Table 5. The timing of the releases during the season varied considerably from year to year. In only three experiments were less than 100 fish released. Many of the tagging experiments appear to have had a goal of about 500 fish. In addition to recovery percentages by type of gear, Table 5 also contains the mean and variance of the days-out

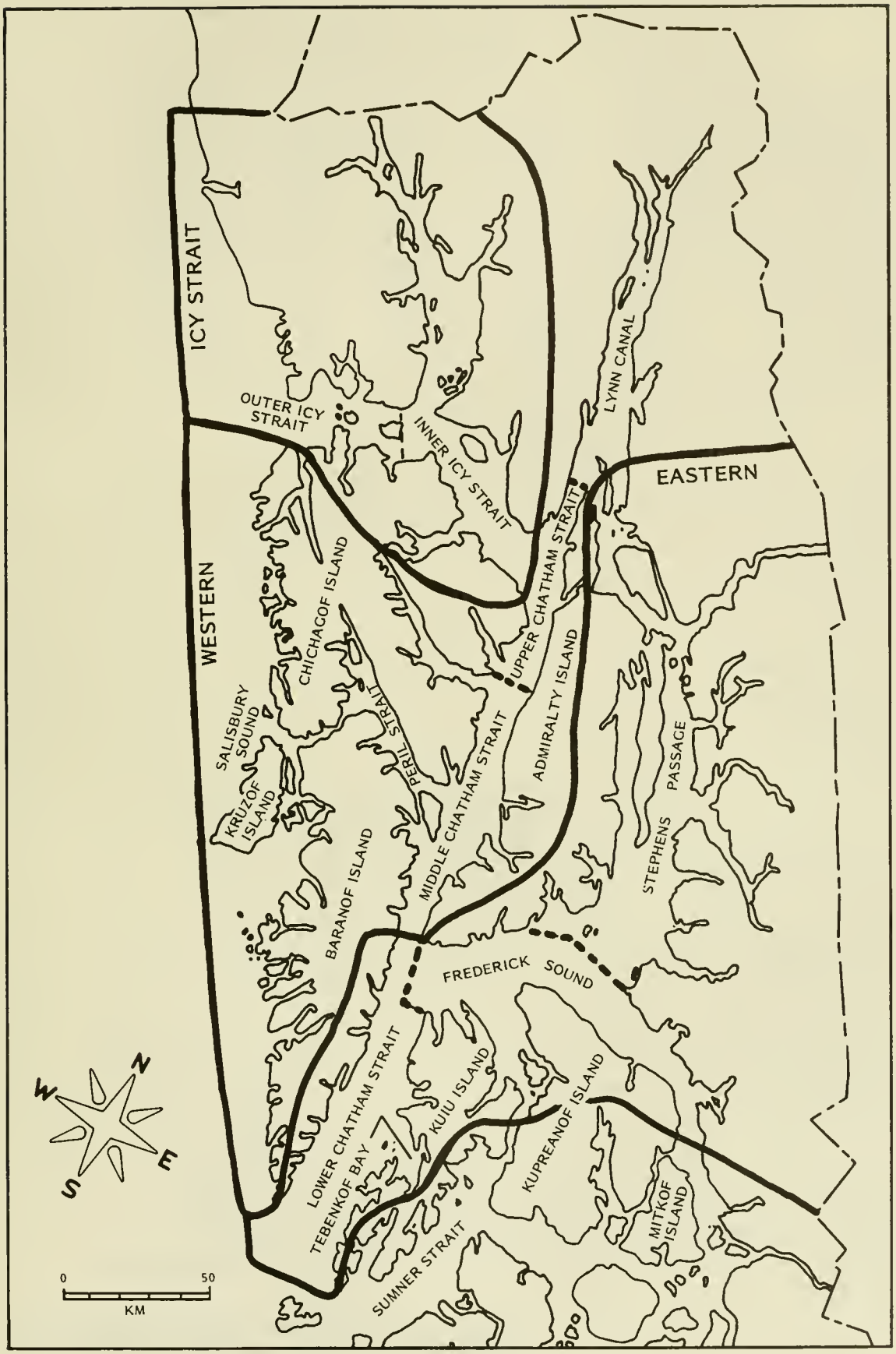


Figure 2.—Northern part of southeastern Alaska showing major statistical areas and subareas used for computer analysis of pink salmon tag recapture data.

Table 1.--Closing dates of fishing season in major statistical subareas in southeastern Alaska as estimated from records of daily trap catches, 1938-42.

Statistical subarea	1938	1939	1940	1941	1942
Outer Icy Strait	5 August	5 August	5 August	5 August	5 August
Inner Icy Strait	7 August	8 August	8 August	8 August	12 August
Lynn Canal	11 August	11 August	9 August	10 August	15 August
Upper Chatham Strait	21 August	19 August	19 August	21 August	21 August
Middle Chatham Strait	21 August	19 August	19 August	21 August	21 August
Lower Chatham Strait	21 August	19 August	19 August	21 August	23 August
Frederick Sound	21 August	19 August	19 August	21 August	23 August
Stephens Passage	21 August	19 August	19 August	21 August	23 August

Table 2.--Number of salmon traps in major statistical subareas in southeastern Alaska, 1938-42 and 1945.

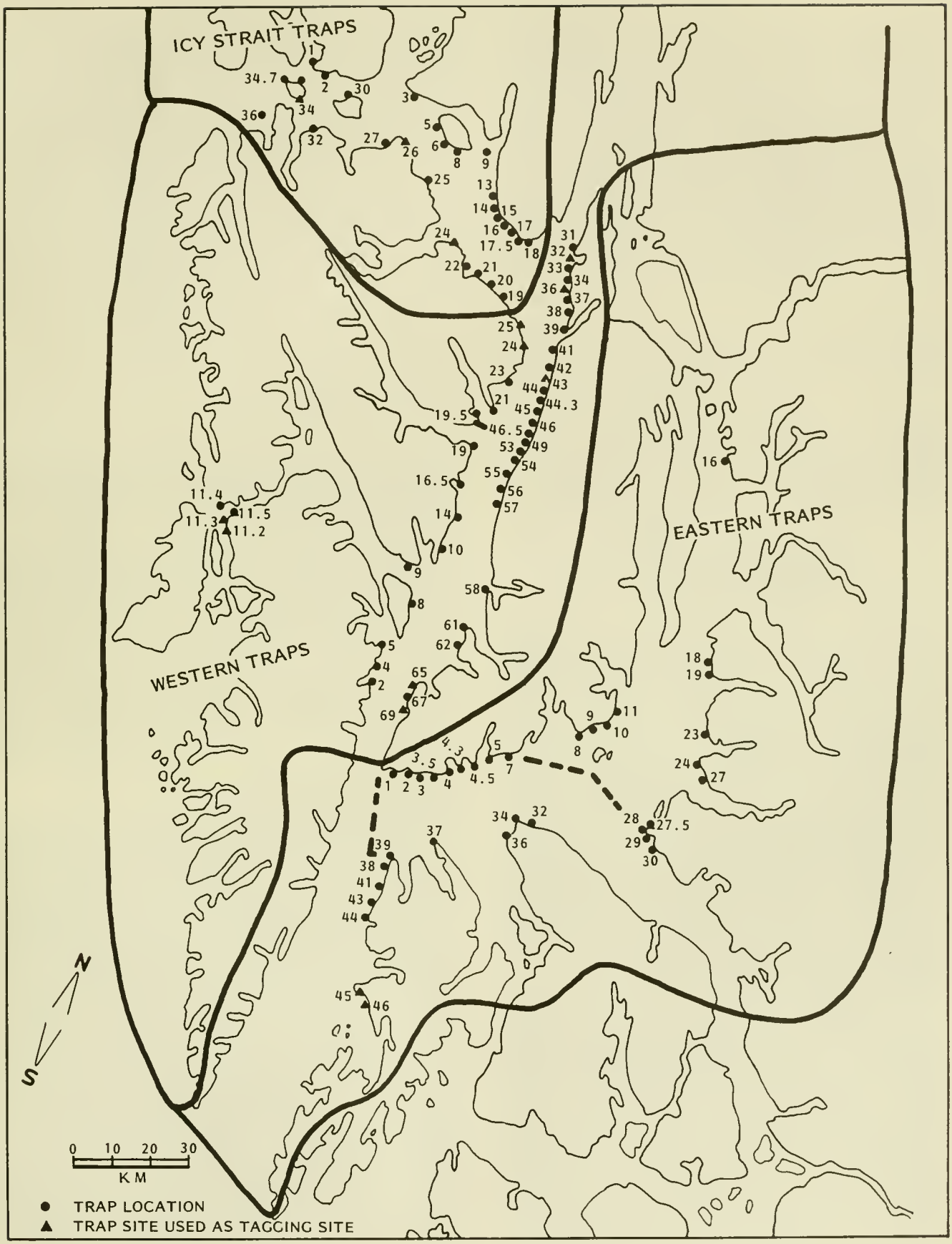
Statistical subarea	1938	1939	1940	1941	1942	1945
Outer Icy Strait	8	8	6	6	6	6
Inner Icy Strait	19	19	17	10	17	16
Lynn Canal	2	2	2	1	2	2
Upper Chatham Strait	19	19	18	13	18	17
Middle Chatham Strait	19	19	18	12	16	17
Lower Chatham Strait	5	5	4	4	4	4
Frederick Sound	16	16	16	16	16	14
Stephens Passage	12	12	11	11	11	13
Total	100	100	92	73	90	89

Table 3.--Number of tagging experiments conducted in southeastern Alaska areas during 1938-42 and 1945.

Area of tagging	1938	1939	1940	1941	1942	1945	Total
Icy Strait	0	0	0	6	3	0	9
Upper Chatham Strait	0	0	2	5	[1]/7	0	14
Middle Chatham Strait	0	0	2	6	2	0	10
Lower Chatham Strait	10	7	0	2	1	0	20
Salisbury Sound	0	0	0	0	0	2	2
Total	10	7	4	19	13	2	55

[1]/Recoveries from two releases from trap WE-24 (Figure 3) on consecutive days, 24 and 25 July, could not be separated because identical tags were applied to all fish. Data from these two releases were pooled and treated as if one release had been made on 25 July 1942 for purposes of this report.

Figure 3.—Locations and code numbers of principal trap sites, including those used as tagging stations, 1938-42 and 1945.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TRAP LOCATION
TRAP SITE USED AS TAGGING SITE

Table 4.--Number of tags released and number recovered in tagging experiments in southeastern Alaska, 1938-42 and 1945.

Year	No. releases	Recoveries in: Traps No.	Traps %	Seines No.	Seines %	Gill nets	Streams[1]	Unknown	Total No.	Total %
1938	2,094	537	25.64	102	4.87	2	1	2	643	30.71
1939	2,100	550	26.19	129	6.14	2	5	5	686	32.67
1940	2,339	553	23.64	105	4.49	0	4	10	668	28.56
1941	7,620	2,534	33.25	396	5.20	0	17	22	2,952	38.74
1942	4,962	1,419	28.60	182	3.67	0	3	21	1,622	32.69
1945	1,357	17	1.25	217	15.99	0	0	222	456	33.60
Total	20,472	5,610	27.40	1,131	5.52	4	30	282	7,027	34.32

[1] Not included in number recovered.

statistic for recoveries in traps and seines and the mean and variance of the number of miles traveled for recoveries in traps.

MIGRATION ROUTES AS DETERMINED FROM TAG RECOVERIES

The capture-recapture method of studying animal migration has the inherent limitation that no information is provided on the actual path followed from the point of original capture to the point of recapture unless multiple recaptures are made. Precise charting of migratory routes requires frequent position determination without disturbing the normal migratory behavior of the animal. Multiple recaptures of the same tag, if any, were not reported for the 1938-42 and 1945 experiments. Determination of migratory pathways was further restricted by locations of release sites and the operation of the commercial fishery that provided the primary recovery effort. Because of these limitations, the analysis presented here is concerned only with broad aspects of the migration patterns.

Migration Between Northern and Southern Southeastern Alaska

The separation of stocks of southeastern Alaska pink salmon into virtually independent northern and southern runs, as mentioned in the historical review above, has been valuable to fishery management because it permits regulation of the pink salmon fishery as two units. Since all experiments covered in this report were conducted in the northern part of southeastern Alaska, evidence of separation consists only of the lack of recoveries in the commercial fishery operating in the southern part. Of 6,435 recoveries in known gear, only 102 (1.6%) were recovered in Sumner Strait, which forms the northern boundary of the southern part of southeastern Alaska. Only one tagged fish was recovered as far south as Clarence Strait (Fig. 1).

The recoveries in Sumner Strait are compared with total recoveries by known gear from all releases in Icy Strait and Chatham Strait in Table 6. The percentage of tagged fish recovered in Sumner Strait increased from Icy Strait southward and was highest for lower Chatham Strait. Only one fish from the releases in Salisbury Sound (Table 3) was recovered in Sumner Strait. These results indicate little transfer of fish from the northern part to the southern part of southeastern Alaska and thus agree with the conclusions of other investigators.

Migration Through Peril Strait

There are three possible channels through which pink salmon can enter the inner waters of northern southeastern Alaska from the ocean: Icy Strait, lower Chatham Strait, and Peril Strait (Fig. 2). Because Peril Strait was closed to fishing during the period of these experiments, no tag recoveries could be expected from that area. The yearly occurrence of major runs in Icy Strait and lower Chatham Strait is well known, but there is little information available concerning migration of pink salmon through Peril Strait.

In 1945, tagging experiments were conducted at the western entrance of Peril Strait in Salisbury Sound (Tables 3 to 5). In the first experiment (5 August), 635 pink salmon were tagged; in the second and third experiments (12 August), 722 were tagged. The 12 August experiments were combined because the release traps were only a few miles apart. Two types of tags, one bearing the single number 11 and the other the number 12, were used to identify fish released on 5 August. On 12 August, tags bearing the number 12

were again used and were distinguishable from those used on 5 August only by a hole punched in them. Tags with the number 13 were also released on 12 August. The original records for 1945 showed considerable confusion in differentiating between number 12 tags with and without the punched hole. Thus, number 12 tags recovered after 11 August could not be assigned to a single release.

A total of 456 (33.6%) of the tags were recovered; 41.6% of the total recoveries were made at the point of release. Four hundred and eight of the tags were recovered in Salisbury Sound, 12 in other inlets on the west coasts of Baranof and Chichagof islands, 1 in Sumner Strait, and 35 in Chatham Strait close to the east end of Peril Strait. No tags were recovered in Peril Strait or in spawning streams.

The 1945 experiments do not provide conclusive evidence on the extent of migration eastward through Peril Strait. The data indicate that most fish in Salisbury Sound in August remained there, but more experiments are necessary.

Only seven recoveries were made in Salisbury Sound of the 19,179 tagged fish released in inside waters during 1938-42. Six of the seven were released in Icy Strait and upper Chatham Strait. They may have traveled west through Icy Strait and then south along the west coast of Chichagof Island. The remaining recovery was released in lower Chatham Strait. The fact that none of the seven were released in middle Chatham Strait suggests that there is no major migration westward through Peril Strait.

Distribution of Trap Recoveries from Experiments in Icy Strait and Chatham Strait

The number and percent of recoveries by statistical area for each experiment are listed in Tables 7 to 10 and illustrated in Figures 4 to 15. These figures were constructed as follows: A line was drawn along the center of the channel starting at the tagging station and extending through the main waterways in northern southeastern Alaska. The line was subdivided into 20-mile intervals in both directions from the tagging station which was taken as the zero point. The number of recoveries per trap in each interval was calculated by alternating 3- and 4-day periods for 2 wk after the release; Sundays (when the fishery was closed) were usually included in the 4-day periods. Thus, each period included about 2¾ days of fishing. The number of tags recovered after the first 2 wk was small. The lines in Figures 4 to 15 connect the points representing average numbers of recoveries per trap per time period plotted at the centers of the 20-mile intervals. Abbreviations used in Figures 4 to 15 are: IS—Icy Strait; CS—upper and middle Chatham Strait; FS—Frederick Sound; SP—Stephens Passage; and LCS—lower Chatham Strait.

In general, the experiments indicated that pink salmon entered the inner waters through Icy Strait and lower Chatham Strait and then spread eastward to Frederick Sound and north into Stephens Passage. For most experiments, fish continued to be recaptured in or near the trap from which they were released until the end of the season. Although the movements of the centers of maximum density for most groups of tagged fish appeared to be directional, these directed movements were accompanied by a wide dispersion of smaller numbers of tags throughout the entire northern portion of southeastern Alaska.

Icy Strait.—Six experiments were conducted in Icy Strait in 1941 (Fig. 4, Table 7) and three in 1942 (Fig. 5, Table 7).

The recoveries from Icy Strait releases in 1941 indicated no clear-cut differences in distribution between the six experiments conducted during July and August. Recoveries of tagged fish in Icy Strait from releases in early August were restricted by the closure of fishing about 8 August. By the third day after release tagged fish from Icy Strait were spread throughout middle Chatham Strait. While some moved rapidly others lagged behind, with the result that the fish were distributed along the entire route traversed. Usually the center of density of the tagged population was found in middle Chatham Strait during the second half of the first week (days out 4-6, Fig. 4). Although the tagged fish appeared to delay at the entrance to Frederick Sound, by the first part of the second week they were well distributed throughout Frederick Sound and lower Stephens Passage. During the third and fourth weeks after release it was usually difficult to recognize any center of density for one of the tagged populations.

There was little migration into lower Chatham Strait of the fish released in Icy Strait in either 1941 or 1942; 1.04% of all releases in 1941 and 0.07% of those in 1942 were recovered in lower Chatham Strait.

There were some striking differences between the movements of the tagged groups in 1941 and 1942. These differences may indicate a difference in the racial composition of the even-year and odd-year stocks in Icy Strait. Tagged pink salmon released in 1942 (Table 7) did not move to the east and south as rapidly as those released in 1941. The proportion ultimately destined for Frederick Sound or Stephens Passage seemed to be less in 1942 than in 1941. This difference is especially large for the release made on 18 July 1942, as compared with the three July releases in 1941. Recoveries in Icy Strait from the July release in 1942 were slightly greater than from the July releases in 1941, but the percentage of recoveries in waters to the south and east in 1942 was markedly reduced. Total percentages recovered for the August releases in the 2 yr were similar; the 1942 experiments showed proportionately more fish recovered in Icy Strait and

Table 5.--Summary of release and recovery information from tagging conducted in southeastern Alaska during 1938-42 and 1945. (See Figure 3 for location of traps where tags were released.)

