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THE MOVEMENT OF HERRING IN BRITISH COLUMBIA WATERS AS DETERMINED BY TAGGING

With a description of Tagging and Tag Recovery Methods

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INTRODUCTION

An extensive tagging and tag recovery study has been carried out on British Columbia herring (Clupea pallasi) since 1936. Originally the study was undertaken to test the validity of the assumed existence of discrete populations deduced from meristic and age-composition studies (Tester. 1937). Subsequently, information was provided on the extent of intermingling of herring stocks, and on various population statistics.

In the present paper the methods of tagging and recovering tags are described, and results pertaining to the geographic limits, and the extent of intermingling of populations are discussed. The data [1] included in the analysis are those accumulated up to and including 1951-52.

The Tagging Program.

The herring tagging program, undertaken in the period from 1936 to 1951, consisted of carrying out 310 individual taggings, involving 555, 521 herring (Table I). In each individual tagging, details of which have been previously published [1], all fish were tagged at approximately the same place and at the same time, the aim being to have each individual tagging comprise fish from a single school. The number of fish involved in individual taggings varied from an average of about 1,100 in the early years of the study to an average of 3,000 in the early 1940's (Tester and Boughton, 1943). The factors involved in determining the number of fish to be tagged in each individual tagging were (1) the necessity of recovering reasonably large number of tags (which required large taggings), and (2) the need for achieving as random as possible a distribution of tags throughout each herring school (which made numerous, and hence smaller taggings, desirable).

A large proportion of the taggings (89 percent, comprising 520,351 fish) was carried out in the spring on fish that were about to spawn, were spawning, or had spawned. By this time fishing operations had stopped, and there was no opportunity for recovery of the tags for at least six months, that is, until after the fish had migrated to offshore feeding grounds and returned to inshore waters. The results presented in this paper are largely based on recoveries from the spring taggings.

Taggings were also undertaken in the fall and winter (Table I) during the period of the fishery to obtain information on the movement and exploitation of herring on the fishing grounds (Hart and Tester, 1938, 1939, 1940). In 8 of the 15 years tagging was carried out at Sooke in the Strait of Juan de Fuca, the purpose being to establish the migration route of herring of the southern portion of the Strait of Georgia.

In the course of the investigation herring were tagged in virtually all parts of British Columbia coast, and in addition three small taggings were made in contiguous waters of the State of Washington in 1938, 1939 and 1940 (Table I). In the first year (1936) while techniques were being developed, the total number of fish tagged was relatively small, and all taggings were carried out on the lower east coast and west coast of Vancouver Island. From 1937 to 1941, tagging operations were spread to all major herring stocks. After 1941, the policy was developed of tagging intensively in a small number of general areas at one time. From 1941 to 1945, particular attention was given to the herring of the lower east coast, middle east coast, and upper east coast of Vancouver Island. Since 1946, concentrated tagging has been maintained on the lower east coast and middle east coast and extended to the west coast of Vancouver Island, as part of an experiment to investigate the relative merits of different methods of herring management (Tester and Stevenson, 1947). In 1950, tagging was resumed in the northern, north central, and south central sub-districts. Thus, by 1951 intensive tagging was undertaken on all major herring stocks except that of the east coast of the Queen Charlotte Islands. [2]

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1) Detailed analysis of each year's data is available in a series of reports published in the Annual Reports of the British Columbia Fisheries Department (Hart and Tester, 1937, 1938, 1939, 1940; Hart, Tester and McHugh, 1941; Hart, Tester and Boughton, 1942; Tester and Boughton, 1943; Tester, 1944, 1945, 1946; Tester and Stevenson, 1947, 1948; Stevenson, 1950; Stevenson and Lanigan 1950; Stevenson, Hourston and Lanigan, 1951; Stevenson, Hourston, Jackson and Outram, 1952).

2) Since 1951, concentrated tagging has been carried out on herring of the east coast of the Queen Charlotte Islands, results of which will be published at a later date.

To assist in interpreting the data presented in the text and tables, the division of the British Columbia coast into districts, sub-districts, and statistical areas is shown in Figure 1.

TAGGING METHODS

Description of Tags.

The tags used in the investigation were designed to be carried in the body cavity of the herring. Nickel-plated iron tags were generally used (Fig.1; Hart and Tester, 1937), but because of the temporary shortage of nickel for non-military purposes, silver-plated tags were employed from 1944 to 1946 (Tester, 1945). Length and width dimensions of the nickel-plated tags, 19.4 mm. by 4.4 mm., were identical to those used earlier by Dahlgren (1936) in southeastern Alaska, but the thickness was increased from 1 mm. to 1.6 mm., to facilitate recovery by tag detectors. The silver-plated tags used in 1944 and 1946 resembled the nickel-plated tags in size and dimensions, but those used for most of the 1945 taggings were shorter (18.6 mm., as compared to 19.4 mm.) wider (4.7 mm., as compared to 4.4 mm.), and thinner (1.2 mm., as compared to 1.6 mm.) than the nickel-plated tags. They were also lighter, having an average weight of 0.76 g., as compared to 0.94 g. for tags of conventional size. All tags were rounded at the ends and had smooth edges. In the early years of the study the tags were serially numbered, but after 1940 each tag in lots of 500 or 1,000, bore a common identifying letter code.

Changing in plating and in dimensions of tags were investigated from the standpoint of their possible effect on tag recovery (Tester, 1945, 1946). Statistical testing of the data showed no significant association between the number of recoveries and the type of tag used.

Tagging Procedure.

Herring seine-boats, sturdy vessels ranging in length from about 65 to 75 feet (Fig. 4, Tester and Stevenson, 1947), have been provided each spring by the fishing companies for tagging purposes. From late February to early April herring investigators aboard these vessels travelled the coastal waters of British Columbia locating herring in near-spawning, spawning or spent condition. Fish were usually caught in shallow water with purse-seines (about 60 fathoms long and 2 fathoms deep), similar in construction to commercial seines but smaller (Fig. 3, Tester and Stevenson, 1948). The fish were transferred to collapsible web pounds (about 6 feet long, 5 feet wide and 6 feet deep). Care was taken in each phase of the operation to prevent excessive loss of scales.

During tagging operations, the web pound was placed between a large herring skiff attached to the seine-vessel and a smaller skiff (Fig. 5, Tester and Stevenson, 1947). Two taggers were seated in the skiff in such a way that their left hands had easy access to the impounded fish. A third man transferred the fish with a dip net, about 50 at a time, to a small strip of web hung over the pound so as to form a shallow through.

The tagger selected from the through a fish in good condition (i.e., one that showed no external abrasions or extensive loss of scales). The fish was held in the left hand in such a manner that the left side of the fish was exposed. The tagging knife, one half of a pair of scissors with the point filed to form a cutting edge, was held in the right hand. With it, scales were scraped away from a small area anterior to the base of the pelvic fin, and in incision, about the width of a tag, was made in the body wall. A tag was pushed anteriorly into the body cavity (Fig.3, Tester and Stevenson, 1947), and the fish was released immediately. The whole operation generally took between five and ten seconds. Care was taken to avoid holding the fish any more tightly than was necessary to prevent its escape.

In the development of this tagging procedure many variations in technique were investigated. In addition to the method of inserting tags already described, three other methods (Hart and Tester, 1939) were used prior to 1944. Two of these methods involved two taggers working together, and the third involved the use of a specially-designed tagging gun (Fig.1, Hart and Tester, 1938). Statistical analysis of the recovery data from taggings in which these various methods were used showed no significant difference in the relative efficiency of the methods (Hart and Tester, 1940; Hart, Tester and McHugh, 1941; and Hart, Tester and Boughton, 1942).

Several different methods were used in catching herring and in holding them prior to tagging. On many occasions, especially while fish were spawning, beach-seines were found more effective than small purse-seines for catching herring. Sometimes commercial bait fishermen provided herring for tagging, and when in the early years of the study tagging was undertaken on the fishing grounds, herring were usually provided from sets made by the commercial seine fleet. Herring which were tagged at Sooke in the Strait of Juan de Fuca were obtained from salmon-traps. On rare occasions, herring were so concentrated on the spawning grounds [illegible] dipped directly from the sea in dip nets.

Occasionally herring were tagged immediately after capture, but usually it was more convenient to impound them for a short time, or overnight, before tagging. Before general use was made of collapsible web pounds wooden bait boxes (Hart and Tester, 1939) were the chief means of impounding herring.

Precautions had to be taken to avoid overcrowding of fish held in confinement. Although deleterious effects of overcrowding were not readily observable during the tagging operation, it was shown that the difference in the recovery of fish tagged from crowded pounds and of fish tagged from uncrowded pounds was highly significant (Hart and Tester, 1939).

Attention was given to possible differences between taggers in their ability to tag without inducing excessive mortality on fish. It appeared likely that inexperienced taggers might tend to hold the fish unnecessarily tightly in the hand, to effect a large loss of scales, to keep the fish out of water too long, and to make the incision too large, thereby causing tags to drop out after the fish were released. In 1947, 1948 and 1949 a number of taggings were carried out, in each of which an experienced tagger and an inexperienced tagger tagged herring at the same place and time (Tester and Stevenson, 1948; Stevenson, 1950; and Stevenson and Lanigan, 1950). The recovery of tags inserted by the experienced tagger was compared statistically with that of the corresponding less-experienced tagger. Although there was a general tendency for the experienced tagger to have the greater tag return, the number of recoveries was significantly greater in only three out of eighteen comparisons. In general it is not considered that the experience of the tagger is great enough to lead to erroneous interpretation of the data.

Tagging Mortality.

Experiments were carried out in eight years of the investigation to determine the amount of mortality due to tagging. Known numbers of herring were tagged, using methods as similar as possible to those employed in regular tagging, and subsequently released into floating wooden boxes or large concrete tanks located in the intertidal zone. Specific numbers of controls were released among the tagged fish. Handling procedures used for tagged fish were duplicated in dealing with the control fish, except that tags were not inserted and tagging incisions were not made. Daily records were made of the fish that died, and the experiments were continued over a three-month period unless circumstances stopped the experiments earlier. At the end of 13 or 14 weeks the tagging incisions were completely healed, and it was considered that tagging mortality was then complete or nearly so. Results of the studies have been completely analysed for only three (1936,1942 and 1944) of the eight years (Hart and Tester, 1937; and Tester and Stevenson, unpublished).

