MOVEMENT OF SALMON
IN THE NORTH PACIFIC OCEAN AND BERING SEA
AS DETERMINED BY TAGGING, 1956-1958

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PART I

MOVEMENT OF SALMON IN THE
NORTH PACIFIC OCEAN AND BERING
SEA AS DETERMINED BY TAGGING
1956 - 1958

By

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September, 1960
FOREWORD

It is a pleasure to me, as one initially concerned with the tagging operations so ably carried out and described in the following report, to say something of the original considerations behind the planning of the research program.

The International Convention for the High Seas Fisheries of the North Pacific Ocean to which the United States, Japan and Canada are parties, requires by its provision, research to determine two things as to salmon; first, the distribution, abundance and migration of American stocks on the high seas; and second, fact as to whether or not these stocks are fully exploited. A provisional line to the eastward of which the terms of the treaty dealing with conservation and abstention apply to salmon is defined in the annex and protocol of the treaty. If research shows areas of intermingling of salmon "of Asiatic origin and salmon of Canadian and United States origin" a more equitable line or lines may be substituted.

It was apparent at the beginning that, had the migrations at sea not been of great extent, the existing line might well have remained unquestioned. The problem of whether or not salmon of American origin were fully exploited would then have been a matter to be determined by statistics and biological studies complete in themselves on the American side of the line.

But when the migrations at sea were found to be extensive, so that American salmon were taken to the westward of the line, and Asiatic salmon to its eastward, the research as well as the economic and diplomatic problems of the treaty became far more involved and difficult.

This was the result of the first tagging research which showed clearly that salmon from each side of the North Pacific did indeed pass the line in large numbers.
In my opinion the first tagging results had great impact on the whole subsequent program of research. Had initial tagging operations on the high seas in the vicinity of the line shown no return from the American streams or the inshore fishery which is characteristic of that continent, the necessity of a very extensive and costly research program on the high seas might well have been in question.

The problems to be met have become in consequence very complex. It is plain that the amount of the high seas catch by other nations must be taken into account in any determination of whether or not the runs of salmon in American rivers are fully exploited as required by the treaty.

It is equally plain that control of the catch and its conservation in any part of the North Pacific will require a knowledge of the distribution of the exploited stocks. Since problems of that kind will be inevitable in any rational international exploitation of the sea, anywhere in the world and whatever the species, the contribution made by these studies will be of general as well as specific interest.

The most direct approach to this problem of sea migrations is and has always been, at least until now, the tagging of the migrants.

But tagging of salmon on the high seas is not as easily done or with such certainty of return as is the case in our estuarial fisheries. Had an initial attempt been made with defective methods, consequently without returns from streams of the United States, the great impact of the research during the crucial early years of the treaty program might have been lost. To have plunged unprepared into such a program was unthinkable.

But consideration of what had been done in prior high seas tagging of salmon, although it showed return from the high seas fishing itself, gave no indication that it would give adequate or reliable returns from our inshore fishery, returns which would then be beyond question from stocks
originating in American streams.

The initial approach, with this at stake, had to be a cautious and well reasoned one. The method to be used and the nature and constancy of the returns had to be tested by preliminary trials within our own waters, or so near them as to be unmistakably on our own stocks of fish. Accordingly, despite the impatience of some of the interested public and their urging that tagging be carried on directly in the midst of the high seas fishing then being done, the initial tagging was along the coast of the United States and British Columbia.

This was necessary for other reasons. We knew that there were concentrations of fish at various places along our coast; and we knew what returns our estuarial tagging gave, for comparison. We were very certain that the use of gill nets at sea required a length of net and a duration of "soak" or fishing time between setting and hauling that could only provide dead or badly injured fish to tag. In using gill nets in our estuary tagging it had been found necessary to use very short lengths of net, set into dense concentrations for very short periods and quickly hauled, to get viable fish. It was believed, too, that prior to the physical and other changes that occur during the approach to the coast, the fish are far more susceptible to injury and that they live in a state of delicate adjustment to their sea environment which could be readily disturbed with fatal results. The use of purse seines seemed the obvious answer, providing enough fish could be caught in that way and providing they lived after tagging. Our trials as far west as Kodiak Island were successful.

The next step was to plan the more extensive mid-Pacific tagging. It was known, from our trials, that near coastal waters there were concentrations to be obtained, adequate for purse seine fishing. The Aleutians stretched
like a great line across the North Pacific into the area of the current high sea fishing and our operations could be along their coasts with a maximum likelihood of success in capture. The islands also provided shelter and the bases needed for operations. Along their length the thrust to the heart of the problem must be staged.

The cost of operation, and the low rate of return to be expected, forbade that the operation should be spread widely over the ocean, in low concentrations where we knew from our initial trials that captures would be fewer. If we were to study the continental origin of high seas stocks within reasonable costs, the most direct line of approach to the center of the fishery, and the most practical from the operational and tagging standpoint, was along the Aleutians. The decision was then in part strategic, in part scientific.

The results must be looked for in the accompanying manuscript.

But it should not be forgotten that some very important questions were quickly settled by the initial tagging operations. They showed, first, that the American red salmon, chums and other species were to be found west of the line and that this established without question the necessity of a great research program to reconsider the location of the provisional line. They showed, second, that Bristol Bay stocks of red salmon came from the Pacific south of the Aleutians as well as from Bering Sea, and third that they were separate from the stocks eastward of Kodiak Island in the Gulf of Alaska in the Aleutians.

The part that tagging will play in the great high seas research program so strongly endorsed by the initial results of the tagging, is for the future to tell. As in all great research programs the more diversified the attack the surer and more far reaching the results will be. The several lines of
investigations, including tagging, must support and supplement each other, for no one of them is completely adequate in itself. The vast reaches of the sea that must be covered, the complexity of the sampling problems to be solved, the constant shift and change of the picture in regard to movements, abundance, and racial composition of the salmon stocks make the present one of the world's greatest research programs.

Above all there must not only be considered its great practical value but also that it is an attack upon what is undoubtedly the most important and yet least known of fundamental biological questions, the relation of reproduction to abundance. This is one of fundamental scientific interest. It is as near as any such problems can come to what is so often called "pure science," and to their international control. In these respects the present research program, of which tagging forms a part, should not be regarded as solely of significance to salmon, but rather one basic to all our fisheries, and to the stocks on which they depend, as well as to the biology of living things in general. It is an approach that must not be brushed aside merely because it has practical and economic implications. It is one that must receive special consideration because of the intensive nature and the great scope of the program which covers each species as a whole and deals with the biological mechanism that lies behind its abundance and survival. It is possible only when carried out by large coordinated staffs of scientists, using special research vessels whose results can have their full value only when they are used to supplement and explain the catch of the fisheries, those tremendous self-sustaining systems of altering and sampling whole populations, systems far beyond the financial reach of the individual scientist or even of governments alone.

W. F. Thompson
Professor Emeritus, University of Washington
Formerly Director, Fisheries Research Institute
ABSTRACT

Salmon tagging experiments in the North Pacific and Bering Seas in the summers of 1956, 1957 and 1958 have contributed much new knowledge about ocean movements of salmon.

The tagging was conducted by the Fisheries Research Institute of the University of Washington under contract with the United States Fish and Wildlife Service as part of the research of the International North Pacific Fisheries Commission (Canada, Japan, United States) to determine the qualitative and quantitative distribution of salmon at sea with respect to continent of origin.

Purse seines were found most successful for catching the salmon because they caused a minimum of injury and took all sizes. Special brailing apparatus, and live-tanks for holding fish aboard the vessels reduced injury to salmon.

Laboratory experiments were conducted to test tags and to study injury caused by catching and handling. Moderate scale loss, and eye abrasion which caused temporary opaque spots on the cornea, were found not to be primary causes of mortality.

Standard disc tags ½ inch in diameter and plastic tube tags 1/16 inch in diameter and 13 inches long were used at sea. Disc tags gave consistently better returns than tube tags, presumably because of better visibility and better probability of being retained in gill nets.
Experiments extended from early May through mid-September. Most operations were within 100 miles north and south of the Aleutian Islands from 160° West Longitude to 170° East Longitude. In addition, some tagging was done in the north central Bering Sea, and in the Gulf of Alaska.

Studies of the direction of movement of salmon according to the direction of "set" of the purse seines showed clear-cut movement patterns in the vicinity of the Aleutian Islands which in turn supplemented the migrations shown by tag returns. Mature red salmon, chum salmon, and pink salmon were found to move strongly westward along the south side of the Aleutian Islands. A northward movement was shown in the larger Aleutian passes. Red salmon were found to be moving eastward in the vicinity of the Pribilof Islands. Pinks were found moving strongly westward in the Bering Sea in 1957. The movements of chums in the Bering Sea were not clearly defined. Some mature chums continued to move westward south of the Islands. Immature red and chum salmon also moved westward along the south of the Aleutians, but were not abundant in the catches until most of the mature fish had passed.

Mature red salmon were mostly taken between late May and June 20. Mature pink salmon in 1957 (the only year with large catches) were mostly taken between late May and July 5. Mature chum salmon, however, were taken throughout our fishing season from late May to mid-September, although in minor numbers after July 1.

A total of 36,383 salmon were tagged in the three years. The great majority were reds, chums and pinks, although some silver and king salmon, and steelhead trout were included.
Tagging in the Central Aleutian area produced returns of salmon from such widespread areas as Japan, Russia (from the Amur River in the south to the Anadyr River in the north), from many areas on the high seas, from Northwestern Alaska (Kotzebue Sound, Norton Sound, Yukon River, Kuskokwim River and Bristol Bay), from Southeastern Alaska, and from the States of Washington and Idaho.

A total of 9,282 red salmon were tagged. Annual returns of matures varied from 5.3% to 17.1%. Immatures which had spent two or three winters at sea when tagged, yielded 3.1% returns. No returns were received from the younger immatures. Results of the tagging of mature red salmon showed Bristol Bay reds to predominate as far west as experiments were conducted (173° East), although numbers tagged in the westernmost areas were small. Immature red salmon tagged in 1956 and recovered in 1957 indicated the predominance of Bristol Bay reds as far west as 165° East Longitude. No data were obtained on the eastward limit of Asian red salmon, because of a complete lack of returns of this species from Asian coastal areas. The presence of Asian reds as far east as 180° was suggested, however, by the return of three reds from the high seas fishery well to the west of the tagging locations. The tagging showed also that in 1957, the red salmon approaching Bristol Bay went much further west than in 1956. Finally, the results showed the absence from the Aleutian area of red salmon originating in streams east of 165° West Longitude and south of the Alaska Peninsula. The single exception was one red salmon recovered at Chignik on the south side of the Alaska Peninsula (158° West). Limited tagging in the Gulf of Alaska showed the presence of Fraser and Skeena River red salmon as far west as 151° West Longitude.
A total of 19,383 chum salmon were tagged. Mature fish yielded annual returns between 3.5% and 7.0%. Immatures which had spent two or more winters at sea when tagged, yielded returns up to 2.8% over a two-year period. Immatures which had spent one winter at sea gave as high as 1.0% returns. The tagging of both mature and immature chum salmon showed American chum salmon predominant to 170° West Longitude, and present in appreciable numbers at least to 177° West. Asian chums were predominant eastward to 170° West Longitude, and present at least to 163° West. Studies of the proportion of tagged chums in Asian catches indicate that chum stocks from all Asian production areas are not equally represented in the Aleutian tagging areas. The results showed the absence from the Aleutian area of chum salmon originating in areas east of 160° West Longitude. One exception was an immature chum tagged south of Adak Island (177° West) in 1956 which was recovered in Southeastern Alaska in 1957.

A total of 7,211 pink salmon were tagged. All but 219 were mature. Annual returns varied from 0.4% to 2.7%. Pink salmon were notably scarce in the Aleutian area in 1956 and in 1958, but were very abundant in 1957. The only pink returned in 1956 was from the high seas fleet. In 1957, the tagging showed the pinks in the Aleutian area to be overwhelmingly Asian. Further, they were destined only for East Kamchatka. No returns were received from Alaska. In 1958, pinks in the Aleutian area were shown to be predominantly Alaskan as far west as 177° East Longitude. None were returned from Asia.
The few silver and king salmon, and steelhead trout tagged, at least demonstrated some notably long migrations of these species. Four silvers tagged south of Atka and Adak Islands (175° - 177° West) were returned from the Kamchatka River, a distance of 900 miles. A king salmon tagged south of Adak in 1956 was recovered in the Salmon River in Idaho (via the Columbia River) in 1957. The minimum distance travelled was 2,400 miles. A steelhead tagged south of Atka Island (175° West) in 1957, was recovered in 1958 in the Chehalis River in the State of Washington, a distance of approximately 2,000 miles.
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INTRODUCTION

Commencing in 1955, Canada, Japan, and the United States have been carrying out various large-scale investigations in the North Pacific Ocean and Bering Sea pointed at gaining an understanding of the oceanic distribution and movements of salmon with reference to continent of origin. This information is needed to resolve one of the basic problems contained in the protocol of the North Pacific Fisheries Convention; that of determining a line or lines at sea which best separate Asian and American salmon.

One of the most direct approaches to the problem is to tag and recover salmon. This phase of the research by the United States section of the International North Pacific Fisheries Commission was awarded in 1955 to the Fisheries Research Institute of the University of Washington under contract with the United States Fish and Wildlife Service.

The work in 1955 was conducted on a small scale in the Gulf of Alaska to work out methods and will not be reported here, except in reference to techniques developed that year. In 1956, 1957, and 1958, tagging experiments were conducted in the North Pacific Ocean and Bering Sea as far west as 170° East Longitude. This report presents the findings of the experiments of those years and shows their application to the protocol problem.

Each year saw an accumulation of data which served to guide the following year's tagging. Each year, areas of abundance and patterns of movement became increasingly clear or in some cases contrasted sharply with other years. Information from the other methods of approach by the United States Fish and Wildlife Service, by Canada, and by Japan contributed much to the picture. In total, the data for the three years have provided much new knowledge of the oceanic movements of both American and Asian salmon.
This first report will be confined to the following principal topics:

1. The gear, equipment, and techniques developed for tagging salmon on the high seas. (With the many problems in successfully tagging salmon at sea this has been a continuing research problem in itself).

2. Presentation of detailed tables on catch, tagging, and returns, and length and age data of salmon tagged.

3. Information regarding direction of movement at time of tagging from "set" direction of purse seine. (The use of purse seines was found to contribute data on movements which are a valuable supplement to the tagging results.)

4. Direct information as to ocean movements and continent of origin derived from tagging and recovery, and from catch data associated with tag returns. Tagging each year extended from May through August, and both mature and immature salmon were tagged. Returns from the 1956 tagging are virtually complete in this report since they include the mature salmon recovered in 1956, plus the immatures recovered in 1957 and in 1958. Returns from the 1957 experiments are almost complete, but some additional returns of immature fish are expected in 1959. From the 1958 tagging, only those returned in 1958 can be reported at this time.

5. Preliminary estimates of proportions of American and Asian salmon in various areas at sea as indicated by proportions of tagged fish taken in respective coastal areas, and by the Japanese high seas fleets.

At the time of planning of the 1956 experiments, surprisingly little was known about the oceanic life history of salmon, particularly in the eastern half of the Pacific. Thus, the present experiments are the first in which distribution of tagging, numbers tagged, and numbers recovered were sufficient to provide comprehensive knowledge of salmon movements in the mid-Pacific.
Following is a brief resume of previous and contemporary tagging experiments and explorations which were available as guides for the high seas tagging in 1956, 1957, and 1958.

On the eastern side of the Pacific Ocean most United States and Canadian salmon tagging studies had been along the coasts and estuaries, within the commercial fishery areas, and in fresh water. The most extensive ocean movements found by tagging were those of troll-caught king salmon and silver salmon which move great distances along the American Pacific Coast from Alaska to California (Washington State Department of Fisheries, 1959, pp. 23 - 34). Some fragmentary knowledge of movements of red, chum, and pink salmon between the commercial fisheries of Cook Inlet, Kodiak, the Alaska Peninsula, and Bristol Bay, had been gained from various coastal tagging experiments in those areas (Gilbert, 1923; Gilbert and Rich, 1925; Rich and Morton, 1929; Thompson, 1930).

Little was known of the distribution of salmon at sea even adjacent to the Aleutian Islands. Commercial salmon fishing in the Aleutian area was principally in the bays of the easternmost islands as discussed by Atkinson (1955).

The first evidence of a salmon crossing the Pacific was that of a chum salmon tagged from a coastal salmon trap in the Shumagin Islands of Alaska on July 4, 1923, and recovered in the Pankara River on the east coast of Kamchatka (Figure 2) on August 18 of the same year (Gilbert and Rich, 1925). In reference to the above recovery, Gilbert states (p. 73), "The record is important in that it indicates the possibility of a mingling, on the feeding grounds, of salmon from both the Asiatic and American shores of the North Pacific."
The first truly offshore explorations for salmon in the eastern Pacific were those conducted by Barnaby (1952) of the United States Fish and Wildlife Service in 1939, 1940, and 1941. This work was concentrated primarily in the Eastern Bering Sea, but in 1941 was extended westward to approximately 180°. Salmon were shown to be available to seines and gill nets in offshore areas of the Bering Sea as far west as 180° and north to 60°. In the area between Unimak Island and the Pribilofs, mature reds were found to be moving primarily eastward as indicated by gill net catches (pp. 19, 20).

Further exploratory fishing in the Aleutian Island area with gill nets and also trolls, long lines, and a non-stationary tramp (Schaefers and Fukuhara, 1954) was conducted in 1953 from the United States Fish and Wildlife Service vessel John N. Cobb. With the gill nets they took salmon in all areas fished, from 165° West to 175° East Longitude both north and south of the Aleutian Islands. The period fished was June 9 to July 28.

Starting in 1955, and continuing annually since, the United States Fish and Wildlife Service has systematically fished the North Pacific and Bering Seas from the Gulf of Alaska to 172° East Longitude in studying distribution and abundance of salmon (INPFC Annual Reports, 1955 - 1957). These experiments have been valuable guides for the tagging work each year. A total of 311 salmon were tagged from the gill net catches of the John N. Cobb which participated in the above work in 1955 (Powell and Peterson, 1957). The distribution of the three returns from these experiments is shown in Figure 1.

Figure 1.—Recovery distribution from tagging by U.S.F.W.S. aboard vessel John N. Cobb - 1955.
Figure 1. Recovery distribution from tagging by U.S. Fish and Wildlife Service aboard vessel John N. Cobb - 1955.

Figure 2. Recovery distribution of chum salmon tagged in pre-World War II period. Also showing chum tagged by Gilbert and Rich (1925) in Shumagin Is. and recovered on E. Kamchatka.

Source: Kubo, T., Y. Hirano and others (1955, p. 78).
Canadian researchers have conducted extensive studies of distribution and abundance in the Gulf of Alaska, and in addition have captured and tagged young salmon as they migrated seaward from the coast of British Columbia. (INPFC Annual Reports, 1955 - 1957; Manzer, 1956, 1958; Manzer and Neave, 1958).

As mentioned earlier, initial tagging experiments were conducted as far west as Kodiak Island by the Fisheries Research Institute in 1955, using two small purse seiners which were also equipped with gill nets. This work helped to make the present experiments more effective, particularly the fishing and fish handling techniques.

On the Asian side, the Japanese had considerable knowledge of coastal distribution of salmon as early as 1900 when long line fisheries were developed off the east coast of Hokkaido Island. In contrast to the American side, pinks and chums are the predominant species of feeding salmon taken in coastal waters. In 1910, chum salmon bearing hooks from the eastern Hokkaido fishery were found in commercial catches in the Amur River, thus indicating a considerable ocean migration of chum salmon (personal communication from Y. Hirano, Hokkaido Regional Fisheries Research Laboratory, Yoichi, Japan).

Actual tagging of salmon off Hokkaido and northward to the coast of Kamchatka was conducted by the Japanese in various experiments from 1917 - 1942. These experiments, summarized by Hirano (1953a, b), indicated the routes used by salmon approaching Asian spawning streams. Most tagging was within 50 miles of shore, although some were tagged farther east.
Hirano concludes that summer-run chum salmon approach the Asian Coast as two principal groups. The major run, traveling westward from the central Aleutian area, strikes the coast between the northern Kurile Islands and central Kamchatka. Some go north to streams of East Kamchatka, and others go south, to enter the Sea of Okhotsk. A minor group strikes the coast between Hokkaido and the southern Kurile Islands enroute to streams of the Okhotsk Sea.

Fall-run chum salmon destined for Hokkaido and northern Honshu apparently approach by a route leading southward via the Kurile Islands from the ocean off East Kamchatka.

Pink salmon bound for the Okhotsk Sea approach via routes similar to the two routes described for summer-run chum salmon. There is no size distinction between the two runs, however.

Red salmon approach Kamchatka and the northern Kurile Islands in a manner similar to the summer-run chums as described above.

The first mid-ocean tagging experiments which yielded returns from coastal fisheries were those by Japanese exploratory gill net vessels operating in the above period. Figure 2 illustrates the results of these experiments. Although the numbers of returns are few, they showed that both Asian and American chum salmon are found far at sea.

Figure 2.—Recovery distribution of chum salmon tagged in pre-World War II period. Also showing chum tagged by Gilbert and Rich (1925) in Shumagin Is. and recovered on E. Kamchatka.
Starting in 1952, the rapidly expanded high seas fishery by Japan has added a wealth of information on distribution and abundance of salmon in vast areas of the western North Pacific and Bering Sea (INPFC Statistical Yearbooks, 1952-1957). Tagging experiments by the Japanese from 1952 through 1957 have not been very conclusive due to the very low survival of salmon tagged from gill net catches, although results in 1957 were much improved (Japan, Fisheries Agency, 1958a). Their experiments in 1958, however, provided excellent results when long line gear was used (Japan, Fisheries Agency, 1958b,c). Reference is made to the 1957 and 1958 experiments later in this report.

Past experiments by the U.S.S.R. have been confined mainly to coastal areas, but they have recently conducted exploratory fishing to ascertain migration routes of salmon approaching Kamchatka (Birman, 1958; Semko, 1958).
ACKNOWLEDGMENTS

Acknowledgment is due first of all to Dr. William F. Thompson, who as director of the Fisheries Research Institute until his retirement in July, 1958, guided the high seas salmon tagging through its difficult beginning to become a very fruitful research project. His thoughts expressed in the Foreword are also much appreciated.

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The following contributed substantially as part-time or full-time assistants in the varied and tedious tasks of preparing the data for analysis: Thomas Calkins and Herman Enge, Assistant Biologists; Michael Dell, Donald Johnson and Robert Pollard, Fishery Aides.

The following individuals served as an Advisory Committee of Fishermen to assist in planning the 1956 Aleutian operations: Harry Guffey, Seattle; Paul Martinis, Sr., Everett; Paul Martinis, Jr., Everett; Peter Xitco, Bellingham. They furnished very valuable advice and suggestions on matters such as the selection of vessels, design of seines, methods of operation, selection of crew, etc.
Captains of the purse seine vessels chartered were: A.K. Andersen, California Rose, 1956, 1957, 1958; Clifford Andersen, Commander, 1957, 1958; the late Edward Haarsager, Renown, 1956; Birger Hansen, Renown, 1957, 1958. Each deserves credit for pioneering a difficult job under adverse conditions, and also for advising in the improvement of gear and methods each year.

Crew member A.K. Larsen, who fished on both the California Rose and the Commander, deserves special mention for his sincere interest in the research and for his many suggestions and innovations for improving methods and gear to better the condition of fish released.

Thanks are due to government fisheries agencies of Canada, Japan, Russia, and the United States for their cooperation in forwarding tags and recovery information from fish recovered by their fishermen.

Canneries, fish processors, fishermen’s unions, and individual fishermen of the four countries are also thanked for returning tags and recovery information.