Trap number and release date	Total releases	Total recoveries	Percent recoveries	No. recoveries in known gear	Percent recoveries in			Days out for recoveries in				Miles traveled for recoveries in traps	
								Traps		Seines			
					Traps	Seines	Other	Mean	Variance	Mean	Variance	Mean	Variance
Icy Strait													
IS-34													
12 Aug. 1941	520	217	41.7	210	87.6	12.0	0.4	7.9	31.3	9.3	57.5	74.9	2,548
19 Aug. 1941	475	235	49.5	230	87.2	11.9	0.9	6.3	22.9	6.1	13.0	70.6	2,250
26 Aug. 1941	602	290	48.2	277	85.5	13.5	1.0	7.5	28.8	9.7	34.5	76.5	2,067
2 Sept. 1941	500	177	35.4	166	80.8	18.6	0.6	7.8	24.9	8.1	24.1	93.0	2,138
5 Sept. 1941	500	141	28.2	131	73.1	25.5	1.4	6.7	19.3	6.9	17.8	83.7	2,159
IS-26													
7 Sept. 1941	300	114	38.0	96	80.7	17.5	1.8	6.4	15.1	4.9	11.2	87.2	1,250
IS-34													
18 Aug. 1942	485	176	36.3	176	77.3	21.0	1.7	8.6	44.1	7.6	35.1	46.0	818
2 Sept. 1942	495	160	32.3	160	78.8	20.0	1.2	7.3	24.2	6.1	54.2	44.1	810
IS-24													
9 Sept. 1942	496	174	35.1	174	92.0	8.0	0.0	5.2	12.3	5.5	18.5	34.6	759
Upper Chatham Strait													
WE-36													
13 Sept. 1940	500	150	30.0	150	85.3	14.7	0.0	2.1	3.0	2.9	6.8	24.9	1,498
WE-25													
13 Sept. 1940	500	127	25.4	120	77.2	22.1	0.7	2.8	3.7	4.5	6.8	38.2	--
WE-24													
13 Aug. 1941	375	116	30.9	116	87.9	12.1	0.0	6.8	29.6	10.5	98.8	56.2	--
19 Aug. 1941	74	25	33.8	24	83.3	16.7	0.0	6.4	23.9	9.9	86.8	26.8	--
26 Aug. 1941	500	257	51.4	247	89.5	10.5	0.0	6.7	27.7	6.9	20.7	55.1	--
2 Sept. 1941	500	172	34.4	161	82.0	15.7	2.3	6.5	16.3	10.4	33.7	52.0	--
9 Sept. 1941	300	101	33.7	90	79.0	17.0	4.0	5.8	8.6	10.7	86.2	46.8	--
25 Aug. 1942	250	85	34.0	84	96.5	2.3	1.2	10.2	50.4	--	--	16.8	--
2 Sept. 1942	249	86	34.5	85	87.2	11.6	1.2	7.6	31.4	--	--	14.7	--
WE-32													
9 Sept. 1942	498	171	34.3	171	96.5	2.9	0.6	5.1	14.6	--	--	24.6	853
16 Sept. 1942	499	157	31.5	157	93.0	7.0	0.0	2.7	2.2	--	--	17.1	338
WE-24													
18 Sept. 1942	499	88	17.6	88	90.9	8.0	1.1	2.0	1.7	--	--	28.3	--
WE-43													
18 Sept. 1942	321	113	35.2	96	--	--	--	--	--	--	--	--	--
Middle Chatham Strait													
WE-69													
12 Sept. 1940	999	322	32.2	320	84.5	13.0	2.5	4.2	3.0	5.6	11.6	32.5	--
16 Sept. 1940	400	69	17.3	68	79.7	18.8	1.5	2.3	1.8	4.0	3.8	38.3	--
WE-65													
13 Aug. 1941	150	59	39.3	59	89.8	10.2	0.0	5.3	12.2	--	--	35.1	--
WE-69													
20 Aug. 1941	424	223	52.6	223	89.7	9.9	0.4	4.4	18.9	10.4	33.7	35.2	--

Table 5.--Summary of release and recovery information from tagging conducted in southeastern Alaska during 1938-42 and 1945. (See Figure 3 for location of traps where tags were released.)--Continued.

Trap number and release date	Total releases	Total recoveries	Percent recoveries	No. recoveries in known gear	Percent recoveries in			Days out for recoveries in				Miles traveled for recoveries in traps	
					Traps	Seines	Other	Traps Mean	Traps Variance	Seines Mean	Seines Variance	Mean	Variance
27 Aug. 1941	500	251	50.2	251	90.8	9.2	0.0	6.1	33.6	10.7	86.2	36.9	--
3 Sept. 1941	500	194	38.8	193	87.1	12.4	0.5	5.3	10.6	6.9	12.7	32.5	--
10 Sept. 1941	300	107	35.7	107	84.1	15.9	0.0	5.6	9.0	7.3	5.4	31.6	--
17 Sept. 1941	400	135	33.8	135	86.7	13.3	0.0	3.0	1.1	3.0	0.8	30.4	--
11 Sept. 1942	177	67	37.9	67	82.1	17.9	0.0	4.3	7.8	--	--	31.8	--
15 Sept. 1942	496	168	33.9	168	97.6	2.4	0.0	3.5	4.4	--	--	23.0	--
	Lower Chatham Strait												
EA-45													
7 Aug. 1938	325	61	18.8	59	91.8	4.9	3.2	7.1	59.9	--	--	14.0	404
8 Aug. 1938	174	27	15.5	27	96.3	3.7	0.0	6.2	52.4	--	--	25.4	918
14 Aug. 1938	100	18	18.0	18	94.4	5.6	0.0	10.6	59.6	--	--	38.4	899
15 Aug. 1938	100	19	19.0	19	94.7	5.3	0.0	16.2	94.3	--	--	63.8	659
23 Aug. 1938	100	24	24.0	24	91.7	8.3	0.0	6.5	34.8	--	--	53.4	783
26 Aug. 1938	71	25	35.2	25	96.0	4.0	0.0	5.8	35.6	--	--	30.9	796
6 Sept. 1938	375	120	32.0	120	80.8	19.2	0.0	6.2	13.2	8.2	11.5	31.2	788
EA-46													
8 Sept. 1938	124	55	44.4	54	80.0	18.2	1.8	3.8	6.2	6.0	3.3	13.6	244
EA-45													
9 Sept. 1938	350	168	48.0	167	82.7	16.7	0.6	3.6	4.7	6.0	8.3	19.7	340
12 Sept. 1938	375	125	33.3	125	74.4	25.6	0.0	3.5	3.8	4.3	4.2	18.1	608
EA-46													
11 Aug. 1939	75	17	22.7	17	82.4	17.6	0.0	10.8	41.7	--	--	47.5	511
EA-45													
16 Aug. 1939	425	131	30.8	129	93.1	5.3	1.5	7.4	39.5	--	--	59.8	314
EA-46													
23 Aug. 1939	115	22	19.1	22	72.7	27.3	0.0	5.6	22.7	--	--	37.0	431
EA-45													
4 Sept. 1939	385	125	32.5	125	81.6	18.4	0.0	5.4	13.5	6.1	9.9	46.4	507
5 Sept. 1939	125	47	37.6	46	76.6	21.3	2.1	7.2	21.1	9.1	12.1	43.2	753
EA-46													
6 Sept. 1939	475	154	32.4	154	78.6	21.4	0.0	5.4	16.6	8.8	10.3	30.2	820
EA-45													
13 Sept. 1939	500	190	38.0	186	73.2	24.7	2.1	3.8	3.1	4.2	1.1	20.6	737
10 Sept. 1941	300	74	24.7	74	90.5	9.5	0.0	4.6	8.5	--	--	41.3	370
16 Sept. 1941	400	66	16.5	65	86.4	12.1	1.5	3.8	1.0	--	--	32.7	217
13 Sept. 1942	497	176	35.4	176	88.7	11.3	0.0	5.9	5.3	6.9	12.6	44.0	607
WE-11.3	Salisbury Sound												
5 Sept. 1945	635	219	34.5	140	3.8	62.2	34.0	--	--	5.7	20.6	--	--
We-11.2													
12 Sept. 1945	722	237	32.8	94	4.1	39.2	56.7	--	--	4.3	12.2	--	--

Table 6.--Comparison between recoveries in Sumner Strait and total recoveries (grouped by release area and month), July and August, 1938-42 and 1945.

Release area and month	Total recoveries[1/]	Sumner Strait recoveries	Percent recoveries in Sumner Strait
Icy Strait			
July	893	2	0.22
August	727	2	0.27
Upper Chatham Strait			
July	471	1	0.21
August	1,114	8	0.72
Middle Chatham Strait			
July	533	9	1.69
August	1,053	25	2.37
Lower Chatham Strait			
July	344	21	6.10
August	1,300	34	2.62
All area combined			
July	2,241	33	1.47
August	4,194	69	1.64
Total	6,435	102	1.59

[1/] Total recoveries include only recoveries in known type of gear and with a known recovery location.

upper Chatham Strait. A direct comparison is difficult, however, because of the proximity of the release dates to the closing dates for the season.

In summary, it appears that although fish tagged in Icy Strait were recovered throughout the fishing grounds in southeastern Alaska, the prevailing movement was eastward through Icy Strait, southward into Chatham Strait, and then eastward into Frederick Sound and Stephens Passage (Figs. 4, 5). Superimposed on this basic directed movement was a prominent nondirected or random type of movement. The proportion of Icy Strait fish going into Lynn Canal and lower Chatham Strait does not appear to be significant. A large percentage of the fish tagged in Icy Strait in 1941 moved very rapidly through Icy Strait into the middle Chatham Strait area.

Upper Chatham Strait.—Tagging experiments were conducted in upper Chatham Strait in 1940, 1941, and 1942.

Two releases were made in 1 day (13 August) in 1940 (Fig. 6, Table 8). One release was at trap WE-36 on the east side of upper Chatham Strait and the other at trap WE-25 on the west side. The fishery in Icy Strait had already closed by 13 August and there were only 6 days remaining until the end of the season in Chatham Strait. The distributions of recoveries from the two releases did not differ greatly. Most recoveries were made in Chatham Strait near the tagging trap; however, by the second half of the first week after release, the tagged fish had scattered throughout Frederick Sound and Stephens Passage. The bulk of the recoveries of the group released from WE-36 was made within a 9-mile radius of the tagging trap (Fig. 6). Aside from the relatively large numbers recovered in the immediate vicinities of the release points, most of the remaining tagged fish moved rapidly to the south and then east into Frederick Sound. Only one tag of the total recoveries from both releases was from lower Chatham Strait.

Data from four releases in upper Chatham Strait in 1941 are shown in Figure 7 and Table 8. In addition, data from one experiment in 1941 (19 July) with fewer than 50 recoveries are included in Table 10.

The general movement of fish tagged and released in upper Chatham Strait in 1941 resembled that of the fish tagged in eastern Icy Strait in 1941. A few tagged

Figure 4.—Tag recoveries per trap by 20-mile intervals measured from points of release in Icy Strait, 1941-42. The average number of recoveries per trap per time period are plotted at the centers of the 20-mile intervals.

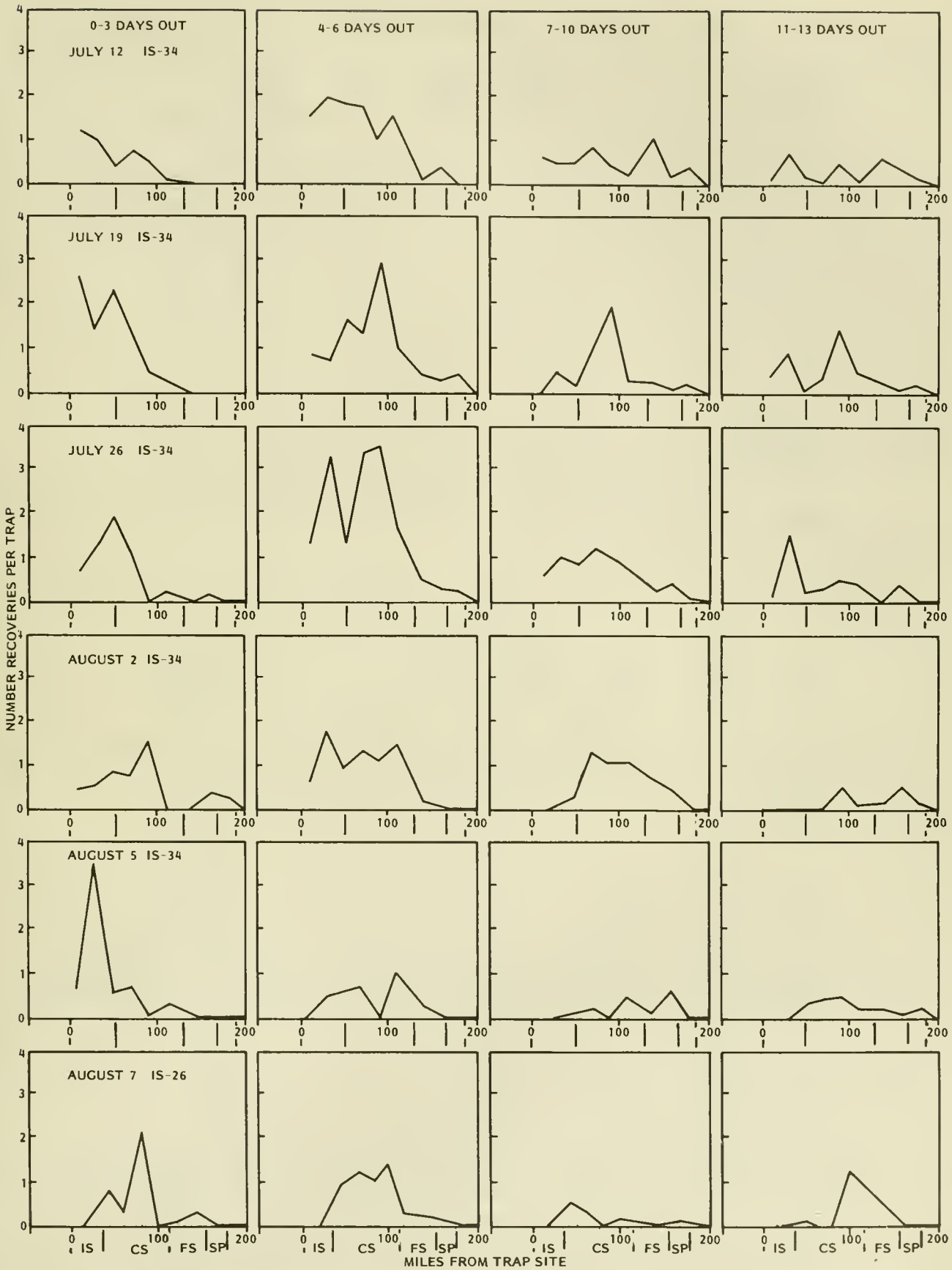
0-3 DAYS OUT
4-6 DAYS OUT
7-10 DAYS OUT
11-13 DAYS OUT
JULY 12 IS-34
JULY 19 IS-34
JULY 26 IS-34
AUGUST 2 IS-34
AUGUST 5 IS-34
AUGUST 7 IS-26
NUMBER RECOVERIES PER TRAP
MILES FROM TRAP SITE
IS
CS
FS
SP

Table 7.--Recovery areas of tags released from traps in Icy Strait, 1941-42.

Year and date of release (trap number in parentheses)	No. releases	Icy Strait		Upper and Middle Chatham Strait		Lower Chatham Strait		Frederick Sound		Sumner Strait		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1941													
12 July (IS-34)	520	63	12.1	90	17.3	6	1.2	30	5.8	1	0.2	190	36.5
19 July (IS-34)	475	70	14.7	107	22.5	6	1.3	22	4.6	0	0.0	205	43.2
26 July (IS-34)	602	70	11.6	138	22.9	5	0.8	35	5.8	0	0.0	248	41.2
2 Aug. (IS-34)	500	23	4.6	84	16.8	4	0.8	31	6.2	1	0.2	143	28.6
5 Aug. (IS-34)	500	22	4.4	59	11.8	3	0.6	18	3.6	0	0.0	102	20.4
7 Aug. (IS-26)	300	0	0.0	62	20.7	5	1.7	21	7.0	0	0.0	88	29.3
Total	2,897	248	8.6	540	18.6	29	1.0	157	5.4	2	0.1	976	33.7
1942													
18 July (IS-34)	485	81	16.7	52	10.7	0	0.0	3	0.6	0	0.0	136	28.0
2 Aug. (IS-34)	495	77	15.6	47	9.5	0	0.0	2	0.4	0	0.0	126	25.4
9 Aug. (IS-24)	496	17	3.4	130	26.2	1	0.2	12	2.4	0	0.0	160	32.3
Total	1,476	175	11.9	229	15.5	1	0.1	17	1.2	0	0.0	422	28.6

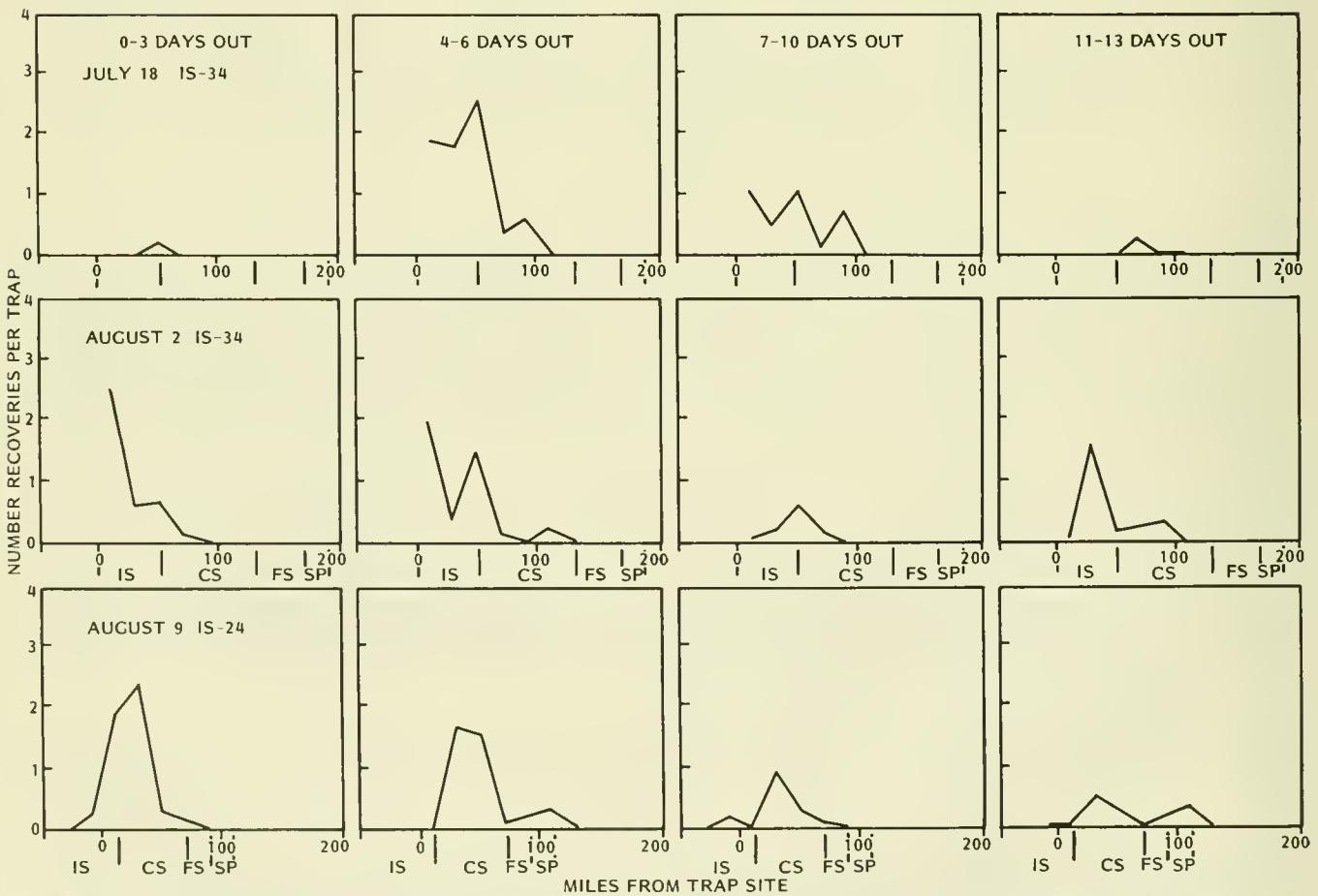

Figure 5.—Tag recoveries per trap by 20-mile intervals measured from points of release in Icy Strait, 1942. The average number of recoveries per trap per time period are plotted at the centers of the 20-mile intervals.