The most successful experiments were those undertaken during the winter of 1944-45, and the spring of 1946. In each experiment, the differential mortality between tagged and untagged fish amounted to approximately 60 percent over the three-month period of the experiments. In the 1944-45 experiment, tagging mortality increased rapidly to the fourth week, reached a peak in the sixth week, and then declined to a low value which was assumed to be constant for the ninth to thirteenth weeks. In 1946 tagging mortality was low for the first two weeks, increased generally with wide fluctuations from the third to eleventh or twelfth week, and then decreased to a low value.

There were indications that mortality among tagged fish was caused in part by infection of the tagging wound and infection of the gonad, if punctured by the tag. There were also indications that both tagged fish and controls died from infection through abrasion and from "disease", but it was impossible to determine whether confinement or "natural" factors were primarily responsible.

In 1947, 1948 and 1949 the mortality due to tagging was overshadowed by a large mortality, among both controls and tagged fish, which was attributed to rough preliminary handling. Circumstances made it necessary to subject the fish to several transfers during the course of the experiments, resulting in much more extensive handling than occurred in previous experiments or in the regular tagging procedure.

Considering all sources of error in the experiments, it was concluded that the estimated tagging mortality of about 60 percent was minimal. In regular tagging, tagging mortality is the combination of mortality due to the actual tagging operation and to handling of the fish prior to tagging, whereas in the experiments, mortality was determined for the tagging operation alone (both controls and tagged fish were subjected to identical prehandling). Not all the factors, however, tended towards a minimal approximation of the tagging mortality; it appeared that confinement of the fish during the experiments might have caused a relatively greater mortality on tagged fish than on controls.

METHODS OF TAG RECOVERY

Herring tags were recovered from the catches in the regular fall and winter fishery (generally from October to March). Two main methods of recovery were employed. Electronic tag detectors were operated in certain plants, and in all plants magnets were installed. Large numbers of tags were also recovered from cracks and crevices in reduction plant machinery (driers, grinders and traps for tramp metal).

The chief advantages of detector recovery lay in the fact that the fishing area from which each tagged fish was recovered was readily determined; in recoveries from magnets and plant machinery (referred to collectively as plant returns) considerable doubt often existed as to the precise location of the recovery. However, whereas magnets were installed in all plants, detectors were operated in not more than four plants in any one season because of the high initial cost of the equipment and the high operating costs. The number of tags recovered by magnets and plant machinery was about 6 times that recovered by detectors (Table II).

Detector Recovery.

The essential feature of detector recovery was an electrically-energized coil placed within an unloading chute or conveyor of a reduction plant. When a fish containing a tag passed through the coil, an electric impulse was generated, amplified, and transmitted to a solenoid-controlled air valve which momentarily reversed the head of compressed air applied to a double-acting piston. The latter was connected to a trap-door installed in the floor on the chute a short distance beyond the coil. The trap-door, pivotted in the centre of an exle extending across the chute was thereby opened a right angles to the flow of fish, allowing fish (untagged fish as well as the tagged fish) to be by-passed from the chute. In opening, the trap-door tilted a mercoid switch sufficiently to break the circuit to the solenoid air valve, and the reversal of air pressure on the piston closed the trap-door. When unloading was completed the by-passed fish were again passed through the coil to isolate the tagged fish.

In six of the eight processing plants in which detectors were installed the electrically-energized coil was operated in a sloping chute (Hart and Tester, 1937, 1938, and 1939; and Hart, Tester and Boughton, 1942). In the other two, the coil was operated on a belt conveyor. The belt, fastened with a non-metallic lacing or clamp, passed through the coil, carrying the fish as it moved (Fig.1, Tester and Boughton, 1943). A double gate system was devised to take the place of the trap-door. When an impulse was transmitted from the detector coil the compressed air system pulled the gate across the belt diverting the fish. The action of the mercoid switch restored the gates to the original position.

The tag detectors employed were of two types, differing in principle of detection. In the original type, used in all years of the investigation, an electrical field was set up by feeding a high-frequency oscillating current into four coils arranged in Wheatstone bridge formation (Dahlgren, 1936 and Hart and Tester, 1937). The detection coil, placed in the chute, consisted of a pair of identical coils, the electrical properties of which were balanced against those in the second pair of identical coils (the balancing coil). At a point close to, but not exactly coinciding with, perfect balance, the field in the detection coil was extremely sensitive to the presence of a metal object such as a tag. The presence of this metal object created an offbalance disturbance in the form of a surge of current which was amplified to activate a sensitive relay which, in turn, operated the compression piston attached to the trap-door. This detector, called the "induction" detector in early reports, has more recently been referred to as the "bridge" detector.

The other type of detector was developed in 1945 (Tester, 1945) and was in use in 1945-46 and subsequent years. In this detector a stable electromagnetic field was set up by feeding a direct current to a primary coil winding. The primary coil was overwound at its ends by two secondary coils which were spaced from each other and separated from the primary by an electrostatic shield. A disturbance in the field caused by the movement of a metal object such as a tag induced a small current in the secondaries, which were connected in series opposition. This current was then amplified, and it operated a sensitive relay as in the bridge detector. The apparatus thus required only one coil case, containing three separate windings, rather than two coil cases each containing two coil windings. The circuits involved in this type of detector (referred to as the "induction" detector) were of simpler design than those in the bridge type.

The basic difference in the two types of detector was, therefore, in the way in which the activating current was produced. In the bridge type the presence of a tag, wither stationary or moving, created an impulse, whereas in the induction type an impulse was created only by a moving tag and the strength of the impulse increased with the speed of movement.

Two models of each type of detector have been used in the course of the investigation (Table II). The second unit of each type was similar to the prototype in all fundamental respects, but for reasons largely unknown these units were less successful than the orginal models in recovering tags.

The two most serious problems encountered in detector recovery were (1) maintenance of the detectors at high sensitivity to the presence of tags and (2) proper timing of the opening of the trap-door so as to ensure recovery of the tagged fish.

The difficulties in connection with maintenance of detector sensivity have arisen because of certain limitations of the detectors themselves and interference from outside sources. The main deficiency within the detectors was the generally high (and fluctuating) level of background noise within the detection circuit in relation to the impulse produced by a tag. It has been shown under experimental conditions that the ratio of the signal (impulse created by the tag) to the intrinsic background noise is only about 2 for the highest sensitivity that can be attained by the present detectors. Fluctuations in the level of background noise were probably brought about by variations in air temperature and moisture content under operating conditions, by variation in the characteristics of standard electronic parts with age, and by other factors not clearly assessed. As a result of this low signal-to-noise ratio, the position of maximum sensitivity was very critical, and constant "drifting" to a point of complete insensitivity occurred (Tester,1946). Frequent testing of the field of the detection coil was necessary, and tuning (regaining electronic balance in the coils) was often necessary every five minutes or less. While retuning, the operation of the trap-door had to be interrupted with the result that some of the fish passing through the coil went untested for tags.

The induction detectors were generally more stable than the bridge detectors, but their maximum sensitivity was less. Speed of fish through the coil was an important factor in the sensitivity of the induction detectors, and hence when conditions were such that fish came down the chute slowly or when the detector operated on a relatively slow-moving belt the sensitivity of the induction sets was impaired. All factors considered, the average sensitivity of both types of detectors was approximately the same.

At the level of average sensitivity both types of detector were generally incapable of detecting tags which passed through the coil sideways, i.e. with the long axis of the tag at right angles to the direction of the flow of fish (Hart and Tester, 1938). Usually a large proportion of the fish passed through the coil so that the long axis of the fish and of the tag was parallel to the direction of flow, but under certain circumstances the inability of the apparatus to detect tags crosswise in the coil resulted in lowered efficiency of recovery (Tester and Boughton, 1943; and Tester, 1944).

Laboratory tests showed that reasonably satisfactory detector operation was possible in spite of this intrinsic problem in detector design. However, when outside interference became a factor during operation in the plants, large surges of current were created in the detection circuit which exceeded that produced by a tag, causing false tripping of the detector. At times, depending on the extent of outside interference, false trips were so frequent that detector operation had to be stopped. Outside interference was caused by electrical interference of plant machinery, variation in voltage of the power supply to the plant and detection equipment, and the presence of large masses of moving or vibrating metal in the vicinity of the coil.

Efforts were made to diminish the effect of outside interference by shielding the coil, using a separate power supply for detection equipment, installing voltage regulators, etc. However, although some improvement in detector efficiency resulted, it was not enough to give any marked increase in tag recovery.

The most obvious solution to the problem was to increase the size of the tag, thereby increasing the signal-to-noise ratio to a point where outside interference would not have greater effect than a tag on the detection circuit. But this was not considered feasible on biological grounds. A recent approach, involving a relatively simple modification of the circuits of the induction detector, has shown promise of reducing background noise and increasing signal strength, such that a signal-to-noise ratio of at least 5 may be attained.

The problem of proper timing of the opening of the trap-door was largely independent of the sensitivity of the detection coil. Tags might be detected by the coil, but unless the trap-door opened at the proper time the tagged fish would not be recovered.

The chief difficulty in timing the action of the trap-door arose from variation in the speed of the movement of fish down the chutes. Movement was slower near the sides of the chute than in the middle, and large fish move faster than small fish. Fish slid down the chute more slowly at the beginning of unloading before the chute was wet and slimy, and fish unloaded some time after they were caught were sticky and tended to have retarded movement (Hart and Tester, 1937). By placing a stream of water in the chute the variation in speed of movement was largely overcome, but this was not always possible since it sometimes interfered with the processing of the fish (Tester, 1946). Speed of fish was relatively constant on belt conveyors, except in one installation where the belt was inclined upwards, causing fish to slide backwards towards the coil (Tester, 1944).

The general approach to most of the problems of timing was (1) to set the distance between the coil and trap-door for average speed of fish, and to make provision for altering the distance (by moving the coil closer to or further from the trap-door) to compensate for fast- or slow-moving fish, and (2) to keep the trap-door open for a period long enough to enable fish moving slightly faster or slower than average to be by-passed. The period of the opening of the trap-door was increased by reducing the air pressure applied to the piston, adjusting the mercoid switch (Hart and Tester, 1937) and by using a specially designed delayed-action system in the trap circuit (Tester, 1946).

Experiments were carried out in various seasons to determine the efficiency of tag detectors in recovering tags from the catch (Table III). The efficiencies were calculated for the period of time in which the detectors were in effective operation (Tester and Stevenson, 1948). Great variation was found in percentage efficiency between the different detectors and from year to year.

Plant Recovery.