The United States Navy and Coast Guard, and personnel too numerous to mention are thanked for their many services and favors extended to scientists and fishing crews during field operations in the Aleutian areas. The research vessels were dependent upon the Navy and Coast Guard for daily radio communication to Seattle, for daily weather reports, for supplies and fuel, and for emergency vessel repairs and hospitalization. Operations in the remote Aleutians would have been prohibitively expensive without such aid. In addition, all vessel personnel deeply appreciated the laundry, shower, and recreation privileges made available to them while in port at Adak and Attu.

Personnel of the North Pacific Salmon Investigations, Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service, Montlake Laboratory, Seattle, cooperated wholeheartedly in the tagging program both in the field and in the laboratory. Research vessels of the Bureau of Commercial Fisheries exchanged catch and weather data by radio with tagging vessels in the field which increased field efficiency of the tagging vessels. Processed data made quickly available to the Fisheries Research Institute were also much appreciated.
METHODS AND PROCEDURES
SELECTION OF GEAR AND VESSELS

GEAR SELECTION

The preliminary experiments of 1955 had shown the feasibility of seining for salmon well offshore, but had also indicated two important limitations to ocean seining. One limitation was the weather conditions under which a seine could be operated. A second was the very small catch per set in areas where salmon were widely scattered. In both cases, gill nets were more efficient, being fishable in rougher weather, and better able to take salmon where fish were scattered. In addition, the 1955 experiments had not extended west of Kodiak Island, so that the practicality of seining in the Aleutian area was still not certain when plans for the 1956 operations were being made. Thus it was decided to make purse seines the principal type of gear, but to provide vessels also with gill nets for use when weather or scarcity of salmon made seining impractical. It was further anticipated that gill nets might be used as a "lead" for increasing seine catches as described by Barnaby (1952).

In addition to seines and gill nets, long lines of the type used for salmon in the Baltic Sea were taken along to be tested.

VESSEL SELECTION

With the gear thus decided, the type of vessel became logically a seiner, since a seiner could also fish gill nets and long lines, but other types of vessels could hardly handle a large seine. The possibility of using a schooner-type vessel for seining was also investigated but abandoned, because of the cost of adapting the vessel for seining.
On the basis of experience in 1955, large seiners were favored for working at sea. The largest tuna seiners were found too costly to charter. Therefore, intermediate-sized sardine- and herring-type seiners between 75 and 85 feet in length were selected for the purpose. Some of the larger of these had successfully seined for tuna off South America. This type was also effective in seining for salmon off Vancouver Island and at Cape Lutke on Unimak Island where seining methods were very similar to those being planned for the high seas tagging.

The Advisory Committee of Fishermen, mentioned in the acknowledgments, helped to decide on vessel capabilities and on the type of equipment required. (Committee members had seined for salmon in the open ocean off Vancouver Island and off Unimak Island.) The Committee further suggested special equipment and adaptations for using both gill nets and a purse seine from one vessel, and for fishing in heavy seas.

**SEINES SUCCESSFUL**

The 1956 operations were sufficient to prove that both vessels and seiners were practical for the Aleutian area. Only minor changes in seiners and equipment were found necessary for 1957 and 1958. Gill nets were used some in the early part of 1956, but were abandoned thereafter. Details of seine and gill net gear and methods of fishing are given in the next section. Long lines were not tried after seiners were found successful.
VESSELS USED

The vessels chartered for each year's operations were as follows:

1956
- California Rose
- Length 78 feet overall
- Renown
- Length 85 feet overall

1957
- California Rose
- Length 81.5 feet overall
- Commander
- Renown

1958
- California Rose
- Commander
- Renown

The vessel Commander is shown in Figure 3A.

Figure 3.--Fishing and tagging operations.

VESSEL EQUIPMENT

The equipment required on each vessel was as follows:

1. Standard purse seine winch and cable reels
2. Purse seine skiff of 18 - 22 feet length powered by 100 - 150 horse power engine
3. Seine table large enough for the large seine used
4. Hydraulic power block for retrieving seine
5. Sufficient water pumps to supply the fish holding tank with a minimum of 200 gallons per minute continuous flow
6. Radar
7. Loran
8. Radio direction finder
9. Two-way radio
10. Ample accommodations for a 7-man crew plus 2 biologists
11. Spare 15 - 20 cu. ft. freezer for holding salmon specimens
12. Ample fresh water, and fuel capacity for 20 - 30 days' operations without replenishing
13. Fathometer

In addition to basic equipment, vessels were required to be sound and seaworthy for extended operations in the Aleutians far from repair facilities or parts supply.

CHREWS

A final important consideration in selection of vessels lay in the captain and crew. It was important to an operation of this sort to find a captain who was interested in the research problem and one who could select a crew of experienced seiners willing to fish for a four- to five-month period under severe weather and sea conditions in one of the most inhospitable parts of the earth.
A— Purse seine vessel *Commander* completing haul.

B— Brailing with dip net.

C— Tagged salmon recovering from anesthesia.

D— Tagging operations using anesthesia and disc tags.

Fig. 3  Fishing and tagging operations.
LIMITATIONS OF VESSELS AND GEAR

The vessels described were not designed for seining at great distances from shore. With the seine and skiff high on the stern, the vessel and gear were vulnerable to damage by large seas. For this reason, seining at distances greater than 24 hours offshore had to be confined to periods when weather was good. When storms arose, it was necessary to return to the lee of the nearest Aleutian Island or harbor.

A larger vessel which would be able to "ride out" an average storm without returning to harbor would certainly permit more fishing time offshore, but probably could not fish in any worse weather than the smaller vessels because of increased strain on the purse seine, and danger to the crews as described below.

The seines were built very heavily with cable on the cork line, chain for the lead line, and heavy duty purse cables as described in the appendix (Section B). Such construction permitted seining under fairly rough sea and wind conditions, but when the wind and sea increased suddenly, the gear was strained to the breaking point in completing the haul. The Renown seine was damaged considerably in 1957 when the strain, caused by the swell, broke a connecting link of the purse cable. Such operations become a danger to the crew, since working on deck and handling heavy overhead gear become very difficult as the vessel rolls in the seas. In addition, there is added danger that a cable might become fouled in the wheel and immobilize the vessel. Actual maximum sea conditions for seining would be hard to define since the direction of swell and chop, and the intended direction of "set" with regard to wind direction must all be considered.
Tide conditions were another limitation to the seining. Even slight tide-rips can render a seine haul ineffective, and major rips have been known in commercial operations to cause loss of an entire seine. Often it was necessary to scout considerable distances to find an area suitable for making a set. In 1956, no seining was attempted near or in the Alutian passes. However, in 1957 and 1958, it was found that hauls could be made in the larger passes during brief periods of slack tide. In some cases the set had to be curtailed due to developing tide-rips, but catches in the passes were often well worth the extra care and risk.

**FISHING GEAR**

**GILL NETS**

Although gill nets were used only a few times in the early part of the 1956 field season, the methods of handling them aboard a purse seine vessel deserve comment.

Each seiner carried a total of twelve 50-fathom shackles of gill nets similar to those described by Powell and Peterson (1957, p. 4). Mesh sizes ranged from $3\frac{3}{4}$" to $5\frac{3}{4}$". Since the mesh sizes used by each vessel were slightly different, the makeup of a standard 10 shackle "set" is listed below for the 2 vessels. All nets were nylon except the $5\frac{3}{4}$" which was linen.

<table>
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<tr>
<th>California Rose</th>
<th>Renown</th>
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<tr>
<td><strong>Mesh size (in inches stretched measure)</strong></td>
<td><strong>No. of shackles</strong></td>
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<td>$3\frac{3}{4}$&quot;</td>
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<tr>
<td>$4\frac{1}{2}$&quot;</td>
<td>4</td>
</tr>
<tr>
<td>$5\frac{3}{4}$&quot;</td>
<td>2</td>
</tr>
<tr>
<td>$5\frac{3}{4}$&quot;</td>
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Nets were stored on deck between the rail and the house on the port side. This was out of the way for normal seine operations, yet convenient for setting and repiling during retrieve. Nets could not conveniently be set over the stern because of the presence of the seine and skiff. Therefore, they were set by feeding them broadside over the port rail as the boat drifted. Under average conditions this took about one hour for 10 shackles.

Retrieving the gill nets was accomplished by using the hydraulic power block normally used for seining. Several methods were tried, but the most successful was by leading the net through a roller secured to the rail just aft of the rigging, and then through the power block which was secured to the winch. With the speed and power controls of the hydraulic system, the gill nets could be smoothly brought aboard. Retrieving required approximately one hour.

**LONG LINES**

Each vessel carried approximately 10,000 feet (450 hooks) of Danish-type salmon long line as described by Larsen (1950). The success of the purse seines, however, made it impractical to spend time in learning the use of this unfamiliar and very specialized gear.

It should be noted, however, that the Japanese, who for many years have fished salmon commercially with long lines, successfully tagged salmon in the Aleutian Island area in 1958 using long line gear. The Japanese gear consists of a light cotton main line suspended near the surface by small floats. Nylon "branch lines" about one meter long are spaced every 3 meters. Hooks are baited with whole salmon (frozen or salted). Danish long lines have longer (3 - 4 meters) branch lines, and spacing is greater (10 - 20 meters).
SEA SCANAR

The vessel Renown was equipped with a sonic fish locator manufactured by the Minneapolis-Honeywell Company called a Sea Scanar. This instrument is a very versatile echo-sounder which can scan any depth angle from the surface down to 90°, and also laterally more than 90° on either side of the bow. The echo is audible and also visible on an oscilloscope showing both direction and range. The depth of an object can be easily obtained from the observed angle of depression and the distance.

Individual salmon are easily indicated by the Sea Scanar, but since scattered salmon are nearly everywhere at sea, it was no help in determining where to set. In order for the instrument to be an aid in seining, salmon would have to be schooled, which apparently is seldom the case.

The Sea Scanar was very useful, however, in finding safe routes into unfamiliar and uncharted anchorages.

PURSE SEINES

DESCRIPTION

Since the purse seine used for taking salmon at sea for tagging has been especially adapted for the purpose, the seine used in 1958 is described in detail in Section B of the appendix. [For a description of the several types of purse seines used on the Pacific Coast, including diagrams of the principles of operation, see Scofield (1951).]

Each year, as experience was gained, various changes were made in the seines as described below.
In 1956, the seines used were standard salmon purse seines rented from the owners of the vessels, except that 3\(\frac{1}{2}\)\" web was substituted for the standard 4\(\frac{1}{4}\)\" mesh size in the upper two strips in order to prevent gilling of small salmon. These nets proved to have two principal drawbacks; first, the 3\(\frac{1}{2}\)\" mesh size was not small enough to prevent gilling of the smaller sizes taken, and second, the heavy knotted material in the bunt of the seine was found to injure the salmon. (The bunt section is the end of the seine in which the catch is held during brailing.) The rolling of the vessel in the ocean swell chafed the knotted web against the salmon, causing serious scaling when seas were rough. Injury was proportionately worse when catches were large due to greater congestion in the net plus a longer period of brailing.

Therefore, in 1957, 3\" mesh size was used in the upper strips, and all but the bottom strip were of 3\(\frac{1}{4}\)\" mesh. This relieved the problem of gilling the smaller salmon, but some of the smallest sizes still were found to gill. To solve the problem of injury in the bunt, knotless synthetic material of 2\(\frac{1}{2}\)\" mesh was tried. This material greatly reduced scaling and injury. Since catches were very large in 1957, the knotless bunts were doubly beneficial.

In 1958, cork-line strips were made of 2\(\frac{1}{2}\)\" web, and bunts were made of 2\" knotless web. These dimensions were small enough to eliminate normal gilling difficulties. However, in August and September the California Rose, in fishing south of Kodiak Island, encountered salmon which had migrated to sea the prior spring. These fish were so small (17 - 22 cm.) that there was still some gilling. Future cork-line strips and bunts will therefore probably require 1\(\frac{1}{2}\)\" material if all gilling is to be eliminated.
METHOD OF OPERATION

The method of making a "tow" haul as developed by seiners off Unimak and Vancouver Islands was found to be practical for the high seas operations. The seine, measuring approximately 400 fathoms long and 35 fathoms deep, is set off the stern of the vessel in a large arc with the concave side facing the expected approach direction of salmon. Setting a 400 fathom net takes approximately 5 minutes. The power skiff tows the bunt end of the seine, while the main vessel tows the other end (towing end). Actually, the net is moved little, if any, through the water; just enough power is used to hold the direction of "set" and shape of the net. At the start of the set there is very little curve to the net, so that the opening is perhaps 300 fathoms wide. Gradually the curve is increased and the depth of the arc is increased until the shape is approximately a semicircle. Thus the opening of a 400 fathom seine would be 250 fathoms. In calm weather, with no tidal influence, the seine might be held open indefinitely, but under average sea and wind conditions the net must be closed in less than an hour in order to prevent flattening of its shape and thus possibly losing fish.

Vessel captains differ in their opinion as to the optimum time for holding open. Records of the hauls showed the timing to vary from 15 minutes to over an hour, but because of other variables, many more tests would be needed to determine an optimum (the standardized time used on the great majority of sets was 30 minutes). The theoretical optimum would be the length of time during which the number of fish entering the net is greater than the number finding their way out again. This probably varies with species, rate of salmon movement, sea conditions, etc.
After approximately 30 minutes of holding open or towing the net, the
skiff and the main vessel close the net by using more power and completing the
circle. Closing requires from 10 to 20 minutes. The skiff or bunt end is then
attached to the davit on the port side of the seiner, and the winch is used to
pursue the bottom of the net by means of the purse cables. When pursing is com-
pleted (15 - 20 minutes), the cork-line forms a large irregular circle off the
port side of the vessel, and the purse rings are all bunched together and
brought aboard. Any salmon now in the net are completely surrounded and
unable to escape. The web is then brought aboard by means of the hydraulic
power block and re-piled for the next set. The retrieving of the web con-
tinually forces the salmon toward the final bunt end of the net where they
may be brailed. Retrieving takes from 15 to 20 minutes. During pursing and
retrieving of the web, the skiff tows the vessel broadside away from the net
in order to keep the net open and away from the boat. This insures swimming
room for the salmon until brailing is complete. Final retrieving of web and
towing by the skiff are illustrated in Figure 3A.

DEPTH OF FISHING

The seine as described in the appendix theoretically should hang about 35
fathoms deep, with variations according to amount of slack allowed during
hanging and according to web shrinkage. However, the effective fishing depth
of a seine must be measured from cork-line to lead-line while the net is being
towed. During towing, the web does not hang straight down, but bows outward,
away from the direction of tow. In addition, the lead-line, being shorter than
the cork-line, tows ahead of the cork-line. On several occasions in 1958, the
cable dragged bottom in an area where the fathometer indicated a steady 36
fathoms of water under the keel. Thus the "fishing depth" during towing is at
least 35 fathoms.
BEHAVIOR OF FISH IN SEINE

Nearly all hauls were made "blind" since jumpers are seldom seen at sea. However, while towing the net and particularly while pursing and retrieving the web, salmon often finned at the surface or jumped. When a haul contained several hundred salmon, jumpers were nearly always evident in the net; sometimes, however, not until the bunt was reached.

During the towing phase of a seine haul, the web bows outward from the cork-line. For this reason, salmon do not find their way over the cork-line even if the swell causes the corks to submerge momentarily. During pursing, when wind and tide are strong, the additional pull of the purse cable may sometimes cause a 50 or 100 foot section of the cork-line to dip under for several minutes. On such occasions, salmon may escape. In 1957, nets had inadequate floats, and during some hauls, salmon were seen escaping over dips in the cork-line during pursing. Additional floats added in 1958 eliminated cork-line sinking except in very strong tides.

At any time during a haul before pursing is complete, salmon have opportunity to escape the net by going under or around the ends. The depth of the net makes it unlikely that fish go under the lead-line except possibly when wind and tide cause the net to "purse shallow". Fishermen state that the wake from the skiff and from the main vessel during towing causes fish which may be leading toward the ends of the net to turn back toward the center again.
On calm days it was possible, with polaroid glasses, to observe the salmon in the net from high in the rigging. Best observations were after half of the net was retrieved. In general, salmon behaved as a loose school moving slowly along the net at a depth of perhaps 5 to 10 feet. Schools did not approach the vessel closely, but turned and circled away as the shallow web was encountered closer to the vessel. Gilling at this stage of a seine haul was apparently caused by a segment of web being bunched or pocketed together by wave action, thus imprisoning a group of fish and causing them to fight the net. Predation by sea lions or by fur seals within the net also resulted in salmon gilling themselves.

Striking differences in behavior of the several species were noted. (Oncorhynchus nerka) (O. gorbuscha)

Red salmon were the most frequent jumpers. Pinks were second in this respect. (O. keta)

Large hauls with few jumpers indicated a catch principally of chum salmon.

In brailing a mixed catch, the reds invariably were among the first to be brailed, while pinks and chums followed in that order. The last several fish to be brailed were always chums staying close to the bottom of the bunt. (O. tshawytscha)

King salmon fought the net the hardest (regardless of size) and were usually the first to injure themselves. Chums were next in this regard, followed by pinks, and finally reds were least injured, probably due to their staying nearer the surface, thus avoiding crowding and chafing at the bottom of the bunt. Too few cohos or steelhead were caught to classify their behavior.

FISH HANDLING METHODS

It was evident from the 1955 experiments that there were numerous problems in holding and handling salmon with a minimum of injury before release. Special equipment and methods designed to reduce handling injuries were therefore applied in 1956 and further improved and modified in 1957 and 1958.
Salmon during their ocean feeding period are much more delicate and easily injured than are mature salmon entering estuaries and rivers. This is particularly true of the younger fish which still have a year or two of ocean feeding before maturity. The skin of salmon at sea is thin, their scales are deciduous, and their slime covering is easily removed. Therefore, care in handling becomes extremely important if fish are to be released with maximum chance of survival.

The sequence of steps in handling the salmon and the attendant problems are discussed below. The methods of handling the few salmon taken in gill nets were substantially the same as in 1955, as reported by Jones.

---


PREPARATION FOR BRAILING

As the last of the seine is brought aboard, the swimming room for the salmon is being constantly reduced until they are finally confined to the bunt section. These few moments are critical, since with so little web remaining in the water, the seas and tide may collapse the web against the boat, thus imprisoning the fish and causing them to lose scales in struggling to free themselves. Two means were used to avoid this difficulty; first, the skiff was directed to continue to tow the vessel away from the web so as to keep an opening for the fish (Figure 3A), and second, long poles were used as "pushers" to hold the cork-line out from the boat, while the skiff approached to assist with brailing. Collapsing of the bunt was a problem only when wind or tide was strong.
With the catch in the bunt, the skiff was brought alongside and the cork-line attached to the rail of the skiff (Figure 3B). The salmon were then in an "apron" of knotless web hanging between skiff and seiner and ready to be brailed. Sufficient web was allowed to give the fish ample room to swim. If seas were rough, it was necessary to head the vessel into the wind to reduce the heaving of the bunt. If the catch was large, the outrigger pole was lowered from the rigging to a horizontal position and the bow of the skiff made fast. This kept the skiff clear of the vessel during brailing. The stern was held off with a "pusher". If seas were calm, little or no injury would have been caused up to this point, but with even slight seas, the chafing in the bunt required prompt removal to the holding tank.

Another type of injury to salmon in the bunt was caused by jellyfish. In some areas, a single haul netted a ton or more of jellyfish which nearly filled the bunt, thus depriving salmon of oxygen as well as stinging them. Sometimes the stings caused welts on the sides of the smaller salmon. The jellyfish had to be brailed overboard prior to brailing the salmon.

**BRAILING**

Two methods of brailing the catch from the bunt to the holding tank were used.
The brailer bucket method utilized a large canvas bucket with a capacity of approximately 110 gallons. This bucket was attached to a standard seine brailer. A curtain of knotless nylon was attached to the rim of the brailer to funnel the fish into the bucket. With the fish concentrated in the bunt, the brailer was carefully dipped at one end and drawn upward by means of the ship's tackle. The fish were thus lifted from the bunt without ever leaving the water. The brailer and bucket were then swung over to the tank, and the contents poured into the tank which had been pre-filled with water. Between 25 and 50 salmon could be handled per brail depending on their size. This method was not used when seas were rough because of the difficulty in handling the full brailer as the vessel rolled. It was also impractical when catches were small because of the time necessary to rig the brailer.

The second method of brailing was done manually with long-handled dip nets hung with fine-meshed knotless nylon (Figure 3B). By taking only 3 or 4 fish at a time and by using shallow nets which do not "bag" the fish, the dipping caused no observable injury.

FISH HOLDING TANKS

Since the greatest injury observed in 1955 was caused by prolonged holding in the bunt, the use of tanks starting in 1956 accomplished a great reduction in injury. After the catch was brailed aboard, the fish were safe from further injury except for that associated with tagging. Motion of the vessel had little effect on the water in the tanks, since they were built with a high coaming. After brailing, the vessel was headed in a direction which minimized motion primarily as an aid to tagging.
DESCRIPTION OF TANKS

The tanks on the Commander and Renown were of 3/4 inch marine plywood and measured approximately 11 feet by 5 feet by 2 1/2 feet high. They were bolted through the deck against the seine table (Figure 3D). A perforated partition in the middle reduced surging of the water. Each section had a 4-foot square opening in the top fitted with an 8-inch coaming. Overflow was through holes drilled in the coaming. Inflow, taken from the ship's pumps, was adequate to fill the tanks in approximately 5 minutes, or at the rate of about 200 U.S. gallons per minute.

Because of limited deck space, the tank on the California Rose was installed vertically in the hold. It measured 5 feet by 5 feet and stood 8 feet high, being mounted on timbers in the hold, with the top flush with the hatch opening. Its 1500 gallon capacity was greater than that of the deck tanks used on the other vessels, but it was somewhat less convenient to use. Overflow was through pipes leading through the hatch coaming to the deck.

FISH CAPACITY OF TANKS

The maximum fish holding capacity of the tanks was not determined, but with full water flow, there was no apparent distress with 500 mature salmon in a deck tank. In some cases, as many as 800 immature salmon were successfully held. The limit appeared to be related to physical crowding rather than oxygen supply. The above numbers of fish were not in the tank long, since tagging and release was progressing at a rate of over 100 per hour.
BEHAVIOR IN TANKS

It was not known at first just how salmon taken from the open sea would react when large numbers were confined in a holding tank, but this proved to be no problem. All species milled quietly about, occasionally finning at the surface. There was no jumping or battering against the walls of the tanks. Fish which were fatigued from being trapped in the net in rough seas were more vigorous after a period in the tank than when first introduced.

Four pink salmon were kept in one tank for four days with only an occasional refreshing of the water, and all appeared strong and vigorous when removed.

Parker and Kirkness (1956, pp. 18 - 20) had found a live-box very helpful both for holding and for tagging troll-caught king salmon off southeastern Alaska.

TRANSFER TO TAGGING BOX

For this step in the handling procedure, a short-handled dip net was used to lift the salmon from the holding tank to the tagging box (Figure 3D). Little, if any, injury occurred at this point, except in rare cases when the salmon was dropped on the deck. With a little practice, it was possible to lift a single salmon from the tank without panic to the fish dipped, or to those left in the tank. If the last few fish remained near the bottom and eluded the net, the water level in the tank was lowered to facilitate dipping.

Dip nets had a light wooden handle about 30 inches long, and an oval-shaped rim approximately 24 inches across at the widest point (Figure 3D). Web used was knotless bobinette of ¼ inch mesh, hung with little slack to prevent the salmon's tangling in the web.
HOLDING IN TAGGING CRADLE

Two types of tagging cradles were used. The first, designed for underwater tagging, was a V-shaped metal trough lined with ¼ inch foam neoprene. This was placed inside the canvas brailer bucket previously described. The bucket was held upright by a metal ring support which clamped to the starboard rail (Figure 3D). Because no apparent advantage was found in underwater tagging, the standard type of tagging cradle was used for most experiments. This was a plywood trough one meter in length, lined with ½ inch foam neoprene. In some cases foam rubber was used and in turn covered with a sheet of smooth vinyl plastic. The trough was clamped to the rail of the boat with the outboard end open for release of the salmon. A shelf under the trough served to hold tagging supplies. On both types of boxes, meter sticks were built into the bottom of the trough in such a way that the salmon was protected from the edges (Figure 3D). The meter sticks were made of solid white vinyl material printed with contrasting black numerals and scales for good legibility.