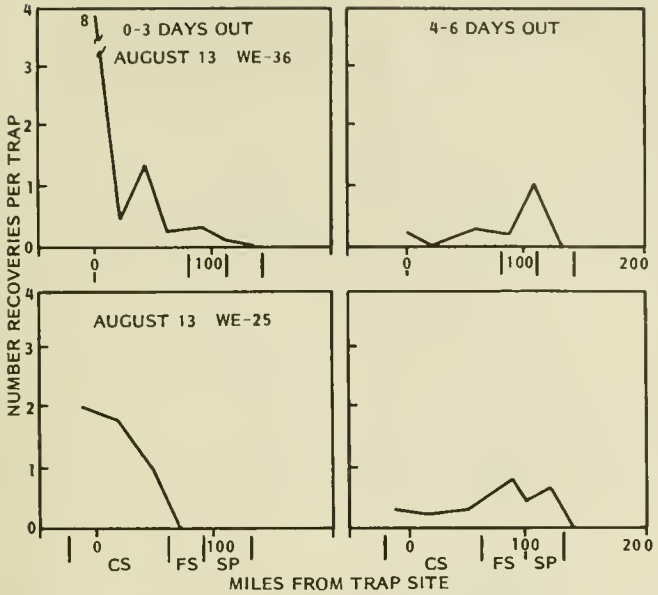

Figure 6.—Tag recoveries per trap per time period by 20-mile intervals measured from the point of release in upper Chatham Strait, 1940.

fish from both the July and August releases in upper Chatham Strait were recovered to the northwest of the point of release in northern Chatham Strait and in Icy Strait, but most tags were recovered in middle Chatham Strait and in Frederick Sound. For all of the 1941 releases except the last one on 9 August, the center of density of the tagged population moved rapidly to the middle Chatham Strait area and remained there for the first 1½ wk after release (Fig. 7). For the 9 August release the center of maximum density shifted from middle Chatham Strait to Frederick Sound at the beginning of the second week. There was a minor movement of tagged fish into lower Chatham Strait in 1941. The major movement, however, was clearly eastward into Frederick Sound from middle Chatham Strait. Most of the recoveries were made in Chatham Strait during the first week after release. Of course, the usual trickle of scattered recoveries continued until the end of the fishing season. The recovery percentage of 46% from the 26 July release was unusually high and was the result of unusually high recovery percentages in both Chatham Strait and Frederick Sound.

Six releases were made in upper Chatham Strait in 1942, all quite late in the season (Fig. 8, Table 8). The

Table 8.--Recovery areas of tags released from traps in Upper Chatham Strait, 1940-42.

Year and date of release (trap number in parentheses)	No. releases	Recoveries in: Icy Strait No.	Icy Strait %	Upper and Middle Chatham Strait No.	Upper and Middle Chatham Strait %	Lower Chatham Strait No.	Lower Chatham Strait %	Frederick Sound No.	Frederick Sound %	Sumner Strait No.	Sumner Strait %	Total No.	Total %
1940													
13 Aug. (WE-36)	500	0	0.0	109	21.8	1	0.2	18	3.6	0	0.0	128	25.6
13 Aug. (WE-25)	500	0	0.0	77	15.4	0	0.0	21	4.2	0	0.0	98	19.6
Total	1,000	0	0.0	186	18.6	1	0.1	39	3.9	0	0.0	226	22.6
1941													
13 July (WE-24)	375	13	3.5	46	12.3	9	2.4	34	9.1	0	0.0	102	27.2
19 July (WE-24)	74	5	6.8	15	20.3	0	0.0	1	1.4	0	0.0	21	28.4
26 July (WE-24)	500	14	2.8	146	29.2	10	2.0	60	12.0	0	0.0	230	46.0
2 Aug. (WE-24)	500	9	1.8	94	18.8	3	0.6	33	6.6	1	0.2	140	28.0
9 Aug. (WE-24)	300	0	0.0	57	19.0	1	0.3	19	6.3	0	0.0	77	25.7
Total	1,749	41	2.3	358	20.5	23	1.3	147	8.4	1	0.1	570	32.6
1942													
25 July (WE-24)	250	21	8.4	56	22.4	0	0.0	5	2.0	0	0.0	82	32.8
2 Aug. (WE-24)	249	12	4.8	59	23.7	0	0.0	4	1.6	0	0.0	75	30.1
9 Aug. (WE-32)	498	18	3.6	134	26.9	0	0.0	13	2.6	0	0.0	165	33.1
16 Aug. (WE-32)	499	0	0.0	143	28.7	1	0.2	2	0.4	0	0.0	146	29.3
18 Aug. (WE-24)	499	0	0.0	71	14.2	1	0.2	8	1.6	0	0.0	80	16.0
18 Aug. (WE-43)	321	0	0.0	71	22.1	0	0.0	2	0.6	0	0.0	73	22.7
Total	2,316	51	2.2	534	23.1	2	0.1	34	1.5	0	0.0	621	26.8

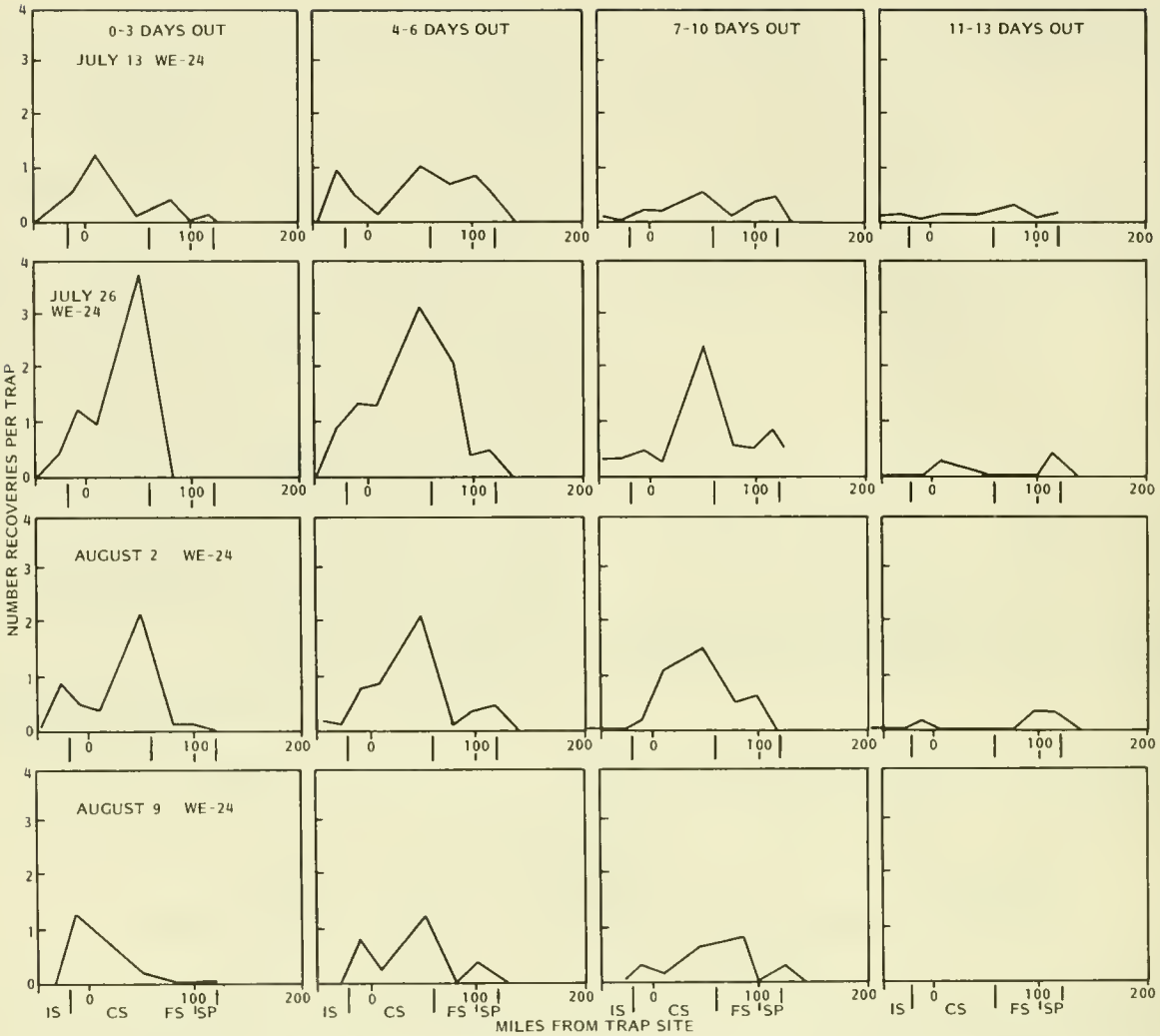

Figure 7.—Tag recoveries per trap by 20-mile intervals measured from the point of release in upper Chatham Strait, 1941.

first release was on 25 July and the last on 18 August. The distributions of recoveries from all releases indicate extensive milling of pink salmon in the eastern end of Icy Strait and throughout upper and middle Chatham Strait. The type of movement observed in 1942 is in direct contrast to that observed in 1941, when the fish moved rapidly to the south.

For the earlier experiments in 1942 the center of density remained at the tagging station and there was a slow diffusion in both directions. In the later releases the closure of the fishing season in Icy Strait restricted recoveries there. Nevertheless there was only a slight shift of the center of density of the tags to the south of the release point. Although there was some movement of tagged fish into Frederick Sound from releases in August, this movement was of a secondary nature. The 1942 experiments did not show any clear progression of centers of concentration to the south and east in successive recovery periods as did the 1941 experiments.

Recoveries from the two experiments on opposite sides of the channel on 18 August 1942 indicate that fish tagged in the northwestern part of upper Chatham Strait (at trap WE-24) had ceased moving rapidly and were probably milling about near the spawning streams, whereas a large pecentage of those tagged to the south on the eastern shore (at trap WE-43) were still moving actively through Chatham Strait headed for the inner waters of Frederick Sound and Stephens Passage.

In summary, the results of the tagging experiments conducted in upper Chatham Strait supported the general movement patterns hypothesized above on the basis of releases made in Icy Strait. In 1941, and to a lesser extent in 1940, fish tagged in upper Chatham Strait moved rapidly southward in Chatham Strait and then dispersed into Frederick Sound. The most dense concentrations of tagged fish remained in the middle Chatham Strait area for the first 1½ wk after release. In 1942, however, the fish tagged in upper

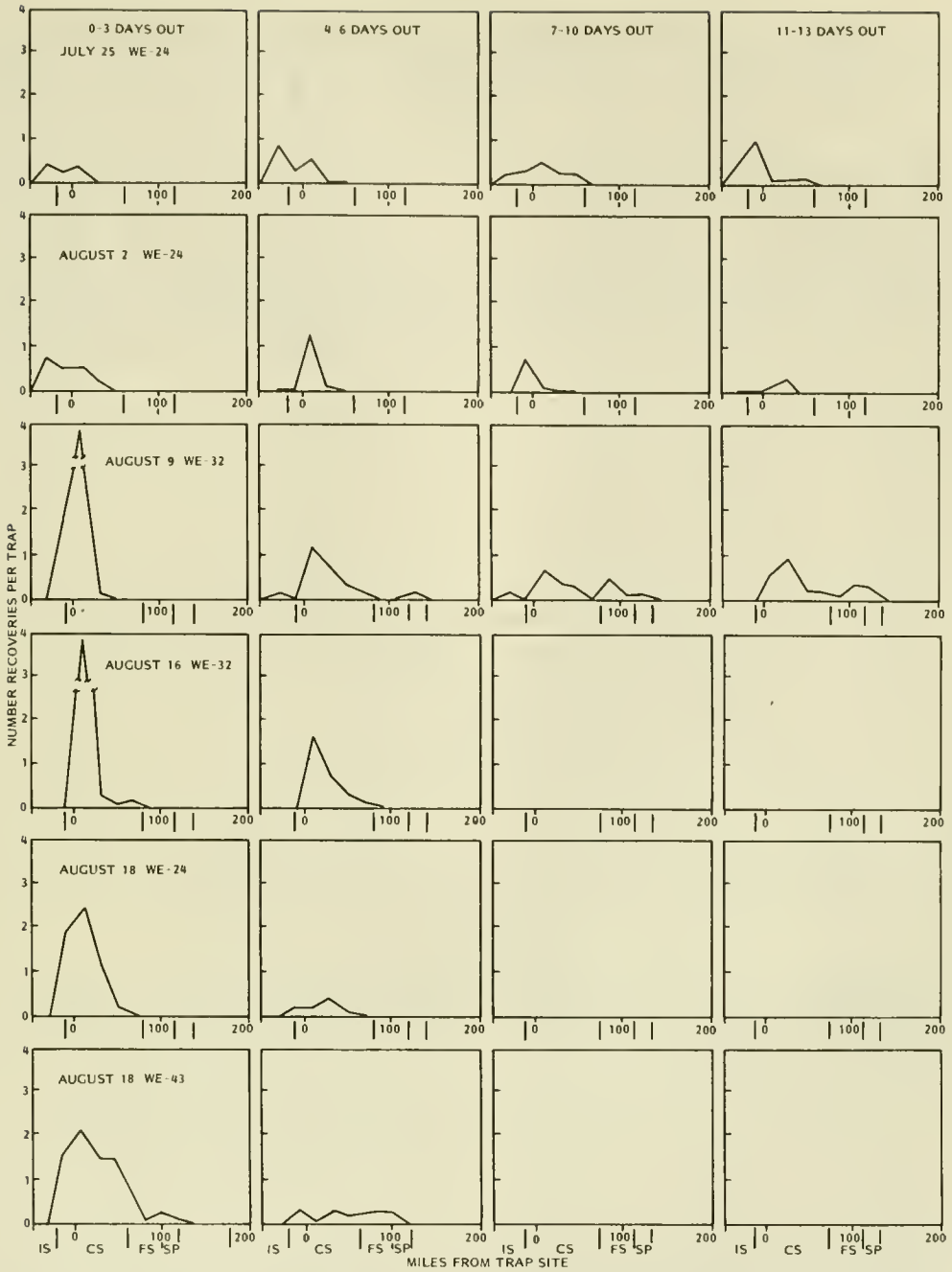

Figure 8.—Tag recoveries per trap per time period by 20-mile intervals measured from the point of release in upper Chatham Strait, 1942.

Chatham Strait exhibited a much stronger tendency to linger in the upper Chatham Strait area and a much weaker tendency to migrate southward and eastward. There appears to be considerable variability from year to year in the racial composition of the pink salmon runs found in upper Chatham Strait in the months of July and August.

Middle Chatham Strait.—Two tagging experiments were conducted in middle Chatham Strait in 1940, six in 1941, and two in 1942. All releases of tagged fish, with the exception of that on 13 July 1941, were made from trap WE-69 within 15 miles of the junction of Chatham Strait and Frederick Sound. The exception was from trap WE-65, 4 miles north of the site of the other releases.

Results from the two 1940 experiments are shown in Figure 9 and Table 9. The first release (12 August) involved 999 tagged fish, and thus constituted the largest single release of the experiments covered in

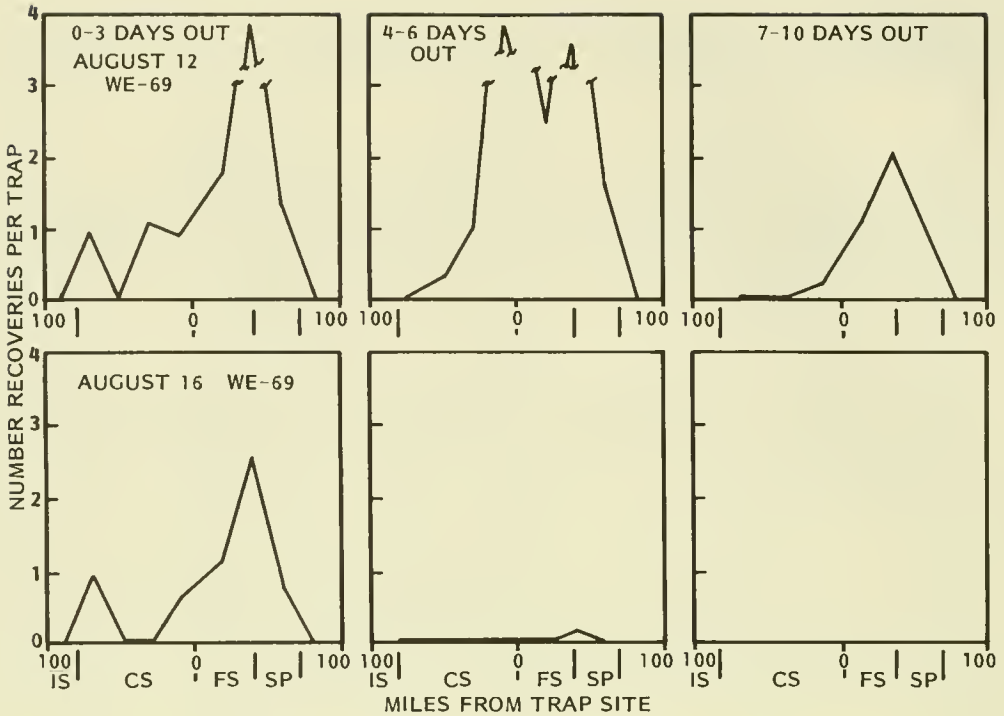

Figure 9.—Tag recoveries per trap per time period by 20-mile intervals measured from the point of release in middle Chatham Strait, 1940.

Table 9.--Recovery areas of tags released from traps in Middle Chatham Strait, 1940-42.