Electromagnets and Alnico permanent magnets were installed in practically all herring reduction plants. They were placed in the meal-line, usually in a chute located between the drier and the grinder (Hart and Tester, 1938, 1939). Tags (and other pieces of metal) passing over the magnet with the herring meal were held by the magnet and later retrieved by plant employees. Tags were also recovered by plant employees from cracks and crevices of plant machinery, from traps designed to remove tramp metal from the meal before it passed into the grinder, and from inside the grinder itself. For every tag returned to the investigators with pertinent information on place of capture of the fish and date of recovery, a reward of 50 cents was paid. This method was used for recovery of herring tags in Alaska (Rounsefell and Dahlgren, 1933; Dahlgren, 1936), and pilchard tags in California (Janssen, 1937) and British Columbia (Hart, 1937, 1943).

Few problems were involved in recovering tags by this method. Occasions in which the magnets failed for some reason to recover tags were rare, and in general plant personnel were cooperative in returning tags promptly with the necessary information.

Experiments were carried out to determine the efficiency of plants in recovering tags (Table IV). They involved inserting a given number of tags in fish just before they were processed (either when the fish were in the packer or in the fish bins), and calculating the percentage of these tags recovered. Results of the tests showed that magnets and plant machinery were on the average, 78 percent efficient in recovering tags for the seven seasons in which tests were conducted. Average efficiency varied from 63 percent in 1946-47 to 83 percent in 1948-49. The average efficiency of the different plants varied from 60 percent to 94 percent.

The most serious problem involved in plant recoveries was determining the particular catch in which each tag originated. Considerable variation existed between plants and even within the same plant in the time taken for tagged fish to move through the plant to the magnet. Thus, although accurate information was available from the captain of the packer boat concerning the fishing ground from which any landing came, it was usually difficult to determine the particular landing from which any recovered tag originated. The problem was especially difficult when fish from two or more fishing areas were unloaded at one plant on the same day. Even when loads of fish from different areas were processed on different days, and even if the fish bins, cookers, and presses were cleaned before the second packer was leading unloaded, there was always the possibility of tags being held over for varying lengths of time in crevices in the drier or in the bottom of the screw conveyor from the drier to the grinder.

Experiments were carried out to determine the extent of this time lag, for the purpose of assisting in the interpretation of plant returns. The tests, which were undertaken in connection with the plant efficiency tests (Table IV), involved calculation of the percentage of test tags obtained after various periods of time (Table V). Great variation in time lag occurred between plants in each year and from year to year for each plant; in certain plants all the tags that were recovered were taken by the end of the first day, while in others tags were recovered weeks (and even months) after processing had begun.

Knowledge of time lag was used in association with the detailed records of the daily plant landings and with information obtained from detector recoveries for making unbiased interpretations of the locality of capture of plant returns. In many cases only a broad area of recovery could be assigned and not a particular fishing ground. In other cases no interpretation could be offered. Efforts were made to adopt a uniform standard of interpretation from year to year. In general this standard was fairly rigidly maintained, but in a few instances when adherence to the standard would have meant discarding a much greater-than-usual proportion of the returns a slightly less critical standard was adopted.

METHODS OF DATA ANALYSIS

Treatment of the Data.

The general method of studying the movements of herring was by relating the actual number of tag recoveries to the total number of tags in the various herring catches. In the case of the study of intermingling between the major populations, adjustments were applied to the actual returns in order to approximate the total number of tags in the catches. These adjustments were applied to the returns from each plant to compensate for loss of tags resulting (a) from partial searching of the landings, (b) from less than perfect efficiency of the plant in returning tags (Table IV), and (c) through part of the landings being canned in the 1941-42 to 1947-48 seasons (Hart, Tester and McHugh, 1941). To these totals the numbers of tags recovered by tag detectors were added. The resulting estimates (combined for all years) are given in Table IX.

For analysis of the relative movement of various individual runs within a major population, there was generally insufficient detailed information to warrant making the previously-mentioned adjustments to the plant returns, and unadjusted plant returns were simply combined with detector returns (Table XII to XVI). This procedure involved the assumption that the actual number of tags returned from taggings of the various runs within a population were proportional to the total number of tags in the catches from which the recoveries were made.

There is some evidence that this assumption is generally applicable. Detector returns of some taggings on the west coast of Vancouver Island were sufficiently numerous in recent years to enable calculation of the total number of tags in the west coast catches. These calculations (Table XII) were made by adjusting the actual number of detector recoveries (1) for detector efficiency, while in operating condition, (Table III), and (2) for the portion of the catch not searched because the detectors were not in operating condition (before and after the period in each season that the detector was operated, and during periods of tuning, repairing, etc.). The generally close agreement between results derived from these adjusted data and those from the non-adjusted data (see Table XII) suggests that some confidence can be placed in the validity of the latter data for study of the relative movement of the individual runs within a population.

To assist in interpreting the tabulated recovery data (Tables VII and IX), it might be pointed out that two general types of analysis are possible. By considering the data in the horizontal rows the relative movement of fish of any particular sub-district to other sub-districts is obtained (as well as as the extent of return to the sub-district of tagging). By considering the data in the vertical columns an indication is given of the extent to which fish of the various sub-districts contribute to the sub-district catches. Thus, it will be noted in Table IX that according to the first (or horizontal) type of analysis 77.4 percent of the northern tags were recovered in northern catches, 17.7 percent in north central catches, etc., whereas according to the second (or vertical) type of analysis, 67.2 percent of the northern sub-district catches was derived from from fish tagged in the northern sub-district, 24.1 percent from north central tagging, etc. It should be emphasized that in the second type of analysis, the composition of only that portion of the catch that was subjected to tagging (i.e. that had spawned at least once) is given. In other words, the portion of the catch made up of newly-recruited fish is not considered.

Factors involved in Data Analysis.

The validity of the foregoing method of treating the data depends upon certain assumptions: (1) that catch is proportional to population abundance, i.e., that the exploitation rate is constant from population to population and from one year to the next, (2) that newly-recruited fish are randomly mixed in the population, (3) that the intensity of tagging (ratio of tagged to untagged fish) is the same in each stock, and (4) that the fish tagged in each population are randomly distributed throughout the population. If the first two assumptions are not applicable to the data the horizontal analysis of the tabulated recoveries will be affected, whereas if the third assumption does not hold, the vertical analysis will be affected. The fourth assumption is basic to both types of analysis.

There is little doubt that instances exist in the data where one or more of the assumptions are not approximated. Marked variations in exploitation rate are obvious in certain stocks as a result of changes in availability of the fish to the fishing fleet and changes in economic conditions. Because estimates of these variations are few in number (Stevenson and Outram, 1953) and probably not highly accurate, adjustment of recovery data to account for them does not appear warranted. On the other hand, some evidence is available suggesting that catch is roughly proportional to abundance, particularly in populations which have not been subjected to fixed catch quotas (Stevenson, 1954). Furthermore, it appears that in combining the recovery data of all seasons the effect of unusually high or low exploitation is somewhat mitigated.

Instances of non-random mixing of newly-recruited fish within a population have been rare. Extensive sampling of the fishing and spawning runs of each major population indicates generally thorough mixing of newly-recruited year-classes with the older portion of the stocks.

Considerable variation has obviously occurred in the ratio of tagged fish to untagged fish from one population to another and from one season to the next. Lack of knowledge concerning population abundance prevents adjusting the recovery data to remove inconsistencies resulting from this factor. Indications of the extent of this variation have been obtained from the concentration of tags in the catch (i.e. number of tags per ton of herring caught - Table X), but such indications were not sufficiently precise to permit applying corrections. Because of the resultant inadequacies in the data, care must be taken in drawing conclusions regarding the proportions of fish in the catches derived from the various tagged stocks (i.e., concerning the vertical analysis of tabulated data).

Several incidences of presumed lack of random dispersal of tagged fish were cited in previous reports (Hart, Tester and McHugh, 1941, and Tester, 1945). On the other hand, a detailed analysis of 332 detector returns from six fishing grounds in Area 23 (south west coast of Vancouver Island) in 1947-48 showed no significant heterogeneity between the relative number of returns from the various taggings (Tester and Stevenson, 1948). It seems probable that in certain instances in which lack of random distribution of tagged fish appeared to be involved, changes in tagging and tag recovery techniques may have been important factors. In other cases, unusually heavy natural mortality of fish during and after the spawning period, such as was noted in 1942 (Tester and Boughton, 1943), and in 1948 and 1949 (Stevenson, 1949), may have affected the randomness of distribution of tagged fish. The practical approach adopted to minimize the occurrence of this problem was to tag each major spawning run as often as feasible throughout the spawning season.

ANALYSIS OF RESULTS

In the sixteen fishing seasons from 1936-37 to 1951-52, the total number of tags recovered was 20,528, or 3.7 percent of the number of herring tagged. About 86 percent of the tag recoveries were taken by magnets and plant machinery, as compared to 14 percent taken by tag detectors (Table II).

All but 14 of the 310 individual taggings produced returns. The number of returns from each tagging was usually less than 5 percent of the number of fish tagged, but percentage recovery as great as 26 percent was noted. Exceptionally high returns were attributed to a combination of excellent opportunity for a large portion of the catch to be searched and of heavy exploitation of the stock.

The percentage recovery of tags varied considerably from year to year. As shown in Table VI, recovery increased sharply during the first few years from 0.56 percent for taggings of 1936-37 to 3.38 percent for 1939-40 taggings.

This was largely a result of increasing the number of magnet installations in the plants. The generally low recovery from taggings of 1940-41 to 1945-46 was mainly attributable to the widespread canning of herring during the late war years and early post war years which reduced the recovery of tags by magnets. The striking increase in percentage tag recovery for the 1946-47 and subsequent taggings resulted partly from increased plant recovery, brought about by the decrease in canning operations and by stimulating plant personnel to recover tags from magnets and plant machinery. It is also considered that generally increased exploitation of the stocks in recent years has been partly responsible for high tag recovery.

Recovery of tags decreased with increase in time between tagging and recovery (Table VI.). When fish were tagged during the fishing season, an average recovery of 6.7 percent was made in catches of the same season, and recovery from certain taggings was as high as 15 percent. Recovery from spring taggings (in which case the tagged fish were not subject to capture for at least six months) was generally less. In the first season after tagging an average of 2.57 percent of the fish tagged was recovered; in the second fishing season, the average recovery was 0.77 percent; and in subsequent seasons the average percentage recovery was 0.19, 0.08 and 0.02. One tag was recovered in the eighth fishing season after tagging.