After the fish was placed in the cradle, it was held as gently as possible by a second man while being tagged and measured, and while a scale sample was taken. The time from dipping to release averaged between 30 and 40 seconds.

In spite of the care taken and the brief time involved, the injury while the salmon was being held in the tagging trough was probably second only to that which occurred in the seine when seas or wind caused complications, as described earlier. This applied particularly to the smaller sizes in both cases, since they lose scales so easily.
Numerous methods were tried to reduce handling injury during tagging, such as tagging underwater, various kinds of rubber and cotton gloves for holding, and even a form-fitted sponge rubber "straight-jacket" type of tagging cradle which held the fish uniformly and gently, but none of these appeared to have reduced injury or scaling.

ANESTHETICS

In 1958 anesthetics were tried aboard the California Rose as a means of reducing the handling in the tagging process. (The following results are from a report on the subject by Albert W. Palmer, 1959, unpublished.) A 60-gallon solution of the anesthetic was prepared in one of the bailer buckets and the bucket placed between the tank and the tagging box (Figure 3D). The fish was dipped from the holding tank to the bucket, and when anesthetized, was transferred to the tagging box. After tagging, the fish was placed by hand in a second bailer bucket supplied with running seawater for recuperation, after which it was released overboard by use of a hand dip net.

Figure 3C shows tagged salmon recuperating in the bucket.

Once the routine was started, handling and tagging were quicker and easier than without anesthesia. The process practically eliminated scaling during tagging.

Anesthetics used were MS-222\(^2\) and Quinaldine\(^3\). Concentrations which

\(^2\)MS-222 = Tricaine Methanesulfonate = Sandoz Pharmaceuticals, Hanover, New Jersey.

\(^3\)Quinaldine = 2 Methylquinoline = Eastman Kodak Stock No. P-216.

immobilized immature salmon in approximately 30 seconds were 2/3 gm per gallon of seawater for MS-222, and 0.25 ml per gallon for Quinaldine. The latter was dissolved in equal parts of acetone prior to mixing with seawater. With either anesthetic, recovery took from 1 to 2 minutes. The fish showed no reaction to MS-222 solution, but in the Quinaldine solution, they darted erratically, sometimes striking the sides of the bucket, and also gaped with jaws and gills prior to relaxing.
FISH INJURY STUDIES

After the 1956 field season, experiments were undertaken to evaluate the two principal injuries noted in salmon tagged. These were scaling, which has been described, and injury to the eyes, which has not yet been mentioned.

SCALING

Since scaling in some degree is unavoidable at sea, it is desirable to know the long-term effects and possible mortality due to various degrees of scaling.

Two sources of fish were used to conduct the tests; trout held in freshwater ponds at Gold Creek Trout Farms, Woodinville, Washington, and young immature silver and king salmon held in a floating live-trap in Shilshole Bay in Puget Sound. At both places, the specimens were tagged and artificially scaled to approximately match the 3 degrees of scaling noted on the tagging forms.

These were:

Scaling degree "1" - Few scales missing - less than 10% of body
"2" - Small patches of scales missing - up to 25% of body
"3" - Large continuous patches missing - up to 50% of body

Fish from both sources were examined after 4 days and again after 35 days. The trout showed almost immediate recovery from scaling degrees "1" and "2", with little evidence of the injury remaining at the first examination. Those with degree "3" scaling showed a lack of mucus and a lighter color where scaling was most severe, but showed no obvious lessening of vitality. By the second examination, the light "dry" patches had disappeared and mucus had again returned.
The salmon in salt water likewise healed quickly from the lesser scaling, but degree "3" scaling resulted in white "dry" patches, some of which persisted for several weeks and became fungused. The salt water tests lacked conclusiveness since numbers were small (9 test specimens and 3 controls) and the salmon would not feed, including the controls. All specimens continuously lost weight, and one of the scaled fish survived the controls in spite of fungus infection.

From the above, it might be concluded that moderate scaling is not a serious problem, but no tests on fish in captivity could duplicate actual conditions of salmon at sea, so that scaling must continue to be suspect.

Returns of tagged fish have not yet been analyzed according to degree of scaling, since this injury applies mostly to the very small fish which have spent but one year at sea, and returns from this group have been too few, which again is reason to suspect scaling injury.

**EYE INJURY**

Another injury caused by the web is abrasion to the cornea of the eye, or ulcerated cornea. (An investigation of the injury, its symptoms and cure in both fish and mammals was made by Herman F. Engle, unpublished, 1956.)

This injury results in the formation of an opaque spot perhaps 2 or 3 mm in diameter in the center of the cornea. The spot does not become apparent until 30 to 60 minutes after the injury.

It was noted on one or both eyes of a large proportion of the salmon caught, when hauls were made in particularly rough weather. Fish which were trapped in the web long before brailing were observed to have the spot when first brought aboard. Those injured in the bunt just before brailing did not show any sign of the injury at brailing, but had developed definite spots within 30 minutes in the tank. The tank was eliminated as a cause by observation of uninjured fish after several hours in the tank. Salmon taken in the gill nets were also noted to have the injury when brought aboard.
The trout and salmon used for the scaling tests were used also for the eye injury observations. The injury was induced by abrading the eyes with tarred cotton web as used in the seines. After 15 strokes, no injury was at first visible, but as at sea, the opaque spots appeared after about 30 minutes. This would have been a very serious cause for concern were it not for the fact that the great majority of injured eyes had completely cleared within 24 hours after injury. One of the test salmon in salt water and one of the trout continued to show a slight spot in one eye for several days, but judging from the initial appearance, the intentionally inflicted spots were more severe than those suffered at sea.

It is reasonable to conclude that the great majority of eye injuries heal in 24 hours or less at sea. However, during the period of reduced vision salmon are undoubtedly more vulnerable to predators.

Notation of specimens having eye injury was made on only a few tagging experiments, since it required time to closely examine each eye. However, for those experiments so noted, the results are shown below. (Chum salmon tagged between June 24 and July 11, 1956. Most were immature, with returns coming in 1957.)

<table>
<thead>
<tr>
<th>Without eye injury</th>
<th>No. tagged</th>
<th>No. recovered</th>
<th>% recovered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>358</td>
<td>4</td>
<td>1.1</td>
</tr>
<tr>
<td>With &quot; &quot;</td>
<td>440</td>
<td>8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

The results are the opposite of what might be expected, but the numbers recovered were obviously too small for a critical comparison. Such results at least indicate that the eye injury cannot be a serious cause of mortality. However, efforts to reduce such injury have continued in all of our operations.
TAGGING PROCEDURES

DISPOSITION OF PERSONNEL

With the catch placed in the tank, the vessel was headed in the direction which caused the least vessel motion, or which gave tagging personnel best protection from wind. If the catch was small, only one tagging crew was used; if large, two were used, one at each rail. Four men were required for each tagging crew; one to dip salmon from the holding tank to the tagging cradle, one to hold, one to tag, and one to record the data. Scales were taken by the man tagging, when both crews were operating; otherwise a fifth man was used. When necessary, a single man could dip for both crews. With two full crews working, there was only one man left to guide the ship. When catches were very large, this man also loaded tube tags on needles to speed the tagging. On the few occasions when very large catches were made, part of the catch had to be left in the bunt. One team then tagged from the bunt, and the second team tagged from the tank, thus reducing congestion in both places.

TAG APPLICATION

Disc tags or tube tags were applied through the body at the base of the anterior half of the dorsal fin. Discs were applied with only a little room for growth even on the smaller fish. Tubes were applied with a loop which placed the knot behind the dorsal fin. Time required for tagging was nearly the same using either type of tag, averaging 30 to 40 seconds, including taking a scale and measuring. Figure 3C shows salmon with tube tags attached.

DATA RECORDING

Forms for recording tag data were kept in duplicate, using waterproof paper and waterproof carbon. For each fish tagged, the following were recorded:

1. Tag number
2. Species
3. Length
4. Scale sample number
5. Condition
6. Remarks
At first, species were difficult to distinguish at sea, especially the younger ages, but with some practice, even the smallest usually could be quickly identified. Scales furnished positive identification later if needed.

Lengths were taken to the nearest \( \frac{1}{2} \) cm by holding the fish's snout against the head of the tagging cradle and sighting the tail-fork against the meter stick in the bottom of the tagging trough.

Scale samples were taken from every fish tagged starting in 1958. In 1956 scales were taken from approximately 50% of fish tagged, and in 1957 from approximately 75%. One or two scales were removed using forceps, and placed in rows on a gummed card, with sculptured side up for later impressing in plastic.

The record of condition of the fish at release was based entirely on scale condition, using the 3 categories described in the section on fish handling. In early 1956, vitality was entered for fish tagged from gill nets, but fish from the seine showed little variation in this regard. Any injured to the point that vitality was obviously low, were not tagged.

Under remarks, were entered such items as injuries due to predators, malformations, marks from gilling in the seine, or a notation if the fish had been dropped in handling.

An attempt was made to record sex in 1956, but few fish were mature enough to show external sexual dimorphism, so this was discontinued.

OTHER DATA COLLECTED

The following data and specimens were collected in addition to the tagging data mentioned above.
FISHING EFFORT FORMS

For each date and location of fishing a "Fishing Effort Form" was filled out to provide a uniform record of the physical conditions pertaining to each set, and of associated observations and data collected. Principal data recorded were:

1. Date, location
2. Time of start and finish
3. Wind, seas, tide, sky
4. Depth, drift direction
5. Direction of "set" of seine
6. Surface water temp., air temp.
7. Water sample number
8. Bathythermograph slide number
9. No. of salmon caught by species
10. " " " tagged " "
11. " " " examined by species
12. Catch other than salmon
13. Observations of birds, pinnipeds, cetaceans
14. Effectiveness of haul
15. Condition of fish caught
16. Remarks

The direction of "set", the catch other than salmon, and pinniped observations are included in the catch tables in the appendix (Tables C1 - C4). Unusual specimens were added to the preserved fish collection of the College of Fisheries of the University of Washington.

SPECIMEN EXAMINATION DATA

A sample of fish from each of the larger catches was saved for determination of sex, maturity, and stomach contents. Observations were:

1. Species
2. Length
3. Sex
4. Egg diameter (average of 5 eggs)
5. Testis width (widest part of largest testis)
6. Scale sample number
7. Stomach condition (full-medium-trace-empty)
8. Stomach contents (brief description of principal items)
9. Remarks (injuries, parasites, malformations, etc.)

The stomach contents data have not been analyzed yet. The gonad measurement data were useful in evaluating the maturity of salmon tagged, although there is a clear need for larger samples throughout the season.
DATA FOR FISH AND WILDLIFE SERVICE INVESTIGATIONS

Samples and observations useful to the U.S. Fish and Wildlife Service North Pacific Investigations were collected by the tagging crew when possible. The necessary instructions, equipment, and forms were provided by the several projects.

Data collected were:

1. Bathythermograph slides and surface water samples for the use of Fish and Wildlife Service oceanographic studies.
2. Blood samples for serology studies.
3. Frozen specimens for the sampling program. (The latter were possible only when very large catches were made.)

TAGS USED

SELECTION OF TAGS

The most effective tag for a particular tagging problem depends upon several considerations such as the fish's structure, habits, swimming speed, size, time at liberty, the gear used for capture, and the processing methods. Of the several types of tags which have been used for salmon in coastal areas, Petersen-type disc tags attached at the base of the dorsal fin have shown widespread acceptance (Roundsefell and Kask, 1945).

In selecting a tag for applying to salmon at sea, it was recognized that the requirements were different than for tagging in coastal areas. It was anticipated that smaller sizes of salmon would be taken at sea, and that the time between tagging and recapture might be as much as two years, consequently the fish would grow considerably between tagging and recapture.

Therefore, two types were chosen for the preliminary experiments of 1955; disc tags because they were well proven in salmon tagging, and would furnish a basis for comparing results, and plastic tube tags because they appeared well adapted to remain on rapidly growing fish for the required period.
Concurrent with the tagging at sea, tag testing experiments on rainbow trout in fresh-water ponds were begun in the spring of 1955 and continued through the summer of 1958. One purpose of the experiments was to test, over a period of time, various tag materials, types of tags, and methods of application, in a search for tags which would better fulfill the requirements of high seas salmon tagging. A second purpose of the test tagging was to evaluate, and to find means to reduce, the injury caused by tags and by handling during capture and tagging.

Many types of tags were tried in an assortment of sizes and point of attachment. The Floy Manufacturing Company, 2909 Blakely Street, Seattle, Washington, was very generous in supplying materials and sample tags which they were developing.

Details of the tag testing experiments will be included in the report now in preparation on the 1955 work. However, none of the new tags tested showed enough promise to be tried in the North Pacific experiments. Therefore, discs and tubes continued to be used in the high seas experiments of 1956, 1957, and 1958.

**DESCRIPTION OF DISC TAGS AND TUBE TAGS**

The disc tags used were of white cellulose acetate \(\frac{1}{2}\) inch in diameter and 0.036 inch thick. The small diameter was chosen to reduce water drag and resultant cutting of the pin through the flesh of the fish. Discs were attached in the usual manner through the body at the base of the dorsal fin using soft stainless steel pins 0.036 inch in diameter. The hole in the center of the tags was also 0.036 inch in diameter.

Discs were obtained from the Howitt Plastics Company, Mollala, Oregon, and pins from the Star Pin Company, Shelton, Connecticut.
The tubes or "spaghetti" tags were patterned after those developed by the California Department of Fish and Game (Wilson, 1953). The material found most satisfactory was obtained from the Irvington Varnish and Insulator Company, Irvington, New Jersey, under the trade name "Ivi-Flex." This material is very soft and pliable, and is easily tied into a small tight knot even when hands are wet and cold.

Tube tags were 1/16 inch in outside diameter and approximately 13 inches long. They were applied through the body at the base of the dorsal fin by means of a special stainless steel needle which was developed by John W. Martin of the Fisheries Research Institute. The needles were 6 inches long and 1/16 inch in diameter. One-half inch of the rear of the needle was turned down to a diameter slightly greater than the inside diameter of the tubing. The tubing was slipped over the shaft and held by friction. The diameter of the puncture through the fish was then no greater than the 1/16 inch diameter of the tag.

Most tubes were white, although some yellow were tried in 1957 and 1958 for comparison. A few smaller-diameter tubes of black material were tried in 1956 on the smaller salmon caught, but were discontinued because the 1956 tagging showed that the standard tubes could be applied satisfactorily to even the smallest salmon taken.
It was found that the Ivi-Flex material could not be labeled with the stamp-type labeling machines due to its extreme softness; therefore, labeling and numbering was done by hand using vinyl ink and a number "O" Leroy pen.

Cost of labeling and numbering was at first approximately 7½ cents per tag. In late 1956, however, a local tag manufacturer developed a machine which could label any type of tube material with vinyl ink. (H.C. McCoy, 16400 - 3rd S.W., Seattle, Washington.) Cost of machine-labeling of the legend was 2½ cents per tag. Since the machine was not able to number consecutively, the numbering was still done by hand at a cost of approximately 2 cents per tag. The cost of Ivi-Flex material was slightly over ½ cent per 13 inch tag. Thus, the final cost per tag came to approximately 5 cents.

The legend placed on tube tags was: "Return F.R.I. U of W Seattle U.S.A. Reward." The number was entered at both ends of the tag to insure a legible number if one should fade or be damaged during removal of the tag. Disc tags carried a similar legend, but without the duplicate number.

Table 1 lists the numbers of each type of tag applied in 1956, 1957, and 1958. The reason for the increase in the percentage of disc tags each year is explained in the following section.

Table 1. Numbers and types of tags applied 1956 - 1958
<table>
<thead>
<tr>
<th>Year</th>
<th>White Plastic Tubes 1/16&quot;</th>
<th>Yellow Plastic Tubes 1/16&quot;</th>
<th>White Discs 1/2&quot;</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>6,342^1</td>
<td>-</td>
<td>1,029</td>
<td>7,371</td>
</tr>
<tr>
<td>1957</td>
<td>11,323^2</td>
<td>1,334</td>
<td>2,712</td>
<td>15,369</td>
</tr>
<tr>
<td>1958</td>
<td>6,626</td>
<td>1,174</td>
<td>5,843</td>
<td>13,643</td>
</tr>
<tr>
<td>Total</td>
<td>24,291</td>
<td>2,508</td>
<td>9,584</td>
<td>36,383</td>
</tr>
</tbody>
</table>

1. Small-diameter black tubes are included here (see text).
2. 370 white tubes of the stiffer "Hyflex" vinyl included here.
COMPARISON OF DISC TAGS AND TUBE TAGS

Although the pond tagging experiments showed both disc and tube tags satisfactory as to materials and time of retention, the results of tagging salmon at sea have shown markedly better returns from disc tags than from tubes. Table 2 provides a summary of results from experiments in which both types of tags may be directly compared. In these experiments, one crew tagged with discs, and the other tagged simultaneously with tubes. Salmon were taken randomly from the same tank. The size distribution of fish within each of the size categories was almost identical, and there was no difference in vitality. Discs consistently provided better returns also in 1957 and 1958 experiments, so that tubes will be discontinued in future experiments except possibly on the smallest sizes taken.

Table 2. Comparison of numbers of disc tags and tube tags recovered from chum salmon tagged June 29 - July 14, 1956 south of Adak Island (Fishing Effort Nos. 34, 36, 39, 40, 42)

 Similar results were obtained by Richard Straty of the U.S. Fish and Wildlife Service in tagging mature red salmon in Bristol Bay in 1956 (personal communication).

Reasons for the better return of disc tags are presumed to be better visibility and more susceptibility to recovery in gill nets. Fishermen have reported finding disc tags but not tube tags in their nets while the fish had escaped.

RECOVERY EFFORT

Since tag returns from the mid-Pacific experiments might be expected from any commercial salmon fishing area or spawning stream, the recovery advertising had to be as widespread as the distribution of salmon.

Tags placed on salmon in the central Aleutian area have been returned from such diverse areas as the states of Washington and Idaho (via the Columbia River), southeastern Alaska, central and western Alaska, the Kamchatka Peninsula, Sea of Okhotsk, and both Hokkaido and Honshu Islands in Japan.
TABLE 2. Comparison of numbers of disc tags and tube tags recovered from chum salmon tagged June 29 - July 14, 1956 south of Adak Island (Fishing Effort Nos. 34, 36, 39, 40, 42)

<table>
<thead>
<tr>
<th></th>
<th>Discs Applied</th>
<th>Tubes Applied</th>
<th>Discs Recovered</th>
<th>Tubes Recovered</th>
<th>Discs Recovered as % of Discs Applied</th>
<th>Tubes Recovered as % of Tubes Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish under 450 mm Fork Length</td>
<td>92</td>
<td>373</td>
<td>6</td>
<td>5</td>
<td>4.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Fish over 450 mm Fork Length</td>
<td>132</td>
<td>301</td>
<td>1</td>
<td>1</td>
<td>1.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Total</td>
<td>224</td>
<td>674</td>
<td>7</td>
<td>6</td>
<td>3.2</td>
<td>1.7</td>
</tr>
<tr>
<td>Recovered in 1956</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td>2.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Small</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovered in 1957</td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td>2.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Small</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovered in 1958</td>
<td></td>
<td></td>
<td>3</td>
<td>2</td>
<td>3.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Small</td>
<td></td>
<td></td>
<td>13</td>
<td>12</td>
<td>9.8</td>
<td>4.0</td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The cooperation of all countries and states bordering the North Pacific Ocean has been excellent in the matter of returning tags.

Canada and Japan, being parties to the Convention, took care of recovery advertising, rewards, and mailing of tags recovered by their nationals. Japan has been very consistent in sending length measurements and scale samples with tag returns. These are very valuable additional data. Scales and lengths were usually taken by government inspectors aboard the motherships. Returns from Hokkaido streams also often included lengths and scales since most stream recoveries came from government egg-taking stations.

Letters were sent to the central and regional fisheries agencies of the U.S.S.R. They in turn printed notices of the high seas tagging and distributed them to fishing centers. Like the Japanese, Russian returns are often accompanied by length, weight, and scale samples.

In the United States, letters, posters, and return envelopes were distributed annually through canneries and fish processors, fishermen's unions, and government fisheries agencies. In remote areas of the Yukon and Kuskokwim Rivers and in Norton Sound, postmasters and merchants were requested to forward tags recovered by resident fishermen. Biologists and fishery management personnel in the field in Alaska were especially helpful in recovering tags and in promoting recovery by fishermen.

The reward paid in Canada and the United States for high seas tags was $1.00. Individuals sending tags were promptly sent the reward, together with a letter of thanks, and a chart showing the tagging location and date, and recovery location and date. In general, fishermen have shown a keen interest in the high seas tagging; in many instances tagging and recovery information was appreciated more than the money.
EXPLANATION OF TABLES IN THE APPENDIX

An explanation of the basic tables and figures in the appendix is now in order prior to discussing results.

The basic data have been divided into:

- Catch Tables
- Tagging Tables
- Recovery Tables

CATCH TABLES

Complete catch tables for each seine set made in 1956, 1957, and 1958 are shown in Tables C2 through C4, of the appendix. The gill net catches of 1956 are shown in Table C1.

For each year, the tables are subdivided by the area divisions illustrated in Figure 4. Within each area division, seine sets are listed chronologically for convenience in following seasonal changes in abundance.

![Figure 4](https://example.com/figure4.jpg)

Figure 4.--North Pacific Ocean and Bering Sea showing numbered areas referred to in text and tables.

The direction in which the net was "held open" is shown for all hauls except a few in early 1956, when this observation was not recorded.

Fishing effort (station) numbers were assigned for each date and location of fishing rather than by individual seine sets. Thus, one fishing effort number applied to all hauls made by one vessel in a day, unless areas fished were separated by more than ten miles.

Exact positions of hauls were determined by radar when vessels were within radar range (approximately twenty miles) of islands. Further offshore, loran was used, which in most areas gave very close readings. In areas where loran reception was not possible, dead reckoning was used, which might be as much as ten miles in error.
The catch by species includes all salmon caught whether tagged or not. Steelhead are also shown and included in the salmon total. The species of salmonids indicated by the letters at the top of the species columns are:

- R Red or sockeye: *Oncorhynchus nerka*
- C Chum or dog: *O. keta*
- P Pink or humpback: *O. gorbuscha*
- S Silver or coho: *O. kisutch*
- K King or chinook: *O. tshawytscha*
- St Steelhead trout: *Salmo gairdnerii*

Comments are shown in the remarks column if the efficiency of a seine haul was affected by weather or mechanical difficulties. The remarks also list fish taken other than salmon. Fur seal and sea lion observations are shown only in the 1957 and 1958 catch tables.

**SPECIES OTHER THAN SALMON**

The following list of fish other than salmon includes all specimens that were large enough to be easily identified. In some hauls, many larval fish were taken, and samples dipped from the bunt, but these have not yet been examined. The basking shark (area 3C, 1957) was too large to bring aboard, but was seen well enough to identify. The lump suckers were of particular interest since they are normally considered a bottom-dwelling species, yet they occurred in the catches far offshore over very deep water. Likewise, the occurrence of sticklebacks (area 7C, 1957; area 9A, 1958) as far as 75 miles from shore was interesting. Bottom fish, such as sculpins and flounders, were taken only where water was shallow enough for the lead-line to nearly touch bottom.
Atka mackerel
Basking shark
Black cod
Blue shark
Boar fish
Capelin
Dogfish
Eel pout
Herring
Handsaw fish
Lancet fish
Ling cod
Lumpsucker
Mackerel shark
Pomfret
Prowfish
Ragfish
Ratfish
Rockfish
Sandfish
Saury
Scad
Starry flounder
Sculpin
Sea poacher
Spiny lumpsucker
Stickleback
Whiting

- Pleurogrammus monopterygia
- Cetorhinus maximus
- Anoplopoma fimbria
- Prionace glauca
- Pseudorhacoceros richardsoni
- Mallotus catervarius
- Squalus suckleyi
- Family Zoarcidae
- Clupea pallasi
- Alepidosaurus aesculapius
- Family Anguillidae
- Ophiodon elongatus
- Family Cyclopteridae
- Isurus nasus
- Bramia raii
- Zaprora silenus
- Icosteus aenigmaticus
- Hydrolagus coliei
- Family Scorpaenidae
- Trichodon trichodon
- Cololabis saira
- Decapterus polyaspis
- Platichthys stellatus
- Family Cottidae
- Family Agonidae
- Eumicrotremus orbis
- Gasterosteus aculeatus
- Theragra chalcogramma
TAGGING TABLES

Tables T1 through T3 of the appendix, list the tagging by date and location for the three years.