Year and date of release (trap number in parentheses)	No. releases	Recoveries in: Icy Strait No.	Icy Strait %	Upper and Middle Chatham Strait No.	Upper and Middle Chatham Strait %	Lower Chatham Strait No.	Lower Chatham Strait %	Frederick Sound No.	Frederick Sound %	Sumner Strait No.	Sumner Strait %	Total No.	Total %
1940													
12 Aug. (WE-69)	999	0	0.0	86	8.6	8	0.8	178	17.8	0	0.0	272	27.2
16 Aug. (WE-69)	400	0	0.0	14	3.5	2	0.5	39	9.8	0	0.0	55	13.8
Total	1,399	0	0.0	100	7.1	10	0.7	217	15.5	0	0.0	327	23.4
1941													
13 July (WE-65)	150	1	0.7	7	4.7	11	7.3	34	22.7	0	0.0	53	35.3
20 July (WE-69)	424	4	0.9	30	7.1	26	6.1	140	33.0	0	0.0	200	47.2
27 July (WE-69)	500	3	0.6	74	14.8	9	1.8	137	27.4	5	1.0	228	45.6
3 Aug. (WE-69)	500	0	0.0	38	7.6	4	0.8	127	25.4	0	0.0	169	33.8
10 Aug. (WE-69)	300	0	0.0	16	5.3	7	2.3	67	22.3	0	0.0	90	30.0
17 Aug. (WE-69)	400	0	0.0	8	2.0	5	1.3	102	25.5	2	0.5	117	29.3
Total	2,274	8	0.4	173	7.6	62	2.7	607	26.7	7	0.3	857	37.7
1942													
11 Aug. (WE-69)	177	0	0.0	24	13.6	2	1.1	28	15.8	0	0.0	54	30.5
15 Aug. (WE-69)	496	0	0.0	81	16.3	0	0.0	74	14.9	0	0.0	155	31.3
Total	673	0	0.0	105	15.6	2	0.3	102	15.2	0	0.0	209	31.1

this report. For the second experiment (16 August), only 13.8% of the tags were recovered because it was close to the end of the fishing season. The most prominent feature of the recoveries from both of these releases was the rapid movement of a large proportion of the tagged fish into Frederick Sound; 66.4% of the total recoveries from both releases were made in Frederick Sound. Less than 1% were made in lower Chatham Strait. Although there was some dispersion northward into middle Chatham Strait, few tagged fish traveled as far north as upper Chatham Strait. It appears that most fish in the vicinity of trap WE-69 in August were en route to streams in Frederick Sound and Stephens Passage.

The most noticeable feature of the distributions of recoveries from the six experiments in 1941 (Fig. 10, Table 9) is the uniformly high percentage returned from Frederick Sound—70.8%. In 1941 the movement of tagged pink salmon from middle Chatham Strait into Frederick Sound was even more rapid and more pronounced than in 1940. Only a negligible movement in the direction of Icy Strait was indicated. Recoveries in middle and upper Chatham Strait were not large, even though they were augmented by heavy recaptures in trap WE-67 just 2 miles from the point of release. Proportionately more of the tagged fish entered lower Chatham Strait in 1941 than in either 1940 or 1942. This was partly the result of the timing of the releases. Only in 1941 were releases made in July; recoveries in lower Chatham Strait from these July releases were higher than from the August releases in any of the 3 yr (Table 9). In 1941, 2.7% of the total recoveries from all six releases were made in lower Chatham Strait.

The geographical distributions of the recoveries from the two releases in 1942 in middle Chatham Strait were similar (Fig. 11, Table 9). The distribution of recoveries in 1942 differed markedly from those in 1940 and 1941. Tagged fish were recaptured in about equal numbers in Frederick Sound and in middle Chatham Strait. The 48.6% of the recoveries made in Frederick Sound are considerably lower than the 66.4% in 1940 and the 70.8% in 1941. Recoveries in lower Chatham Strait were scarce in 1942; only two tagged fish were reported from there. Recovery patterns for both experiments in 1942 were symmetrically distributed about the release point.

In summary, tagged fish released in middle Chatham Strait showed little movement into the lower Chatham Strait area. In 1941, and to a somewhat lesser extent in 1940, there was a strongly directed movement of tagged pink salmon from middle Chatham Strait into Frederick Sound and southern Stephens Passage. Fish tagged in 1942 did not exhibit a strongly directed movement but rather milled about in the general area of the release point in middle Chatham Strait, gradually dispersing both northward into Chatham Strait and eastward into Frederick Sound. The difference between the migratory behavior of fish tagged in 1942 and those tagged in 1940 and 1941 in middle Chatham Strait is exactly the same as observed for fish tagged in Icy Strait and upper Chatham Strait in these 3 yr.

Lower Chatham Strait.—There were 10 experiments in lower Chatham Strait in 1938, 7 in 1939, 2 in 1941, and 1 in 1942. Only four of the experiments in each year in 1938 and 1939 provided enough recoveries to give a coherent picture of the movement of the tagged fish. All of the releases in lower Chatham Strait were made from either trap EA-45 or trap EA-46 in Tebenkof Bay.

The results of the 1938 experiments (Fig. 12, Table 10) show that the tagged pink salmon were recaptured mainly in lower Chatham Strait—79.5% of the recoveries were made in the six traps along the west coast of Kuiu Island within 22 miles of the point of release. Of the combined recoveries from the four releases, 15.8% were made in Frederick Sound, 2.1% in middle Chatham Strait, and 2.6% in Sumner Strait.

Although the total percentage of recoveries from the 1939 experiments (Fig. 13, Table 10) remained remarkably constant from the first release on 16 July until the last on 13 August, the geographic distribution of the recoveries changed drastically between the first and last releases. The percentage recoveries returned from Frederick Sound were as follows: 91.8% for the 16 July release, 62.7% for 4 August, 33.1% for 6 August, and 16.5% for 13 August. And, as the percentage of recoveries taken in Frederick Sound decreased, the percentage taken in lower Chatham Strait increased (Table 10). The strong movement into Frederick Sound for the earlier releases in 1939 is in sharp contrast to the results obtained in 1938. Although the timing of the 1938 releases was similar to that of the 1939 releases, the relative numbers of recoveries made in Frederick Sound and Stephens Passage were consistently low for all of the 1938 experiments.

There was a minor movement of tagged pink salmon into middle Chatham Strait and into Sumner Strait in 1939; 6.4% of the recoveries were from middle Chatham Strait and 5.2% from Sumner Strait. For the last release in 1939, as in 1938, the fish showed a strong tendency to linger in Tebenkof Bay near the release trap.

The distribution of recoveries from the two tagging experiments in lower Chatham Strait in 1941 are shown in Figure 14 and Table 10. Releases were made on 10 and 16 August; the recoveries were restricted because it was close to the end of the fishing season. For both experiments the recoveries were apportioned in a similar manner between general recovery areas (Table 10): 62.4% of the pooled recoveries were from Frederick Sound, 32.0% from lower Chatham Strait, and 5.6% from upper and middle Chatham Strait. The center of density of the tagged fish released on 10

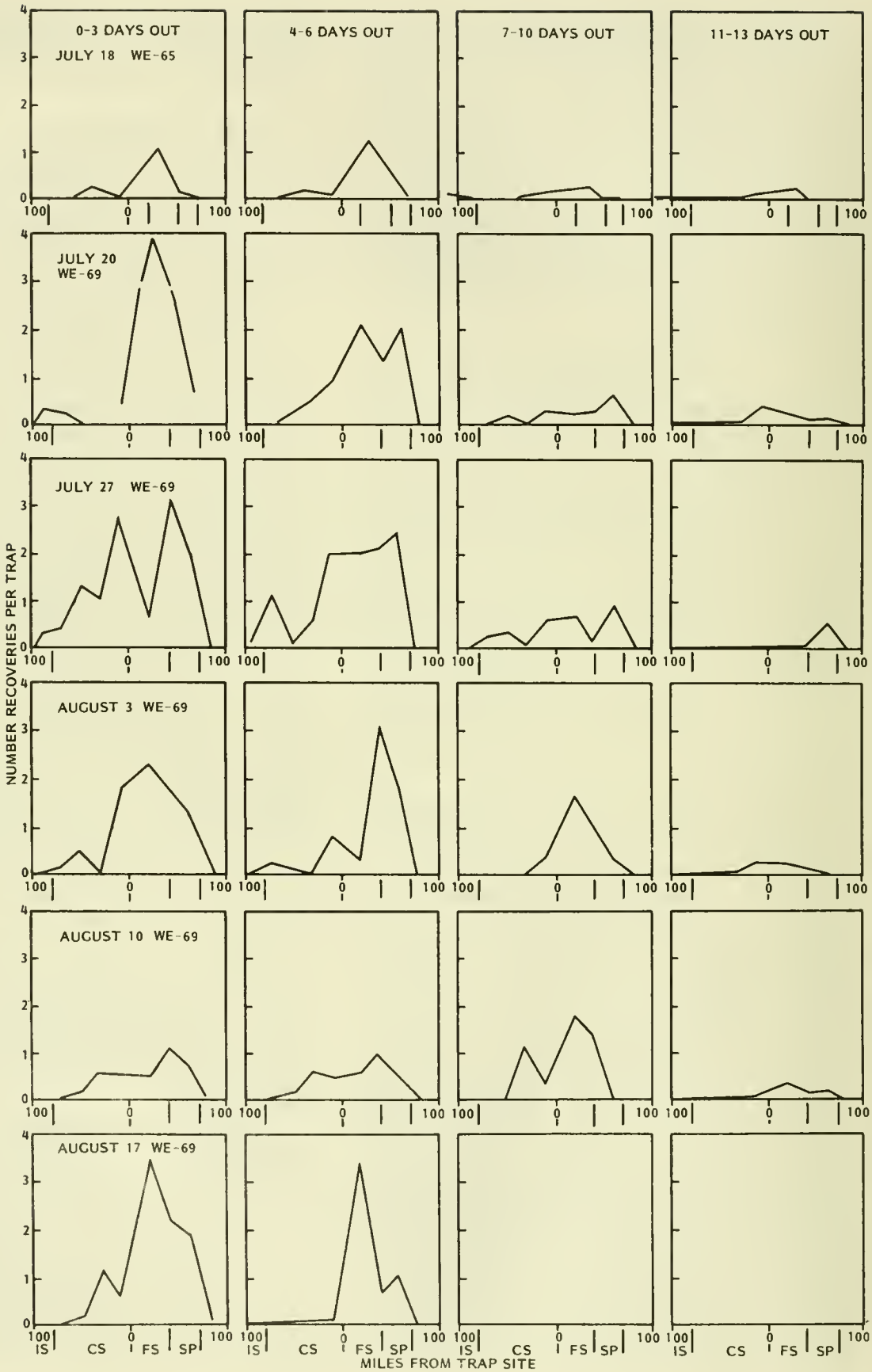

Figure 10. — Tag recoveries per trap per time period by 20-mile intervals measured from the point of release in middle Chatham Strait, 1941.

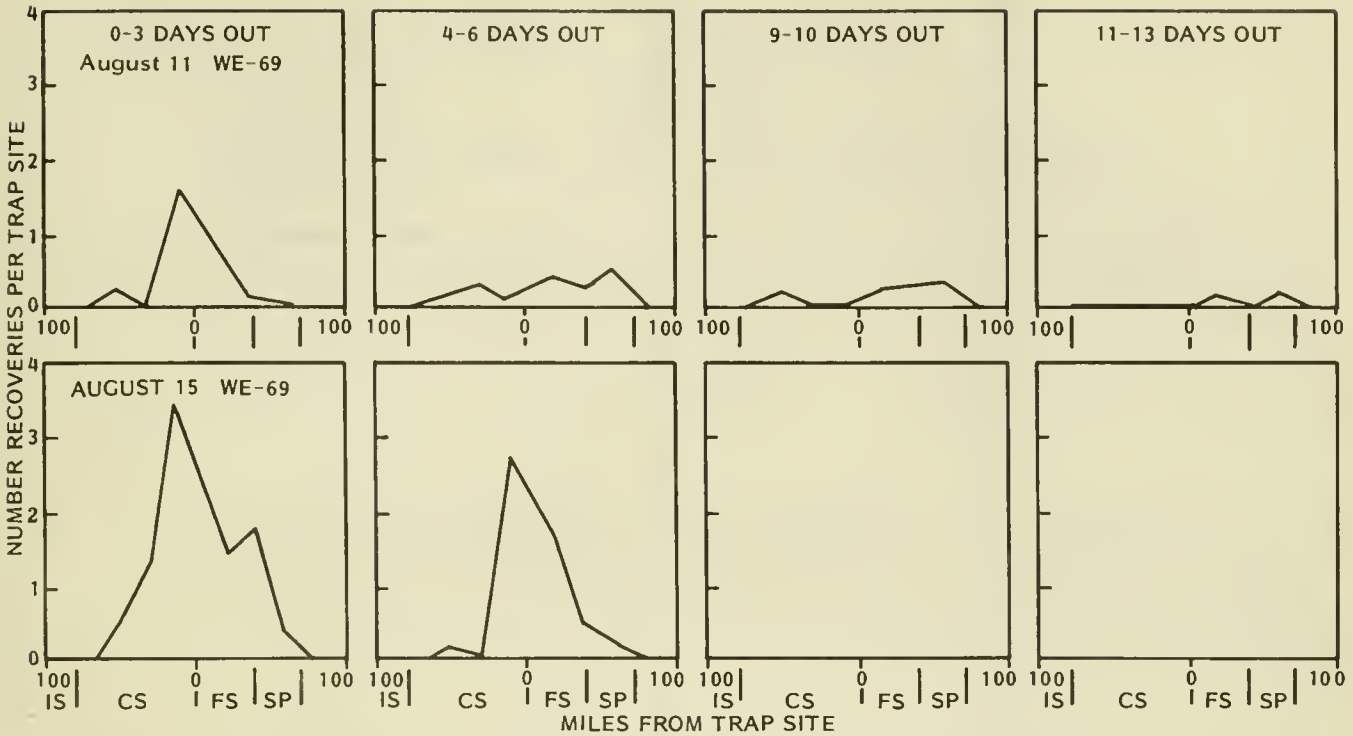

Figure 11.—Tag recoveries per trap per time period by 20-mile intervals measured from the point of release in middle Chatham Strait, 1942.

August had moved into Frederick Sound during the latter part of the first week and during the second week continued to drift eastward. Thus, in 1941 the migratory behavior of fish tagged during August in lower Chatham Strait was quite different from that of those tagged during August in 1938 and in 1939, when more of the fish remained near the tagging station instead of moving into Frederick Sound.

The infrequent recoveries in lower Chatham Strait from releases in Icy Strait and in upper and middle Chatham Strait in 1941, coupled with the sparse recoveries in the northern areas from releases in lower Chatham Strait, indicate that most of the fish moving through lower Chatham Strait in mid-August of 1941 were en route to streams in lower Chatham Strait, Frederick Sound, and Stephens Passage.

The results from the single release in lower Chatham Strait in 1942 are given in Figure 15 and Table 10. For 68 of the tags recovered from this experiment, only the date of recovery was given. The distribution of the recoveries for which the locations were known was similar to the distributions observed for the 1941 experiments except that relatively more tagged fish were recaptured in middle Chatham Strait. However, unless it is assumed that the 89 tags with known recovery locations constituted a representative sample of the recoveries, the movements indicated cannot be accepted without serious reservation.

Summary and Discussion of General Migration Patterns as Determined from Tag Recaptures

From each of the pink salmon tagging experiments a sequence of spatial distributions of tag recaptures per unit of effort during successive recovery periods was determined. The apparent migratory pattern generated by the recaptures from a single release may be described as the result of an interaction of two basic types of movement—one directional, the other random. The directional component is defined as a movement with complete spatial orientation, whereas the random component is a nondirected movement in which the fish disperse in all possible directions about a center of density. It is obvious, of course, that any particular geographical distribution of recoveries is affected by the distribution of recovery effort and also by the particular mixture of racial stocks represented in the population of tagged fish.

Verhoeven (see footnote 6) concluded that pink salmon migration consisted largely of a random to-and-fro movement. He was influenced by multiple recaptures of several fish tagged in the Ketchikan area of southeastern Alaska, and it is not possible to determine if the successive recapturing altered the natural migratory behavior of the fish. The experiments reported here neither confirm nor definitely refute Verhoeven's hypothesis of random to-and-fro movement. However, the results of these experiments do

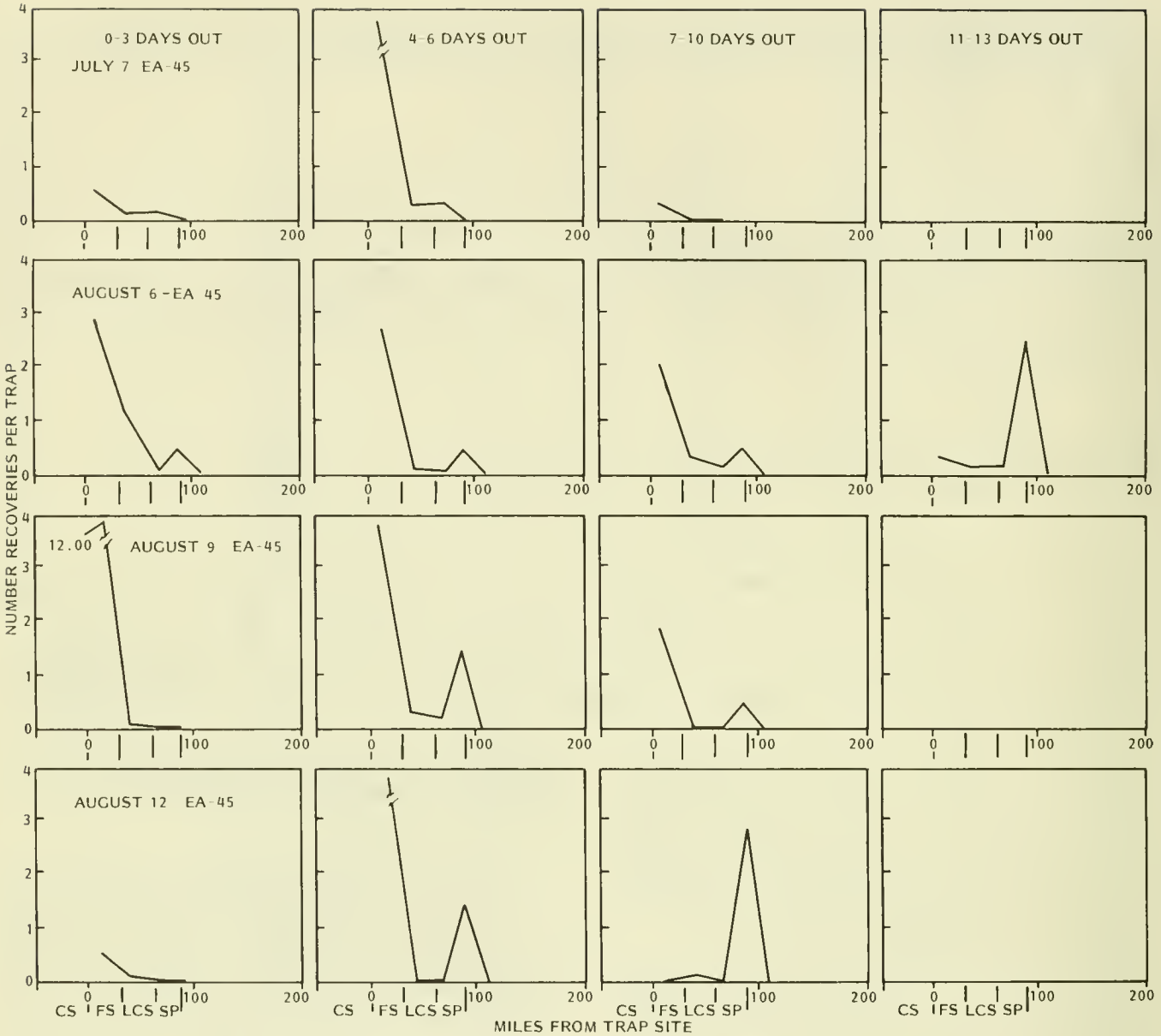

Figure 12.—Tag recoveries per trap per time period by 20-mile intervals measured from the point of release in lower Chatham Strait, 1938.

indicate that the movement of pink salmon can be more adequately described as consisting of a random and a directional component with the relative importance of the two components varying from year to year. In 1942 fish tagged in Icy Strait, upper Chatham Strait, and middle Chatham Strait distributed themselves as might have been predicted on the basis of the random to-and-fro hypothesis. In 1941 the movements of fish tagged at the same locations showed a much stronger directional component. These tagged fish migrated in large numbers to the Frederick Sound-Stephens Passage region. Thus, it appears that the particular mixture of racial stocks in a given sector of the fishing grounds varies greatly from year to year. There was some indication from these experiments that the random component of movement was relatively stronger in even years.