Detailed analysis of decrease in tag recovery with length of time after tagging, from which information on fishing and natural mortality will be obtained, is beyond the scope of the present paper. Results of partial analysis of the data have been reported (Tester, 1945; Tester and Stevenson, 1948; Stevenson, 1950; Stevenson and Lanigan, 1950; and Stevenson, Hourston and Lanigan, 1951).

Identification of Populations.

The first step in the study of herring movement is to determine whether there is a tendency for the various herring runs to form populations which persist from year to year, and if so, to delineate the geographical region in which herring of each population spawns and is fished. In other words, the first problem is to establish whether there is a relationship between herring found on the spawning grounds in the spring and those comprising the fishery in the same coastal waters in the following fall and winter. Detector recoveries from spring taggings, combined for all years of the study (Table VII), are best suited to this purpose for two reasons: (1) accurate information exists on the localities from which all detector recoveries were taken, and (2) fish tagged in spring tagging have opportunity for widespread movement before recovery takes place. On the other hand, the fact that the detector recoveries were relatively few in number is a disadvantage which results in these data being mainly of qualitative, rather than quantitative, value. The recovery data revealed a striking tendency for tags to be recovered in or near the area of tagging (Table VII). Herring tagged in Areas 5, 6, 7, 12, 13, 18, 23, and 25 were mostly recovered in the area in which they were tagged, whereas those tagged in other areas were recovered mainly from areas situated close to the tagging area. It is inferred from this that herring, which normally leave coastal waters after spawning in the spring, return to the same coastal waters in the fall and winter, and spawn the following spring in the same general locality that they spawned the previous year. It is, therefore, apparent that British Columbia herring comprise a limited number of more or less discrete populations. This is in general agreement with studies carried out independently on meristic characters (Tester, 1937), and on age-composition and growth.

On the basis of detector returns, seven major and two minor populations are recognized. The sub-districts (Fig. 1) in which the former are located are (1) northern, (2) north central, (3) south central (outer part), (4) middle east coast of Vancouver Island, (5) lower east coast of Vancouver Island, (6) south west coast of Vancouver Island, and (7) north west coast of Vancouver Island. The latter are found in (1) the south central sub-district (part) and (2) the sub-district of the upper east coast of Vancouver Island. In addition, there is evidence from plant returns and various other data that an eighth major population exists on the east coast of the Queen Charlotte Islands, and that other minor populations are present within the north central, middle east coast, and lower east coast sub-districts.

The features distinguishing these two types of herring aggregations are:

(1) Population abundance. On the basis of catch and extent of spawn deposition, it is evident that major populations greatly exceed minor populations in abundance. The eighth major populations account for about 95 percent of the catch.

(2) Seasonal migration. The major populations appear to leave costal waters after spawning, to remain offshore (probably in the vicinity of the continental shelf) for summer feeding, and to return to inshore waters in the fall and winter. The minor populations, on the other hand, seem to remain in inshore waters all year round. They have in certain years provided a small summer fishery, as well as a winter fishery. The seasonal migration routes of the major populations of the lower east coast and middle east coast of Vancouver Island have been fairly well established through tagging data, details of which will be discussed later. Because of this distinction between the populations, the terms "migratory" and "resident" populations have been adopted.

(3) Growth and age-composition. Significant differences in growth rate and age-composition are generally noted between migratory and resident stocks located within the same sub-district. The growth rate of the latter is generally small, possible a result of poorer feeding in inshore waters than offshore.

(4) Location of spawning grounds. Spawning grounds of resident stocks are generally located towards the head of long inlets, whereas migratory stocks tend to spawn near the mouths of the inlets along the edge of the outer coast.

(5) Homogeneity of individual runs. A relatively high degree of homogeneity exists between the various runs comprising each migratory population. On the other hand, the resident population are generally complex assemblages of small individual runs which vary greatly in the extent of their intermixture.

Migratory populations.

The areas of inshore concentration of the eight major populations can be reasonably well defined from tag recoveries, and from information on the location of the main spawning and fishing grounds. These sources of data are also useful in providing some general knowledge on the inshore route of migration and on the probable location of the offshore feeding grounds. While the data on the latter are generally inconclusive, chiefly because of the lack of fishing, and hence lack of tag recovery, in offshore waters, they suggest that the offshore feeding grounds of most populations are located south of the region of their inshore concentration.

Northern population. -

The Northern population spawns and is fished in Areas 3, 4, and 5, a region extending from the British Columbia - Alaska boundary to Caamano Sound. Detector returns (Table VII) show that fish tagged on the spawning grounds of Areas 4 and 5 were largely recovered in Area 5. Opportunity was lacking for detectors to search catches in seasons when most of the catch was taken from Area 4, but plant returns strongly indicate that in those years the Area 4 catch was comprised mainly of fish that spawned in both Areas 4 and 5.

It appears that northern herring approach inshore waters from Hecate Strait at two main points, Edye Pass (Area 4) and Ogden Channel (Area 5). Whether Area 4 or Area 5 provides the bulk of the catch in any one year depends on which of these two routes of entrance into the sub-district is taken. The general movement within the sub-district is in a northerly direction, a few schools penetrating as far north as Area 3 by the time spawning occurs.

North central population.

The north central population is confined in the western portion of Area 6, in waters extending from Caamano Sound to Milbanke Sound. Fish tagged on the main spawning grounds, located along the west shore of Princess Royal Island were strongly returned from catches taken in this same general locality.

The north central population appears to approach inshore waters from the southern part of Hecate Strait and to enter the sub-district in the vicinity of Milbanke Sound, from where it moves through Laredo Sound in a northerly direction. As will be discussed later, the herring to the east of Princess Royal Island show no close relationship to the major migratory north central stocks.

South central population.

The south central population is located in Area 7 and in the outer waters of Area 8. The main fishery takes place near the boundary separating Area 7 and Area 8, in Kildidt Sound (Area 7) or Kwakshua Passage (Area 8). Most of the spawning occurs in Area 7 in the vicinity of Kildidt Sound, and tagging of this spawning run shows that both of the main fishing grounds are supplied with herring from this run. Because of the lack of spawning in Area 8, tagging in this area has been infrequent. While there has been no opportunity to obtain detector returns from the rare Area 8 taggings, plant returns from them have been numerous in both Area 7 and Area 8 catches.

It is considered that offshore distribution of the south central population is probably in Queen Charlotte Sound, and that inshore movement into the sub-district takes place in the vicinity of the Area 7-Area 8 boundary. As the fishing season progresses there is a tendency for the herring to move northward into Area 7. There is evidence, discussed later, that the small herring runs located in the long inlets of the adjacent mainland coast (in Areas 8, 9, and 10) do not belong to the migratory south central stocks.

Middle east coast population.

The spawning grounds of the herring population of the middle east coast of Vancouver Island are located in Discovery Passage and the coastal waters of the northern part of the Strait of Georgia (Areas 13, 14, 15, and 16). The fishery takes place almost exclusively in Areas 13 and 14. Tag returns indicate that this is probably the least independent and most complex of the migratory populations. Only fish tagged in one of the four areas (Area 13) showed marked returns to the area of tagging, and a pronounced movement to the lower east coast occurred from certain middle east coast runs. At least some of the small runs in Areas 15 and 16, particularly those in the long inlets of the mainland coast, give evidence of being resident populations that are not closely associated with the major migartory population. A detailed discussion of middle east coast herring will be given later when the relative movement of the individual runs within the populations are considered.

The inshore migration route of the middle east coast population appears to be from the north through Queen Charlotte Strait, Johnstone Strait, and Discovery Passage. The annual sequence of the middle east coast fisheries leads to this conclusion. The first middle east coast catches of each season are almost invariably made in Area 13 (Discovery Passage). Fishing further south in Area 14 follows later in the season, but in certain years when heavy and continous fishing effort is applied to the runs passing through Area 13 the Area 14 catch is small or comprised of fish which differ greatly in age-composition from the migratory fish taken in Area 13.

The fact that Area 13 catches contained a relatively large proportion of fish from the upper east coast is accepted as indirect evidence that inshore seasonal movement of middle east coast fish is from the north. Of the 234 tags recovered in Area 13 catches, 36 were from taggings made outside the middle east coast sub-district, and of these 36 tags 23 or about two-thirds were from upper east coast taggings (Table VII). As the migratory stock moved south into Area 14 the concentration of upper east coast tags in the catch was decreased -- only 4 upper east coast tags out of 22 in Area 14 catches, as compared to 23 out of 36 in Area 13 catches. This change in the composition of the main middle east coast stock appears to be a result of mixture with local resident runs and immigration of lower east coast fish.

Results from tagging in the Strait of Juan de Fuca (Table VIII and Fig.2), which are dealt with in the discussion on the lower east coast population, provide strong evidence that the middle east coast population does not move inshore from the south through the Strait of Juan de Fuca.

Lower east coast population.

The population of the lower east coast of Vancouver Island spawns and is fished in Areas 17 A, 17 B, and 18, mainly inside the row of small islands which follow the Vancouver Island shoreline. Although negligible quantities of herring spawn or are caught in Areas 19 and 20 (in the Strait of Juan de Fuca) these areas are considered within the lower east coast sub-district for the reason that they contain the inshore migration route of population.

Evidence indicating that the lower east coast population moves from offshore feeding grounds (probably off the Washington coast) to inshore waters by way of the Strait of Juan de Fuca was obtained from tagging in the Area 20 (near Sooke) in late September and early October just prior to the commencement of the lower east coast fishery. In eight different years a total of 8,643 herring was tagged (Table I). The data (Table VIII and Fig. 2) showed that 95 percent of the tags recovered in the season of tagging (293 out of 307) were returned from lower east coast catches. The three returns from middle east coast catches suggest that a small number of these fish moves through the lower east coast sub-district and mingle with the middle east coast fish. Although no detector recoveries were made in south west coast and north west coast catches, a few plant recoveries were interpreted as coming from these catches. While as pointed out previously, caution has to be used in basing conclusions on small numbers of plant returns, one of these recoveries possessed a particularly high degree of reliability as to recovery area (Area 23). It appears, therefore, that a small number of these fish do not complete the migration to lower east coast waters, but rather move seaward again and join runs to the west coast of Vancouver Island.