As with the catch tables, tagging experiments are arranged chronologically within the area divisions of Figure 4. The same fishing effort numbers used in the catch tables identify the tagging experiments. However, all salmon tagged at each date and location (one fishing effort) are lumped in the tagging tables, whether one or several seine sets were made. Where two or three hauls were made a few miles apart, the tagging location shown is an average. Totals for each area division are also given.

The numbers of each species tagged are the corrected figures after species had been verified by scale examination and thus differ slightly from some figures in preliminary reports. Totals for each area division are also given.

The tagging tables are divided into matures and immatures, and the immatures are further broken down into separate year classes. This facilitates relating the numbers tagged with the returns in the year of tagging and in subsequent years. By "mature" is meant a salmon which is destined to spawn in the year of tagging. Figure 5 was prepared to summarize the maturity and age breakdown of reds, chums, and pinks tagged in 1956, 1957, and 1958. The 1958 age data are based entirely on scale readings. The 1956 and 1957 age data are based partly on lengths, since scales were not taken from all fish tagged.

Figure 5.—Numbers of red, chum, and pink salmon tagged in 1956, 1957, and 1958 by ocean age and maturity.
Figure 5. Numbers of red, chum, and pink salmon tagged in 1956, 1957, and 1958 by ocean age and maturity.
DETERMINATION OF MATURITY

Since the determination of maturity of the salmon tagged is important in the analysis of the tag returns, this subject is discussed in detail for each species in the sections on Tag Returns. However, the general method that was used is outlined below.

No external manifestation of maturity of salmon taken on the high seas has been discovered, and of course it was impossible to examine gonads of tagged fish. Therefore, the following criteria were taken into account in classifying tagged salmon as to maturity:

1. Length
2. Later comparison of length (at tagging) of those returned in the year of tagging, with those returned in subsequent years
3. Age
4. Date and location of catch
5. Gonad measurements of samples from the catch

Length

Length was the basic criterion for separating matures and immatures. The procedure used was to make length-frequency tabulations of each individual sample tagged, and to arrange them in chronological order for each area of tagging. In 1957 and 1958, tabulations were further broken down by ocean age from scale readings. Thus, the sequence of modes in the length distributions showed the various age groups and their seasonal growth, plus the disappearance of the larger, mature sizes as the season progressed.

Sizes of fish of the same age varied considerably by date and location of catch. For example, fish in the Gulf of Alaska were larger than those near the Aleutians. The length for dividing matures from immatures was, therefore, not the same in all areas and at all times. For reds and chums, the dividing length was near 50.0 cm, but varied from a minimum of 45.0 cm early in the season to a maximum of 55.0 cm late in the season. The lengths of salmon tagged, and lengths (at tagging) of those recovered, are given for each species by year in the discussions of tag returns.
Length and year of recovery

The distribution of sizes (at tagging) of salmon recovered in estuaries in the year of tagging showed the size range of the mature salmon. Correspondingly, returns a year or more later demonstrated the sizes of immature salmon. In some cases, the original maturity breakdown was later changed as returns in the year of tagging or a year later showed the first classification to be in error.

Age

Since ocean age is a valuable guide to the maturity of Pacific salmon, the following generalizations regarding maturity may be made.

In the case of reds and chums, all age groups were tagged, from the youngest which had spent no winters at sea, to the oldest which had spent four winters at sea. Some few chums showed five winter marks on their scales.

The zero-winter and one-winter age groups may safely be considered immature, since reds and chums rarely spawn after only one year at sea.

For red salmon the three-winter age group may be considered overwhelmingly mature, since very few reds remain at sea beyond this age. Only one of the 269 mature reds tagged in 1958 had spent 4 winters at sea and only two of the 729 tagged in 1957 were of this age (Figures 27 and 38). Thus, the two-winter age group reds are the principal group which must be divided into matures and immatures.

For chum salmon, the four-winter age group may be considered overwhelmingly mature, but both the two-winter and three-winter age groups may be either mature or immature. Only one chum that had spent 5 winters at sea was tagged in the 3 years' operations (Figure 64).
For *pink* salmon, the life history is very clear-cut. Those of zero age are definitely immature, and those of one-winter age, mature. Ages are clearly separated by size. As seen in Figure 70, the zero-winter age group average about 22.5 cm and the one-winter age group, 45.0 cm.

For *silver* salmon, the life-history is clear-cut, with nearly all maturing after one winter at sea. The zero-winter and the one-winter groups are easily distinguished by size and by scale readings.

*King* salmon and *steelhead*, however, vary considerably in ages at maturity. Therefore, neither length nor age are satisfactory indicators of maturity unless specimens are very large.

So few *silver* salmon, *king* salmon, and *steelhead* were tagged or recovered, that determination of maturity was not a problem with these species.

Thus our principal problem has been to determine the maturity of *reds* that have spent 2 winters at sea and chums that have spent 2 or 3 winters at sea.

**Date and location of catch**

In most instances, the date and location of catch separated the mature and immature red salmon. Rarely did both occur in appreciable numbers in the same catches. Up to the second or third week of June, most reds taken were matures; after that, the matures quickly diminished, and the immatures increased. *Chum* salmon, on the other hand, were more often mixed as to maturity, especially in the latter part of the season when some fall-run matures continued to be present in the large catches of immatures. In addition, certain locations (for example, the eastern half of the Bering Sea) produced both reds and chums that were almost all mature even in late June when immatures were appearing in the catches elsewhere. Classification in such cases was no problem.
These factors and the bases for decisions about the maturity of each group tagged are discussed in more detail in the section on directional movements and in the discussions of tag recoveries.

Gonad measurements

Gonad measurements were taken on fish saved for examination as described in the section on Other Data Collected. However, samples examined were insufficient to calculate accurately the proportions of matures and immatures for the sizes and ages where maturity overlaps. Large samples from each location and time period would be needed, since the size and age of maturity varies, especially in the case of chum salmon. The gonad samples served mainly as a check on the general maturity status of the larger samples.

The gonad measurements, however, did suggest an approximate division line between gonad measurements of matures and immatures. Reds and chums sampled from catches which proved to be mature by tag returns showed testis widths of 10 mm or more, and egg diameters of 2 mm and more. For immatures, testis widths were 6 mm or less, and egg diameters 1.5 mm or less. These figures applied to one-winter and two-winter reds, and to two- and three-winter chums. Maturing chum salmon showed more variability than reds in gonad measurements, which is perhaps a reflection of the longer range of spawning times for this species.

Summary and application of maturity data

It is evident that no method can positively classify the maturity of every individual fish tagged at sea, but the methods used greatly reduced the numbers of doubtful specimens. In addition, the data contain many large samples with well-defined maturity, suitable for more critical analyses.
In the present treatment of the data there is no effort made to draw firm conclusions on points requiring exact knowledge of maturity classification unless the samples considered were clearly identified as to maturity. The principal points made are the differences in distribution of matures and immatures, and these are positively identified by year of return (where recoveries were from coastal areas). There are cases of salmon classified as immature being recaptured at sea in the year of tagging, in which cases specific evidence of immaturity is cited.

RECOVERY SUMMARY TABLES

Recovery summary tables for all three years are shown in appendix Tables R1 through R12. Tables are grouped first by species, then by year of tagging. Again Figure 4 is used as the basis of area breakdown. The totals tagged by age are repeated from the area totals in the tagging tables.

Numbers of tags returned are then listed by recovery location, and by year of recovery. Percentage returns are also shown by year of recovery based on the numbers tagged in the respective age groups.

It must be borne in mind that complete returns from 1957 and 1958 are not discussed here. As seen in Figure 5, numerous immatures were tagged which will be returned in 1959 and 1960.

DETAILED RECOVERY TABLES

The detailed recovery Tables R13 through R15 list both release and recovery data for each tag return. These are arranged by year of tagging, by area of tagging, by species, and by year of recovery.
DISTRIBUTION OF FISHING AND TAGGING

ANNUAL COVERAGE

Figure 6 shows the locations of fishing and tagging for 1956, 1957, and 1958.

Figure 6.—Distribution of tagging, 1956, 1957, 1958.

In 1956, efforts extended only as far west as Adak except for a small amount of gill net fishing near Kiska. Coverage in 1957 was expanded westward to Attu Island and north to the Pribilof Islands. In 1958, tagging was extended further west of Attu, further offshore in the central Bering Sea, and for the first time the large area south of Kodiak Island was included.

PLAN OF OPERATIONS

The basic plan of the first three years' tagging was to obtain widespread east-west distribution of tagging, and at the same time to tag as many salmon as possible. Offshore fishing was recognized as desirable, but not at the expense of numbers on an east-to-west distribution. Thus, although a considerable amount of offshore tagging was accomplished, the great majority of tagging was close to the south side of the islands, where seine catches were most productive (Areas 2C to 6C; Figure 1). The offshore areas in the Bering Sea and south of Kodiak were given special effort because of the abundance indicated in those areas by the United States Fish and Wildlife Service research vessels. Tagging in these locations helped to supplement the results shown by the tagging along the Aleutians.

ITINERARIES

The itineraries of the vessels used each year are given in Table 3. Approximately thirty days of the charter time was required for the round trip from Seattle to the central Aleutian area. Fishable weather averaged approximately fifteen days per month from June through August.

Table 3. Dates of operation and itineraries of tagging vessels, 1956, 1957, 1958
EVIDENCE OF SALMON MIGRATION ROUTES FROM SEINE CATCHES

Observations of the seine catches according to the direction of set have indicated migration routes at sea which in turn have provided a more complete movement pattern than that shown by tag returns alone.

DIRECTIONAL ASPECT OF A PURSE SEINE "TOW HAUL"

As described in the section on fishing gear, the seines were held open in a given direction for approximately 30 minutes, thus collecting salmon moving toward the opening of the seine. In areas which had not been fished previously, the direction of the first haul was only a guess, and at least two hauls were required to determine the most productive direction.

EVIDENCE OF SALMON MIGRATION ROUTES FROM SEINE CATCHES

Observations of the seine catches according to the direction of set have indicated migration routes at sea which in turn have provided a more complete movement pattern than that shown by tag returns alone. This data is discussed prior to tagging results, because a presentation of movements of fish at the time and in the areas of tagging logically precedes that of subsequent movements as indicated by tag recoveries. In addition to direction of movement, the catches showed relative abundance and timing of the major bodies of fish passing through the tagging areas. Therefore, it provides a basis for evaluating the importance of the stocks tagged, which in turn greatly enhances the significance of the tag results. Finally, since abundance and movements of salmon in areas of tagging relate immediately to stocks being fished by the Japanese high seas fleet, this data is of prime importance in interpreting tag returns from fish intercepted by this important fishery.
Figure 6. Distribution of tagging, 1956, 1957, 1958.
<table>
<thead>
<tr>
<th>Vessel</th>
<th>Date Departed</th>
<th>Date Returned</th>
<th>Areas Operated</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>California Rose</td>
<td>April 12</td>
<td>Sept. 15</td>
<td>Eastern and central Aleutians plus Gulf of Alaska and off S.E. Alaska and Vancouver I. on return trip</td>
<td>Released from high seas charter during period July 4 - Aug. 6 for fish packing in Prince William Sound</td>
</tr>
<tr>
<td>Renown</td>
<td>April 12</td>
<td>Sept. 15</td>
<td>Same</td>
<td></td>
</tr>
<tr>
<td>Renown</td>
<td>May 6</td>
<td>Sept. 15</td>
<td>Central and western Aleutians plus Gulf of Alaska and Vancouver I. enroute to Seattle</td>
<td></td>
</tr>
<tr>
<td>Commander</td>
<td>May 16</td>
<td>Sept. 15</td>
<td>Same</td>
<td></td>
</tr>
<tr>
<td>California Rose</td>
<td>May 16</td>
<td>Sept. 15</td>
<td>Pribilof Is. and central and eastern Aleutians plus Gulf of Alaska and Vancouver I. enroute to Seattle</td>
<td></td>
</tr>
<tr>
<td>Renown</td>
<td>April 24</td>
<td>Sept. 2</td>
<td>Central and western Aleutians</td>
<td></td>
</tr>
<tr>
<td>Commander</td>
<td>May 8</td>
<td>Sept. 2</td>
<td>Central and western Aleutians plus central Bering Sea and Pribilof Is.</td>
<td></td>
</tr>
<tr>
<td>California Rose</td>
<td>June 8</td>
<td>Sept. 20</td>
<td>Gulf of Alaska</td>
<td>Released from high seas charter during period June 27 - July 16 for tagging in Cook Inlet</td>
</tr>
</tbody>
</table>
Figure 7. Diagram of purse seine "tow haul" showing possible approach directions of fish.
Repeated sets in several directions are desirable, but in practice too few hauls could be made in a day to warrant frequent checks in a "poor" direction, after a proven direction had been found. Therefore, in the following section on migration paths, most of the deductions are based on the results of sets made in one direction with few "check hauls" in other directions. However, the catches in the areas of good fishing were so consistent throughout the season and from year to year, that few "check hauls" were required. With few exceptions, the rule was found to apply, that wherever catches were consistently good in one direction, catches in the opposite direction were poor or nil. In some few cases, one species was found to be moving opposite to another, as will be discussed.

In addition to direction of movement, the rate of movement is also an important factor in determining the numbers of salmon taken in a purse seine set. However, at present, very little is known about a salmon's rate of travel at sea, or of the factors influencing rate. (The average rate of travel in miles per day is shown for mature salmon of each species in the section on Tag Returns.)

It should be emphasized also that salmon so seldom jump at sea, that sets had to be made "blind", which is a complete departure from the usual commercial practice of setting on jumping salmon. Thus the directional movement and relative abundance to be discussed are based on the results of seine sets which may be considered random as to visible evidence of the best location, time, or direction to set.

MIGRATION PATHS

The principal migration paths observed from the seine sets were:

1. Westward along the south side of the Aleutian Islands
2. Northward through the Aleutian passes
3. Eastward and/or westward in the Bering Sea depending on species
The basic data for the discussion below is in the "direction open" column in the catch tables for all three years (Tables C2, C3, and C4). In referring to the direction of set of the seines, the cardinal directions E. vs. W. or N. vs. S. are being compared. Thus seine openings for all directions between N.E. and S.E. are included with the east hauls, etc.

**WESTWARD ALONG THE SOUTH SIDE OF THE ALEUTIANS**

The best-defined migration observed was the westward movement of reds, chums, and pinks along the south side of the Aleutian Islands. Catch data for areas 7C westward through 2C illustrate the trend in these areas.

**AREA 7C, 160° - 165° WEST LONGITUDE**

Each year from late May through early July, commercial fishing vessels seine for mature reds, chums, and pinks at Cape Lutke on the south side of Unimak Island. Through repeated experience, they have found that catches were productive only when the net was held open to the east.

In 1956, the tagging vessels made no check hauls with the net open toward the west in Area 7C, but the very sizes of the catches open to the east were good evidence of a westward movement of salmon. Between June 19 and July 1, seventeen hauls were made with the net open to the east or northeast. Red salmon catches varied from zero to 126, averaging 24; chums from zero to 126, averaging 29; pinks from zero to 24, averaging 4 (1956 was a poor year for pinks in the whole Aleutian area).

In 1957, ten hauls were made between May 27 and 29, all of them 60 or more miles offshore. On May 28 and 29 results were poor regardless of direction of set. On May 27, three hauls open to the east produced consistent results, averaging 27 reds, 16 chums, and 60 pinks. Unfortunately again there was no check haul to the west, but a haul to the south-southwest produced 4 reds, 12 chums, and 24 pinks. Fish in this catch could have approached from the southeast so that it is not a good check on the other hauls. It suggests an onshore movement from the south in addition to the westward movement shown by the other three hauls.
To summarize for Area 7C, no seine hauls were made to show the lack of an eastward movement, but both commercial fishing and the high seas seining suggest a strong westward movement of reds, chums, and pinks during the period when matures are available. No seining was done later in the season to indicate the movement of immatures in this area.

**Area 6C, 165° - 170° West Longitude**

In Area 6C, an unmistakable westward movement was found in all three years.

Between June 7 and 28, 1956, a total of 31 hauls open to the east produced average catches of 48 reds, 21 chums, and 3 pinks. Four hauls open to the west produced a total of only 1 red and 2 pinks. One haul open to the south produced no salmon. During this period, all salmon were mature. (Figure 10).

In 1957, five sets were made on June 13 and 14 in Area 6C. All four open to the east produced mature salmon, averaging 6 reds, 7 chums, and 23 pinks. The one set open west produced nil. Results of this kind indicate that the directional trend is discernible even when numbers are small. Six sets were made between July 3 and 6, 1957. The 5 hauls open to the east produced an average of 5 reds, 103 chums, and 15 pinks. The one open to the west took only 1 chum. In the latter period reds were immature and chums were of mixed maturity.

In 1958, 3 hauls open to the east were made in Area 6C on July 2, 3, and 4. Although no check hauls were made with opening to the west, the size of the catches indicated a very strong westerly movement of reds, chums, and pinks. King salmon were also taken in more than incidental quantity for the first time. The three hauls averaged 506 reds, 636 chums, 25 pinks, and 29 kings. The great majority of reds, chums, and kings were immature, while the pinks were mature.
On August 21, two more hauls were made open to the east, with a total catch of only 24 reds. These were the very small fish which had migrated to sea in the spring of 1958. The poor results of these two hauls conform to the poor catches of single hauls of August 18, 1957, and August 13, 1956, perhaps suggesting few fish in the area late in the summer. No check hauls to the west were made during the late period.

In Area 6C, then, mature reds, chums, and pinks were found moving positively westward during June of 1956 and 1957. The area was not fished in June of 1958. During early July of 1957 and 1958, immature reds and chums, plus some mature chums and pinks, were moving westward also in Area 6C. The flow of immature reds and chums in 1958 was particularly heavy and included fair numbers of king salmon as well. The few hauls made during August produced too few salmon to indicate direction of movement.

AREA 5C, 170° - 175° WEST LONGITUDE

The three hauls made in Area 5C on June 23, 1956 were in decided contrast to those of only two days previously in Area 6C. Hauls in Area 6C through June 21 had shown consistently large catches and a strong westward movement of mature reds and chums. On June 23, the first haul open to the east in Area 5C took only 1 red and 6 chums, suggesting that the westward "flow" of salmon in Area 6C did not continue in Area 5C, but had perhaps gone northward through Amukta Pass. (Other evidence discussed in the section on Tag Returns strongly supports a northward movement through Amukta Pass in 1956.) The other two hauls of June 23 were made with opening to the west, taking a total of 12 reds, 2 chums, and 1 pink. This would suggest at least a small movement of reds toward the east in this area. Again, it was in contrast to the four hauls held open west in Area 6C which produced only one red. Perhaps reds were approaching Amukta Pass from both directions, but principally from the east.
A single haul open to the east on August 15, 1956 took 34 chums, and 6 kings, but no check haul was made in the opposite direction. At this same time, however, there was a strong westward movement of immature reds and chums in Area 4C, adjacent to the west, as will be discussed later.

In 1957, a greater amount of fishing was done in Area 5C, providing better movement data. On June 6, two sets open to the east showed a consistent westward movement of mature reds, chums, and particularly pinks, by producing an average of 53 reds, 61 chums, and 349 pinks. On June 7, the first haul with opening to the east was nullified by the tide sinking the corks. A second haul, this time open to the west, and not affected by the tide, took only 2 reds and 1 chum, thus confirming that there was little eastward movement.

On July 6, a haul by the California Rose with opening toward the east, netted 6 reds, 867 chums, and 154 pinks. Reds were immature, chums mixed mature and immature, and pinks mature. On July 16, a haul in practically the same location and also open east, produced no salmon. It is probable that the great variability was due to the strong tidal currents of Amukta Pass, which is just north of the fishing location. In both instances, the vessel was obliged to search for a place to fish free of tide rips. Such great variability of hauls occurred also where heavy tides prevailed in Area 3C further west. The westward movement seen in the large catch on July 6, however, was consistent with the westward movement demonstrated by catches of July 3, 4, 5, and 6 in Area 6C.

On July 17 through 19, six hauls were made in Area 5C about 100 miles offshore. The only haul which produced no salmon was the one open to the southwest. The three open to the southeast took an average of 12 reds and 9 chums per haul, and the one to the south took 58 reds and 5 chums. The one to the northeast took only 1 red and 2 chums. These catches were small but are consistent with a westerly and northerly movement of the salmon.
On August 16 in Area 5C, about 30 miles offshore, two hauls open to the east averaged 25 reds and 10 chums, again indicating the westward movement.

In 1958, only two hauls were made in Area 5C. The one on May 22 (open to the east) took no salmon, possibly indicating a lack of salmon in the area at this early date. On July 6, one haul open to the east yielded 74 reds, 90 chums, and 9 pinks, which was consistent with the westward trend in Area 6C on July 2, 3, and 4, and also with the trend in Area 4C at the same time, as discussed next.

To summarize directional movements found in Area 5C, one haul on June 23 of 1956 showed practically no westward movement of mature reds and chums, in contrast to the strong westerly movement seen in Area 6C that year. Two hauls on the same date indicated a light eastward movement of mature reds.

On June 6 and 7 of 1957, a strong westward movement of mature reds, chums, and pinks was noted and a check haul showed no easterly movement. In one haul on May 22, 1958, no salmon were caught, suggesting that the westward movement had not yet begun in this area. Immature reds and chums were found to be moving westerly in Area 5C between July 6 and August 16, 1957. The same strong westerly trend was found in 1958 for immature reds and chums.

AREA 4C, 180° - 175° WEST LONGITUDE

Area 4C was fished with considerable regularity each year, providing an excellent series of data on annual and seasonal abundance and on directional movement as illustrated in Figure 8.

Figure 8.—Daily catch of reds, chums, and pinks per seine set in Area 4C, 1956 - 1958. (Bars indicate catch of hauls open east. Average shown where more than one haul made per day.)
Figure 8. Daily catch of reds, chums, and pinks per seine set in area 4C, 1956 - 1958. (Bars indicate catch of hauls open east. Average shown where more than one haul made per day.)
In Figure 8, the numbers of reds, chums, and pinks taken in hauls open to the east are shown by date of fishing as vertical bars, while numbers caught in hauls open to the west are entered as numerals preceded by a "W" above the date of fishing. Too few salmon were taken in hauls open to the west to show them as bars. Hauls open to the east which produced no salmon are indicated by a pointer under the appropriate date. Catches which were predominantly mature salmon are shown as shaded bars. The unshaded bars indicate immatures were predominant. Detailed data on numbers of matures and immatures tagged are given in the Tagging Tables (T1, T2, and T3).

In 1956, the first sets were made on May 29, and the last on August 15 (Figure 8).

The three sets open to the west on May 29 and 30 produced only 3 chum salmon. Another set made on May 29 is not shown since the direction of opening was not recorded. The catch was nil (Table C2). The results of these early sets at least indicate no appreciable eastward movement of reds or chums at this time and location.

From June 24 through August 15, a fairly regular series of hauls open to the east showed a continuous westward flow of reds and chums. A haul open to the west on July 14 took but 1 red and no chums, while two hauls open to the east on that date averaged 64 reds and 132 chums. Results of fishing on July 21, 22, and 23 indicated a period of low abundance in the westward flow of reds and chums. On July 23, one haul was made with opening to the east, and one to the west. In both cases, the catch was nil, indicating that the low abundance was not due to a reversal in direction of travel. Starting July 31, the abundance of both species increased again until August 15 when the vessels departed for Seattle.
Figure 8 indicates a very small westward movement of pink salmon from June 24 through July 22, 1956, using relative numbers taken in east versus west seine sets.