The apparent random component of the migration of pink salmon may be an inherent characteristic of this species, which spawns in a large number of widely dispersed streams. A different behavior might be expected for sockeye salmon, *Oncorhynchus nerka*, seeking one major spawning ground. The results of these experiments do not provide information on the cause of the random dispersion of tagged fish. This effect could be caused either by the erratic wanderings of tagged fish or could be the result of the superimposition of a great number of directional migrations

Table 10.--Recovery areas of tags released from traps in Lower Chatham Strait, 1938-39 and 1941-42.

Year and date of release (trap number in parentheses)	No. releases	Recoveries in: Icy Strait No.	%	Upper and Middle Chatham Strait No.	%	Lower Chatham Strait No.	%	Frederick Sound No.	%	Sumner Strait No.	%	Total No.	%
1938													
7 July (EA-45)	325	0	0.0	1	0.3	47	14.5	8	2.5	0	0.0	56	17.2
6 Aug. (EA-45)	375	0	0.0	4	1.1	55	14.7	30	8.0	8	2.1	97	25.9
9 Aug. (EA-45)	350	0	0.0	1	0.3	124	35.4	12	3.4	2	0.6	139	39.7
12 Aug. (EA-45)	375	0	0.0	2	0.5	80	21.3	11	2.9	0	0.0	93	24.8
Total	1,425	0	0.0	8	0.6	306	21.5	61	4.3	10	0.7	385	27.0
1939													
16 July (EA-45)	425	0	0.0	0	0.0	2	0.5	112	26.4	8	1.9	122	28.7
4 Aug. (EA-45)	385	0	0.0	12	3.1	19	4.9	64	16.6	7	1.8	102	26.5
6 Aug. (EA-46)	475	0	0.0	10	2.1	63	13.3	40	8.4	8	1.7	121	25.5
13 Aug. (EA-45)	500	0	0.0	9	1.8	105	21.0	23	4.6	2	0.4	139	27.8
Total	1,785	0	0.0	31	1.7	189	10.6	239	13.4	25	1.4	484	27.1
1941													
10 Aug. (EA-45)	300	0	0.0	6	2.0	20	6.7	41	13.7	0	0.0	67	22.3
16 Aug. (EA-45)	400	0	0.0	1	0.3	20	5.0	37	9.3	0	0.0	58	14.5
Total	700	0	0.0	7	1.0	40	5.7	78	11.1	0	0.0	125	17.9
1942													
13 Aug. (EA-45)	497	0	0.0	23	4.6	11	2.2	55	11.1	0	0.0	89[1]	17.9

[1] Does not include 68 tags which were recorded as trap recoveries and were accompanied by the dates of recovery but not the locations.

for tagged groups composed of a variety of racial stocks spawning in streams located in different directions from the point of release.

In spite of the considerable intraseasonal and interseasonal variability observed, the following salient features of these experiments are still of considerable interest for determining management policy for fisheries in southeastern Alaska.

1. Results of these experiments confirm the findings of other investigators showing the virtual separation for pink salmon management of southeastern Alaska into a northern and a southern part with Sumner Strait composing the northern boundary of the southern part.

2. The pink salmon stocks found in Icy Strait, upper Chatham Strait, and middle Chatham Strait appear to be fairly distinct from those found in lower Chatham Strait. There was only a limited exchange of fish between lower Chatham Strait and middle Chatham Strait. Fishing in Icy Strait, upper Chatham Strait, and middle Chatham Strait would not be expected to have a major effect on spawning escapements in the lower Chatham Strait area and correspondingly the fishery in lower Chatham Strait would not have a great effect on the stocks from middle Chatham Strait, upper Chatham Strait, and Icy Strait. Any effect would diminish with increasing distance moving northward from lower Chatham Strait.

3. Stocks spawning in the watersheds adjoining Frederick Sound and Stephens Passage use both Icy Strait and lower Chatham Strait as major passageways from the ocean. The numbers of fish reaching Frederick Sound and Stephens Passage would be influenced by the intensities of fishing along both of these routes of entry. The experiments reported here do not provide any information on the relative numbers of fish using these two routes of entry.

4. There was a strong intraseasonal trend in the movement patterns. It was generally observed that the earlier in the season the group was tagged, the larger was the proportion of fish destined for spawning grounds distant from the point of release. Usually fish tagged later in the season exhibited a more restricted range of movements about the point of release.

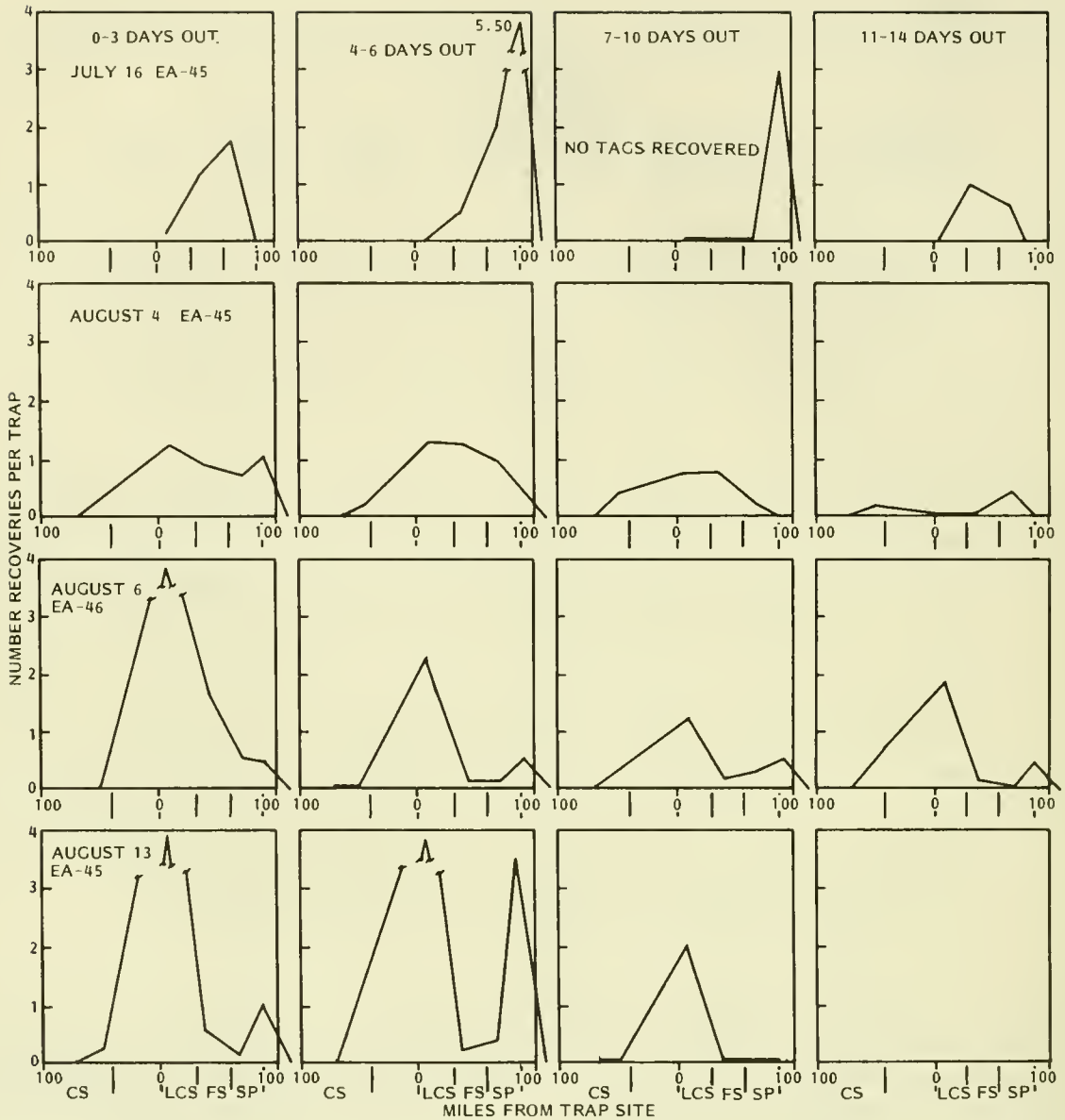

Figure 13.—Tag recoveries per trap per time period by 20-mile intervals measured from the point of release in lower Chatham Strait, 1939.

RELATIVE ABUNDANCE AND MIGRATION AS DETERMINED FROM TRAP CATCH DATA

Neither total trap catch nor catch per trap could be used to estimate the size of the pink salmon runs in the different years because in all years and in all areas the fishing season closed about the time of greatest abundance of fish. Thus, catch data did not measure the late parts of the runs. Furthermore, no information was available on seine catches or on escapement to spawning streams. Both total trap catch and catch per trap by statistical area are listed in Table 11. The number of traps used in the calculations was the number of traps for which weekly catches were known. The catch per trap and total catch in different years were not proportional; in particular, the largest catch was taken in 1941 when the fewest traps operated. The total catch was influenced more by the number of fish available than by the number of traps.

Both total catch and catch per trap show that the largest run was in 1941 and the smallest in 1945. Runs in 1938 and 1940 were approximately equal and were larger than the 1939 run but smaller than the 1942 run.

The catch data and tagging data are in general agreement with respect to the indicated paths of

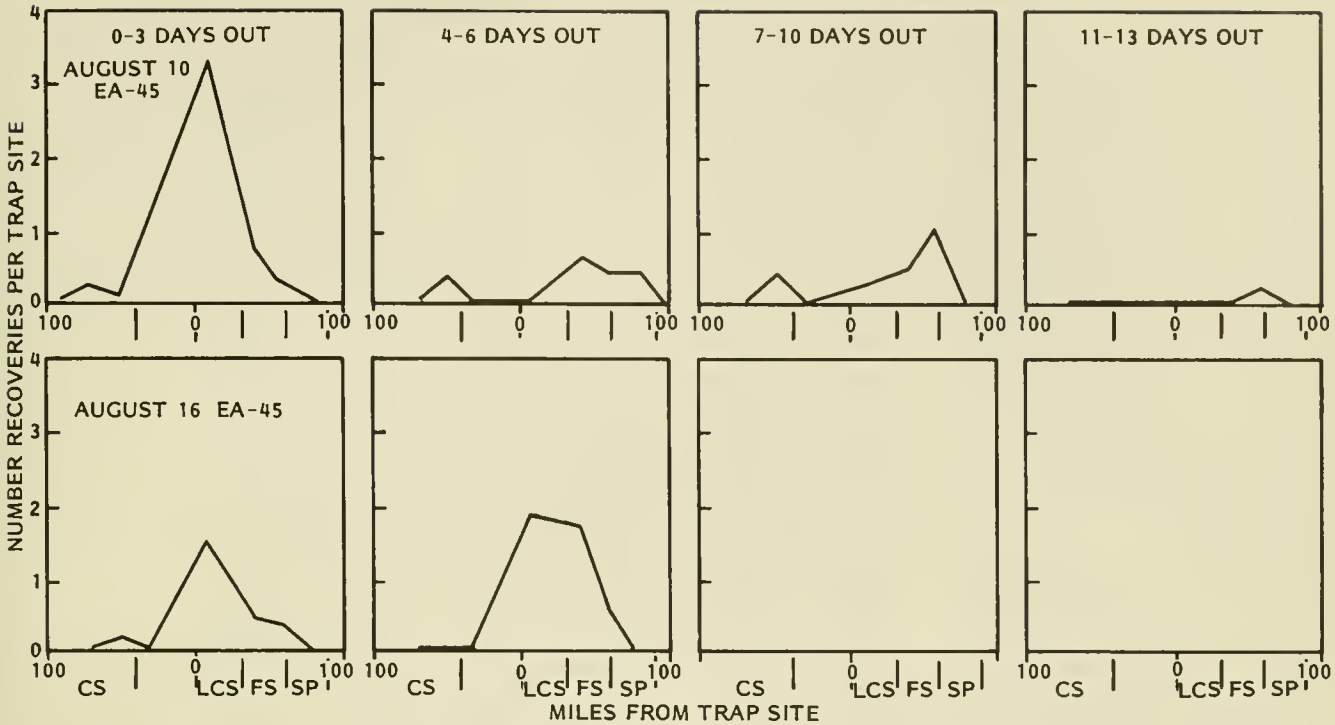

Figure 14.—Tag recoveries per trap per time period by 20-mile intervals measured from the point of release in lower Chatham Strait, 1941.

migration. Both types of data show two main migration routes, one starting in Icy Strait and leading south through upper and middle Chatham Strait into Frederick Sound and the other leading from lower Chatham Strait into Frederick Sound. In Figures 16 to 20, the weekly catch per trap is plotted against time in weeks for the major statistical subareas for the years 1938-42. Lynn Canal is included with upper Chatham Strait. The vertical lines represent the dates, obtained by linear interpolation, at which the catches per trap were 10,000 and 20,000 fish per week. The time difference in days between the 10,000- and 20,000-fish-per-week levels in outer Icy Strait and four inner areas is given in Table 12. The catch per trap during the seventh week in inner Icy Strait in 1938 reached 19,806 but not 20,000 and, although omitted from Figure 16, the time difference was calculated and is given in Table 12. Table 13 lists time differences between lower Chatham Strait and two inner areas.

In all years, the average catch increased first in outer Icy Strait and then in inner Icy Strait, upper Chatham Strait, and middle Chatham Strait in that order, as would be expected if the fish were entering through Icy Strait and moving south. Since traps in

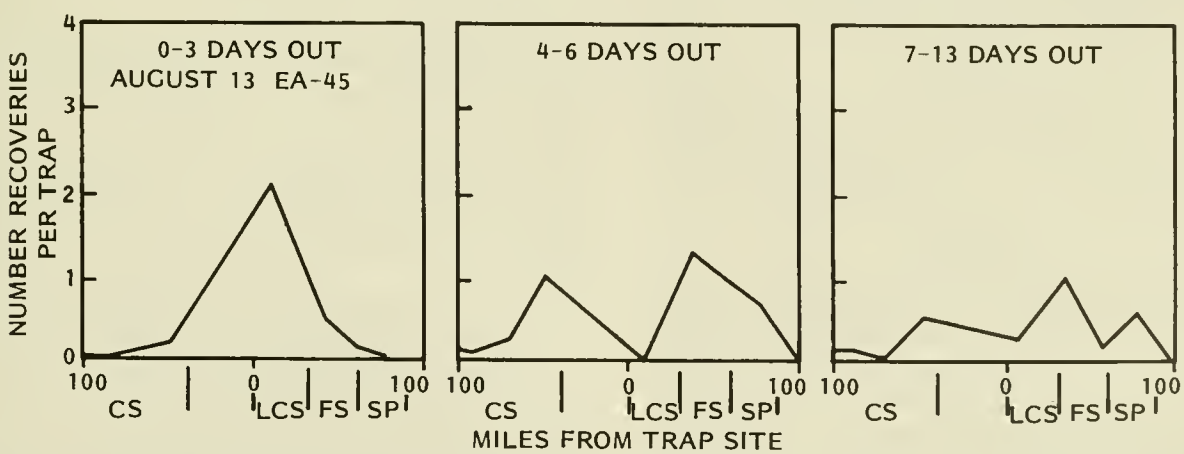

Figure 15.—Tag recoveries per trap per time period by 20-mile intervals measured from the point of release in lower Chatham Strait, 1942.

Table 11.--Total trap catch and catch per trap in major statistical subareas in southeastern Alaska, 1938-42 and 1945. (See Table 2 for number of traps in each area.)

Statistical subarea	1938		1939		1940	
	Catch	Catch/trap	Catch	Catch/trap	Catch	Catch/trap
Outer Icy Strait	584,181	72,023	258,991	32,374	379,451	54,207
Inner Icy Strait	604,388	31,810	249,440	13,128	860,957	45,314
Lynn Canal	86,230	43,115	51,105	25,553	53,947	26,974
Upper Chatham Strait	2,188,491	115,184	844,979	44,473	2,503,038	125,152
Middle Chatham Strait	1,627,369	81,368	817,293	43,015	1,318,151	73,231
Lower Chatham Strait	608,327	101,388	531,542	106,308	515,610	171,870
Frederick Sound	1,239,817	82,654	1,464,014	97,601	1,066,645	66,665
Stephens Passage	483,807	40,317	917,698	76,745	710,431	64,585
Total	7,422,610	73,491	5,135,062	51,869	7,408,230	77,169

	1941		1942		1945	
	Catch	Catch/trap	Catch	Catch/trap	Catch	Catch/trap
Outer Icy Strait	1,209,224	201,537	425,860	70,977	176,234	29,372
Inner Icy Strait	1,934,492	193,449	1,121,161	65,951	395,678	24,730
Lynn Canal	102,915	102,915	136,218	68,109	44,806	22,403
Upper Chatham Strait	4,701,101	361,623	2,616,757	145,375	827,868	48,698
Middle Chatham Strait	2,866,237	238,853	940,765	58,798	647,114	38,066
Lower Chatham Strait	2,622,128	655,532	824,650	206,163	413,057	103,264
Frederick Sound	5,139,320	321,208	1,962,959	122,685	681,857	48,704
Stephens Passage	2,794,745	254,068	1,088,965	98,997	421,055	32,389
Total	21,370,162	292,742	9,117,335	101,304	3,607,669	40,536

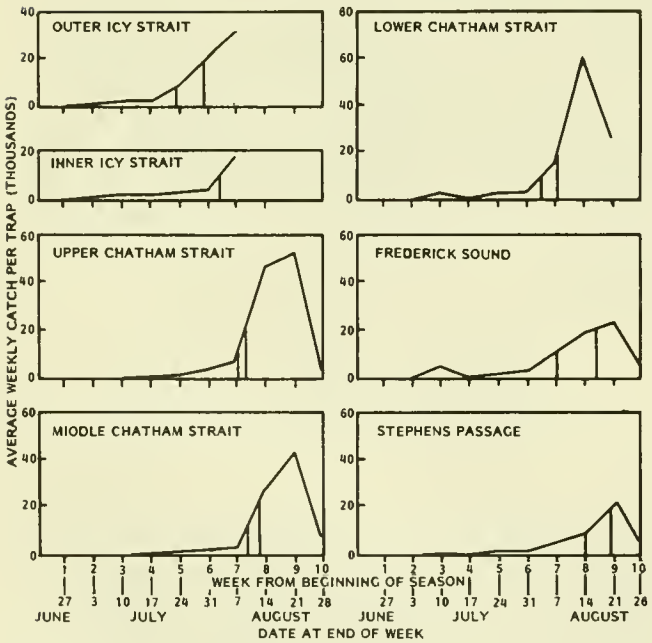

Figure 16.—Average number of pink salmon caught per trap per week in each major statistical area in 1938. The approximate dates on which the catch per trap per week reached 10,000 fish and 20,000 fish are shown by the vertical lines.