The percentage recovery of the Strait of Juan de Fuca tags (3.6 percent in the first season of recovery) was low in relation to that of taggings carried out on the fishing grounds during the period of the fishery (6.7 percent in the first season). This was no doubt due at least in part to the generally rough handling that the fish had to undergo prior to tagging. The low recovery suggests the possibility that appreciable quantities of fish may have moved to contigenous waters of the State of Washington (around San Juan Islands or into Puget Sound) where opportunity of recovering tags is very limited. Present knowledge of herring in these American localities does not support this possibility. No recoveries were made from two taggings carried out at Holmes Harbour and Seal Rock in Puget Sound in 1939 and 1940. There is some evidence that fish in Birch Bay (close to the international boundary) intermingle to some extent with lower east coast stocks; 3 of the 4 recoveries from a tagging carried out there in 1938 were from lower east coast catches (the fourth recovery was from fish caught off the mouth of the Fraser River). Present indications are that these herring comprise a small resident stock similar to those off Point Grey and in Active Pass. Its contribution to the migratory lower east coast stocks is undoubtedly slight. Whether the movement takes place directly or whether it occurs through nearby resident stocks (such as that of Active Pass) is not known.

South west coast population.

The inshore distribution of the population of the south west coast of Vancouver Island extends from Pachena Point to Esteban Point, comprising the waters of Areas 23 and 24. The main fishing localities and spawning ground are located along the north west shore of Barkley Sound (Area 23 B-- see Fig.3).

It is considered that the offshore feeding area of the south west population is probably located off the coast of Washington, some distance south of the spawning and fishing areas. One source of evidence for this is found in the only tag recovery to be recovered in offshore waters. This tag, from a fish tagged in Barkley Sound (Area 23), was taken about 120 miles south of the tagging area at a point about 20 miles off Grays Harbour, Washington (Tester and Stevenson, 1948). Analysis of the general sequence of the catches in the various fishing grounds of the sub-district also suggests that seasonal inshore movement takes place in a general northerly direction.

North west coast population.

The population of the north west coast of Vancouver Island, in its inshore distribution, extends from Esteban Point to Cape Scott (Areas 25, 26, and 27). As found in connection with the south west coast population, the main spawning and fishing grounds are in the southern portion of the range - in Nootka Sound and Esperanza Inlet (Area 25). While no direct evidence is available on the route of migration it is thought likely that the offshore feeding grounds are located off Area 25, or perhaps somewhat further south. In general the Area 25 fishery is the first north west coast fishery to develope in each season, followed later in the season by the area 26 fishery. No commercial fishing has taken place in the Area 27 between 1945-46 and 1951-52.

Queen Charlotte Islands population.

It appears probable that the herring of the east coast of the Queen Charlotte Islands (Areas 2 B-East and 2 A-East) constitute a separate population on the basis of age-composition studies. Tagging data are too sparse to give reliable confirmation. No detector returns were obtained from two small taggings carried out in 1940 (Table I), due mainly to the lack of opportunity for detectors to search catches from the Queen Charlotte Islands and from other northern British Columbia sub-districts in the years immediately following tagging. Eight returns were taken by magnets, all of which were interpreted as coming from Queen Charlotte Island catches (Table IX).

The main fishing and spawning grounds on the east coast of Queen Charlotte Islands are located in the southern part of the sub-district (in the vicinity of Skincuttle Inlet - Area 2 B-East), suggesting that the offshore feeding grounds are in the southern portion of Hecate Strait. There appears to be good prospects of testing this possibility when tag returns are sufficiently numerous to assess the extent of intermixture between this population and those of the adjacent mainland shore which are also considered to move offshore to feeding

Resident populations.

The geographic limits of most of the resident populations are imperfectly known. Only five of the approximately 20 resident stocks were tagged, and only three were subjected to relatively intensive tagging. To provide a more or less complete understanding of the resident populations, an amount of tagging out of proportion to their contribution in the fishery would be required, in view of the large number of stocks involved, their complex interrelations, and the sporadic fishing effort to which they are usually subjected.

North central resident populations.

Herring, located in four main localities of the inner waters of Area 6 (in bays and inlets east of Princess Royal Island), were considered to be independent of the nearby runs of the north central migratory population on the basis of (1) their low concentration of north central tags (Hart, Tester, and McHugh,1941; and Tester, 1946), and (2) differences in age-composition and growth. These resident stocks were fished in (1) Aaltenhas Inlet, (2) Tolmie Channel, (3) Poison Cove, and (4) Gardner Canal. Since none of these runs has been tagged and since all have not been fished in any one year, it is not possible to determine whether or not they represent four separate resident stocks.

South central resident populations.

Three or more resident stocks are located in the long inlets of Areas 8, 9, and 10. Those in Area 9 (Rivers Inlet) and Area 10 (Smiths Inlet) are the largest, and in most years one or the other has provided a small fishery. The herring of these two areas were tagged in three different years (Table I). Recovery data show that few tags were returned from catches in the tagging areas (Table IX). While this fact could be interpreted as indicating that an unusually large proportion of these stocks moves to the neighbouring migratory population, it appears more likely to be a result of low exploitation of the stocks in Areas 9 and 10. The latter interpretation is supported by the fact that the percentage recovery of tags from Areas 9 and 10 taggings was low in relation to that for taggings or nearby populations (Table X).

No fish tagged in one of the two areas were recovered in the other. Although this cannot necessarily be interpreted to mean that no movement occurs between Areas 9 and 10, it suggests that the two stocks are essentially separate.

Little is known regarding the resident stocks in the inlets of Area 8, partly because they have been fished infrequently, and partly because they have not been tagged. It seems likely that the runs located near Bella Coola, in Kwatna Inlet, and in Cousins Inlet are separate stocks.

A striking feature of all south central resident stocks is their extremely slow growth.

Upper east coast resident populations.

Six resident stocks have been recognized on the upper east coast of Vancouver Island and adjacent mainland shore (Areas 11 and 12), on the basis of tag returns, age-composition, and growth. The general localities in which these stocks are located are A, Seymour Inlet (Area 11), B, MacKenzie Sound, C, Belleisle Sound, D, Retreat Passage, E, Clio Channel, and F, upper Knight Inlet. Three of the stocks (C, D and E) were subjected to relatively intensive tagging, involving a total of 34,231 fish (Table I).

Considering the combined tag returns from all taggings, it is evident that the upper east coast herring maintain a considerable degree of isolation from the major migratory population (Tables VI and IX). There is an indication that a significantly higher proportion of D tags move outside the upper east coast than either C tags or E tags (Table XI). This conclusion is of particular interest in view of the high growth rate of D fish, which suggests offshore feeding conditions (Tester, 1941; Stevenson, 1946).

It will be noted (Table XI) that a much higher proportion of E tags were taken in the E fishery (76 percent - 427 out of 563) than either C tags in the C fishery (19 percent - 11 out of 58) or D tags in the D fishery (18 percent - 51 out of 289). In addition, a pronounced recovery of C and D tags in E catches is shown in the data. The conclusion to be drawn from these results, viz., that immigration into E exceeds emigration out of E, is supported by age-composition and growth data and by the fact that this stock is the largest upper east coast stock, providing the most dependable fishery in the sub-district. However, the suggested difference in the extent of immigration and emigration to and from this stock is probably exaggerated because of the relatively high exploitation of E stocks and the resulting high recovery of E tags (4.7 percent, as compared to 2.9 and 1.4 - Table XI).

The lack of recovery of C, D or E tags in catches from A or F suggests a high degree of isolation of the latter stocks. The A and F herring show extremely slow growth. The consistent lack of older fish in F catches suggests either that the stock is small and heavily exploited or that extensive migration from it occurs.

Other resident populations.

There are indications that other resident populations are located in Jarvis Inlet and Sechelt Inlet (middle east coast sub-district), at Porlier Pass and Active Pass (lower east coast sub-district), and in Skidegate Inlet (east coast of Queen Charlotte Islands). Most of the evidence has been derived from meristic studies (Tester, 1937) or age- and growth studies, rather than from tagging. Information on the herring of the west coast of the Queen Charlotte Islands is too sparse to indicate whether they are resident or migratory.

Extent of Movement between Populations.

Tag recovery indicates that approximately one-quarter of the migratory herring move from the sub-district in which they were reared and join other populations (Table IX). The lower east coast population shows the smallest emigration to other populations (16.4 percent - 210 tag recoveries out of 1,278), whereas the middle east coast population shows the greatest (45.5 percent - 495 out of 1,088).

The amount of emigration from one population to another varied with distance between the populations. Thus emigration was invariably greatest to nearby stocks, as shown in Fig.3 and in the following tabulation:

Population	Percent Emigrating	Population receiving: Largest Proportion of Emigrants	Population receiving: Second-largest Proportion of Emigrants
Northern	22.6	North Central (17.7%)	South Central (3.0%)
North Central	23.7	Northern (11.8%)	South Central (10.3%)
South Central	17.9	North Central (12.1%)	Northern (1.8%)
Middle East Coast	45.5	Lower East Coast (27.6%)	Upper East Coast (7.7%)
Lower East Coast	16.4	Middle East Coast (6.7%)	South West Coast (6.6%)
South West Coast	28.5	North West Coast (22.0%)	Lower East Coast (5.3%)
North West Coast	30.8	South West Coast (25.3%)	South Central (2.3%)

Conversely, the greater the distance between populations, the smaller the intermixture. The most northerly stock (the northern population) and the most southerly stock (that of the south west coast of Vancouver Island) showed an extremely small interchange of fish. Only about three percent of the tag returns from taggings in populations north of Cape Caution were recovered south of Cape Caution, and a similar percentage of returns from taggings in populations south of Cape Caution was taken in the north.

The results on extent of intermingling indicate that the herring of British Columbia form a series of intergrading populations along the coast, a conclusion previously arrived at from meristic studies (Tester, 1937).

In general the percentage movement from one major population to another is similar to the movement in the reverse direction. The only noteable deviation from this condition is in the extent of movement between the middle east coast and lower east coast, where the migration in the southerly direction greatly exceeds the northerly movement (27.6 percent as compared to 6.7 percent). Considering the reciprocal movements between the major migratory populations there is no significant tendency for greater net movement in either a southerly or a northerly direction ($P = 0.3$). The tendency is even less significant, if instead of percentage movement, the numbers of fish moving between populations (calculated by assuming population abundance porportional to catch) is considered ($P = 0.8$).