In 1957, Area 4C was fished intermittently from May 26 through August 31 (Figure 8).

The three hauls of May 26 and 27 open to the east took only 3 chums, and the one open to the west caught nil. Two of the hauls to the east were nullified by strong tide, but results still suggest that salmon were not abundant in Area 4C in late May regardless of direction of movement.

A strong westerly movement of red and chum salmon was indicated by fishing of June 8, 12, and 13 similar to that seen in Area 50 on June 6. Three hauls open to the east took an average of 63 reds and 95 chums. (The first haul of June 12 was not included because tide sank the corks. Salmon were seen escaping over the cork line while the net was being pursed.)

The westerly trend continued throughout the season as immature reds and chums began to dominate the catches. Abundance of immature reds was very low compared to 1956 and 1958. Immature chums were abundant in the early part of the season, but decreased continually after July 20 with no late season increase as in 1956 and 1958.

Too few check hauls were made in 1957 to prove a lack of eastward movement, but considering the uniformity of movement in 1956 and 1958, it seems a safe assumption that the westerly trend prevailed also in 1957, but that numbers were smaller. The single check haul open west on June 21 took 1 red and 3 chums as against 4 reds and 64 chums with the net open east, which indicates the westward trend at least during that period. Both hauls of June 21 were approximately 60 miles from shore, indicating the trend continued well offshore.
Pink salmon in Area 4C showed a very positive westward movement in 1957 in conformance to that seen in adjacent Areas 5C and 3C. Four sets open to the east on June 8, 12, 13, and 20 averaged 767 fish (Table C2). Such large and consistent catches require no check hauls to establish directional trends. The first haul of June 12 was not included because its effectiveness was nullified by tide. The only check haul made was that of June 21, in which 3 pinks were taken with net open west; while 69 pinks were taken in the haul open east. The latter pair of hauls were made approximately 60 miles offshore, while those of June 8 through 20, were made within 10 or 12 miles of shore. This suggests a decreased abundance offshore, but similar directional movement. Abundance tapered quickly sometime between June 20 and July 2, in the productive area near shore. After July 3, only occasional pinks were caught.

In 1958, Area 4C was fished from June 9 through August 17 (Figure 8). The three hauls (open to the east) of June 9 yielded no red salmon and an average of only 4 chums. Pink salmon, however, averaged 12 per set, suggesting a westward movement of this species in limited numbers. No check hauls were made in the early period.

When this area was fished again, starting June 25, immature reds and chums were abundant in hauls open to the east, and continued abundant through August 17. Abundance of reds and chums varied roughly in unison. Check hauls open to the west on July 31 and again on August 6 took no reds or chums, indicating the positive nature of the westward direction of travel.

Pink salmon catches, though small, suggest a westward movement of this species from June 9 through July 31. Three hauls open to the east as late as July 31, took 5 pinks, while the one haul open to the west took none.
In summary, movement of reds, chums, and pinks in Area 4C was consistently westward in all three years. The time that the westward flow began was best defined in 1957 when catches on May 26 and 27 yielded very few salmon, but when fishing was resumed on June 8, substantial numbers of mature reds, chums, and pinks were found traveling westward. The dates upon which the westward flow of reds and chums changed from matures to immatures showed some variation from year to year. In 1956, mature reds predominated until June 27, while immature chum salmon were predominant starting June 24, except for the one sample of June 27. In 1957, immature reds became predominant June 13. Mature chums in 1956 were predominant through June 13. In 1958 the first substantial catches of reds and chums were made on June 24, at which time immatures were already overwhelmingly predominant. In all years, immature reds and chums continued available through the date of departure of the vessels. This was August 15, 31, and 17, respectively, for the years 1956, 1957, and 1958.

Mature pink salmon were in such low abundance in 1956 and 1958 that the peak period of migration was not defined. However, in 1956 some pinks moved westward from June 24 through August 11; in 1958, from June 9 through August 11.

In 1957, pinks were not taken on May 26 and 27, but from June 8 through 21 they were moving westward in abundance, and were still taken in fair numbers July 2 (Figure 3). Only a few pinks were taken from July 3 through August 6, after which none were caught.

**AREA 4D, 180° - 175° WEST LONGITUDE**

This area was fished only in 1957. A haul open east on July 20 took 1 chum (plus 7 silvers and 2 kings), while the haul open west took nil. The reduced abundance well offshore was again shown.
AREA 3C, 180° - 175° EAST LONGITUDE

Before discussing movements in Area 3C, it should be pointed out that most fishing in this area was within 5 - 15 miles of the south sides of Amchitka and Kiska Islands. These two islands are oriented more north and south than are the larger islands to the east and they are adjacent to Amchitka and Buldir Passes through which there is a large exchange of water between the North Pacific and Bering Sea. Currents are strong and changeable in contrast to the more stable conditions along the south sides of the islands to the east. In addition, salmon travel northward and southward through the passes as will be shown later. Such conditions no doubt account for the inconsistency of salmon movements seen in Area 3C, as described below. Because of the inconsistency of directional movement, check hauls in other directions were made more frequently.

Area 3C was fished only with gill nets in 1956 (Table C1) yielding no information on movements.

In 1957, two hauls open to the east on June 14 took an average of 44 reds, 105 chums, and 1,098 pinks (Table C3). No opposed hauls were made, but such large catches indicate a strong westerly movement of the three species on that date. Of the red salmon tagged on June 14, 36 were mature and 37 immature, while 35 of the chums were mature against 157 immature (Table T2). In this case, both mature and immature reds and chums were mixed.

On June 26 one haul open east netted 6 reds, 2 chums, and 8 pinks, while two hauls open west averaged 7 reds, 22 chums, and 2 pinks. At this time reds and chums were mainly immatures. These results show a mixed movement pattern, which prevailed from June 26 through August 23. During this period 18 hauls open to the east netted an average of 19 reds and 15 chums, while 9 hauls open west took an average of 13 reds and 10 chums. Too few pinks were taken to indicate direction of travel.
In 1958, the set made on May 22 was nullified by a broken purse cable. The haul on May 25 open to the east, however, took no salmon, suggesting a scarcity at this early date. Between June 7 and August 5, fifteen hauls open east took an average of 14 reds and 53 chums while two hauls open west took an average of only 1 red and 4 chums. The latter two hauls were both in June, however, and do not furnish a comparable check on movement. Two hauls open south netted an average of 5 reds and 28 chums (June 15 and July 19).

In both 1957 and 1958, then, hauls open to the east indicated a fairly constant westward movement in Area 3C. However, unlike Area 4C, sets held open to the west in 1957 also produced regularly. The inconsistency in direction is thought to be due to the highly variable currents in the area and to the movements of salmon through the adjacent passes which will be discussed later. If the eastward trend was a positive and continuous movement, it should have been manifest in Area 4C to the east. Such was not the case. Therefore, the variability was probably only a local "milling" movement due to currents and fish movements through the passes. The net movement was still westward as seen also in Area 2C as discussed next.

**AREA 3D, 180° - 175° EAST LONGITUDE**

Three hauls were made on July 21, 1957. The haul open east took 2 reds and 9 chums, while the set open west took 1 red and 15 chums. The third set open south, took 1 red and 15 chums. These catches, though small, are consistent with a westerly and northerly movement in this offshore area.

**AREA 2C, 175° - 170° EAST LONGITUDE**

This area also was not fished in 1956, but considerable data is available for 1957 and 1958. Most fishing was done fairly close to the south side of Attu and Agattu Islands, although some fishing was well offshore and in the passes. Here again, there are large passes on each side of the islands and also between the islands, causing strong and variable currents.
In 1957, fishing was conducted intermittently from June 8 through August 25 in Area 2C. Referring to Table 3C, four hauls open to the east on June 8, 9, and 10 produced a total of 1 red, 3½ chums, and 22 pinks. Two hauls open west yielded only 1 red. During this time, reds and chums were mature.

Between June 13 and July 13, 18 hauls open east took an average of 11 reds, 66 chums, and 56 pinks indicating a continued strong westward movement, although only one opposed haul was made to check the degree of counter-movement. That haul, open southwest on July 13, took but 2 chums, indicating little eastward movement at least for the time and location of the set. During the above period, reds and chums were predominantly immature as may be seen in Table T2.

After July 13, pink salmon practically disappeared from the catches, indicating that the westerly flow of pinks in this area took place between early June and July 13. Between July 13 and August 24, reds were less abundant, averaging only 2 fish for the 21 hauls open to the east. Chums averaged 3½ for the same 21 hauls. Insufficient check hauls were made to show the amount of counter-movement. The one haul open west on July 23 took only 1 red, again showing little eastward movement at least for the time and place of the set.

In 1958, Area 2C was fished frequently from May 28 through August 14. Between May 23 and May 30, results of hauls open east, west, and south showed small catches of reds, chums, and pinks, and no particular directional trend. From May 31 through August 12, sets open to the east caught reds and chums consistently, averaging 27 reds and 76 chums for 24 hauls. There was a definite peak of abundance between July 17 and 20 when 5 hauls averaged 90 reds and 267 chums. The transition from nature to immature was on June 16 for reds, and sometime between June 16 and July 13 for chums, although some few mature chums continued in the catches through the entire period. Pink salmon were available consistently through June 13. Only occasional single specimens were taken after that date.
In 1958, no hauls open to the west were made during the period of abundance, but the consistency of the catches open to the east suggests a strong westward movement as in 1957.

SUMMARY OF MOVEMENT SOUTH OF THE ALEUTIAN ISLANDS

The prevailing direction of movement of red, chum, and pink salmon in Areas 7C through 2C (Figure 4) in 1956, 1957, and 1958 was westward, as indicated by purse seine catch data.

The westward movement was especially consistent from Unimak Island to Adak Island (Areas 7C to 4C). Here the island masses are larger than those further west, and are oriented in such a way that along their south sides there is little effect of current from the passes. There was, however, a noticeable westward current averaging about 1 knot as indicated by drift of the vessels while fishing.

In the vicinity of Amchitka and Kiska Islands (Area 3C) directional movements became more variable, which is thought to be only a local shifting of direction caused by strong ocean currents from the passes, and to complications brought about by movements of salmon through the large passes nearby.

Further west, south of Attu and Agattu Islands (Area 2C), the westward trend was again strong.

The westward migration was manifest in both mature and immature salmon. Catches were mainly mature salmon (reds and chums) until the middle part of June, after which the matures diminished and the immatures increased, but the direction of flow continued toward the west. Pink salmon, though very few in 1956 and 1958, traveled westward with the reds and chums. In 1957, they were very abundant from late May through early July, also moving west.
The time that the westerly trend began was not well defined, because of lack of early fishing, but by the first week in June it was well underway in the years under discussion. In all years, catches continued productive through the date that the vessels departed in August. Figure 8 illustrates the trend of abundance for the three years in Area 4C south of Adak Island.

The distance offshore that the trend persisted was also indefinite, since most fishing was within 15 or 20 miles of shore, but a few sets showed similar movement as far as 60 miles offshore.

The distance inshore that the trend continued was also not certain, since tidal currents and the depth of the nets prevented fishing closer than approximately 3 miles. Up to this point, both abundance and direction of movement continued the same. At Cape Lutke on Unimak Island, commercial seiners sometimes make their best catches in shallow water very close to shore. They use a shallower net and also a shallow "lead" on the shoreward end. This would suggest that there may be areas on the south side of the central and western Aleutians where the salmon similarly approach very close to shore in their westward migration.

The eastern limit or "beginning" of the movement was not defined because of insufficient fishing east of Unimak Island.

From tagging and recovery results, the movement toward the west continued on to the Asian spawning streams for some mature chums and pinks. Red salmon and others of the chums and pinks turned northward through the passes as discussed below. Immature reds continued west at least as far as 172° E. Longitude in 1958 (Figure 40).
As a summary of eastward versus westward movements of salmon south of the Aleutians, Figure 9 was prepared. In the upper half of the figure are plotted the number of hauls according to size of catch for all hauls open to the east, and in the lower half, those open to the west. All hauls in areas 2C through 7C in 1956, 1957, and 1958, are included except those rendered ineffective by tide or net damage. Total salmon catches are shown irrespective of species. The sizes of catches are divided into 9 convenient class intervals as shown. The frequency of hauls within each class interval is expressed in percent for comparison.

It is immediately apparent that hauls open to the east were consistently productive, and those open west non-productive. The mean catch of hauls open east using the 9 categories illustrated, falls in the 50 to 99 category, while the mean of the hauls open west falls in the 5 to 9 category. In addition, all the catches of more than 10 fish in hauls open west were made in 1957 in Area 3C where temporary mixed movement was brought about by mixed sea currents as described earlier. Thus the true average of hauls open west would probably be less than 5.

Since seine hauls open west were interspersed with the hauls open east during periods when the latter were productive as well as non-productive, it may be concluded from Figure 9 the the easterly movement of salmon south of the Aleutians is only a small fraction of the westerly movement.
Figure 9. Comparison of catches in seine hauls open east vs. seine hauls open west in areas south of Aleutians - 1956, 1957, and 1958 combined.
NORTHWARD THROUGH THE ALEUTIAN PASSES

The movement of salmon northward through the Aleutian Passes is logically an extension or "branching off" from the westward flow along the south side of the islands. Because of the difficulty in fishing the passes, too few hauls were made in the passes to establish the direction of movement by seining alone. As will be discussed later, tag returns show an important northward movement of mature salmon tagged on the south side and subsequently recovered north of the islands. This was true particularly of reds, chums, and pinks going to Bristol Bay and Western Alaska, and of pinks destined for the Karaginski area of eastern Kamchatka. Most of the chums enroute to Asian areas probably continued westward on the south side.

Immature salmon, on the other hand, were found going both north and south in Amchitka and Buldir Passes, but with the northward direction being predominant.

The seining data suggested that certain passes were probably more important than others as salmon migration passages, and also showed a scarcity of salmon along the north side of the islands in contrast to the abundance on the south side.

These observations are similar to those reported by Bogdanov (1946, pp. 9-10) regarding salmon movements near the Kurile Islands. Migrating salmon are much more abundant along the southeast, or outer coast of the Kurile Islands, than on the northwest, or inner coast. This he attributes to a southwestward movement of salmon close to the outer Kurile Island coast prior to going through the passes into the Okhotsk Sea, after which they proceed away from the islands, rather than migrating close to the inner shores.

The seine hauls which indicate movement or abundance in the passes are discussed below (see also Catch Tables C2, C3, C4).
UNIMAK PASS (165° WEST)

No seining was done in Unimak Pass. The large fishery at Cape Lutke on Unimak Island being so close to the Pass would suggest this pass as a route for salmon going into the Bering Sea. The gill net catches by the United States Fish and Wildlife Service sampling vessels in 1956 and 1957 (Figure 24) show rather small catches of red salmon just north of Unimak Pass as compared to locations further west in the Bering Sea, suggesting that the more western passes are more important.

UNIMAK PASS (168° WEST)

Four sets made in the north entrance of this pass on June 11, 1956 (Area 6B, Table C2) took a total of only 7 reds and 3 chums. This was at a time when seining immediately south of the pass (Area 6C) was producing an average of 20 reds and 18 chums per haul (June 7 through 11; hauls open east). These data suggest Unimak Pass to be a minor one for salmon passage, which is in keeping with its water volume compared with the larger passes.

AMUKTA PASS (171° WEST TO 172°30' WEST)

Amukta Pass was not fished in 1956.

On June 5, 1957 three hauls were made in Amukta Pass with the net open to the south (Area 5B). The second and third hauls were ineffective due to strong tide, but the first haul made at slack tide took 25 reds, 7 chums, and 128 pinkos. Although no opposed hauls were made, the size of the catch was sufficient to indicate an important northward movement of all three species. The second haul, in spite of the tide, took 3 reds, 9 chums, and 11 pinks, further supporting the strength of the northward trend. At this time salmon were mature. No data are available on movements of immatures in Amukta Pass.
The only set made in Amukta Pass in 1958 was on May 21 (Area 5B). With
the net open south, no salmon were caught, perhaps indicating that it was too
early for the run to be moving through the area. A set open to the east in
Area 5C nearby on May 22 also produced no salmon, indicating that the west-
ward flow along the south side was not yet in progress. For this reason, a
northward movement in Amukta Pass would not yet be expected.

ATKA PASS (175°30' WEST)

Three hauls were made just north and east of Atka Pass (Area 4B) on
June 26, 1956, at a time when there was a strong westward movement of reds
and chums just to the south in Area 4C. Although three different directions
were tried, the total catch was a single king salmon. Two hauls in the same
area on July 8, 1957, produced only one chum. A haul on July 6, 1956, just
north of Adak Island in Area 4B also produced nil, while fish were abundant
on the south side in Area 4C.

These hauls indicate the very low abundance on the north side of the
islands as compared to the south side, and also show a lack of salmon move-
ment through Atka Pass during the periods fished.

AMCHITKA PASS (178° WEST TO 179°30' EAST)

Amchitka Pass was not fished in 1956.

On June 27, 1957, two hauls were made in the north entrance to Amchitka
Pass (Area 4B) with the net open south. The catch averaged 3 reds, 122 chums,
and 36 pinks in spite of the fact that the first haul was seriously affected
by tide. Pinks were mature; chums and reds immature.
On July 6, 1957, two hauls were again made in the same general area as above. The set open southwest took 3 reds, 198 chums, and 4 pinks. The haul open northeast took only 1 red and 2 chums. The results confirm the northward trend of June 27, this time with an opposed haul to check the predominance of the northward movement. On July 13 and 14, three more hauls in Amchitka Pass, two open southeast and one open south-southeast, took an average of 49 chums, again confirming a northerly trend, but without check hauls to the north. A similar haul on July 31 took but 1 chum, possibly suggesting the run had ceased. On August 24, two opposed hauls were made (Area 3B). The one open southeast yielded only 1 red while the one open northwest gave 5 reds and 23 chums. This may indicate a southerly movement late in the season.

BULDIR PASS (174° EAST TO 177° EAST)

This is a large deep pass lying partly in Areas 2B, 3C, 3D, and 3E (Figure 4). Much of the flow of fish taken in Area 3C with the net open southeast could have been going through Buldir Pass. Too few hauls open north or south are available to show positively the actual north and south flow of salmon in this pass, but the several hauls that were accompanied by check hauls are worth considering.

On August 12, 1957 (Table C3) in Area 3B, two opposed hauls were made simultaneously less than 10 miles apart by the Renown and Commander. [Fishing Efforts R-39 (second haul) and C-40]. The haul open to the south caught 63 reds and 8 chums, while that open to the north took 1 red and 10 chums. This pair of hauls suggests a northward movement of reds and perhaps a random movement of chums.
The other pair of opposed hauls of August 12 were also made simultaneously and within two miles of each other, but here the hauls were not in the open pass, but just 5 miles north of Buldir Island. The zero results are typical of hauls made close to the north side of the islands as discussed earlier.

A single haul in Area 2C on August 25 with net open to the north took 11 reds and 16 chums, suggesting a southerly movement late in the season (as perhaps also in Amchitka Pass just to the east), but unfortunately no check hauls were made.

In 1958 (Table C4) catches of two sets open south-southeast in Area 2B on July 14 took an average of 6 reds and 369 chums. No opposed set was made in that exact location, but on July 13, two hauls were made in Area 2C less than 50 miles to the southwest. The set open to the south-southeast took 13 reds and 78 chums, while the set open north took but 3 reds and 2 chums.

To summarize movement in the passes, too little fishing was done early in the season to show movements of mature salmon through Buldir and Amchitka Passes, except that mature pinks were shown to be going north through Amchitka Pass on June 27, 1957. Mature reds, chums, and pinks were also going north through Amukta Pass on June 5, 1957.

Immature red and chum salmon tended to go north more than south through Buldir and Amchitka Passes during July and perhaps more south than north during August.

Very small catches just north of Atka and Umnak Passes during the time that salmon were abundant on the south side indicated a lack of northward movement through these two passes.

EASTWARD IN THE BERING SEA

Some fishing was done over a considerable area of the central and eastern Bering Sea in 1957 and 1958 (Areas 4A, 4B, 5A, 5B, 6A, 6B). However, the only results which were consistent enough to show positive directional movement were those from fishing fairly close to the Pribilof Islands.
In 1957, a total of 25 hauls were made between June 17 and June 29 in Areas 5A, 6A, and 6B, yielding an average of 25 reds and 2 chums. All hauls were open roughly southwest. All salmon were mature. Less than one pink was taken per haul. A single check haul open to the northeast was made on June 29 and took but 1 king salmon.

In spite of considerable variability in the catches, and the shortage of check hauls, the results show an important movement of red salmon eastward toward Bristol Bay as would be expected in this area, and as was shown also by tag returns (Tables 62, 83).

In 1958, results of fishing well offshore in Areas 4A, 6B, and 5A were extremely variable for both reds and chums, never indicating the presence of an important mass of salmon regardless of direction of set. In Area 6A near the Pribilofs, however, six hauls open west between June 26 and 27 netted an average of 23 reds, 5 chums, and 1 pink per haul. Again a substantial eastward movement of reds was indicated.

The limited amount of seining in the central and eastern Bering Sea was insufficient to locate the major "run" or migration route of red salmon approaching Bristol Bay. It would seem that if such a route exists, catches would be larger and more consistent as seen along the south side of the Aleutians. The gill net catches of the United States Fish and Wildlife Service research vessels show a considerable spread of red salmon catches as seen in Figure 24, except in 1956 when a very great concentration was found just south of the Pribilof Islands.

A final important point regarding catches in the central and eastern Bering Sea is the fact that all species were almost 100 percent mature. This prevailed at least through June 29 in 1957 and 1958, when immature salmon were showing in large numbers south of the Aleutians.
WESTWARD IN THE BERING SEA

A westward movement of pink salmon was demonstrated in 1957 in the central and western Bering Sea (Areas 4B, 3B, and 2B). As will be shown later, tag returns bore out the consistency of the trend. Movement was also northward through the passes, so that the most clear-cut evidence from hauls well offshore away from the influence of the passes.

On June 28, 1957, three hauls were made in Area 4B at 54° North Latitude. The haul open west took 3 pinks, the one open east took 82, and the one open south took 9. In Area 3B, two hauls on July 7 produced 8 pinks with the net open east and none when open west. The reduced abundance was probably due to the late date. In Area 2B on June 28, a haul open east took 75 pinks, and one open west took none. Two hauls open east on July 8 averaged 28 pinks, while the one open west took none.

Such consistent results show that the westward trend for pinks observed along the south side of the Aleutians also prevailed in the Bering Sea in 1957. Too few pinks were taken in 1958 to indicate direction of movement in the Bering Sea.

Too few mature reds and chums were taken in the western Bering Sea to establish directional trends. Several hauls in 1957 demonstrated a westerly movement of immature chum salmon in two areas well north of the influence of the passes. On July 8 in Area 2B two hauls open east yielded an average of 29 immature chums, while the haul open west produced only 2. Similarly, on July 15, in Area 4B one haul open east took 235 chums, while a haul open west took 17.

Other than the above, fishing in the western Bering Sea was too close to the passes to indicate clearly the movement. Results were inconsistent and probably dependent on sea currents.
SUMMARY OF DIRECTIONAL MOVEMENT

Figures 10 and 11 summarize the movements of red salmon and chum salmon, respectively, using all 1956, 1957, and 1958 data. Seine catches for the three years are combined and shown as averages according to area and direction of fish movement by 15-day periods.

Pink salmon are not shown in this manner, because of their scarcity in 1956 and 1958, and because their movement was clearly westward in all areas in 1957. The recovery figures to be discussed later adequately illustrate pink salmon movements each year.

RED SALMON

Figure 10 depicts the trends of red salmon movement from late May through late August. Most salmon were mature in all areas through June 15. Between June 16 and 30 catches in areas east of 175° West Longitude were mature, while to the west, immatures had become predominant. After July 1, few mature salmon remained in any area.