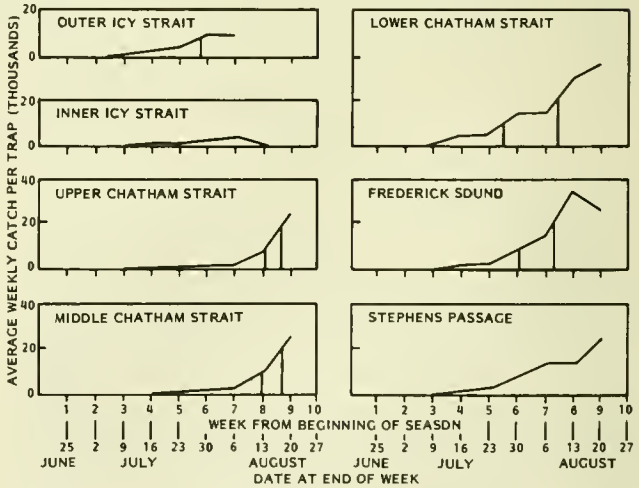

Figure 17.—Average number of pink salmon caught per trap per week in each major statistical area in 1939. The approximate dates on which the catch per trap per week reached 10,000 fish and 20,000 fish are shown by the vertical lines.

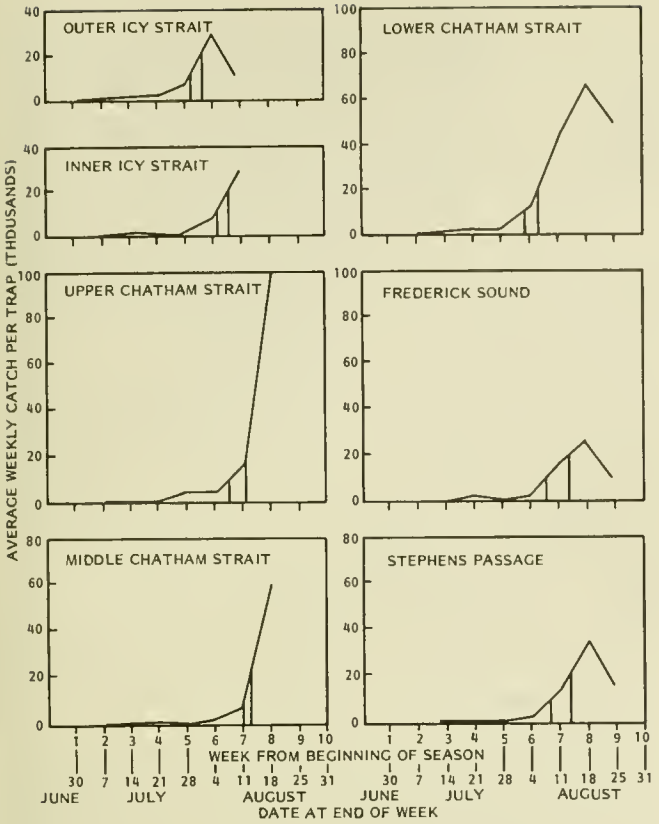

Figure 18.—Average number of pink salmon caught per trap per week in each major statistical area in 1940. The approximate dates on which the catch per trap per week reached 10,000 fish and 20,000 fish are shown by the vertical lines.

lower Chatham Strait reached the 10,000- and 20,000-fish levels before traps in middle Chatham Strait, it is unlikely that many fish moved from middle to lower Chatham Strait. The movement from middle Chatham Strait into Frederick Sound shown by the tagging experiments is not immediately apparent from trap catch data. Average catches reached the 10,000-fish level in Frederick Sound and Stephens Passage shortly after that level was reached in lower Chatham Strait and shortly before it was reached in middle Chatham Strait, except in 1939. In that year Frederick Sound reached the 10,000-fish level 2 days after lower Chatham Strait, 1 day after outer Icy Strait, and 16 days before middle Chatham Strait. Catches in Frederick Sound probably contained fish from both middle and lower Chatham Strait, for the catch buildup would have been less rapid if fish had come from only one source.

A rough estimate of the rate of migration was obtained by dividing the distance between the midpoints of two areas by the time difference between fixed catch levels in the areas. The rates of travel between outer Icy Strait and inner Icy Strait, upper Chatham Strait, and middle Chatham Strait; and between lower Chatham Strait and Frederick Sound and Stephens Passage were calculated. Results of the

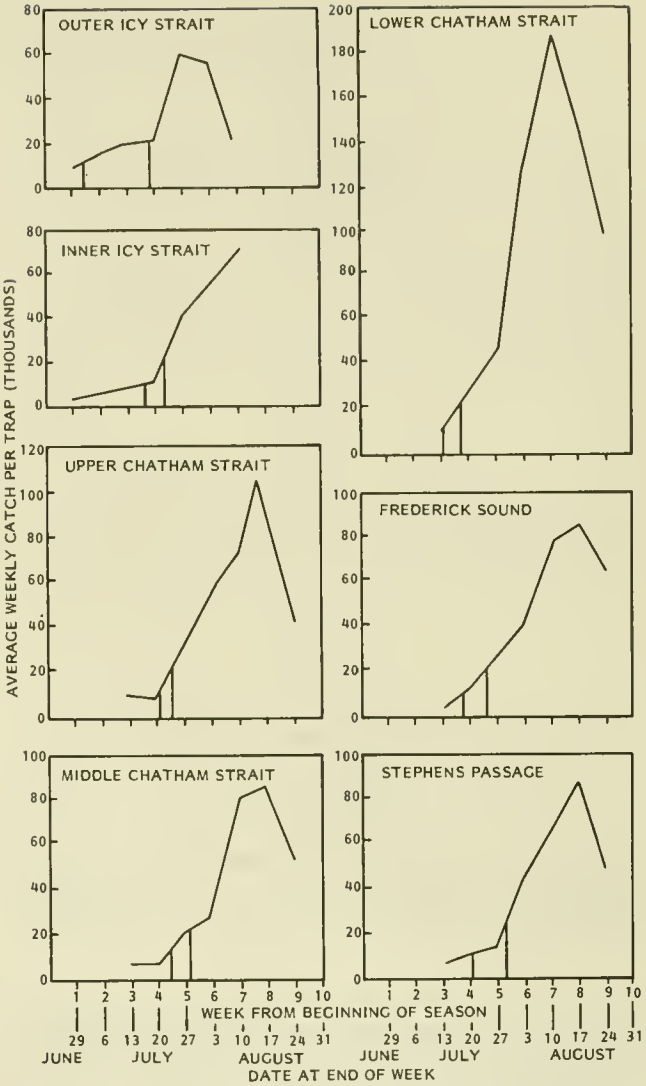

Figure 19.—Average number of pink salmon caught per trap per week in each major statistical area in 1941. The approximate dates on which the catch per trap per week reached 10,000 fish and 20,000 fish are shown by the vertical lines.

first set of calculations are shown in Table 12 and of the second set in Table 13 in the columns headed M/D. The rate between outer Icy Strait and lower Chatham Strait was not calculated, for the data indicated few fish from Icy Strait entered lower Chatham Strait.

The rate of travel seemed to increase as the bulk of fish moved south. For example, in 1939 the rates between outer and inner Icy Strait were 3.3 and 4.1 miles per day, whereas the rates between outer Icy Strait and middle Chatham Strait were 5.8 and 7.0 miles per day.

The rates between lower Chatham Strait and Frederick Sound and Stephens Passage (Table 13) are much higher than those calculated for more northern areas. In 1939 the rates between lower Chatham Strait and Stephens Passage were 72.0 miles per day at both the 10,000- and 20,000-fish levels. The second greatest

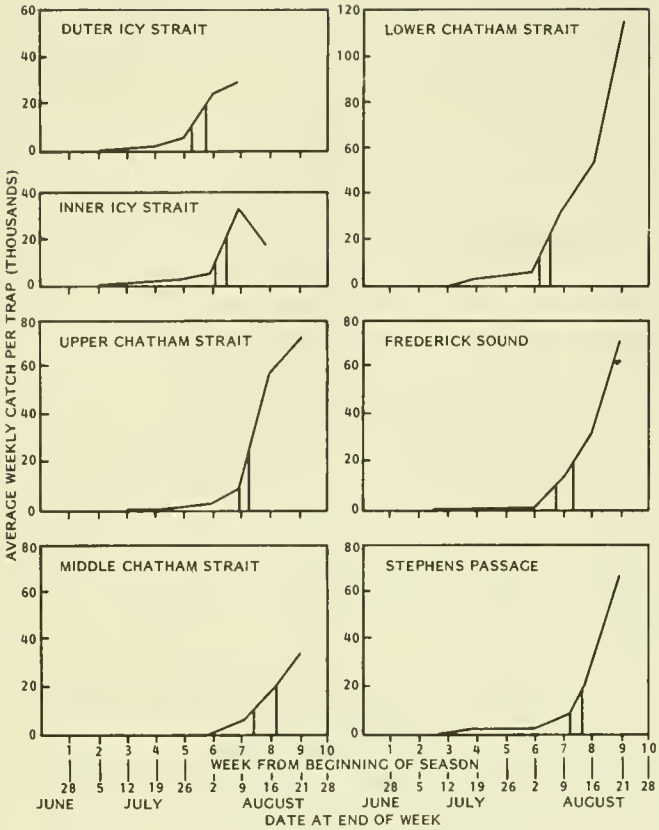

Figure 20.—Average number of pink salmon caught per trap per week in each major statistical area in 1942. The approximate dates on which the catch per trap per week reached 10,000 fish and 20,000 fish are shown by the vertical lines.

rate was 25.5 miles per day between lower Chatham Strait and Frederick Sound at the 10,000-fish levels in 1939 and 1945. Little credence should be given to these high rates.

The rates of travel shown in Tables 12 and 13 should not be interpreted as representing the actual rate of travel of individual fish but rather the rate of movement of a certain density (not the maximum density) of catchable fish.

RATE OF TRAVEL DETERMINED FROM TAGGING DATA

Computation and interpretation of the rate of travel are complicated by the extensive wandering movements and also by the complex mixture of racial stocks represented in a single release of tagged pink salmon. In this section only the movements along the main routes of travel as defined in the section entitled "Migration Routes as Determined from Tag Recoveries" will be considered. The objective of the analysis presented here is to determine how long it takes the population at a particular location in the fishery to reach other locations in the fishing areas. It is assumed that tagged fish continued their normal migration after release.

The rate of travel of both the center of density of a group of tagged fish and also of the leading edge of the tagged population are of interest. On any given day after release, tagged fish were recovered in traps at varying distances from the tagging station. If all recoveries on a given day are ordered with respect to distance, the median recovery provides a first approximation of the location of the center of density of the group, and the second farthest recovery provides a measure of the location of the leading edge of the tagged group on the day in question.

For each group of tagged pink salmon with sufficient numbers of recoveries, the approximate rate of travel of the center of density (called the median rate) was calculated from the recoveries on the first through the 14th day after release. The location in miles from the tagging station of the median recovery each day was regressed on the number of days out. The slope of this line is an estimate of miles traveled per day. There were no essential differences between the estimates obtained by weighted and unweighted regression lines if weights proportional to the numbers of recoveries taken in the trap making the median recovery were employed. Results of these computations are given in Table 14.

In the calculation of the rate of movement of the leading edge of the distribution of tagged fish from a single release, recoveries within 30 miles of the tagging station were ignored. Because of the possibility that reports of isolated recoveries at great distances might be in error or might represent abnormal fish, the second farthest rather than the most distant recovery was used to estimate the rate of movement of the leading edge. Recoveries on the first through the 14th day after release were used. Again the rate of travel in miles per day was estimated by the slope of the regression line. Results for releases for which four or more days were available for calculating these rates are shown in Table 14.

The rate of movement of the leading edge varied from 9.05 to 33.37 miles per day and averaged about 18 miles per day. In general, rates from different experiments within the same major area and the same year agreed with one another, with the exception of the experiments in upper Chatham Strait in 1942. The rate of movement of the leading edge of the distribution of recoveries from the release made on 9 August from WE-32 on the eastern shore of upper Chatham Strait was 9.05 miles per day while the corresponding rate for the release from WE-24 on the western shore on 18 August was 20.56 miles per day.

The highest rate of movement of the leading edge observed for releases made in Icy Strait in 1942 (13.30 miles per day) was considerably less than the slowest rate of movement observed (18.19 miles per day) for releases in Icy Strait in 1941. Thus, the 1941 and 1942 Icy Strait experiments showed little intraseasonal variation in rate of movement of the leading edge, but the rates in 1941 were consistently higher than those

Table 12.--Time difference (in days) between average weekly catches of 10,000 and 20,000 fish in traps in outer Icy Strait and four inner areas and miles traveled per day (M/D) calculated from the time difference.

Year and catch level	Inner Icy Strait		Upper Chatham Strait		Middle Chatham Strait		Lower Chatham Strait
	Days	M/D	Days	M/D	Days	M/D	Days[1]
1938							
10,000	10	3.3	15	4.3	17	5.8	12
20,000	8	4.1	10	6.5	14	7.0	9
1939[2]							
10,000	(3)	(3)	16	4.1	17	5.8	-1
1940							
10,000	6	5.5	9	7.2	13	7.5	5
20,000	6	5.5	10	6.5	12	8.2	5
1941							
10,000	16	2.1	20	3.2	27	3.6	13
20,000	7	4.7	9	7.2	12	8.2	3
1942							
10,000	6	5.5	11	6.0	15	6.5	7
20,000	5	6.6	10	6.5	17	5.8	7
1945[2]							
10,000	(3)	(3)	13	5.0	14	7.0	11

[1] Miles per day not computed for outer Icy Strait-lower Chatham Strait route.

[2] Twenty thousand fish per week not reached in outer Icy Strait.

[3] Ten thousand fish per week not reached.

in 1942. In 1941 the rate of movement decreased from July to August for releases in upper Chatham Strait and increased from July to August for releases in middle Chatham Strait. In other years rates for August releases in middle Chatham Strait remained high. In 1941, the year with the best distribution of tagging experiments, the rate of movement of the leading edge was greatest for releases in Icy Strait, intermediate for releases in upper and lower Chatham Strait, and least for releases in middle Chatham Strait.

The rate of travel of the median tag recoveries varied from 0.52 to 15.35 miles per day; the overall average was about 8 miles per day. Differences between the rates of movements of leading edges and of medians varied from 0.39 to 30.93 miles per day. For most experiments the difference ranged between 5 and 15 miles per day. As the season progressed in 1939, the median rates decreased for fish tagged in lower Chatham Strait and the rates of movement of the leading edges of the populations increased. For those experiments for which both rates were calculated, the rate of movement of the leading edge averaged 29.06 miles per day and the rate of travel of the median averaged 7.88.

Knowledge of the rate of movement of the leading edge of a population and also of rate of drift of the center of density should be useful in formulating fishing regulations and in allocating recovery effort in future tagging experiments. The data indicate that the leading edges of the tagged populations moved at rates somewhat less than 25 miles per day and that the centers of density drifted at an average rate of about 8 miles per day but that these rates varied considerably from year to year and from area to area. The significance of these seasonal as well as the areal and annual variations should be included as an objective of future tagging experiments.

MORTALITY RATES

For a given release the decrease in number of tags recovered per unit time during successive time periods provides a measure of the rate at which the tagged population vanishes from the fishing area. It is convenient for management purposes to work in terms of survival rates. Factors contributing to the disappearance of both tagged and untagged fish from the fishing area are fishing mortality, natural mortality,

Table 13.--Time difference (in days) between average weekly catches of 10,000 and 20,000 fish in traps in lower Chatham Strait and two inner areas and miles traveled per day (M/D) calculated from the time difference.

Year and catch level	Frederick Sound		Stephens Passage	
	Days	M/D	Days	M/D
1938				
10,000	3	17.0	10	7.2
20,000	8	6.4	12	6.0
1939				
10,000	2	25.5	1	72.0
20,000	0	--	1	72.0
1940				
10,000	4	12.8	4	18.0
20,000	8	6.4	9	8.0
1941				
10,000	4	12.8	4	18.0
20,000	6	8.5	11	6.6
1942				
10,000	3	17.0	6	12.0
20,000	6	8.5	7	10.3
1945				
10,000	2	25.5	4	18.0
20,000	5	10.2	(1/)	(1/)

1/ Twenty thousand fish per week not reached.

and migration out of the fishing area, either into spawning streams or into closed areas. Tagged fish were also exposed to possible immediate mortality from the tagging process, continuing mortality caused by the attached tag, and a spurious mortality through loss of the tag. Nonreporting of tags by the fishermen decreases the apparent fishing mortality or exploitation rate, but if the fraction of recoveries that are unreported is constant during all recovery periods, nonreporting of tags does not affect the estimate of the total survival rate when the estimation method described by Paulik (1962) is used.

Only trap recoveries were used in the survival rate computations. All recoveries, regardless of the type of recapture gear, were used to estimate the exploitation rates. Although the seines took about 30% of the catch, only 16% of the tag recoveries were made by seiners. It is possible that the seine fleet may have been operating on stocks not adequately sampled by the trap-based tagging operations or that the recovery of tags from seine catches was less efficient than from trap catches.

The hypothesis that the mean days out for seines was less than or equal to the mean days out for traps was tested for each release for which 10 or more seine recaptures with known recapture dates were available. If the trap and seine variances did not differ significantly, the usual t-test was used; if the variances were significantly different, the modified t-test proposed by Welch (1938) was used. The t-values obtained are listed in Table 15. The results of the individual tests were combined by means of Fisher's chi-square statistic (Fisher 1950). The overall conclusion based on the results of Fisher's test is that the average days out for the seine recoveries is significantly greater than the average days out for trap recoveries. It appeared that in many cases the seines were more likely to be the last gear encountered by salmon before entering the spawning streams. Since the mean number of days out has an inverse relationship to the negative natural logarithm of the survival rate, this difference between the gears would be expected to affect the survival rate estimates. For this reason the survival rate estimates were computed from the trap recoveries only.

Excluding seine recoveries when the average days out is greater than for traps could introduce a negative bias in the estimates of survival rates. That is, our estimates would usually be slightly more if we had included them. However, the difference in days out was usually not great enough to introduce an important bias, and considering the various inadequacies of the seine recoveries, we do not believe their inclusion would improve the conclusions of this report.