There is evidence that the amount of emigration from any particular population changes from year to year. For instance, the calculated emigration from the combined west coast populations to the lower east coast varied from 10.1 percent in 1949-50 to 0.6 percent in 1951-52, as shown in the tabulation on the next page:

Season	Percentage Emigration		
	Based on Detector Returns	Based on Magnet Returns	Average
1946-47	1.8	0.0	0.9
1947-48	5.8	1.3	3.6
1948-49	3.3	2.4	2.8
1949-50	10.9	9.3	10.1
1950-51	4.0	7.2	5.6
1951-52	1.2	0.0	0.6

An indication of the relative importance of immigration in the composition of the catches from the major populations is provided by the data presented in Table IX. This is obtained by an analysis of the data in the vertical columns of the table, a brief summary of which is as follows:

Population fished	Percentage of catch composed of immigrant fish	Population Supplying	
		Largest proportion of immigrants	Second-largest portion of immigrants
Northern	32.8	North Central (24.1)	South Central (6.2)
North Central	29.3	South Central (18.6)	Northern (7.0)
South Central	21.5	North Central (6.0)	North West Coast (4.3)
Middle East Coast	28.3	Lower East Coast (10.4)	Upper East Coast resident stock (5.6)
Lower East Coast	41.1	Middle East Coast (16.5)	South West Coast (15.4)
South West Coast	31.9	North West Coast (29.8)	Lower East Coast (1.5)
North West Coast	22.1	South West Coast (20.0)	South Central (0.7)

As in the case of emigration, the extent of immigration tends to vary in relation to the distance between populations. The data suggest that from about 20 to 40 percent of the catches of the major populations is comprised of migratory fish. As discussed previously, newly-recruited fish, i.e., fish which were not subjected to tagging, are not considered in these calculations.

The relatively small total number of lower east coast tags in the various sub-district catches (1.278 - Tables IX and X), and the similarly small number of tags (1,813) from taggings of all populations in the lower east coast catch is inconsistent with the fact that this population was the most heavily tagged (Table I) and probably the most intensively exploited (Stevenson and Outram, 1953). Two factors were probably involved: (1) underestimation of the loss of tags in canning operations (a much greater proportion of the lower east coast catch was canned in the 1940's than any other), and (2) the heavy mortality referred to previously, of both tagged and untagged fish that was noted in certain years on the lower east coast during and after spawning. The combined effect of the resulting inconsistencies in the data would tend to lead to general underestimation of the extent of movement from all populations to the lower east coast, and also to overestimation of the extent to which the lower east coast catch is comprised of immigrant fish. It can be shown, however, that even if these factors produced errors in the estimated total number of tags in the lower east coast catch as great as 100 percent, the validity of general conclusions drawn from the data would not be appreciably affected.

The Relative Movement of Individual Herring Runs within Major Populations.

Considerable differences exist between populations in the relative amount of emigration exhibited by the different herring runs comprising the population. In one population the amount of emigration from each of the individual herring runs to a neighbouring population shows no significant differences, suggesting that the runs are freely mixing and highly homogeneous. In most instances, significant differences occur, which indicate that the runs could be considered as separate sub-populations. Within the latter populations an intergradation of individual herring runs is shown which is related to distance separating the runs. This reflects, on a smaller scale, the general intergradation found between the major herring populations.

West coast populations.

Four main herring runs have been distinguished in each of the two west coast populations, on the basis of the relative concentration of tags in the catches of the two populations (Table XII). The most southerly of the eight runs, that of the southern and eastern section of Barkley Sound (Area 23 A), produced an exceedingly high tag recovery in the catches of the south west coast populations, while runs located further north showed a progressively smaller concentration in south west coast catches and a correspondingly greater concentration in catches of the north west coast (Fig.4). The differences in the recovery from taggings of each neighbouring pair of herring runs were tested statistically using the Chi-square contingency test, and the following results were obtained:

Pairs of Runs Tested	Probability Value (P)	
	Using Actual Number of Tag Returns (detector and plant returns combined)	Using Estimated Number of Tags in the Catches (based on detector returns only).
Areas 23 A and 23 B	Less than 0.001	Less than 0.001
Areas 23 B and 24 A	" " 0.001	" " 0.001
Areas 24 A and 24 B	" " 0.001	" " 0.001
Areas 24 B and 25 A	" " 0.001	" " 0.001
Areas 25 A and 25 B	" " 0.001	" " 0.001
Areas 25 B and 26	0.001	" " 0.001
Areas 26 and 27	0.02	0.12

Regardless of whether unadjusted or adjusted recovery data are considered, all differences in recovery from taggings of adjacent runs were highly significant, with one exception. The lack of significance in the recovery pattern of tags from Areas 26 and 27 may be a result of the relatively small number of Area 27 recoveries, rather than an indication of a particularly close relationship between the runs of the two areas.

The almost equal recovery of Area 24 B tags in the catches of the two west coast populations poses the problem of which population this small run should be considered to form a part. Taking in account that the north west coast stocks have generally been less heavily exploited than the south west coast stocks it might be concluded that this run is more closely allied to the north west coast populations. However, in view of the fact that striking differences occur in the recovery pattern of Area 24 B from year to year the run will continue to be included in the south west coast stocks.

The most southerly herring run (Area 23 B) on the south west coast of Vancouver Island shows relatively great movement to the lower east coast (8.7 percent - Table XIII). The movement from runs located further north was progressively less (Fig.5). The differences in the relative movement of adjacent south west coast runs were statistically significant, but no significant differences in the movement to the lower east coast were found in the case of the north west coast runs. These results suggest that mixture of west coast and lower east coast fish probably occurs at or south of the latitude of Area 23 A.

The general pattern of movement of west coast stocks to the central and northern populations (Table XIII and Fig.5) is generally similar to that noted in the movement of west coast fish to the lower east coast. In this case, greater movement is shown by the north west coast population than by the south west coast population, and the most northerly run of the north west coast population (that of Area 27) shows a significantly more extensive migration (18.7 percent) than any other north west coast run. Differences in amount of movement of the various south west coast runs to the central and northern stocks are not statistically significant.

The pronounced movement of Area 27 fish to the north (18.7 percent) as compared to that of the neighbouring Area 26 run (2.3 percent) suggests the existence of a barrier to northerly migration between Area 26 and 27. Much consideration was given in earlier years to the status of the Area 27 herring run, and for some years it was administered as a separate stock (Tester, 1945). However, as information was accumulated indicating that the extent of southerly movement was limited to no greater degree than would be expected considering its distance from other north wes coast runs, the tendency has been to consider it a more or less typical intergradin unit.

Lower east coast population.

There is a striking contrast between the interrelation of the various lower east runs and that of the runs of the west coast populations. The distribution of lower east coast recoveries either in lower east coast and west coast catches or in lower east coast and middle east coast catches is not appreciably affected by the location of the taggings within the lower east coast sub-district (Table XIV and Fig. 6). In other words, there is no significant difference in the degree of homing or the extent of emigration between fish tagged in the most northerly lower east coast area (Area 17 A) and fish tagged in the more southerly lower east coast area (Area 18). The various runs of lower east coast herring are unlike those of most other herring populations in failing to show significantly loss intermixture with increase in distance separating the spawning grounds of the runs. The remarkable homogeneity of the lower east coast herring is probably in some way associated with the single inshore migration route of the population (Stevenson, 1954). As pointed out previously, herring move inshore through the Strait of Juan de Fuca and proceed in a northerly direction through the narrow channel between the lower east coast of Vancouver Island and a long chain of small islands which parallel the coast. In 1938-39, direct evidence of a northerly movement through the sub-district during the fishing season was obtained through tagging on the fishing grounds (Hart and Tester, 1939). Thus, whether or not fish tagged in one lower east coast area are recovered in the catches of that area in the following fishing season depends largely on where along this inshore migration route the fishing fleet happens to locate the fish.

Middle east coast population.

Analysis of recovery data from middle east coast taggings (Table XV and Fig. 7) suggests that the middle east coast runs intermingle to a much less extent than the lower east coast runs. Two patterns of association are discernible in the middle east runs: (1) the runs of the more southerly areas of the sub-district (Areas 14 and 16) show significantly more extensive movement to the lower east coast than the runs of the more northerly areas (Area 13 and 15), and (2) the runs of the more westerly areas (Areas 13 and 14) show greater movement (also statistically significant) to herring populations north of the middle east coast (i.e., to the upper east coast, central, and northern sub-districts) than the runs of the more easterly areas (Areas 15 and 16).

The large southerly movement of fish from Areas 14 and 16 is presumably related to the proximity of these areas to the main areas of inshore concentration of the lower east coast stocks. It appears that this emigration takes place directly and occurs within the Strait of Georgia, probably during the fall and winter.

The relatively free intermingling between herring of Areas 13 and 14 and the strong movement of these fish to northerly stocks is taken as evidence that these runs comprise the main migratory middle east coast stocks that seasonally move through Discovery Passage, Johnstone Strait, and Queen Charlotte Strait to off-shore feeding grounds. The runs of Areas 15 and 16 are considered to be largely resident stocks which are partially separated from the migratory runs by the Strait of Georgia.

The only middle east coast tags recovered on the south west coast were from taggings in Areas 14 and 16. In view of the extensive southerly emigration from Areas 14 and 16, it is supposed that the movement represented by these recoveries takes place by way of the Strait of Juan de Fuca - the route of migration of lower east coast fish. Area 14 taggings produced more recoveries in the north west coast that other middle east coast taggings, and it is considered that this emigration is most likely a consequence of offshore migration through Discovery Passage and Johnstone Strait. The total number of west coast recoveries of middle east coast fish was too few to permit statistical analysis.

Central and northern populations.

Tagging in the central and northern populations was not sufficiently intensive to permit a detailed analysis of the relationship of the individual runs within each population. Considerable doubt exists that all the main runs have been tagged, and, of those that were tagged, recoveries were frequently too few to permit statistical treatment. From the data that are available, however, it appears that each population contains a series of intergrading runs similar to that found within the populations of the west coast of Vancouver Island.

The results of two taggings made in 1951 in the north central sub-district and two taggings carried out in the northern sub-district in 1945 are considered (Table XVI and Fig.8). Both sets of data show that the relative amount of emigration from the two runs within the same population was dependent upon the geographical location of the runs, and hence the distance of movement. The more northerly-located north central run showed significantly greater movement to the northern population (16.7 percent) than the more southerly-located run (4.9 percent). Similarly, the more southerly-located northern run showed a significantly greater southerly movement (88.9 percent) than the more northerly-located run (66.0 percent). In the latter case, it will be noted that recovery in central catches exceeded the homing tendency, but this was primarily a result of the unusually low exploitation of northern stocks in the 1945-46 fishing season.