The arrows of major abundance clearly illustrate the pronounced westward movement along the south side of the Aleutians for both mature and immature reds as far as 175° East Longitude. Lesser arrows show opposed movement to be only slight or lacking. West of 175° East Longitude, movement becomes more mixed, but westward movement is still pronounced. Northward movement through Amchitka and Bula Passes is indicated positively only later in the season when immatures were present. In the Bering Sea, the eastward route near the Pribilof's is shown between June 16 and 30.
Figure 10. Direction of movement of red salmon in Aleutian Island area as determined by purse seine catches. (Av. catch/set by area and by 2-week periods, 1956 - 1958 combined.)
The lack of red salmon in the central Aleutian area during the latter half of May is significant in itself, showing that the run of mature reds had not yet arrived. Areas 2B and 2C to the west show a few reds but no clear direction of movement. In Area 7C the westward trend is already apparent.

The results in offshore areas where arrows indicate less that 10 reds taken, should not be considered as establishing movement, since they are based on only one or two hauls in a single year (Areas 2A, 3A, 4A, 5D, 6D). It is significant that the offshore areas were uniformly less productive.

The strong northward movement indicated in Area 5C (July 27 - 31) was inferred from a single haul well offshore, and therefore is not an established movement comparable to the westward movement, for instance.

The low abundance of immature reds east of 175° West Longitude in August suggests that the major concentrations had passed to the west by this time.

Also in the period July 16 - 31, the low abundance south of the central Aleutians requires explanation. As seen in Figure 8, the catches of red salmon were at a low ebb during this period, and in 1953 the area was fished only the last two days of the period. The evidence suggests this to be a period "between runs". In spite of low abundance, however, the westward trend is still in evidence.

CHUM SALMON

The general trend of chum salmon movements seen in Figure 11 is similar to that of the red salmon. Mature chums predominated until approximately July 1, but substantial numbers of matures continued to be taken in some catches as late as the vessels fished. Tagging Tables T1, T2, and T3 give maturity breakdowns for each day's fishing. There was a lack of salmon in the central Aleutians in late May, showing that chums as well as reds had not yet arrived in abundance.
Figure 11. Direction of movement of chum salmon in Aleutian Island area as determined by purse seine catches. (Av. catch/set by area and by 2-week periods, 1956 - 1958 combined.)
The consistent westward flow south of the Aleutians is very pronounced after June 1, and continues strongly further west than in the case of red salmon. The eastward movement near the Pribilof Islands is much weaker than for red salmon during the period of fishing there (June 16 - 30).

In the westernmost areas, it is obvious that chums were considerably more abundant than reds. Movement through Bilibir and Amchitka Passes was both north and south, and in the Bering Sea, movement was definitely mixed.

**Application of migration paths to tag recovery figures**

In accordance with the movements described, the migration routes of salmon tagged south of the Aleutians were always shown as passing northward through the next major pass west of the point of tagging in all cases where recovery was north of the Aleutians. This was also done with immatures returned one or two years later, but in such cases the choice of route was merely for uniformity. (The one exception to the rule is seen in Figure 21. The few mature reds tagged in this area were moving east at time of capture.)

**UNANSWERED QUESTIONS OF MOVEMENT**

The oceanic source of the fish comprising the "stream" is not known, but it seems unlikely that all are coming from areas east of Unimak Island. It is possible the salmon move northward from the open sea, and then swing westward at whatever point they may encounter the narrow Aleutian shelf.

The location of immatures early in the season is another unanswered problem.

There is also the long period of fall, winter, and spring in which nothing is known about movements.
Finally, there is the contrast in the type of movement seen south of the Aleutians and that seen in the large offshore area south of Kodiak Island and in the Gulf of Alaska. In the latter area, evidence to date shows no consistent direction of movement. Catches, though never large, showed little correspondence to direction of set. Perhaps this indicates random feeding movements of fish. The salmon in the westward "flow" south of the Aleutians are also feeding fish, but are apparently following at the same time, some migratory path.

SIGNIFICANCE OF MOVEMENT DATA

The fact that red, chum, and pink salmon have been found each year moving westward in a concentrated stream along the south side of the Aleutians during the summer months is in itself an important contribution to our knowledge of salmon behavior at sea. Although the immediate "source" of the salmon comprising the flow and their relationship to salmon of adjacent areas is little understood, tagging has shown the salmon in the westward flow to originate in streams of both America and Asia. Sometimes fish from both continents were tagged from the catch of a single seine set. Thus it seems probable that at one time or another, the flow includes a great part of the salmon stocks which feed in the Aleutian area. Future research, therefore, in tagging, in distribution, and in sampling, must take such concentrations into account in attempting to better delineate the immediate source, timing, and extent of this important group of salmon.
STOCKS COMPOSING THE WESTWARD FLOW

An illustration of the various groups passing at different times through Area 4C, for example, is shown in Figure 12. Here the lengths of the chum salmon tagged in Area 4C in the 1957 season are shown for four successive time periods. In Section A, matures predominate, and even these include a large range of size groups. Later, various size groups appear, disappear and re-appear in varying proportions. Some of the variation in the series is due to growth, of course, but the varying proportions of the several age and racial groups overshadow this factor. This phenomenon was seen in most areas of fishing, particularly with chum salmon. Such a progression of distinct units emphasizes the heterogeneity of the stocks passing, and the desirability of repeated sampling or tagging in one area.

ESTIMATE OF NUMBERS IN WESTWARD MOVEMENT

The purse seine catches provide a means to estimate the "volume" of the "stream" of salmon passing south of the Aleutians. Results, though admittedly rough, are presented because they furnish some idea of the numbers passing, and therefore the importance of the stocks in areas where most tagging was done.

Catches in Area 4C should provide the most reliable figures since movement was consistent there, and seining extended over an appreciable length of time each year as shown in Figure 8.

Table 4 presents the estimates of the numbers of reds and chums passing Area 4C in 1956, 1957, and 1958 during the comparable time periods shown. The
Figure 12. Lengths of chum salmon tagged in area 4C by time period, 1957.
TABLE 4. Estimate of numbers of salmon passing westward south of the Aleutian Islands during specified periods - 1956, 1957, and 1958, compared with the numbers tagged

<table>
<thead>
<tr>
<th>Area</th>
<th>Year</th>
<th>Inclusive Dates</th>
<th>Species</th>
<th>No. of Sets</th>
<th>Average Catch/Set</th>
<th>Estimate of Total in Millions</th>
<th>Number Tagged</th>
<th>Proportion Tagged</th>
</tr>
</thead>
<tbody>
<tr>
<td>4c</td>
<td>1956</td>
<td>6/24-8/15</td>
<td>Red</td>
<td>44</td>
<td>41</td>
<td>8.3</td>
<td>1,602</td>
<td>1 : 5,200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chum</td>
<td></td>
<td>44</td>
<td>70</td>
<td>14.2</td>
<td>2,290</td>
<td>1 : 6,200</td>
</tr>
<tr>
<td>4c</td>
<td>1957</td>
<td>6/20-8/31</td>
<td>Red</td>
<td>41</td>
<td>6</td>
<td>1.7</td>
<td>226</td>
<td>1 : 8,700</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chum</td>
<td></td>
<td>41</td>
<td>41</td>
<td>11.5</td>
<td>1,584</td>
<td>1 : 8,700</td>
</tr>
<tr>
<td>4c</td>
<td>1958</td>
<td>6/25-8/17</td>
<td>Red</td>
<td>34</td>
<td>42</td>
<td>8.7</td>
<td>1,336</td>
<td>1 : 6,500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chum</td>
<td></td>
<td>34</td>
<td>92</td>
<td>19.1</td>
<td>3,012</td>
<td>1 : 6,300</td>
</tr>
</tbody>
</table>

1 See Figure 4.
calculations are based on simple space and time extrapolations of the average
seine catches. Only those seine hauls were considered in which the set was
within twenty miles of shore, in which the net opening was toward the east,
and in which the "effectiveness of haul" was satisfactory.

The data and assumptions for making the calculations are as follows:

\[ \begin{align*}
N & \quad \text{Total number of salmon passing during period being considered.} \\
\bar{x} & \quad \text{Average number of each species per set in the time period considered. (The assumption is made that seine hauls were sufficient to furnish a usable average for the period considered. It is recognized that within the period of fishing, abundance fluctuated, sometimes with a definite trend. In some instances, the trend of abundance was increasing at the time fishing ceased, in which case the total numbers passing during the season were far in excess of the numbers passing during the period considered.)} \\
w & \quad \text{Width of seine opening (averaged \( \frac{1}{4} \) mile).} \\
w & \quad \text{Width of "stream" of salmon (20 miles). Twenty miles was chosen as an arbitrary safe minimum. Most hauls were made between 5 and 15 miles of shore with no consistent difference within those limits. Seining demonstrated the western movement to prevail at least to 50° North Latitude (90 miles offshore), but numbers of hauls were insufficient to compare abundance. Fish and Wildlife Service vessels in 1957, for example, showed undiminished abundance to 50° North.} \\
t & \quad \text{Time (in hours) of seine opening (average, 30 minutes).} \\
T & \quad \text{Time (in hours) of period in which seine data are available. (The assumption is made that movement continues day and night.)}
\end{align*} \]
Thus the number of a given species passing westward through an area for the specified time was calculated as:

\[ N = \frac{W}{T} \cdot \frac{W}{t} \]

The estimates of the totals show that very substantial numbers of reds and chums passed westward through Area 4C each year during the periods indicated. Red salmon were considerably less abundant in 1957 than in either 1956 or 1958. Since most reds during this period were immature, and not due to spawn until the following year, it is possible that the lack seen in the westward flow was an advance token of the very low abundance in Bristol Bay in 1958. The Bristol Bay catch plus escapement was only 6.5 million in 1958 as against 11.8 million in 1957 and 25.2 million in 1956 (Table 6).

The proportions tagged, of course, are no more accurate than the estimates of the totals, but again, the figures listed furnish at least an approximation of the tagged-to-untagged ratio within the time and area limits described.
TAG RETURNS

The tag returns and conclusions therefrom, will be discussed according to species. Sufficient numbers of red, chum, and pink salmon were tagged and recovered to provide considerable data on their ocean movements and their continent of origin. The numbers of silvers, kings, and steelhead tagged and recovered, however, were sufficient only to demonstrate that these species travel surprisingly great distances during their ocean residence.

Summaries of tag returns are shown in Tag Return Tables R1 through R12 in the appendix according to species, year of tagging, and area of tagging. For convenience, the data from the return tables are also shown as recovery distribution figures placed in appropriate sections of the text. Finally, detailed release and recovery data are presented in the appendix in Tables R13, R14, and R15, respectively, for 1956, 1957, and 1958.

The data shown in the above tables and figures include all tags received through June 1, 1959. Each year some few tags have been received which were actually recovered by the fishermen one or two seasons previously. Thus, a few additional tags recovered in 1956, 1957, or 1958, but which were delayed for one reason or another, will probably be received in the future. Returns from mature salmon are, therefore, virtually complete. It is unlikely that the few tags still to be received will alter the principal conclusions drawn.

Returns from immature salmon tagged, however, are far from complete, and can be reported here only through the June 1, 1959 date. Returns of immatures from 1956 are probably complete since there have been two fishing seasons (1957 and 1958) for their return. Returns from 1957 immatures were received in 1958, and more of these are expected in the 1959 season. The greatest number of returns are expected in 1959 from the 1958 immatures, with some additional ones in 1960.
Figure 5 shows a summary by species of the numbers of mature and immature salmon tagged each year. More than 3,000 immature reds were tagged in 1958, and more than 8,000 chums, so that a substantial part of the results from that year's tagging are yet to be received.

In considering the tag returns, frequent reference will be made to Figures 13, 14, 15, Table 5, and Figure 16. The first three figures show the distribution of monthly fishing effort by Japanese Aleutian fleet, May, June, and July, 1956. (Data from Table 2, INPFC Annual Report for 1956.)

Figure 13.--Distribution of monthly fishing effort by Japanese Aleutian fleet, May, June, and July, 1956. (Data from Table 2, INPFC Annual Report for 1956.)

Figure 14.--Distribution of monthly fishing effort by Japanese Aleutian fleet, May, June, and July, 1957. (Data from Table 2, INPFC Annual Report for 1957.)

Figure 15.--Distribution of monthly fishing effort by Japanese Aleutian fleet, May, June, and July, 1958. (Data from Table 2, INPFC Annual Report for 1958.)

Table 5. Effort, catch, and catch per unit of effort by Japanese fleet in Aleutian waters in 1956, 1957, and 1958. (Three area divisions shown in Fig. 15)

Figure 16.--Three area divisions for Japanese Aleutian salmon statistics shown in Table 5. (Japanese statistical areas per Figure 1, page 3, INPFC Statistical Yearbook for 1957.)

distribution of the Japanese fishing effort in the Aleutian area by month, for the years 1956, 1957, and 1958, respectively. In Table 5, the fishing effort, catch, and catch per unit effort for reds, chums, and pinks are shown grouped for three major areas; north of the Aleutians, south of the Aleutians, and west of 165° East Longitude. The boundaries of each of these areas are shown in Figure 16. The three areas were chosen in order to illustrate important points regarding the distribution of returns of tagged salmon from the high seas fishery.
Figure 13. Distribution of monthly fishing effort by Japanese Aleutian fleet, May, June, and July, 1956. (Data from Table 2, INPFG Annual Report for 1956.)
Figure 14. Distribution of monthly fishing effort by Japanese Aleutian fleet, May, June, and July, 1957. (Data from Table 2, INPFC Annual Report for 1957.)
Figure 15. Distribution of monthly fishing effort by Japanese Aleutian fleet, May, June, and July, 1958. (Data from Table 2, INPFC Annual Report for 1958.)
TABLE 5. Effort, catch, and catch per unit of effort by Japanese fleet in Aleutian waters in 1956, 1957, and 1958
(Three area divisions shown in Fig. 19)

<table>
<thead>
<tr>
<th>Year Location</th>
<th>Effort (No. of tans in millions)</th>
<th>REDS Catch (No. of fish in millions)</th>
<th>Catch per tan (No. of fish)</th>
<th>CHUMS Catch (No. of fish in millions)</th>
<th>Catch per tan (No. of fish)</th>
<th>PINKS Catch (No. of fish in millions)</th>
<th>Catch per tan (No. of fish)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956 N. of Aleutians</td>
<td>2.0</td>
<td>2.2</td>
<td>1.1</td>
<td>4.5</td>
<td>2.3</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>5.6</td>
<td>5.0</td>
<td>0.9</td>
<td>9.5</td>
<td>1.7</td>
<td>1.3</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>2.1</td>
<td>1.2</td>
<td>2.1</td>
<td>1.2</td>
<td>10.5</td>
<td>6.2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>9.3</td>
<td>9.3</td>
<td>1.0</td>
<td>16.1</td>
<td>1.7</td>
<td>11.9</td>
<td>1.3</td>
</tr>
<tr>
<td>1957 N. of Aleutians</td>
<td>1.4</td>
<td>6.0</td>
<td>4.3</td>
<td>1.6</td>
<td>1.1</td>
<td>4.0</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>2.9</td>
<td>8.6</td>
<td>3.0</td>
<td>4.9</td>
<td>1.7</td>
<td>5.0</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>2.3</td>
<td>5.3</td>
<td>2.3</td>
<td>2.8</td>
<td>1.2</td>
<td>12.0</td>
<td>5.2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>6.6</td>
<td>19.9</td>
<td>3.0</td>
<td>9.3</td>
<td>1.4</td>
<td>21.0</td>
<td>3.2</td>
</tr>
<tr>
<td>1958 N. of Aleutians</td>
<td>0.3</td>
<td>0.3</td>
<td>1.1</td>
<td>0.8</td>
<td>2.7</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>4.3</td>
<td>7.2</td>
<td>1.7</td>
<td>7.9</td>
<td>1.8</td>
<td>2.0</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>4.0</td>
<td>4.5</td>
<td>1.1</td>
<td>8.5</td>
<td>2.1</td>
<td>11.1</td>
<td>2.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>8.6</td>
<td>12.0</td>
<td>1.4</td>
<td>17.2</td>
<td>2.0</td>
<td>13.2</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Figure 16. Three area divisions for Japanese Aleutian salmon statistics shown in Table 5.
(Japanese statistical areas per Figure 1, page 31, INPFC Statistical Yearbook for 1957.)
RED SALMON RETURNS

Each year red salmon were tagged over an increasingly larger part of the North Pacific and Bering Seas (Figure 6), with most emphasis in the Aleutian Island area.

The three years' tagging in the Aleutian and Bering Sea areas have consistently shown the importance of Bristol Bay red salmon. All estuarine returns of reds have come from Bristol Bay or adjacent locations. Therefore, the tagging results have shown much more about these stocks than about Asian red salmon. The reason for the predominance of Bristol Bay red salmon is evident from Table 6, which presents the 1956, 1957, and 1958 catches of this species in Bristol Bay, U.S.S.R., and by the Japanese Aleutian fleet. If we assume that the U.S.S.R. catch is equal to the U.S.S.R. escapement, then it is evident that the Bristol Bay red salmon stocks overshadowed those of U.S.S.R. in all three years. Further reference to Table 6 will be made regarding tagging results for individual years.

Each year the tagging results have expanded our knowledge of the extent of seaward distribution of Bristol Bay red salmon. Principal results have come from mature reds recovered the same year as tagged. In 1957, however, the return of immatures tagged in 1956 provided valuable additional data on the limits of seaward distribution and on the relative abundance of Bristol Bay reds in the areas of the Japanese fleet operations.


<table>
<thead>
<tr>
<th>Year</th>
<th>U.S.S.R. Catch¹</th>
<th>Japanese Aleutian Area Catch</th>
<th>&quot;Bristol Bay&quot;² Catch</th>
<th>Total Catch All Nations</th>
<th>&quot;Bristol Bay&quot; Escapement</th>
<th>Total Return to &quot;Bristol Bay&quot; (Catch plus Escapement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>1,974</td>
<td>9,247</td>
<td>10,252</td>
<td>21,473</td>
<td>14,743</td>
<td>24,995</td>
</tr>
<tr>
<td>1957</td>
<td>1,275</td>
<td>19,323</td>
<td>6,631</td>
<td>27,729</td>
<td>4,840</td>
<td>11,871</td>
</tr>
<tr>
<td>1958</td>
<td>344³</td>
<td>11,971</td>
<td>3,460</td>
<td>15,775</td>
<td>2,776</td>
<td>6,236</td>
</tr>
</tbody>
</table>

¹ U.S.S.R. data converted from metric tons to numbers of fish using 6.4 lbs. average weight per Pravdin (1940).
² Includes catch on north side Alaska Peninsula and in eastern Aleutians.
³ Kamchatka Peninsula only (Kamchatka catch was over 90% of total in 1956 and 1957 per reference for those years).

Source: 1956, 1957, and 1958 Japanese catches and Bristol Bay catches are from INPFC Statistical Yearbooks.


In addition, the tagging results, when considered with data on abundance by area, have been valuable in showing the major routes followed by red salmon approaching Bristol Bay. These routes differed significantly from year to year, as will be shown in the respective years’ discussions. The data contributing to the determination of routes are:

1. Directional information from seine catches
2. Abundance from seine catches
3. Tag recoveries from the Bristol Bay area and from the Japanese high seas fleet
4. Abundance data from Fish and Wildlife Service research vessels, using gill nets
5. Abundance data from Japanese high seas catches

1956 TAGGING

In 1956, the red salmon tagging was confined principally to Areas 4C through 7C close to the islands (Figure 6). A few reds were tagged from gill nets early in the season further west, but no returns resulted (Table E1). Operations in Areas 5C, 6C and 7C were conducted between June 7 and July 1, and all reds tagged were mature. In Area 4C tagging was done between June 24 and August 15. Reds tagged after June 28 were predominantly immature. The daily breakdown of mature and immature fish among those tagged is shown in Table T1.

LENGTHS, AGE AND MATURITY

Length, ocean age, and maturity of the salmon tagged are necessary elements in analyzing the tag results. The number of matures must be known in order to evaluate the return in the year of tagging. In addition, distribution and movements at sea have often been found to vary according to maturity, as discussed earlier. Age is important to indicate the probable year of return of immatures. Length is valuable in showing the success of return of different sizes within an age group. Lengths have also shown size differences between immatures and matures of the same age, and are further valuable in measuring growth between tagging and recovery.
The general methods used to determine maturity were discussed in the section entitled "Explanation of Tables in the Appendix". The following paragraphs discuss specifically the length, age, and maturity of the red salmon tagged in 1956.

The length-frequency distribution of all reds tagged in 1956 is shown in Figure 17, together with bar graphs depicting the lengths (at tagging) of those returned in 1956, 1957, and 1958. The discrepancy between the number (3,396) shown in the graph and the number tagged (3,403 - Table 41) is due to seven reds for which no length was obtained. Similar discrepancies apply to other length-frequency graphs shown later.

Insufficient scales were taken in 1956 to show separate curves for each age group, as was done in 1957 and 1958 (Figures 27 and 38) but the approximate size ranges of the several ages may be seen by comparing Figure 17 with Figures 27 and 38. The immatures that had spent one winter at sea stand out with a sharp mode at 37 cm and gave no returns, probably due to tagging mortality (Figure 17). (As mentioned earlier, the larger mesh size used in 1956 allowed gilling and injury to the small-sized salmon.) The larger mode consists of three groups of fish; two-winter\(^4\) immatures with a mean size of approximately 43 cm, two-winter matures averaging approximately 51 cm, and three-winter matures averaging about 60 cm.

\(^4\)We refer repeatedly in this discussion to one-winter, two-winter, and three-winter salmon. We mean the number of winters spent at sea as determined by scale reading.
Figure 17. Lengths of red salmon tagged in 1956, and lengths (at tagging) of those recovered in 1956, 1957, and 1958.
In order to show more clearly the size groups mentioned, the reds tagged in Areas 4C and 6C are presented separately in Figure 18.

**Figure 18.**—Lengths of red salmon tagged in areas 4C and 6C in 1956, and lengths (at tagging) of those recovered in 1956, 1957 and 1958.

In the upper half of the figure, the one- and two-winter immatures of Area 4C are clearly defined by the modes. A slight skewness to the right is caused by the few larger matures. Solid bar graphs depict the four matures returned in 1956, and the open bar graphs depict the immatures returned in 1957, plus the one returned in 1958.

In the lower half of the figure are plotted the lengths of mature reds tagged in Area 6C. The two-winter size (54 cm) greatly predominate. The few three-winter fish (60 cm) are contained in the skewness to the right of the mode. It is noteworthy that the Bristol Bay run in 1956 was also over 80% two-winter-in-sea red salmon (Fisheries Research Institute Bristol Bay Research, unpublished data). The lengths (at tagging) of those returned are very similar to the lengths of the total sample tagged, showing a predominant mode of two-winter fish and a skewness to the right accounting for the three-winter fish.

Red salmon tagged in Area 6C were recovered only in the year of tagging, thus showing that few, if any, were immature. Gonad samples showed the fish to be mature, and in addition, sexual maturity was beginning to show externally. By the same token, the great majority of those tagged in Area 4C showed no signs of sexual maturity and gonad samples indicated immaturity. This was especially true after July 1, when matures made up a very small part of the catches (Table T1).
Figure 18. Lengths of red salmon tagged in areas 4C and 6C in 1956, and lengths at tagging of those recovered in 1956, 1957, and 1958.
The above points are emphasized in order to show that there was little problem in determining the maturity of most of the red salmon released. The principal problem was with the two-winter age group, and among these, the mature fish were larger and abundant only until June 20-25. In addition, matures and immatures never occurred mixed in the same catches in large numbers. This fact suggests that the maturing fish had "broken away" from the immatures at some time prior to our fishing in Area 6C. There is the possibility also, that the two groups had never been mixed, but had followed independent courses in their ocean feeding.