The information on days out for the trap recoveries, although considered to be more accurate than for the seine recoveries, is also suspect. During much of the season the traps were not lifted every day. Nevertheless the original tag recovery records showed an exact date of recapture for nearly every recovery. For a representative sample of experiments, recapture dates for all tag recoveries made in a particular trap were compared to the recorded lifts of that trap as reported in the daily catch records. A recovery reported on a day when no lift was made was tabulated as a disagreement. It is obvious that this analysis yields only a minimum estimate of the actual misclassification because if daily lifts were made, no misclassifications could be detected. The percent disagreement per tagging experiment ranged from 7% to 48%. For most releases tag recaptures were reported during the weekend closures. Because of this factor and the difficulty in determining the exact day of recapture, weekly time periods were used to estimate survival rates. The number of weekly recovery periods was approximated to the nearest week.

Weekly survival rates were calculated for 30 groups of tagged fish for which the total recovery period extended two or more weeks. None of the groups tagged in 1940 and 1945 met this criterion. It was assumed that the weekly survival rate remained constant for each group from the time of release until the end of the fishing season. The computational method used

Table 14.--Rate of travel of tagged fish estimated by regression technique using the second most distant recoveries and the median distance traveled per day.

Area, trap number, and release date	Leading edge miles/day	Median miles/day
Icy Strait		
IS-34		
12 July 1941	18.19	11.24
19 July 1941	20.61	10.90
26 July 1941	20.87	10.36
2 Aug. 1941	25.25	13.72
5 Aug. 1941	21.44	12.35
IS-26		
7 Aug. 1941	18.52	12.25
Average, 1941	20.81	11.80
IS-34		
18 July 1942	9.48	7.33
2 Aug. 1942	9.22	5.64
IS-24		
9 Aug. 1942	13.30	4.71
Average, 1942	10.67	5.89
Upper Chatham Strait		
WE-36		
13 Aug. 1940	26.55	15.35
WE-25		
13 Aug. 1940	24.13	14.18
Average, 1940	25.34	14.76
WE-24		
13 July 1941	17.26	11.26
26 July 1941	16.49	11.66
2 Aug. 1941	14.66	10.47
9 Aug. 1941	12.99	8.06
Average, 1941	15.35	10.36
WE-24		
2 Aug. 1942	--	0.52
WE-32		
9 Aug. 1942	9.05	4.01
16 Aug. 1942	--	4.22
WE-24		
18 Aug. 1942	20.56	--
Average, 1942	14.80	2.92
Middle Chatham Strait		
WE-69		
12 Aug. 1940	16.95	7.04
WE-65		
13 July 1941	11.36	8.22
WE-69		
20 July 1941	16.00	6.95
27 July 1941	16.72	8.62
3 Aug. 1941	21.20	7.48
10 Aug. 1941	22.03	8.07
17 Aug. 1941	22.00	--
Average, 1941	18.22	7.87
WE-69		
11 Aug. 1942	9.11	8.72
15 Aug. 1942	13.52	7.07
Average, 1942	11.32	7.90
Lower Chatham Strait		
EA-45		
6 Aug. 1938	11.30	3.90
9 Aug. 1938	--	3.79
Average, 1938	11.30	3.84
EA-45		
16 July 1939	20.48	12.10
4 Aug. 1939	33.33	9.11
EA-46		
6 Aug. 1939	--	4.17
EA-45		
13 Aug. 1939	33.37	2.44
Average, 1939	29.06	6.96
EA-45		
10 Aug. 1941	15.00	9.62
16 Aug. 1941	16.45	--
Average, 1941	15.73	9.62
EA-45		
13 Aug. 1942	17.13	8.50

Table 15.--List of t-values for comparison between mean days out for trap recoveries and mean days out for seine recoveries. (Only releases with 10 or more seine recoveries included.)

Area, trap number, and release date	t-value	Area, trap number, and release date	t-value
Icy Strait		Middle Chatham Strait	
IS-34		WE-69	
12 July 1941	0.895 n.s.	12 Aug. 1940	4.827**
19 July 1941	-0.768 n.s.	16 Aug. 1940	3.889**
26 July 1941	6.399**	20 July 1941	15.900**
2 Aug. 1941	0.915 n.s.	27 July 1941	1.671*
5 Aug. 1941	0.686 n.s.	3 Aug. 1941	5.559**
IS-26		10 Aug. 1941	6.440**
7 Aug. 1941	-4.763 n.s.	17 Aug. 1941	-0.202 n.s.
IS-34		Lower Chatham Strait	
18 July 1942	-2.551 n.s.	EA-45	
2 Aug. 1942	-0.961 n.s.	6 Aug. 1938	7.518**
IS-24		9 Aug. 1938	16.483**
9 Aug. 1942	0.952 n.s.	12 Aug. 1938	6.249**
Upper Chatham Strait		EA-46	
WE-36		8 Aug. 1938	8.359**
13 Aug. 1940	1.708*	6 Aug. 1939	14.153**
WE-25		EA-45	
13 Aug. 1940	3.567**	4 Aug. 1939	2.506**
WE-24		5 Aug. 1939	3.897**
13 July 1941	1.330 n.s.	13 Aug. 1939	1.299 n.s.
26 July 1941	1.551 n.s.	13 Aug. 1942	5.360**
2 Aug. 1941	1.296 n.s.		
WE-43			
18 Aug. 1942	-7.148 n.s.		

n.s. Not significant.

* Significant at 0.05 level.

** Significant at 0.01 level.

was the modification of the Chapman-Robson catch curve analysis described by Paulik (1962). The weekly survival rates obtained are listed in Table 16.

The total rate of exploitation was computed for each group of tagged fish by dividing the total number of tags recovered from all sources by the number of tagged fish released. Since neither time nor place of recapture affects the estimation of total exploitation rate, complete information on individual recoveries was not needed. For ease in computing total exploitation rates, the 30 stream recoveries were included in the total of 7,027 recoveries used. No more than one stream recovery was made for any one experiment.

Total exploitation rates may be converted to weekly exploitation rates by the following procedure when estimates of weekly survival rates are available.

Let R_i = number of recaptures in ith week, $i = 1,\ldots,k$,
N_i = number of fish released,
μ_T = total exploitation rate for k weeks, and
μ = weekly exploitation rate.

Then the expected number of recoveries in the ith week is given by the formula

$$R_i = \mu s^{i-1} N.$$

Table 16.--Weekly survival rates (s), weekly exploitation rates (μ), experimental fishing mortality rates (F), and other-loss rates (X) for 30 groups of tagged fish.

Area, trap number, and release date	s	μ	F	X
Icy Strait				
IS-34				
12 July 1941	0.417	0.251	0.504	0.481
19 July 1941	0.414	0.312	0.624	0.385
26 July 1941	0.377	0.306	0.629	0.484
2 Aug. 1941	0.556	0.190	0.311	0.334
5 Aug. 1941	0.421	0.176	0.315	0.613
IS-26				
7 Aug. 1941	0.482	0.256	0.467	0.365
Average, 1941	0.444	0.248	0.475	0.444
IS-34				
18 July 1942	0.401	0.223	0.457	0.550
2 Aug. 1942	0.441	0.198	0.350	0.543
IS-24				
9 Aug. 1942	0.438	0.244	0.436	0.482
Average, 1942	0.427	0.222	0.414	0.525
Upper Chatham Strait				
WE-24				
13 July 1941	0.312	0.219	0.440	0.818
26 July 1941	0.360	0.334	0.710	0.458
2 Aug. 1941	0.421	0.215	0.430	0.519
9 Aug. 1941	0.638	0.206	0.330	0.190
Average, 1941	0.433	0.244	0.478	0.504
WE-24				
25 July 1942	0.665	0.142	0.207	0.234
2 Aug. 1942	0.546	0.187	0.307	0.364
WE-32				
9 Aug. 1942	0.361	0.252	0.516	0.607
Average, 1942	0.524	0.194	0.343	0.402
Middle Chatham Strait				
WE-65				
13 July 1941	0.220	0.310	0.708	0.957
WE-69				
20 July 1941	0.145	0.452	0.208	0.992
27 July 1941	0.316	0.347	0.706	0.599
3 Aug. 1941	0.310	0.276	0.559	0.732
10 Aug. 1941	0.745	0.204	0.298	0.060
Average, 1941	0.347	0.397	0.696	0.668
WE-69				
11 Aug. 1942	0.279	0.296	0.644	0.755
Lower Chatham Strait				
EA-45				
7 July 1938	0.201	0.151	0.402	1.287
6 Aug. 1938	0.550	0.206	0.358	0.316
9 Aug. 1938	0.139	0.421	1.162	1.054
Average, 1938	0.297	0.259	0.641	0.886
EA-45				
16 July 1939	0.312	0.214	0.429	0.828
4 Aug. 1939	0.320	0.246	0.559	0.704
EA-46				
6 Aug. 1939	0.330	0.225	0.443	0.761
Average, 1939	0.321	0.228	0.477	0.764
EA-45				
10 Aug. 1941	0.396	0.177	0.324	0.672
13 Aug. 1942	0.305	0.271	0.595	0.711
Overall average	0.394	0.250	0.514	0.595

Summing over i

$$\sum_{i=1}^{k} R_i = \mu N \sum_{i=1}^{k} s^{i-1}$$

and, since

$$\mu_T = \frac{\sum_{i=1}^{k} R_i}{N}$$

it is evident that

$$\mu = \mu_T \frac{1-s}{1-s^k} .$$

Values for s and μ for the 30 experiments with recovery periods of 2 wk or more are listed in Table 16. Weekly survival rates varied from 0.139 for the group released on 9 August 1938 in lower Chatham Strait to 0.745 for the group released on 10 August 1941 in middle Chatham Strait and averaged 0.394. Weekly exploitation rates varied from 0.142 on 25 July 1942 in upper Chatham Strait to 0.452 on 20 July 1941 in middle Chatham Strait and averaged 0.250.

Once μ and s have been estimated, the exponential fishing mortality rate, F, and "other-loss" rate, X, (Paulik 1963) for the tagged fish can be calculated.

The other-loss rate for both tagged and untagged fish includes natural mortality and outmigration. In addition, the other-loss rate for tagged fish is augmented by tag dropoff and any additional natural mortality caused by the tag. Although no information was available on the relative importance of the different contributors to the other-loss rate, it is believed that escapement to spawning streams was the dominant factor. Continuing tag dropoff may have been a significant factor in these experiments. The type of tag used was a strap tag attached to the dorsal edge of the caudal fin. As mentioned above, the fishing mortality rate would be underestimated if there were either immediate tagging mortality or incomplete recovery and reporting of recaptured tagged fish. Original correspondence which accompanied some of the tag returns indicated that there was substantial nonreporting of tags during these experiments. Unfortunately there is not sufficient information to estimate the magnitude of this type of error. In the opinion of the authors the estimated fishing mortality rates given in Table 16 are too low.

The estimates of F and X given in Table 16 were calculated from the values of μ and s under the assumption that the fishery during the years of these experiments was periodic; i.e., the fishing season was open for 5.5 days and closed for 1.5 days of each week. The method of calculation will be outlined briefly:

Let F = weekly exponential fishing mortality rate,
X = weekly exponential other-loss rate,
Δ_1 = length of first part of weekly open period,
Δ_2 = length of weekly closed period,
Δ_3 = length of second part of weekly open period, and

$$\Delta_1 + \Delta_2 + \Delta_3 = 1.$$

Then

$$s = e^{-(F(\Delta_1+\Delta_2)+X)}$$

$$\mu = \frac{F}{F+X}(1-e^{-(F+X)\Delta_1}) + e^{-(F\Delta_1+X(\Delta_1+\Delta_2))}\frac{F}{F+X}(1-e^{-(F+X)\Delta_3}).$$

Since the length of the weekly closed period was 1½ days, $\Delta_2 = 1.5/7$ and $\Delta_1 + \Delta_3 = 5.5/7$. It was assumed that $\Delta_3 = 0$ for releases on Sunday and that $\Delta_1 = 0$ for those on Saturday. Values of Δ_1 and Δ_3 for midweek experiments were assigned on the assumption that releases were made exactly at midnight of the tagging day. The two nonlinear equations shown above were solved for the unknowns F and X by an approximation technique using nomographs.

The estimates for F and X for each of the 30 experiments together with their averages by area and year are listed in Table 16. The F values varied from 0.207 to 1.208 and averaged 0.514. The X values ranged from 0.234 to 1.287 and averaged 0.595. Thus, for these experiments the estimated rate of removal of tagged fish by the fishery was slightly less than the rate of removal by all other causes.

Estimates of F and X computed from the results of the tagging experiments conducted in 1950 in Icy Strait by Elling and Macy (1955) were reported by Paulik (1963). The opening date for the commercial fishing season in 1950 (15 August) was later than the closing dates of the seasons during the years 1938 through 1945. In 1938-45 the season in Icy Strait was usually opened about 20 June and closed the first week in August. Elling and Macy (1955) tagged fish on consecutive days from 25 July through 14 August. Using their data Paulik (1963) obtained an intraseasonal weekly X value of 0.641 and a weekly F value of 1.230. Although the value for X in 1950 agrees fairly well with the overall average of the X values for the tagging experiments in 1938-42 and 1945, the 1.230 value for F in 1950 is considerably higher than the average F of 0.514 for 1938-42 and 1945. We suggest that the discrepancy between these F values is due in a large degree to nonreporting of recaptured tags in the earlier experiments.

In 1941 the X rate increased as the release site was moved from Icy Strait to middle Chatham Strait (Table 16). The F values appear to be highest for middle Chatham Strait. Although the intraseasonal variability in F and X values was extremely high, there appeared to be an increasing trend in the values of F and X during the season.

To estimate the fraction removed by the fishery of the total run entering the northern part of southeastern Alaska during a given year, it is necessary to take into account the pattern of recruitment of pink salmon into the fishing areas during the fishing season. A computer program which calculates the rate of exploitation as a function of the fishing mortality rate and the temporal pattern of fishing (i.e., opening and closing dates and the number of days of fishing per week) when there is intraseasonal recruitment is decribed by Paulik and Greenough (1966). To use this program it is necessary to assume that the recruitment into the fishing area can be approximated by a triangular entry pattern. Data input to this program includes the times of the beginning, the peak, and the end of the entry pattern; the beginning and the end of the fishing season; and seasonal variations in the fishing mortality rate and the other-loss rate.

The cumulative catch at any time during the season is calculated by means of two simple algorithms:

$$C_i = C_{i-1} + \frac{\bar{F}_i}{\bar{F}_i + \bar{X}_i}\{1\text{-exp}[-(\bar{F}_i + \bar{X}_i)]\}S_{i-1} + \frac{\bar{F}_i}{\bar{F}_i + \bar{X}_i}\{1\text{-exp}[-(\bar{F}_i + \bar{X}_i)/2]\}R_{i-½}$$

and

$$S_i = S_{i-1}\ \text{exp}[-(\bar{F}_i + \bar{X}_i)] + R_{i-½}\ \text{exp}[-(\bar{F}_i + \bar{X}_i)/2],$$

where

C_i = total catch in numbers at time $t = i$,
S_i = number of fish surviving in fishery at $t = i$,
$R_{i-½}$ = number of recruits entering fishery in pulse at $t = i$-½,
$\bar{F}_i$ = average exponential fishing rate between $t = i$-1 and $t = i$ if season is open,
$\bar{F}_i$ = 0 if season is closed between $t = i$-1 and $t = i$, and
$\bar{X}_i$ = average exponential other-loss rate between $t = i$-1 and $t = i$.

The seasonal rate of exploitation is found by dividing the total catch at the end of the season by the size of the total run. The exploitation rate may now be represented as a response surface that is a function of two variables, a fishing intensity multiplier that is used to scale all of the exponential fishing rates used during the season and the fraction of the basic period that the fishery is open (Paulik and Greenough 1966).

Exploitation isopleths were computed for 1938, 1939, 1941, and 1942. The various times associated with entry patterns and fishing seasons were estimated from Figures 16, 17, 19, and 20 and Table 1. It was necessary to approximate the entry patterns from the weekly catch-per-trap data. Of the several different entry patterns tried, the one that showed the closest agreement with both the catch data and the tagging data for all years peaked 5 wk after starting and ended 2 wk after the close of the season. For the isopleth calculations it was assumed that the exponential fishing mortality rate remained constant from the beginning to the middle of the fishing season and then increased linearly so that its value at the end of the season was 1½ times what it had been at the beginning. The yearly averages given in Table 16 of the other-loss rates computed from tagging experiments were used in the isopleth computations for 1938, 1939, and 1942. For 1941 the other-loss rate was set equal to 0.444 (the average value for tagged fish released in Icy Strait) from the beginning of the entry triangle to its peak and was then increased linearly to 0.820 (the average for the middle Chatham Strait releases, excluding the anomalous results obtained from the release of 10 August). This intraseasonal modification of the other-loss rate followed from the assumption that the average rate of escapement for the total run at any time during the season in 1941 depended on the location of the center of density of the run, which varied with time.

Exploitation isopleths for the years 1938, 1939, 1941, and 1942 are shown in Figures 21-24. In these figures the number of days in the weekly open period is shown on the abscissa and the weekly exponential fishing mortality rate (the constant rate applied during the first half of the season) on the ordinate. The maximum rate of exploitation in each of these figures appears at the upper right-hand corner of the figure when fishing is permitted for 7 days a week and the exponential fishing mortality rate is highest. The highest fishing exponential rate in this series of figures is 1.19 for the first part of the season, which corresponds to an average rate of 1.34 for the entire season. The highest fishing rate computed from a single tagging experiment was 1.21, which is very close to the value of 1.23 obtained using data from the 1950 tagging experiments by Elling and Macy (1955). For a 5½-day weekly open period the total seasonal rate of exploitation at the highest F value was 0.46 in 1938, 0.43 in 1939, 0.61 in 1941, and 0.56 in 1942. The average over the 4 yr (0.51) indicates that the fishery captured about one-half of the total run entering the northern part of southeastern Alaska. It is of interest to note that if the same computations were carried out for a weekly fishing period of 7 days, the seasonal exploitation rate would be increased to 0.56.

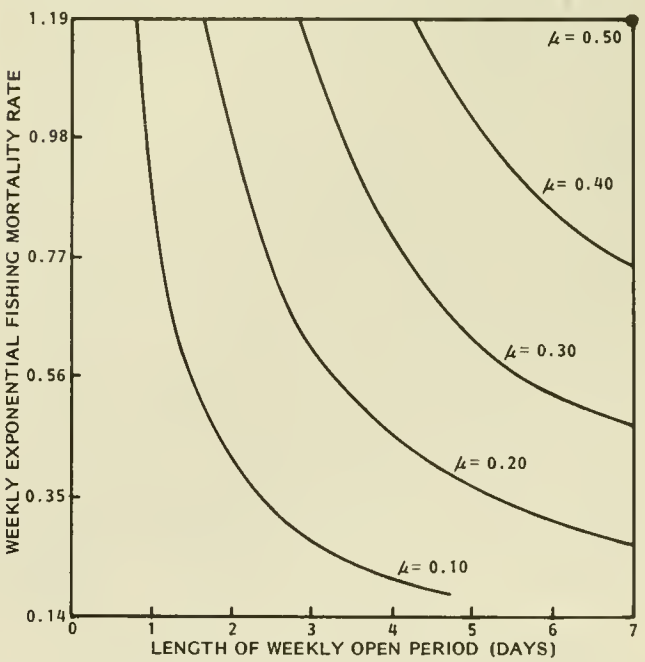

Figure 21.—Exploitation isopleth for the total pink salmon run entering the northern part of southeastern Alaska, 1938. Triangular entry pattern and periodic fishery assumed; μ = rate of exploitation or fraction of run taken in catch.