SUMMARY

The tagging and tag recovery program on British Columbia herring was undertaken primarily to determine the degree of discreteness of herring populations and to delineate the region of inshore concentration of each.

From 1936 to 1951, the number of herring tagged amounted to 555,521 comprising 310 individual taggings. All the fish in each individual tagging were tagged at the same place and at the same time, the object being to have each such tagging consist of fish from a single school.

Taggings were carried out on all main herring stocks in British Columbia waters, but certain stocks were tagged more consistently and more intensively than others. In the early years of the investigation a general coastwise tagging program was undertaken, but in later years intensive tagging was carried out on the major herring stocks, one after another.

Tagging was undertaken in three main periods of the year; (1) in late winter and early spring after the fishery was over and when the fish were in spawning condition, (2) in the early fall (in the Strait of Juan de Fuca) at which time fish were moving inshore, and (3) during the period of the fishery. Most of the individual taggings (89 percent) took place on spawning or spent fish. Recovery from these taggings was particularly useful in determining extent of intermingling of stocks since at least six months elapsed between tagging and recovery. Recovery was not possible until the herring returned to inshore waters from summer offshore feeding grounds and were subjected to the regular fall and winter fishery.

The tagging procedure involved catching and impounding the herring, making a small incision in the body wall of each fish, and inserting a nickel-plated iron tag through the incision into the body cavity. In the course of the investigation numerous variations in procedure occurred with regard to type of impoundment, length of time the fish were impounded before tagging, method of making the incision, and type of tag used. Differences in recovery arising from these changes in procedure were not statistically significant. It was found,however, the overcrowding of fish in the impoundments prior to tagging led to reduced recovery of the tagged fish..

Results of experiments suggested that tagging mortality was at least 60 percent. These experiments showed that great care was required in handling the fish prior to tagging and in inserting the tags,

Differences were found in tag recovery from taggings carried out by experienced and by inexperienced taggers, but such differences were seldom significant.

Two types of equipment were used in the processing plants to recover tags: electronic tag detectors and magnets. The essential features of detector recovery were an electrically-energized coil placed in a conveyor chute of the plant,which detected the passage of a tag in the chute, and a trap-door system located a few feet further down the chute, which automatically by-passed the tagged fish. The tag detectors were of two types: the bridge type, in which the presence of a tag created an impulse by upsetting the electrical balance of four coils in Wheatstone bridge formation, and the induction type, in which a tag created an impulse by inducing a current in a secondary coil which was connected to a coil with a primary winding. Two models of each type of detector were operated.

The second method of recovering tags involved the installation of electromagnets and permanent magnets in the meal-line of herring reduction plants. Tags passing over the magnets with the herring meal were held and later picked off the magnets by plant employees. Tags were also obtained from cracks and crevices

of plant machinery, and these tags together with those from magnets were referred to as plant recoveries. A reward of 50 cents a tag was paid to plant employees for returning the tags to herring investigators with pertinent information on date and place of capture.

The chief problems in detector recovery were maintenance of high sensitivity in the field of the detector coil and proper timing of the opening of the trap-door to ensure the recovery of tags detected by the coil. The basic difficulty in maintaining high sensitivity to the presence of tags stemmed from the fact that the impulse created by a tag was never greater (and generally less) than twice the general level of inherent interference within the detection circuit. Outside interference, arising from several sources, sometimes created impulses in the detection circuit which exceeded that produced by tags, resulting in low detector efficiency. Various methods were employed to reduce the effect of outside interference, but they were only partially successful.

Because of the high cost of manufacturing, maintaining, and operating tag detectors it was possible to install detectors in relatively few processing plants. On the other hand, magnets were installed in all plants at relatively low cost. Over six times as many tags were recovered by magnets and plant machinery as by detectors.

Plant recoveries were less useful in studying herring movements than detector recoveries because a certain amount of doubt that always existed with regard to the exact fishing locality from which each plant recovery was taken. This uncertainty arose from the fact that a variable period of time elapsed between the unloading of a tagged fish at a plant and the passage of the tag over the magnet. Thus,while knowledge of where a particular load of fish was caught readily identified the area of capture of detector recoveries, this knowledge was insufficient to give positive identification of the locality of capture of tags taken from magnets or plant machinery. The extent of the time lag in various plants was investigated, and this information was sometimes helpful in interpreting the area of recovery of plant returns. The efficiency of plants in recovering tags from the catches was generally greater than the efficiency of detectors.

The general method of studying the intermingling of herring stocks necessitated relating the actual numbers of tag recoveries to the estimated total number of tags in the catches. Certain assumptions were involved in this method of analysis, they pertained to rate of exploitation, recruitment, intensity of tagging, and random distribution of tagged fish in the stocks.

The total number of tags recovered in the fishing seasons from 1936-37 to 1951-52 was 20,328 or 3.7 percent of the number of fish tagged. The percentage recovery was considerably greater in the later years of the study than in the early years, due mainly to increased opportunity for plant recovery and generally increased exploitation of the herring stocks. All but 14 of the 310 individual taggings produced returns. Recovery of tags decreased with increase in time between tagging and recovery.

The recovery data revealed a strong tendency for tags to be recovered in or near the area of tagging, indicating that most herring return in the fall and winter to the inshore area in which they spawned the previous spring. It was concluded that British Columbia herring comprise a limited number of more or less distinct populations, a conclusion which is in general agreement with results from studies on meristic characters, age-composition, and growth.

Migratory and resident herring populations were distinguished on the basis of population abundance, seasonal migration, growth and age composition, location of spawning grounds, and homogeneity of individual runs. Eight migratory populations were identified according to general coastal regions in which they spawn and are fished - (1) the east coast of the Queen Charlotte Islands, (2) northern mainland coast, (3) north central mainland coast, (4) south central mainland coast, (5) middle east coast of Vancouver Island, (6) lower east coast of Vancouver Islands, (7) south west coast of Vancouver Island, and (8) north west coast of Vancouver Island. There is a tendency for the main fishing and spawning grounds of each population to be located in the more southerly part of the region (or sub-district) of their inshore concentration, and for movement within each sub-district to be northerly. This has suggested that the route of migration from offshore feeding grounds to inshore waters is also northerly, and this indication is supported by the only tag recovery taken from offshore waters. The migratory populations provide about 95 percent of the annual herring catch.

The numerous small resident populations are mostly concentrated in the long inlets of the north central, south central and upper east coast regions. Information on their movements is sparse since not all have been tagged. They show a considerable degree of isolation from neighbouring migratory populations and from each other.

Herring of resident populations are relatively slow-growing, suggesting that their summer feeding areas are less productive than the offshore feeding areas of the migratory stocks.

The recovery data indicated that about one-quarter of the fish of each population emigrated to other populations. Fish of the middle east coast of Vancouver Island showed the greatest emigration (45 percent) an indication that this population was the least independent stock. Least emigration occurred from the lower east coast population (16 percent).

The amount of emigration from one population to another varied with the distance separating the populations. It was concluded that the herring of British Columbia tend to form a series of intergrading populations.

The individual herring runs of the south west coast and north west coast of Vancouver Island showed a type of intergradation which resembled, on a smaller scale, the intergradation of the major migratory populations. There was evidence that the individual runs within the northern and north central populations also followed this pattern. In contrast, the runs within the population of the lower east coast of Vancouver Island appeared to be freely mixing and homogeneous, showing no differential emigration outside the sub-district.

Emigration from individual herring runs of the middle east coast resembled that of the runs of the west coast populations in certain respects. However, the presence within this sub-district of resident or partially resident stocks, as well as a migratory stock, resulted in a relatively complicated situation.

REFERENCES

DAHLGREN, E.H.	1936	"Further development in the tagging of the Pacific herring (Clupea pallasii)." Journal du Conseil International pour l'Exploration de la Mer, 11, 2, pp.229-247.
HART, J.L.	1937	"Tagging British Columbia pilchards (Sardinops caerula (Girard)); Methods and preliminary results". Rept. British Columbia Fish. Dept., 1936, pp.49-54.
" " "	1943	"Tagging experiments on British Columbia pilchards." Jour. Fish. Res. Bd., Canada, 6, 2, pp.164-182.
HART, J.L. and TESTER, A. L.	1937 a	"The tagging of herring (Clupea pallasii) in British Columbia: Methods, apparatus, insertions, and recoveries during 1936-37." Rept. British Columbia Commissioner of Fisheries, 1936, pp.55-67.
" "	1937 b	"Tagging mortality of herring". Biol. Bd. Canada, Progress Reports (Pacific), No.31, pp.19-20.
" "	1938	"The tagging of herring (Clupea pallasii) in British Colombia: Apparatus, insertions, and recoveries during 1937-38." Rept. British Columbia Fish. Dept., 1937, pp. 64-90.
" "	1939	"The tagging of herring (Clupea pallasii) in British Columbia: Apparatus, insertions, and recoveries during 1938-39." Rept. British Columbia Fish. Dept., 1938, pp.51-78.
" "	1940	"The tagging of herring (Clupea pallasii) in British Columbia: Insertions and recoveries during 1939-40". Rept. British Columbia Fish. Dept., 1939, pp.42-66.
HART, J.L., TESTER, A.L. and BOUGHTON, R.V.	1942	"The tagging of herring (Clupea pallasii) in British Columbia: Apparatus, insertions and recoveries during 1941-42." Rept. British Columbia Fish. Dept., 1941, pp. 49-78.
HART, J.L., TESTER, A.L. and MCHUGH, J.L.	1941	"The tagging of herring (Clupea pallasii) in British Columbia: Insertions and recoveries during 1940-41." Rept. British Columbia Fish. Dept., 1940, pp.47-74.

JANSSEN, J.F. 1937 "First report of sardine tagging in California." California Fish and Game, 23, 3, pp.190-204.

ROUNSEFELL, G.A. and DAHLGREN, E.H. 1933 "Tagging experiments on the Pacific herring (*Clupea pallasii*) Journal du Cons.Int. p. l'expl. de la Mer, 8,3,pp.371-384.

STEVENSON, J.C. 1946 "Growth of herring along the upper east coast of Vancouver Island." Fish.Res.Bd.Canada, Progress Reports (Pacific), No.67, pp.32-35.

" " " 1949 "The mortality of herring at Mud Bay, March 1949." Fish. Res.Bd. Canada,Pacific Biological Station Circular, No.18, pp.1-3.(Multilithed).

" " " 1950 "Results of the west coast of Vancouver Island herring investigation, 1948-49." Rept. British Columbia Fish.Dept., 1948, pp.37-85.