RETURNS BY AREA OF TAGGING

Tag returns from the 1956 experiments will be discussed by area, and comparisons with results in 1957 and 1958 will be made where pertinent. Reference is made to Table R1 in the appendix.

Areas 3C, 4B, and 4C

The total of 17 mature, and 3 immature reds tagged in Areas 3C, 4B, and 4C in the period May 2 through 30 were nearly all tagged from gill net catches. The lack of returns was, therefore, probably due to tagging mortality.

Area 4C (Figures 19 and 20)

In Area 4C, 93 mature reds were tagged between June 21 and August 15.

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Of the 4 returns, 3 were from Bristol Bay and one from the north side of the Alaska Peninsula. This was the farthest west that effective tagging was done in 1956, and in spite of the heavy Japanese fishery to the west (Figure 13) no tags were taken there. Since the salmon were moving west at the time of tagging, it is presumed that they turned northward through Amchitka Pass in returning toward Bristol Bay. Accordingly, this route is shown in Figure 19.
Figure 19. Recovery distribution of mature red salmon tagged in area 4C in 1956.

Figure 20. Recovery distribution of immature red salmon tagged in area 4C in 1956.
Of the 1,509 immature salmon tagged in Area 4C, 996 were the larger size that had spent two winters at sea (including a very few which had spent three winters at sea), and 513 were the smaller fish that had spent but one winter at sea. Thirty returns were received in 1957 from the large two-winter immatures, and one in 1958. None of the small one-winter immatures were returned. Of the thirty returned in 1957, 17 were taken by the high seas fleet and 13 in Bristol Bay. Their distribution is illustrated in Figure 20. Since these recoveries pertain to the distribution of salmon in 1957 and 1958, they will be discussed with those years' results.

Area 5C (Figure 21)

From a total of 11 mature reds tagged, 2 were recovered in Bristol Bay. As mentioned in the section on Direction of Movement, the few reds tagged in Area 5C were taken in hauls open to the west. Thus, in Figure 21, their route is shown going through Amukta Pass instead of passes to the west, as in other return figures.

Areas 5B and 6B

No returns were received from the total of 10 mature reds tagged in these two areas.
Figure 21. Recovery distribution of mature red salmon tagged in area 5C in 1956.

Figure 22. Recovery distribution of mature red salmon tagged in area 6C in 1956.

Figure 23. Recovery distribution of mature red salmon tagged in area 7C in 1956.
Area 6C (Figure 22)

Figure 22.—Recovery distribution of mature red salmon tagged in area 6C in 1956.

A total of 1,386 mature reds tagged in Area 6C between June 7 and 28, resulted in 66 returns from Bristol Bay, one from Chignik, and one from the high seas north of Adak. The returns emphasize the importance of Bristol Bay reds in the westward "flow" of reds previously described in this area. The one from the high seas apparently continued west and was intercepted after going north through Amchitka Pass. This corresponds to the probable route of those tagged in Area 4C (Figure 19), but is even better illustrated by results in 1957 (Figures 30 and 35). The return from Chignik was the only red tagged in the Aleutian area that was returned from south or east of the Alaska Peninsula. The large size, and the scale pattern, indicated the fish to be a typical Chignik red salmon.

Area 7C (Figure 23)

Eleven of 372 matures tagged in Area 7C were returned; 8 from Bristol Bay

Figure 23.—Recovery distribution of mature red salmon tagged in area 7C in 1956.

and 3 from the Alaska Peninsula. The route shown is north through Unimak Pass, but it is probable that some went north through Amukta Pass or even at points further west.

Unknown area of tagging

In addition to the above returns, 16 tagged reds were observed, but not recovered at the counting towers operated by the Fisheries Research Institute on the Kvichak River. Fourteen were white tube tags, and 2 were white disc tags. Since in 1956 there were no other tagging experiments in which the above tags might have been applied, they were added to the total returns, but without a specific area of tagging. Since the major part of the matures were tagged in Areas 6C and 7C, it is probable that most of the observed tags originated in these locations.
Summary of returns

Mature red salmon tagged in 1956 south of the Aleutians as far west as Adak Island (177° West Longitude) were overwhelmingly of Bristol Bay origin. Ninety-nine out of 101 recoveries were from Bristol Bay. Of the two remainder, 1 was taken on the high seas north of Adak, and 1 at Chignik on the south side of the Peninsula. The lack of returns from the large high seas fleet to the west of the tagging locations emphasizes that few, if any, Asian reds were tagged.

1956 Migration Routes

Available information about red salmon in the Aleutian area in 1956 suggests that the runs approaching Bristol Bay did not migrate as far west as did the 1957 run. Evidence is built upon seine catch data and tag return data, plus abundance and distribution data from the United States Fish and Wildlife Service research vessels, and from the Japanese Aleutian fleet.

The largest catches of mature reds during the three years' seining were made in 1956 south of Unmak and Unalaska Islands. Between June 7 and 21, catches were large and consistent, averaging 49 per set (Table C2, Area 6C). Tag returns from experiments in Area 6C came almost entirely from Bristol Bay.

Upon moving to Area 5C on June 23, catches of reds dropped sharply, and in Area 4C from June 24 and later, mature reds declined in abundance and soon disappeared from the catches. Purse seine catches thus showed the abundant westward flow of reds in Area 6C did not continue in Areas 5C and 4C.
This, and the results of other fishing, suggests that the Amukta Pass area (169° - 173° West Longitude) was an important route for reds moving into the Bering Sea in 1956. The gill net fishing by the United States Fish and Wildlife Service research vessels in 1956 showed a great abundance of red salmon between Amukta Pass and the Pribilof Islands on June 20 and 21 (Figure 24). However, the catch per unit effort by the Japanese fleet in


June, 1956 (Figure 25) indicates only nominal numbers of red salmon in the Aleutian area west of 175° West Longitude. This is in sharp contrast to

Figure 25.--Red salmon catch/unit effort of Japanese high seas fishery in Aleutian area during the month of June, 1956, 1957, and 1958.

the large catch per unit effort in 1957, also shown in Figure 25. As seen in Table 5, the season's average red salmon catch per ton was only one in 1956 as against three in 1957. In addition, the total catch of the Japanese fleet in 1956 was but 9.2 million reds as against 19.8 million in 1957 (Table 6). When it is recalled that the catch plus escapement in Bristol Bay was approximately 25 million in 1956 and only 11.5 million in 1957 (Table 6), it becomes obvious that in approaching Bristol Bay, the major part of the 1956 run did not migrate as far west as did the run in 1957.
Figure 26. Principal routes used by mature red salmon approaching Bristol Bay in 1956, 1957, and 1958 as suggested by tagging results and by distribution of abundance.
LENGHTS, AGE, AND MATURITY

The age makeup, and, therefore, the lengths of the mature and immature reds tagged in 1957 were in sharp contrast to those of 1956. As shown in Figure 27, the mature reds in 1957 were mainly three-winter fish. In 1956 (Figure 17 and 18) both matures and immatures were predominantly two-winter fish. It is logical that three-winter matures should predominate in 1957, since two-winter immatures predominated in 1956. The Bristol Bay red salmon catches in 1957 were 75% three-winter fish, similar to the age makeup seen at sea. (Fisheries Research Institute, Bristol Bay Research unpublished data.)

In 1957 sufficient scales were taken that the lengths could be shown for each age group. A total of 37 lengths were omitted because scales were not taken, or were illegible. Most of those not shown were of the small size which typically had spent one year at sea.

It is at once obvious that the modal size of one-winter-in-sea reds in 1957 was smaller than in 1956 (35 cm as against 37 cm, Figures 27 & 17). This is due to two factors: the smaller mesh size used in 1957, and the earlier date that immature reds were taken in 1957. The reds of this age group were markedly smaller in the early catches in area 2C where immature reds were taken as early as June 13 (Table T2). The smaller meshes used in 1957 prevented small fish escaping through the net as was experienced in 1956. Thus the 1957 sample is more representative of the true size distribution of one-winter reds. The large 1958 sample shows a similar size distribution (Figure 38). The single red 29 cm in length, which had not yet spent a winter at sea, was taken in August when the one-winter-in-sea group averaged over 35 cm in length.
The two-winter-in-sea group contained both mature and immature reds. The size modes of immatures and matures are approximately 58 and 53 cm, respectively. These are very similar to the sizes found for the same two groups in 1956 (Figure 18).

The three-winter-in-sea group is quite distinct from the two-winter group, although there are a few small specimens extending well down into the range of the younger fish. Only two four-winter fish were tagged, as shown.

The lengths (at tagging) of fish recovered in 1957 show a distribution which includes the larger of the two-winter fish, plus the entire range of the three-winter fish.

The lone return in 1958 from the immature two-winter fish provided only a 0.2 percent return, as compared to 3.0 percent from the same age group tagged in 1956 (Tables R2 and R1). The reason for such a great disparity is unknown.

The one-winter-at-sea group gave no returns from a total of 774 tagged (Table R2). This was extremely disappointing, since the smaller mesh size and improved handling methods in 1957 had resulted in the small fish being in better condition at release than in 1956. Since there was also a very low return of two-winter-in-sea reds from the 1957 tagging, it is possible that both groups suffered poorer survival than those of 1956.

RETURNS BY AREA OF TAGGING (Table R2)

The 1957 tagging provided a series of experiments along the full length of the Aleutians. Numbers tagged in the westernmost areas (2B, 2C) were very few, however. Tagging in the central Bering Sea and near the Pribilofs showed the eastward movement toward Bristol Bay from these areas. The results confirmed the migration routes suggested by the tagging south of the Aleutians. Tag returns from the large catch of reds in 1957 by the Japanese fleet both north and south of the Aleutian Islands (Table 5), were further helpful in defining migration routes of reds in the Aleutian area.
Area 2B

Although substantial numbers of chum and pink salmon were tagged in the area north of Attu Island, very few reds were taken. Of the four tagged, none were returned.

Area 2C (Figure 28)

Figure 28.—Recovery distribution of mature and immature red salmon tagged in area 2C in 1957.

From 16 mature reds tagged south of Attu Island, one was returned from Bristol Bay, and one from the high seas just west of the point of tagging. The former return is unmistakable evidence of Bristol Bay reds as far west as 172° East Longitude. The latter had moved too little to suggest its destination.

The single immature red returned in 1958 was from 76 two-winter-in-sea reds tagged in this area in 1957. It was recovered south and east of the point of tagging, but due to the long period at liberty, the return offers no indication of the actual migration during the intervening period.

Area 3B

No returns resulted from the 73 reds tagged in Area 3B. Poor results would be expected since 65 were the small size group which gave no return from any of the tagging areas.

Area 3C (Figure 29)

Figure 29.—Recovery distribution of mature red salmon tagged in areas 3C and 4B in 1957.

The 41 mature reds tagged in Area 3C gave two returns from Bristol Bay and one from the high seas south of the Komandorski Islands. The latter may have been destined for an Asian stream, since it was recovered on July 9 (Table R11), a date too late for the long journey to Bristol Bay.
Figure 27. Lengths of red salmon tagged in 1957 by ocean age, and lengths (at tagging) of those recovered in 1957 and 1958.
Figure 28. Recovery distribution of mature and immature red salmon tagged in area 2C in 1957.

Figure 29. Recovery distribution of mature red salmon tagged in areas 3C and 4B in 1957.

Figure 30. Recovery distribution of mature red salmon tagged in area 4C in 1957.
Area 3D

Only two immature reds were tagged in this area in 1957, with no returns.

Area 4B (Figure 29)

Only four mature reds were tagged in this area, but one was recovered in
Bristol Bay. The location of tagging was 52° north and 177° 25' west, where
the Japanese fleet enjoyed very heavy red salmon catches in June (Figure 25).
Unfortunately, the dates (June 27-28) on which the tagging vessels operated
in Area 4B, were too late to intercept the peak of abundance.

Area 4C (Figure 30)

The 136 mature reds tagged in Area 4C resulted in three returns from the
high seas west and north of the tagging point, plus one from Bristol Bay.
The results help to indicate the movement pattern described in the section
on salmon movements. At the time of tagging, the salmon were moving westward
south of Adak. The high seas returns clearly show Amchitka Pass as an avenue
into the Bering Sea, and the Bristol Bay return indicates the final destina-

As shown in Table R2, no returns were received in 1958 from the 137 two-
winter immature reds tagged in Area 4C in 1957. However, the 996 two-winter
reds tagged in this area in 1956 resulted in 30 returns in 1957, and one in
1958 (Table R1). The 30 returns from the 1956 tagging will be discussed at
this point, since they are most pertinent to the movements of red salmon in
1957.
One of the problems in tagging mature red salmon at sea is securing adequate distribution of tags during the short period of availability. Weather severely limits vessel operations prior to June in most years. If early and widespread distribution could be obtained, returns would indicate the farther limits of migration, and even the earliest runs of salmon would have an equal chance of being tagged.

The tagging of immature salmon a year prior to recovery, offers a solution to the above problem. Tagging a year prior to spawning is certainly early enough to include fish destined for the earliest streams regardless of continent of origin, and the extent of seaward migration will be known at least within the limits of the time and space coverage of the following year's high seas fishery. In line with the above considerations, the returns in 1957 from the immature red salmon tagged in 1956, have provided extremely valuable information on the distribution of salmon many months after tagging.

One important finding from the returns of these 30 salmon in 1957 was that the oceanic distribution of red salmon tagged in Area 4C, after a year at liberty, was far greater than that indicated by the limited tagging of matures during 1957. Those at liberty a year (Figure 20) were taken over a wide area southwest of Kiska and Attu Islands, and also in Amchitka Pass and north of Adak. Matures (Figure 30) were taken only in Amchitka Pass and north of Adak. Both groups, of course, also gave returns from Bristol Bay. The more limited distribution shown by the matures would be expected, since they were obliged to travel more directly to their spawning streams.

In evaluating the significance of Figure 20, the following points should be borne in mind:
1. The returns shown are from the total of 996 two-winter-in-sea immature red salmon tagged during the period June 24 - August 15, 1956, in Area 4C. At the time and place of tagging, the salmon were moving consistently westward as determined by direction of seine set. The numbers of reds passing during the period of tagging was estimated as approximately 8 million (Table 4).

2. The distribution of returns at sea is dependent on the time and space distribution of the Japanese gill net fleet. The catch distribution of the Japanese fleet for May, June, and July is shown in Figure 31 with the tag returns by month superimposed on the respective month's catch chart. The distribution of returns matches roughly the general areas of large catch with the exception of the area west of 165° East Longitude, where in spite of an increasing catch from May through July, no tags were recovered. The high seas recovery from far to the north (59°) during May appears to be a case of misrecording and possibly should have been 49°. The single high seas recovery in July just north of the central Aleutians was presumably taken by a scout boat since no catch is shown in the area during July (Figure 31).
Figure 31. Red salmon catch by Japanese high seas fishery in Aleutian area by month in 1957, also showing red salmon tag returns in 1957 from 1956 tagging in area 4C. (Statistical areas and catch data from INPFC Annual Report for 1957.)
3. A total of 11 were recovered in the Bristol Bay commercial fishery, plus two from the spawning grounds, while none were returned from Asian estuaries or spawning grounds. The lack of returns from Asian estuaries is in line with the lack of returns from the large catch by the high seas fishery west of 165° East Longitude (Figure 31 and Table 5). This suggests that Asian reds were not present in the area of tagging in 1956. Therefore, the large flow of immature red salmon moving westward through Area 4C in 1956 must have been overwhelmingly American in origin.

The conclusion becomes inescapable that the distribution of returns as seen in Figure 31 is an indication of the limits of seaward migration of Bristol Bay red salmon in 1957. The indication applies as previously stated, only to the times and places of Japanese high seas operations, but these were sufficient to indicate limits to the west and south. The limits were approximately 165° East Longitude to the west and 49° North Latitude to the south.

Areas 5A and 6A (Figures 32 and 33)

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Figure 32.--Recovery distribution of mature red salmon tagged in area 5A in 1957.
Figure 33.--Recovery distribution of mature red salmon tagged in area 6A in 1957.
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Since the tagging in both of these areas was in the vicinity of the Pribilof Islands, results will be considered together. For both areas a total of 21 returns were received from 286 red salmon tagged. All were from Bristol Bay except one from the north side of the Alaska Peninsula.
Figure 32. Recovery distribution of mature red salmon tagged in area 5A in 1957.

Figure 33. Recovery distribution of mature red salmon tagged in area 6A in 1957.

Figure 34. Recovery distribution of mature red salmon tagged in areas 5B and 6B in 1957.
Area 5B (Figure 34)

Figure 34.—Recovery distribution of mature red salmon tagged in areas 5B and 6B in 1957.

The 27 mature reds tagged in this area were all taken June 5 in Amukta Pass. The direction of seine set showed the fish to be going northward at time of capture. The one return was from Bristol Bay.

Area 5C (Figure 35)

Figure 35.—Recovery distribution of mature red salmon tagged in area 5C in 1957.

Mature reds were moving strongly westward in this area in 1957 as described earlier. From 111 tagged, 11 were returned from the high seas in Amchitka Pass and north of Adak, and 9 from Bristol Bay. The array of returns delineates remarkably the route of movement toward Bristol Bay. The results suggest Amchitka Pass as their principal avenue into the Bering Sea, although Buldir Pass might also have been used. Here again, the lack of returns from high seas gear to the west could only mean a lack of Asian reds in the area of tagging.

The percentage return (18%) was the highest received from any experiment. The percentage is more remarkable because of an extra high return from both the Japanese fleet and the Bristol Bay fishery.

Area 6B (Figure 34)

The 13 mature reds tagged here gave a single return from Bristol Bay.

Area 6C

No returns were received from 17 mature reds tagged in Area 6C.
Figure 35. Recovery distribution of mature red salmon tagged in area 5C in 1957.

Figure 36. Recovery distribution of mature red salmon tagged in area 7C in 1957.

Figure 37. Recovery distribution of red salmon tagged by Japan in 1957, all areas combined. Source: Japan, Fisheries Agency (1958a).
Area 7C (Figure 36)

Figure 36.—Recovery distribution of mature red salmon tagged in area 7C in 1957.

The 76 mature reds tagged here gave 4 returns from Bristol Bay. It is interesting to note that although the tagging in Area 7C was on May 27 – 29, or almost a month prior to the Bristol Bay fishery, the 5.3% return was not greatly less than the 7.8% received from all mature reds tagged in 1957 (Table 42). These fish were at liberty for an average of 41 days (Table 41), thus averaging only 12 miles per day from tagging point to recovery point. As will be discussed later, the average rate of travel for mature reds approaching Bristol Bay was approximately 30 miles per day. Therefore, it is likely that they traveled considerably further than the direct 480 miles to Bristol Bay. The extra distance traveled was probably westward, prior to entering the Bering Sea.

Summary of Returns by Area of Tagging

Red salmon tagged in 1957 at all locations as far west as Attu Island (172° East) have been returned overwhelmingly from Bristol Bay. No returns have been received from Asian estuaries or rivers. A large Japanese fleet operating in the tagging areas, and west of the tagging areas, took one tagged red south of the Komandorski Islands, which may have been enroute to Asia. The remaining fifteen high seas recoveries were on the route followed by red salmon destined for Bristol Bay. This route is discussed next, using data similar to that described for 1956.

1957 Migration Routes

Catch data and tag return data in 1957 were consistent in showing that red salmon destined for Bristol Bay went further west along the Aleutians than did the 1956 run.
A comparison of purse seine catches in areas east of Amukta Pass (169°

and areas west of Amukta Pass showed a far greater abundance to
the west. In Area 6C (east of Amukta Pass), four hauls on June 13 and 14
averaged only 14 rods. In Areas 4C and 5C (west of Amukta Pass), five seine
sets between June 6 and 13 took an average of 61 rods. In both areas, salmon
were moving predominantly west as previously discussed. The greater abundance
in Areas 5C and 4C suggests that passes west of Area 4C (Amchitka and Buldir),
were important in 1957. As previously discussed, the 1956 results indicated
Amukta Pass as the major pass used that year.

Fishing on June 5, 1957 (Table C3, Area 5B), showed some reds going north
through Amukta Pass at that time, but in the light of other evidence, it
probably was not the major route in 1957.

The very large catch per unit effort by the Japanese gill net fleet in
the central and western Aleutian area during June, further supports the con-
tention that Bristol Bay reds were far to the west in 1957 (Figure 25 and
Table 5). In addition, the catches by the United States Fish and Wildlife
Service research vessels during June indicate good numbers of reds at 175°
West Longitude in the Bering Sea (Figure 24). This agrees with the particu-
larly high abundance found by the Japanese fleet in the central Bering Sea
between 175° West and 175° East Longitude (Figure 31).

The returns from tagging in Areas 4C and 5C (Figures 30 and 35), as
already discussed, showed a strong westward movement of reds through these
areas prior to going northward through Amchitka and possibly Buldir Passes.

The high seas distribution of returns in 1957 from the immature reds
tagged south of Adak in 1956 indicated Bristol Bay reds scattered widely
southwest of Kiska and Attu Islands (Figure 31). Returns of the same group
of fish later from Bristol Bay, and from intermediate points in the central
Bering Sea strongly suggest that they moved through Buldir Pass enroute to
Bristol Bay.
From the foregoing, it may be concluded that in 1957, red salmon approached Bristol Bay from farther west than in 1956, and also that Amchitka (180°) and possibly Buldir (176° East) Passes, were important avenues of passage from the North Pacific to the Bering Sea. The routes suggested by the above are illustrated in Figure 26.

PROPORTIONS OF BRISTOL BAY RED SALMON AT SEA IN 1957

The return data from the immatures tagged in 1956 provide a means to evaluate the proportions of Bristol Bay red salmon in various areas of the high seas fishery in 1957. Referring back to Figure 31, the immature reds tagged in Area 4C in 1956 were recovered in 1957 over a wide area southwest of Kiska and Attu Islands, and also north of Kiska and Adak Islands. Because coastal returns came only from Bristol Bay and because none were returned from the high seas fishery west of 165° East Longitude, it was concluded that the overwhelming majority of the immature reds tagged in Area 4C in 1956 were from Bristol Bay, and that few, if any, were Asian reds. It was concluded further, that the distribution seen in Figure 31 showed the seaward dispersion of Bristol Bay reds in May and June of 1957.

The above conclusions, however, make no presumption as to the presence of Asian reds in the areas of recovery illustrated in Figure 31. It is probable that Asian reds were mixed with Bristol Bay reds, particularly in the westernmost areas of recovery by the Japanese fleet.

By using the proportion of tagged to untagged red salmon in the Bristol Bay catches as a standard, it is possible to estimate the percentage of Bristol Bay reds in the several areas of the high seas fishery.
Briefly restated, the two points underlying these conclusions are:

1. Essentially all of the immature reds tagged south of Adak in 1956 were from Bristol Bay, and therefore the proportion of returns in the Bristol Bay catch may be used as an index of the expected proportion of Bristol Bay reds wherever they are caught.

2. Tag returns at sea in 1957 show the general areas where Bristol Bay reds were mixed, and therefore the proportion of tagged fish in these areas indicates the proportion of Bristol Bay reds in the catches at sea.
Table 7 shows the proportions of tagged red salmon in fishery areas from west to east and also the calculated percentage of Bristol Bay reds in each.

Table 7. Number of tagged red salmon returned from various fishery areas, and estimated percentages of Bristol Bay red salmon (From returns of immature red salmon tagged in 1956 and recovered in 1957)

The 11 tag returns out of the 6.6 million reds caught in Bristol Bay is the proportion which can be expected in catches which are 100% Bristol Bay reds. The catch in the U.S.S.R. estuaries, of course, contains no Bristol Bay reds as shown. Because no tags were returned from the 5 million catch at sea west of 165° East Longitude, the proportion of Bristol Bay fish there is shown as zero also. The 9 returns from the 8.5 million catch south of the Aleutians result in an estimated 63% of Bristol Bay reds. Similarly, the 7 returns from the 6 million caught north of the Aleutians indicate 70% Bristol Bay reds. The total east of 165° East Longitude is calculated to be 67% Bristol Bay reds.