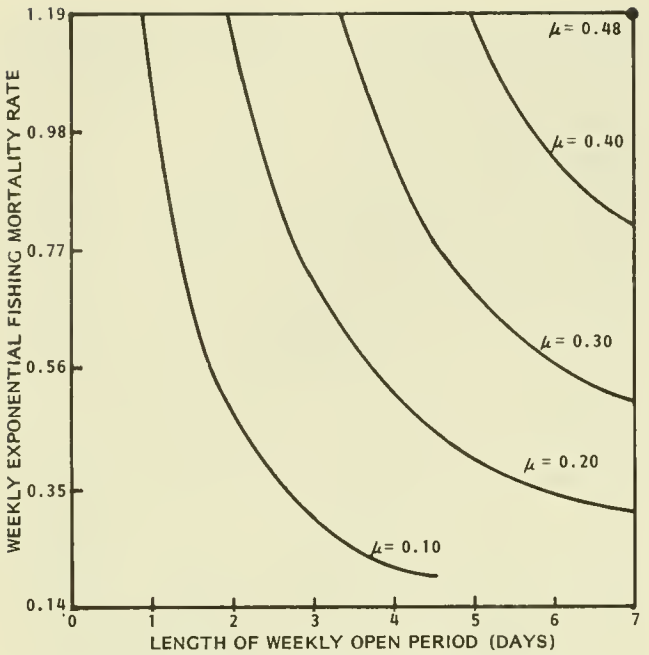

Figure 22.—Exploitation isopleth for the total pink salmon run entering the northern part of southeastern Alaska, 1939. Triangular entry pattern and periodic fishery assumed; μ = rate of exploitation or fraction of run taken in catch.

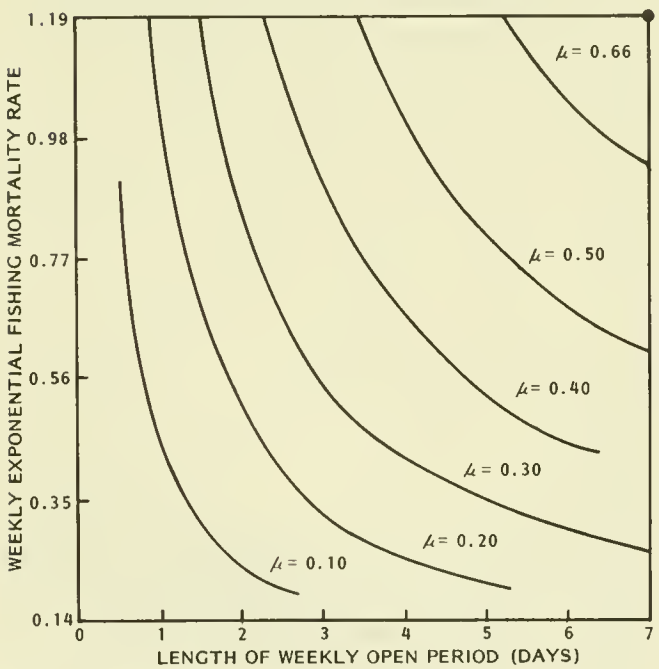

Figure 23.—Exploitation isopleth for the total pink salmon run entering the northern part of southeastern Alaska, 1941. Triangular entry pattern and periodic fishery assumed; μ = rate of exploitation or fraction of run taken in catch.

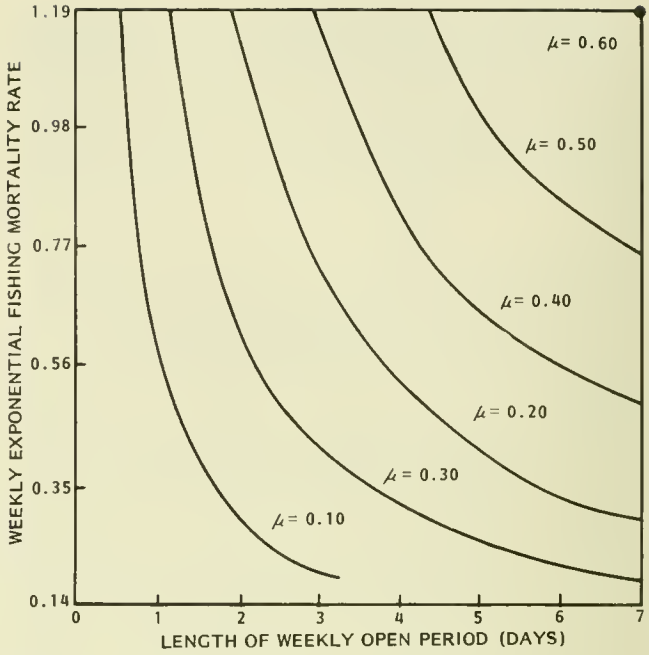

Figure 24.—Exploitation isopleth for the total pink salmon run entering the northern part of southeastern Alaska, 1942. Triangular entry pattern and periodic fishery assumed; μ = rate of exploitation or fraction of run taken in catch.

The computations of exploitation rates of about 50% are completely dependent on the assumption that incomplete reporting or immediate tag loss and mortality or both caused about half of the tagged fish to become "unavailable." If, however, the overall average F value of 0.514 computed directly from the 1938-42 and 1945 tagging data is correct, the average rate of exploitation for these years drops to 0.32. For the reasons mentioned earlier, the authors feel that the higher rate of exploitation is more nearly the correct value. Of course, the rate of exploitation on any particular stock may have been quite different than the overall average. In the exploitation isopleth computations, the fractions removed by fishing from stocks in the first part of the entry triangle were considerably higher than from stocks in the second part. Approximately 7% of the fish in the entry patterns used to calculate Figures 21-24 entered after the season had been closed and for that reason suffered no fishing mortality.

RECOMMENDATIONS FOR THE DESIGN OF FUTURE TAGGING EXPERIMENTS

Tagging experiments are a basic method of generating knowledge needed to determine optimum policies for managing the pink salmon resource of southeastern Alaska. A primary objective of management is to regulate the commercial fishery to allow the quantity and quality of escapement that will max-

imize either biological or economic productivity of the resource.

It is obvious that any tagging experiment should be designed to answer specific questions which are clearly stated at the time the experiment is being designed. The suggestions offered here are general and applicable to most tagging experiments regardless of whether their primary objective is to determine migratory routes, rates of travel, rates of exploitation on various stock units, rates of escapement into particular watersheds, racial compositions of populations in various fishing areas at different times, numerical abundance of particular stock components, or any combination of these.

Establishment of an efficient data collection system is essential. Accurate and complete records of tag releases, recoveries, commercial effort (in terms of standardized units and catches by time-area strata of appropriate size), and timing and abundance of escapements into various watersheds are needed. Release information should include hydrological and meteorological data. Fish should be released in groups, and conditions prevailing at the time of release should be recorded.

Exact locations and recapture times for a purse seine fishery can probably be obtained only through a logbook system. Logbooks also should be used to collect data on the number and location of the sets made each day by an individual boat.

To determine the amount of incomplete recovery and reporting of recaptured tags, trained fishery biologists should sample the catch independently in a manner that does not interfere with normal recovery procedures used by fishermen. Sampling designs for estimating the extent of incomplete reporting are given by Paulik (1961). In some circumstances it is advisable to include double tagging experiments to determine tag loss (Gulland 1963).

Data collection and record-keeping methods should be standardized, and data forms that allow immediate transfer of field data to punch cards should be used. With proper mechanization and data-handling procedures, it is feasible to carry out an analysis of partial data from an experiment while the experiment is still in progress. Feedback from this type of simultaneous analysis permits an evaluation of experimental techniques that would not otherwise be possible until it was too late to correct faulty procedures.

A special effort should be made to collect recovery information on a daily basis in the immediate vicinity of release sites. These data can be used to develop correction factors to adjust mortality rate estimates for the bias caused by nonavailability of tagged fish shortly after their release (see discussion of type C error in Ricker 1958, p. 122-126).

The method of capturing fish for tagging and the types of tags applied should not interfere with the objectives of the experiment. Installation of salmon traps at key locations along primary migration routes should be considered for major tagging experiments. These traps would be used for the sole purpose of capturing fish for tagging and would assure a fixed point of release and permit closer control of tagging techniques than would be possible with purse seines. Traps should also provide holding facilities so that fish could be released in batches of some minimum critical size. Migratory delays should be held to a minimum to reduce the possibility of abnormal behavior. If tagging is carried out from both seines and traps, simultaneous releases should be made to allow a comparison between the two methods of tagging. The numbers of tags released at any one time should be as large as feasible, e.g., at least 500 fish, or if a breakdown of recoveries into fine time-area strata is desired, 1,000 fish. The use of re-releases of recaptured tagged fish and also the possibility of tagging a selected subsample of fish with battery-powered transmitting tags should be investigated for studies of migratory behavior.

The spatial and temporal distribution of the releases should cover the entire geographical region-time space occupied by the populations being studied. Extrapolation of tagging results to populations found at times and in places not included as part of the tagging experiment is generally not advisable. In some cases it may be necessary to make preseason releases, closed-period releases, and postseason releases. Preseason and closed-period releases provide data for separating the fishing mortality rate from the escapement rate and for testing various hypotheses about temporal changes in the escapement rate. The possibility of using simultaneous translocation experiments to study migratory patterns should be investigated.

It is advisable, if funds are limited, to make fewer releases and to allow sufficient funds for an adequate recovery program. Depending somewhat on the objectives of the experiments, it is usually desirable to conduct spawning ground surveys in major watersheds and to enumerate spawning populations wherever possible. Even if great effort is expended on tagging, the results of a tagging experiment will be inconclusive if the recovery effort is inadequate.

When possible, new experiments should maintain continuity with earlier experiments. Experimental methods should be standardized and changes thereafter should be made only with proper duplication using old and new techniques at the same time and place to obtain correction factors that will allow assimilation of the new findings with knowledge gained from past experiments.

It has now become technically feasible to integrate a great deal of information concerning the dynamic behavior of a complex system such as the pink salmon fishery in southeastern Alaska into a large-scale computer simulation program. Agencies concerned with

managing the salmon resources in southeastern Alaska should investigate the practical feasibility of establishing and maintaining an open-ended computer simulation model of this resource for use as a basic planning tool. Alternative policies could be evaluated on this type of simulation model to determine which ones are most promising. Such a simulation model would be an invaluable aid in designing future tagging experiments. This type of model could be used to optimize the distribution of tagging and recovery effort and would aid in development of techniques for analyzing and interpreting tagging data. A more detailed discussion of the uses of simulation models for planning resource management strategies is given by Paulik (1967).

SUMMARY

Records of pink salmon tagging experiments conducted by the U.S. Fish and Wildlife Service in the northern part of southeastern Alaska each year from 1938 through 1942 and in 1945 were transferred to punch cards and analyzed using electronic data processing equipment.

During these 6 yr 55 releases were made: 20,472 fish were tagged and 7,027 of the tags were recovered. No spawning ground surveys were made, and only 30 tagged fish were recovered in streams. Total recoveries from all sources other than streams varied from a low of 28.6% in 1940 to a high of 38.7% in 1941; 79.8% of the recoveries were from traps and 16.1% from seines. The analysis of tag recoveries is supplemented by an analysis of the recorded daily catches of pink salmon from about 100 traps that operated in the northern part of southeastern Alaska during these years.

In most years (with the exception of 1941 and to a lesser extent 1942) releases of tagged fish were restricted to a few localities and were not well distributed in time. No multiple recaptures were reported. Little information could be found on the size and distribution of the seine fleet, and the recorded data accompanying tag recoveries by seines were incomplete. The analysis is restricted for the most part to trap catches and trap recoveries.

Recoveries in the southern part of southeastern Alaska, i.e., to the south of Kuiu, Kupreanof, and Mitkof islands, were infrequent from these releases, which were made in the northern part. The lack of movement to the south confirms findings of earlier investigators that exchange of pink salmon between the northern and southern parts of southeastern Alaska is of no practical significance and that the pink salmon runs in these areas should be regarded as distinct from one another and managed as two independent units.

None of the tagged fish released in middle Chatham Strait were recovered in Salisbury Sound on the west coast of Baranof Island, which indicates that there was no westward movement through Peril Strait. Limited tagging in Salisbury Sound in 1945 suggests that Peril Strait is not an important entryway into inner waters, but the experiments were too few to establish the magnitude of the eastward movement through Peril Strait.

The geographical distribution of recoveries showed that one main migration route is through Icy Strait and upper Chatham Strait to middle Chatham Strait; from there the pink salmon disperse eastward into Frederick Sound and Stephens Passage. The other major passageway from the ocean is through lower Chatham Strait into Frederick Sound and Stephens Passage. While some segment of each tagged group moved rapidly along one of the main migratory paths, others lagged behind, with the result that tagged fish were distributed along the entire way traversed and recoveries continued to be made from all points along the route until the end of the season. Some fish released in Icy Strait moved through upper and middle Chatham Strait in 1 to 2 days and were found in Frederick Sound within 3 to 5 days.

The data show there was not a major exchange of fish between lower Chatham Strait and middle Chatham Strait. The stocks found in Icy Strait, upper Chatham Strait, and middle Chatham Strait are to a large extent distinct from those found in lower Chatham Strait.

Fish tagged later in the season exhibited a more restricted range of movements about the point of release than those tagged earlier. Groups tagged earlier in the season contained larger proportions of fish destined for spawning grounds distant from the release points.

The movement pattern of a group of tagged pink salmon appears to be made up of a random component superimposed upon a directional component. The relative strengths of these two components vary considerably from year to year. Also the particular mixture of racial stocks in a given sector of the fishing ground at any time during the season varies greatly from year to year.

Analysis of data on catch per trap per week confirmed the major migratory routes as determined from the analysis of the tagging data. Catches increased in an orderly fashion for traps along the northern entry route. The buildup of catches in Frederick Sound and Stephens Passage was earlier than in middle Chatham Strait but never preceded the increase in lower Chatham Strait. The timing of catch increases in lower Chatham Strait was similar to that in inner Icy Strait. The populations in Frederick Sound and Stephens Passage were composed of a mixture of fish that had entered through both the northern and the southern entryways.

The rate of movement of the center of density of a single release of tagged fish was estimated from locations of median tag recaptures on successive days; the rate of movement of the leading edge was estimated from the second farthest recovery each day.

The leading edge moved at rates of 9.1 to 33.4 miles per day and averaged about 18 miles per day, and the center of density moved at rates of 1.0 to 15.4 miles per day and averaged about 8 miles per day. In 1942 both of these measures of rate of travel for tagged fish were considerably lower than in 1941.

Weekly rates of survival and exploitation were calculated for 30 experiments which had sufficient numbers of recoveries adequately distributed in time. For these experiments the average weekly survival rate is 39.4% and the average weekly exploitation rate is 25.0%. A comparison of the exponential fishing rate of 0.514 with the exponential other-loss rate of 0.595 indicates that the rate of removal of tagged fish by the fishery was slightly less than the rate of removal from all other causes combined. The estimates of exponential fishing rates were considerably lower than estimates obtained from tagging experiments in Icy Strait in 1950. Part of the discrepancy between the estimated fishing rates in 1950 and in the earlier years appears to be the result of incomplete detection and reporting of recaptured tags in the earlier experiments.

A computer program that calculates the total rate of exploitation on a run of salmon when recuitment, outmigration, and fishing occur simultaneously was used to estimate the fraction of the total run removed by the fishery in 1938, 1939, 1941, and 1942. The timing of the entry of pink salmon into the fishing ground was determined from an analysis of the catch data. The average rate of exploitation on the total run during the years included in this analysis is between 32% and 51%. The exact figure cannot be estimated without further knowledge of the extent of incomplete reporting and tag loss.

A series of recommendations for designing future tagging experiments is presented. It is suggested that the planning and design of tagging experiments could be improved significantly by first simulating the experiments on an open-ended digital computer simulation model of the pink salmon fishery in southeastern Alaska.

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LITERATURE CITED

DAVIDSON, F. A., and L. S. CHRISTEY.
1938. The migrations of pink salmon (*Oncorhynchus gorbuscha*) in the Clarence and Sumner Straits regions of Southeastern Alaska. U.S. Bur. Fish., Bull. 48:643-666.

ELLING, C. H., and P. T. MACY.
1955. Pink salmon tagging experiments in Icy Strait and Upper Chatham Strait, 1950. U.S. Fish Wildl. Serv., Fish. Bull. 56:331-371.

FISHER, R. A.
1950. Statistical methods for research workers. 11th ed., rev. Oliver and Boyd, Edinb., 354 p.

GULLAND, J. A.
1963. On the analysis of double-tagging experiments. Int. Comm. Northwest Atl. Fish., Spec. Publ. 4:228-229.

PAULIK, G. J.
1961. Detection of incomplete reporting of tags. J. Fish. Res. Board Can. 18:817-832.
1962. Use of the Chapman-Robson survival estimate for single- and multi-release tagging experiments. Trans. Am. Fish. Soc. 91:95-98.
1963. Exponential rates of decline and type (1) losses for populations of tagged pink salmon. Int. Comm. Northwest Atl. Fish., Spec. Publ. 4:230-237.
1967. Digital simulation of natural animal communities. *In* T. A. Olson and F. J. Burgess (editors), Pollution and marine ecology, p. 67-85. Intersci. Publ., N.Y.

PAULIK, G. J., and J. W. GREENOUGH, JR.
1966. Management analysis for a salmon resource system. *In* K. E. F. Watt (editor), Systems analysis in ecology, p. 215-252. Acad. Press, N.Y.

RICH, W. H.
1927. Salmon-tagging experiments in Alaska, 1924 and 1925. U.S. Bur. Fish., Bull. 42:109-146.

RICH, W. H., and F. G. MORTON.
1930. Salmon-tagging experiments in Alaska, 1927 and 1928. U.S. Bur. Fish., Bull. 45:1-23.

RICH, W. H., and A. J. SUOMELA.
1929. Salmon-tagging experiments in Alaska, 1926. U.S. Bur. Fish., Bull. 43(Part 2):71-104.

RICKER, W. E.
1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Board Can., Bull. 119, 300 p.

SIMPSON, R. R.
1960. Alaska commercial salmon catch statistics 1951 - 1959. U.S. Fish Wildl. Serv., Stat. Dig. 50, 115 p.

WELCH, B. L.
1938. The significance of the difference between two means when the population variances are unequal. Biometrika 29:350-362.

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