A basic assumption in the above calculations is that return efficiency from the high seas and from the Bristol Bay fishery are similar. There also remain many unknowns in the movements and seasonal distribution of red salmon at sea which could have a bearing on results. It is recognized that there are large confidence limits to the proportions cited, due to the small numbers of returns available, but even so, results are surprisingly consistent in indicating that a high proportion of the red salmon to 165° East were from Bristol Bay. No doubt this percentage diminished somewhat from east to west, but returns were insufficient to warrant a finer breakdown.
<table>
<thead>
<tr>
<th>Tags Recovered(^3)</th>
<th>USSR Estuary</th>
<th>W. of 165° E. Long.</th>
<th>E. of 165° E.</th>
<th>Bristol Bay(^2)</th>
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<tr>
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<td>0, 5,253</td>
<td>0, 8,561</td>
<td>0, 6,009</td>
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<td>Percentage Bristol Bay Salmon</td>
<td>-</td>
<td>0</td>
<td>63</td>
<td>70</td>
</tr>
</tbody>
</table>

1 See Figure 16.
2 Include N. side Alaska Peninsula and Aleutian Island district catches.
3 One high seas return not included because recovery location was unknown. Bristol Bay returns include only those from commercial fishery. (Two returned from spawning grounds not shown.)

It is also evident that the percentages of Bristol Bay reds as calculated, are not out of harmony with the relative production in 1957 of Bristol Bay versus Kamchatka red salmon, as seen in the catches shown in Table 6. The Bristol Bay catch was approximately five times that of Kamchatka.

Any immature American red salmon taken by the Japanese fleet would tend to bias the tag proportions in favor of Asian reds rather than American, because immatures are not taken in the Bristol Bay fishery which was used as the basis of comparison. Immature reds were taken in areas of tagging starting about June 20, and presumably they would be taken also in the areas fished by the Japanese.

RESULTS OF JAPANESE TAGGING IN 1957

The results of the Japanese tagging experiments in 1957 were in harmony with the results of the United States experiments.

Figure 37 shows the distribution of the 13 returns from 621 reds tagged by the Japanese in 1957 (Japan, Fisheries Agency, 1958a).

Figure 37.—Recovery distribution of red salmon tagged by Japan in 1957,
all areas combined.
Source: Japan, Fisheries Agency (1958a)

The low (2.1%) rate of return from the Japanese tagging was probably due to injury by the gill nets used for taking the fish for tagging. In addition, some immature salmon may have been involved. The available data gives no breakdown as to maturity.

The two returns from experiments just west of Attu Island were taken on the high seas east of the point of tagging, but the distance involved was too little for conclusions as to continent of origin. An experiment immediately north of Adak produced only one return, and that from Bristol Bay.
The tagging in the central Bering Sea at about 54° North Latitude and 177° West Longitude is of special interest since it was in this general area that the Japanese fleet enjoyed very heavy red salmon catches (Figure 25). Five reds were returned out of 72 tagged (6.9%). Four out of the 5 returns were recovered a short distance east of the point of tagging. The fifth was from a short distance west. Since the Japanese fleet was dispersed both east and west of the tagging location, the results indicate an easterly movement, and at the same time a very high efficiency of recovery, since the tagging location was not far from the abstention line (175° W.).

In the tagging south of the Pribilofs, 180 reds were tagged, producing 5 returns. All were from Bristol Bay, as were returns from American tagging in this area (Figures 32 & 33).

1958 Tagging

The distribution of tagging in 1958 was similar to that of 1957, but with additional areas in the central Bering Sea and also in the Gulf of Alaska south and southeast of Kodiak Island (Figure 6).

The 1958 season was characterized by a scarcity of mature reds in all areas fished. The United States Fish and Wildlife Service research vessels found a similar scarcity in their gill net catches (Figure 24).

Lengths, Age, and Maturity

The age distribution of the reds tagged in 1958 was radically different from either 1956 or 1957. As seen in Figure 5, only 269 mature reds were tagged, and only 323 two-winter immatures. One-winter immatures, however, were very abundant, and 3,247 were tagged. The 91 very small reds which had just this season migrated from their parent streams were taken late in the season in Areas 6C, 8A, 9A, and 12A (Table T3).
The lengths of the red salmon tagged in 1958 are particularly interesting because they illustrate the relative lengths of all ocean ages of red salmon from zero-winters to four-winters at sea (Figure 38).

Figure 38.—Lengths of red salmon tagged in 1958 by ocean age, and lengths (at tagging) of those recovered in 1958.

The zero-winter-in-sea group shows a size mode at about 22.0 cm, while the one-winter group peaks at about 35.0 cm. The immature two-winter fish show a mode at 47.0 cm, while the matures of this age have a rather indistinct peak at about 56.0 cm. The three-winter fish show an irregular mode at 60.0 cm, similar to the sizes of this age group in 1956 and 1957. A single four-winter fish measured 66.0 cm.

The bar graphs illustrate the lengths (at tagging) of those recovered in 1958. These are representative of the entire range of three-winter reds, and of the larger mature two-winter reds.

Figure 38 also shows the lengths (at tagging) of four reds returned in August, 1958, which by all available evidence were immature at time of tagging. These were the first examples of immature reds being returned in the same year as tagged. Three were tagged in Area 2C on July 18 and 20, and were recovered on August 8 and 9 in the same area. The fourth was tagged on June 27 in Area 4C and recovered August 7 near Attu (see Figures 39 and 40). At the time of tagging mature reds had practically vanished, and catches had the characteristics of immature salmon. The long periods at liberty without approaching coastal areas also suggests only feeding movements rather than spawning migrations. The lengths of the four are within the range of immature two-winter reds, although the largest (54.0 cm) is among the larger of this group.
Figure 38. Lengths of red salmon tagged in 1958 by ocean age, and lengths (at tagging) of those recovered in 1958.
In 1959, some returns should be received from the remainder of the two-
winter immatures and from the large number of one-winter immatures. Some of
the latter group may not return until 1960.

RETURNS BY AREA OF TAGGING (Table R3)

Areas 1C, 2A, and 2B

The few reds tagged in these western areas were mostly immatures and gave
no returns in 1958.

Area 2C (Figure 39)

Figure 39.—Recovery distribution of mature and immature red salmon tagged
in area 2C in 1958.

Out of 21 mature reds tagged in Area 2C, one was retaken in Bristol Bay,
and two on the high seas south and west of the tagging location. One of the
latter was the first red returned from west of 165° East Longitude. It is
logical that these two fish were destined for Asian spawning grounds,
especially the one recovered west of 165° East Longitude, since it was taken
on July 20 (Table R15).

The other three reds were immature when tagged and were recaptured within
Area 2C in August, as explained earlier.

Area 3B (Figure 40)

The six mature reds tagged here gave one return from Bristol Bay.

Figure 40.—Recovery distribution of mature and immature red salmon tagged
in areas 3B and 4C in 1958.

Areas 3C, 4A, and 4B

No returns were received from the few mature reds tagged in these areas.
Figure 39. Recovery distribution of mature and immature red salmon tagged in area 2C in 1958.

Figure 40. Recovery distribution of mature and immature red salmon tagged in areas 3B and 4C in 1958.

Figure 41. Recovery distribution of mature red salmon tagged in area 5A in 1958.
Area 4C (Figure 40)

From only 7 mature reds tagged, one was retaken in Bristol Bay. In addition, one out of 98 two-winter immatures tagged was retaken on the high seas near Attu, as discussed earlier. The return of this fish from near Attu shows that the immatures moving westward through Area 4C continue at least as far as 172° East Longitude.

The large number (1,231) of one-winter immatures is expected to produce returns in 1959.

One immature red tagged in Area 4C in 1956 was returned in 1958. To date, this has been the only red returned after two years at liberty. As shown in Figure 20, it was recovered at about 49° North Latitude and 169° East Longitude near where some from the same tagging experiments had been recovered in 1957. As shown in the discussion of the 1957 results, tagged reds recovered in this area illustrated the limits of distribution of Bristol Bay reds that year. In view of the 1957 results, this return in 1958 may also have been a Bristol Bay red salmon. It was recovered on June 6, which is early enough that it could have reached Bristol Bay by the peak period of the run.

Areas 5A and 6A (Figures 41 and 42)

Figure 41.—Recovery distribution of mature red salmon tagged in area 5A in 1953.

Figure 42.—Recovery distribution of mature red salmon tagged in area 6A in 1953.

The total of 166 mature reds tagged in these two areas produced 35 returns or 21.1 percent. Two returns were from the north side of the Alaska Peninsula, 99 from Bristol Bay, and one from the Kuskokwim River. Most were tagged between the Pribilof Islands, and were moving eastward as determined by the direction of set of the seine. As in 1957, the percentage return was higher than for other areas, presumably due to the lesser time and distance to Bristol Bay.
Figure 42. Recovery distribution of mature red salmon tagged in area 6A in 1958.

Figure 43. Recovery distribution of mature red salmon tagged in areas 9C and 10A in 1958.

Figure 44. Recovery distribution of red salmon tagged by Japan in 1958, all areas combined.

Area 5C

Only immatures were tagged in Area 5C in 1958 due to the timing of fishing.

Area 6C

This area was also fished too late to intercept many matures, but as shown in Table C3, immature reds were very abundant here on July 2, 3, and 4. On July 4, 817 reds were taken in a single set with the seine open to the east. This was the largest catch of red salmon in the three years' fishing. Returns in 1959 will, therefore, represent a very large body of red salmon from this area.

Areas 8A, 10A, 9A, and 12A

No reds were returned from tagging in these areas. Most of those tagged were immatures.

Areas 9C and 10A (Figure 43)

Figure 43.--Recovery distribution of mature red salmon tagged in areas 9C and 10A in 1958.

Although only 28 mature reds were tagged in these two areas, 6 were returned. Five were from the approaches to the Fraser River in British Columbia, Canada, and one was from the weir on the Babine River which is a tributary of the Skeena River, also in British Columbia. As seen in Table 43, returns were in late August and early September; much later than from the Aleutian tagging.

Returns from this area were of special interest, since it was the first year of tagging in the Gulf of Alaska. In addition, it was a cycle year of large abundance in the Fraser River.
Unfortunately, the vessel operating here was not able to start fishing until mid-June, and then was committed to other research work in Cook Inlet during late June and the first two weeks of July. Although salmon were found in all areas fished, no large catches were made (Table 6).

1958 MIGRATION ROUTES

Although there was much less data for indicating the principal migration routes of Bristol Bay reds in 1958, the available data suggest that the majority of the run followed a route similar to that followed by the 1956 run (Figure 26). Catches by the Japanese fleet are not indicative since they operated only south and west of the Aleutians in 1958 (Figure 25).

The catches by the United States Fish and Wildlife Service research vessels showed a scarcity in the areas to the west (Figure 24). Their largest catches were made between Amukta Pass (169° - 173° West) and the Pribilof Islands, suggesting that as in 1956, reds approached Bristol Bay via this route.

The tagging vessels did not fish or tag in areas adjacent to Amukta Pass during the period that matures were available, so neither seine catch nor tag return data are available for this area, as in previous years.

The three returns to Bristol Bay from experiments in the central and western Aleutians (Figures 39 and 40), show that at least some Bristol Bay reds passed through these areas. However, the scarcity of reds suggested this as a minor part of the run. The low overall abundance was in accord with the very low abundance of Bristol Bay red salmon in 1958 (catch plus escapement was approximately 6 million, compared to 11.5 million in 1957, and 25 million in 1956, Table 6).
RESULTS OF JAPANESE TAGGING IN 1958

The Japanese tagging experiments in 1958 provide a valuable supplement to the United States experiments, particularly in the areas west of 170° East Longitude. Using long lines to capture their salmon, they tagged 1,137 reds.

Data are from Japan, Fisheries Agency, 1958 b,c, and from a table released by the Japanese Fisheries Agency, Feb. 1959, entitled, "Release and Recapture Data for Salmon Tagged by Japan and Recovered by USSR in 1958".

Returns totaled 102 or 9.0%. This cannot be compared directly with the 17.1% return from mature reds tagged in the United States experiments in 1958 (Table R.3) since the Japanese total includes immature fish. In addition, the locations of tagging, the types of tags used, and the proximity of commercial fisheries were quite different for the two countries' experiments.

Results from their experiments near 175° West Longitude were typical of United States experiments in this area. All four returns were from Bristol Bay (Figure 4h).

Figure 4h.---Recovery distribution of red salmon tagged by Japan in 1958, all areas combined. Source: Japan, Fisheries Agency (1958 b,c), and table prepared by Japanese Fisheries Agency, Feb. 1959, entitled, "Release and Recapture Data for Salmon Tagged by Japan and Recovered by U.S.S.R. in 1958."

From the experiments near 180°, two reds went west to approximately 165° East Longitude. Their lengths at tagging (56.1 and 57.5 cm), and the dates of recovery (July 7 and 9), suggest that they probably were mature salmon destined for Asian spawning streams. The one tagged at 178°57' West Longitude is the easternmost limit of Asian red salmon to be shown by tagging.
Since United States tagging did not extend west of 170° East Longitude, the Japanese western experiments are of particular interest. These experiments (Figure 14) show a positive westward movement from all areas of tagging, including some returns from the Sea of Okhotsk and from Kamchatka estuaries. Thus, the presence of Asian reds is positively shown to about 165° East Longitude.

It should be pointed out regarding results from the western tagging, however, that the pattern of returns was greatly influenced by the distribution of the high seas fleet operating in the immediate vicinity at the time. There was little high seas gear to the east of the tagging locations as illustrated by Figure 15 (month of July). Since experiments in areas west of 165° East Longitude were between July 5 and August 18, it would seem probable that many of those tagged were immature. Until data on maturity are available, the results cannot be fully evaluated. Finally, it should be pointed out that the Japanese experiments west of 170° were too late to show the presence or absence of mature Bristol Bay red salmon. As will be discussed later, the rate of travel of red salmon approaching Bristol Bay is approximately 30 miles per day. Since the peak of the Bristol Bay run is prior to July 15, tagging near 170° East Longitude would have to be done in May or early June in order to intercept mature Bristol Bay reds.

SUMMARY OF RED SALMON TAGGING RESULTS - 1956 THROUGH 1958

SUMMARY OF RETURNS FROM ALEUTIAN EXPERIMENTS

Although abundance and distribution of red salmon in the Aleutian areas varied considerably in 1956, 1957, and 1958, the distribution of tag returns shows a consistent pattern when totaled for the three years.
Table 8 presents a summary of tag returns from mature red salmon tagged in the Aleutian area for the three years combined. Both tagging and recovery areas are arranged from west to east for convenience. The three areas of high seas returns are shown in Figure 16.

The lack of returns from Asian estuaries or spawning grounds is at once apparent. No red salmon tags have been returned from the Asian side to date, although chum, pink, and silver salmon have been returned from numerous tagging locations (Tables R4-11).

A single red salmon was recovered from the high seas west of 165° East Longitude, and as seen in the table, it was tagged in Area 2C. Since the high seas fleet annually took large catches of reds west of 165° East (Table 5), these results indicate a low proportion of Asian reds in tagging areas to the east of Area 2C.

From the high seas area (Figure 16) south of the Aleutians, three mature reds have been returned; two were tagged in Area 2C, and one in Area 30 (Figures 28, 29, and 39). The large numbers tagged east of Area 30 (180°) gave no returns from the heavy high seas fishery south of the Aleutians. It is not certain whether the above three returns were destined for Asian or American streams, but as discussed earlier, the two shown in Figures 29 (Area 30, 1957) and 39 (Area 26, 1958), were probably Asian, while the one in Figure 28 (Area 2C, 1957) might have been either American or Asian.
TABLE 8. Summary of returns from mature red salmon tagged in Aleutian Island area (1956, 1957, and 1958 combined)

<table>
<thead>
<tr>
<th>Areas of Tagging, from West to East (See Fig. A)</th>
<th>2A</th>
<th>2B</th>
<th>2C</th>
<th>3B</th>
<th>3C</th>
<th>4A</th>
<th>4B</th>
<th>5A</th>
<th>5B</th>
<th>5C</th>
<th>6A</th>
<th>6B</th>
<th>6C</th>
<th>7C</th>
<th>Total</th>
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<td>No. Returned in Asian Estuaries or Streams</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. Returned West of 165° East&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>1</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
<td>3</td>
<td>0</td>
<td>11</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>9.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>No. Returned in Bristol Bay and vicinity</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>16</td>
<td>1</td>
<td>11</td>
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<td>1</td>
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<td>4.3</td>
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<td>2.5</td>
<td>7.0</td>
<td>3.6</td>
<td>9.0</td>
<td>17.9</td>
<td>4.5</td>
<td>4.8</td>
<td>3.3</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>13.5</td>
<td>14.3</td>
<td>6.5</td>
<td>11.1</td>
<td>3.8</td>
<td>7.0</td>
<td>3.6</td>
<td>18.0</td>
<td>17.9</td>
<td>4.5</td>
<td>4.8</td>
<td>3.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td>16</td>
<td>1</td>
<td>22</td>
<td>40</td>
<td>1</td>
<td>68</td>
<td>15</td>
<td>182</td>
<td></td>
</tr>
<tr>
<td>Percent</td>
<td></td>
<td>13.5</td>
<td>14.3</td>
<td>6.5</td>
<td>11.1</td>
<td>3.8</td>
<td>7.0</td>
<td>3.6</td>
<td>18.0</td>
<td>17.9</td>
<td>4.5</td>
<td>4.8</td>
<td>3.3</td>
<td>6.6</td>
<td></td>
</tr>
</tbody>
</table>

1 Does not include 17 tagged from gill nets in 1956.
2 See Figure 16.
A total of 15 reds were returned from high seas gear north of the Aleutians. All were tagged in Areas 4C, 5C, and 6C south of the Aleutians. There is little doubt that all fifteen were destined for Bristol Bay, since they were taken along the typical migration routes followed by red salmon approaching Bristol Bay from south of the Aleutians, as demonstrated by the tagging and seineing.

The returns from Bristol Bay show clearly the presence of Bristol Bay reds at least as far west as 172° East Longitude (Area 2C). There is no significant diminishing in the percentage returns of Bristol Bay reds from east to west, which suggests the relative unimportance of Asian reds even in the westernmost areas of tagging. Numbers tagged west of 180° are unfortunately small, however.

It might at first seem illogical that interception by the Japanese fleet did not cause a reduction in rate of return to Bristol Bay from the western tagging experiments. This is explained, however, when it is remembered that 1957 was the only year of the three in which dates of tagging and dates and location of Japanese operations could have resulted in interception. Such interception was serious in 1957. As illustrated in Figures 30 and 35, over one half of the recoveries from experiments in Areas 4C and 5C were taken at sea on the route to Bristol Bay. In 1956, the four returns from Bristol Bay (tagged in Areas 4C and 5C) were tagged in late June or early July, thus probably passing through the Bering Sea after the Japanese operations there. In 1958, the Japanese fleet did not operate in the central Bering Sea. Results suggest that if large numbers were tagged in a series of locations across the Aleutians, interception by the Japanese would reduce Bristol Bay returns from the western experiments.
Asian Red Salmon

The data provide no positive indication of the eastern extent of Asian red salmon movements, since no tags were returned from Asian estuaries or rivers. A few returns from the high seas suggest the probability of some Asian reds in the tagging experiments west of 180° on the south side of the Aleutians.

Japanese experiments in 1958 (Figure 44) show Asian reds to be present at least as far east as 178° West Longitude.

RATE OF TRAVEL

The rate of travel of salmon at sea, as calculated from the tag returns, has many applications in the analysis of the ocean movements of salmon. Regarding red salmon, the subject will be discussed only as to the average rate of travel of mature reds approaching Bristol Bay. This rate in turn may be related to the expected timing of Bristol Bay reds passing through various areas at sea.

The average rate of travel of 60 mature reds tagged in Area 6C in June, 1956, and recovered in the Bristol Bay fishery, was 24 miles per day. Time at liberty varied from 12 to 40 days. In making the distance measurements, it was assumed that the fish went through Amukta Pass immediately west of Area 6C. The average rate of travel is probably still low, however, since some may have continued west further than Amukta Pass. By using rates based on returns from experiments far to the west, or from north of the Aleutians, this difficulty should be eliminated. Accordingly, 4 such returns (two from Area 2C, one from 3B, and one from 4B) show an average of 30 miles per day. Reds tagged near the Pribilof Islands should also give a truer picture of rate of travel. Twenty-seven returns from tagging in Area 6A (1958) averaged 31 miles per day with a standard deviation of 6.6. Time at liberty varied from 8 to 27 days. Extreme rates of travel were 15 and 50 miles per day.
Thus, 30 miles per day is probably a fair average rate of travel for mature reds within the last 40 days at sea.

Since the great majority of Bristol Bay reds have entered the estuaries by July 20, their disappearance from the central Aleutian area (900 miles away) should be approximately 30 days earlier, or June 20. This is in agreement with the dates of decline of mature reds in the central Aleutian area as discussed in the section on movements.

PERCENTAGE RETURNS

The percentage returns of tagged mature red salmon have shown an increase (as shown below), but they are still much less than the normal 30% to 40% return from coastal tagging experiments. The annual percentages returned of mature red salmon as shown in the tag recovery tables are:

<table>
<thead>
<tr>
<th>Year</th>
<th>% Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>5.3</td>
</tr>
<tr>
<td>1957</td>
<td>7.8</td>
</tr>
<tr>
<td>1958</td>
<td>17.1</td>
</tr>
</tbody>
</table>

The reasons for the increase in returns each year are more easily explained than the overall low return. One reason for the increase in success of return in 1957 over 1956 was the dual fishery through which red salmon passed. Fourteen red salmon tagged in Areas 4C and 5C in 1957 were captured by the Japanese fleet north of the Aleutians, while others were recaptured in Bristol Bay (Figures 30 and 35). Only one such return occurred in 1956 (Figure 22). Also, tagging in 1957 was extended to Area 6A which was much closer to the Bristol Bay fishery than any tagging in 1956. Returns from that area were 10.6% (Table A2). In addition, the smaller-meshed nets used in 1957, and the improved techniques of handling should have contributed to the increase.
The high overall percentage of returns for 1958 was due to two known
factors; first, the large proportion tagged near the Pribilofs where percent-
ages are higher due to proximity to Bristol Bay, and second, the use of more
disc tags which have consistently given better returns than tube tags. This
subject was discussed in the section on Tags Used, but another comparison of
tubes and discs might be made at this point. In 1957, tube tags were used
on 85 of the 94 reds tagged in Area 6A. Ten (11.3%) were returned. In 1958,
one-hundred twenty-nine reds were tagged in Area 6A, all with discs. Thirty
(23.3%) were returned. The only known variable was in the time at liberty.
In 1957 tagging was between June 17 and 21 and the average time at liberty
was 21 days, while in 1958 tagging was from June 24 to 27 and the average
time at liberty was only 14 days (Tables R14 and R15). Such a difference
in time at liberty could hardly account for the large advantage shown by the
disc tags. Thus, disc tags must have been responsible for a large share of
the increase in percentage returns in 1958.

In spite of the variable character of the percentage returns, the 6.4%
total return shown in Table 8 is probably an average figure which may be
expected from mature reds tagged well out at sea using present methods. The
use of disc tags can be expected to increase the figure somewhat, but the
great disparity between results from oceanic and coastal tagging remains.
The disparity is not unreasonable, however, since the factors influencing percentage returns from tagging at sea are undoubtedly more numerous and complex than for coastal tagging. Among the most important differences would be the greater variability in the condition of salmon tagged at sea, and the greater time and distance between tagging and recovery. The greater fragility of salmon at sea, even of those maturing, has been discussed. Salmon in the estuaries have thicker skin and mucous, and scales are firmly imbedded. The 111 returns from the Bristol Bay commercial fishery, from the 1956 and 1957 experiments, averaged 27 days at liberty. This compares with only a few days, or even hours, in coastal tagging. Such long periods, coupled with the great distances traveled, would be expected to reduce returns due to mortality caused by tagging. Furthermore, fish tagged at sea must include some that are destined for smaller streams with only resident subsistence fisheries from which the probability of return is poorer.