" " " 1954 "A research project in herring management." Trans.Seventh British Columbia Resources Conference,Victoria, B.C.

STEVENSON, J.C. and LANIGAN, J.A.[1] 1950 "Results of the west coast of Vancouver Island herring investigation, 1949-50." Rept. British Columbia Fish.Dept., 1949, pp.41-80.

STEVENSON, J.C. and OUTRAM, D.N. 1953 "Results of investigation of the herring populations on the west coast and lower east coast of Vancouver Island in 1952-53." Rept.British Columbia Fish.Dept.1952,pp.57-84.

STEVENSON, J.C. HOURSTON, A.S., and LANIGAN, J.A. 1951 [1] "Results of the west coast of Vancouver Island herring investigation, 1950-51."Rept. British Columbia Fish.Dept., 1950, pp.51-84.

STEVENSON, J.C. HOURSTON, A.S. JACKSON, K.J. and OUTRAM, D.N. 1952 [1] "Results of the west coast of Vancouver Island herring investigation, 1951-52." Rept. British Columbia Fish.Dept., 1951, pp.57-87.

TESTER, A.L. 1937 "Populations of herring (*Clupea pallasii*) in the coastal waters of British Columbia."Jour.Biol.Bd.Canada,3,2, pp.108-114.

" " " 1941 "Queen Charlotte Sound herring." Fish.Res.Bd.Canada, Progress Reports (Pacific), No.47, pp.10-11.

" " " 1944 "Tagging of herring (*Clupea pallasii*) in British Columbia: Insertions and recoveries during 1943-44."Rept.British Columbia Fish.Dept., 1943, pp.53-74.

" " " 1945a "Tagging of herring (*Clupea pallasii*)in British Columbia: Insertions and recoveries during 1944-45." Rept.British Columbia Fish.Dept., 1944, pp.45-61.

" " " 1945b "A new type herring tag detector."Fish.Res.Bd.Canada, Progress Reports (Pacific),No.64,pp.62-63.

" " " 1946 "Tagging of herring (*Clupea pallasii*)in British Columbia: Insertions and recoveries during 1945-46." Rept.British Columbia Fish. Dept., 1945, pp.43-66.

TESTER, A.L. and BOUGHTON, R.V. 1943 "Tagging of herring (*Clupea pallasii*) in British Columbia: Apparatus, insertions, and recoveries during 1942-43." Rept.British Columbia Fish.Dept.,1942, pp.44-69.

TESTER, A.L. and STEVENSON, J.C. 1947 "Results of the west coast of Vancouver Island herring investigation,1946-47."Rept.British Columbia Fish.Dept.,1946, pp.42-71.

" " "[1] 1948 "Results of the west coast of Vancouver Island herring investigation, 1947-48." Rept. British Columbia Fish.Dept. 1947, pp.41-86.

[1] Reprints were published in year following [illegible]

LEGENDS TO FIGURES

Fig. 1 - Map showing the statistical areas into which the British Columbia coast is divided, the sub-districts marking the regions of inshore distribution of herring populations, the administrative districts, and the location of herring processing plants.

Fig. 2 - The destination of herring moving through the Strait of Juan de Fuca in the fall, as determined by tagging near Sooke - data from Table VIII.

Fig. 3 - The extent of emigration from the various herring populations of British Columbia - data from Table IX(1). (Length of arrows is proportional to distance of emigration, and area of circles is indicative of average annual catch).

Fig. 4 - The extent of intermixture of individual herring runs of the south west and north west coasts of Vancouver Island - data from Table XII (1). (Area of circles is indicative of average annual catch of each run.

Fig. 5 - The extent of movement of individual herring runs of the south west and north west coasts of Vancouver Island to the lower east coast of Vancouver Island and to the northern-central sub-districts - data from Table XIII. (Area of circles is indicative of average annual catch of each run).

Fig. 6 - The extent of movement of individual herring runs of the lower east coast of Vancouver Island to the middle east coast of Vancouver Island and to the west coast of Vancouver Island - data from Table XIV. (Area of circles is indicative of average annual catch of each run).

Fig. 7 - The extent of movement of individual herring runs of the middle east coast of Vancouver Island to the lower east coast of Vancouver Island and to the northern-central-upper east coast sub-districts - data from Table XV. (Area of circles in Area 13 and 14 is an indication of relative size of catch in those areas; catch in Areas 15 and 16 is negligible)

Fig. 8 - The relative movement of individual herring runs of the northern sub-district to the north central sub-district, and the relative movement of individual herring runs of the north central sub-district to the northern sub-district - data from Table XVI.

Table I.

Number of herring tagged in each area and in each season, prior to the fishing season (P), during the fishing season(F), and on the spawning ground(S).

Sub-district	Area	Time of Tagging P-prior to fishing F-in fishing season S-on spawning ground	Season of Tagging 1936 - 37	1937 - 38	1938 - 39	1939 - 40	1940 - 41	1941 - 42	1942 - 43	1943 - 44	1944 - 45	1945 - 46	1946 - 47	1947 -48	1948 - 49	1949 - 50	1950 -51	Totals
East Coast Queen Charlotte Island	2B(E)	F				400												400
Northern	4	F			755													755
		S			2696	2299	2491										5091	12577
	5	S									6049					2548		8597
North Central	6	F			1299	1799												3098
		S					1797				4973					6578	5092	18440
South Central	7	S		1395	2192	2197	2685	1497	3493	3011	6205					4404	7507	34586
	8	F			1195													1195
		S					1495											1495
South Central (inner part)	9	S			1297	300				3121								4718
	10	S									3172					1012	3027	7211
Upper East Coast of Vancouver Is.	12	S				3796	200	5465	5077	6023	11979	1691						34231
Middle East Coast of Vancouver Is.	13	S				997		1498	2989	3999	3319	1617						14419
	14	S		1196	1000	1197		2000	3695	3190		4208	496	2514	2531	2019		24046
	15	S				1498		2988	2495	3830	3166	3085	5121	1988	2984	4046	4087	35288
	16	S			999		998	1579	5489	4043		2754						15862
Lower East Coast of Vancouver Is.	17 A	S	700	2587	2942	2186	3949	4007		9507	3555	3952	2008	6079	2013	6090	5129	54704
	17 B	F	2300		447													2747
		S			997	1200		1993	6893	5021	1934	4506	3525	3049	1996	3082	2058	36254
	18	F	4790	4086	2078	495	1197											12646
		S	1198	699		1499		1494			3227	1570			3494		4074	17255
	19	S			152													152
	20	P	1500	1199	1454	897		496	697		1409						991[1]	8643
South West Coast of Vancouver Is.	23	F		2798	99													2897
		S	2097	2299	1494	1397	2195					7459	15180	9219	7650	8025	8583	65598
	24	S		899	1363	2150	1193			4220		7462	6583	5579	3036	2011	4077	38573
North West Coast of Vancouver Is.	25	F			197													197
		S	1697	2288	1491	2195	2192					7503	8638	9017	11170	10081	8109	64381
	26	S	1898		1599	1100	2190					5724		3558		4510		20579
	27	F			798													798
		S		1198		1595	1989							4574		2029		11385
Puget Sound and vicinity, Washington, U.S.A.		S		797	497	500												1794
Total			16180	21441	27041	29697	21571	23017	30828	45965	48988	51531	41551	45577	34874	56435	57825	555521

1) Tagging of 991 herring in Area 20 (Sooke) which took place in September and October, 1951, i.e., in the 1951-52 season, is for convenience listed under 1950-51 taggings.

Table II.

Numbers of plant recoveries (P) and detector recoveries (D) in each season, according to the plants at which the recoveries were made.

Season	Type of Tag Recovery-- P-Plant Recovery D-Detector Recovery	Number of Recoveries According to Processing plants																						Miscelleneous Recoveries	All Plants
		Kildonan	Ecoole	Toquart	Port Albion	Nootka	Ceepeecee	Hecate	Imperial	Gulf of Georgia	Colonial	Phoenix	North Shore	Shingle Bay	Galiano Is.	Redonda Bay	Alert Bay	Namu	Butedale	Port Edward	Seal Cove	Tuck Inlet	Pacofi		
1936-37	P																								–
	D														43^{+}										43
1937-38	P	76	289	120	199	38	54	2																	778
	D				55^{x}										104^{+}										159
1938-39	P	44			64	119	169		217									56	15	112		88	0		884
	D				5^{x}	34^{+}									28^{+}									1	68
1939-40	P	26			54	110	87		90								8	104	87	74		45	2	1	688
	D				2^{x}	12^{+}																			14
1940-41	P	77		33	42	89	72		24								227	37	60	9		2	4		676
	D				20^{x}	88^{+}																			108
1941-42	P	40			49	169	95		4								14	10	20	23		2			426
	D				0^{x}				42^{+}															1	43
1942-43	P				17	64	59		24									12	9					5	190
	D								55^{+}	22^{x}															77
1943-44	P	2			9	4			4	4						6	222	168	128	63					610
	D								95^{+}	16^{x}															111
1944-45	P	3			16	41	26		2	26							58	62	18	7					259
	D								199^{+}								1^{+}								200
1945-46	P				13		7		8	26							102	41	189	58					444
	D								145^{+}								$57^{\wedge}$								202
1946-47	P	28	26		137	29	43	12	13	20							37		26	16					387
	D	$29^{\wedge}$				0^{z}			328^{+}																357
1947-48	P	123	424		311	199	170	79	4	221		2				18	44	27	34	6				1	1663
	D	$127^{\wedge}$				15^{z}			420^{+}																562
1948-49	P	303	212		263	354	411	391	172	243	189	140	136			28	38	21	21	18					2940
	D	$27^{\wedge}$				0^{z}			173	30															230
1949-50	P	146	112		160	93	58	16	118	78	114	5	81				3	12							996
	D	2^{x}				4^{z}			66^{+}	$65^{\wedge}$															137
1950-51	P	101	60		212	204	181		231	86	161	53	64	40			86	230	244	105					2058
	D	10^{x}							146^{+}	$103^{\wedge}$															259
1951-52	P	43			42	132	244	33	497	235	447	369	317	42			56	686	753	522	95				4513
	D	0^{x}							59^{+}	$178^{\wedge}$											9^{z}				246
All years	P	988	1121	153	1584	1645	1676	533	1408	939	911	569	598	82	–	52	894	1466	1599	1013	95	137	6	9	17512
	D	195			82	153			1728	414					175		58				9				2816

+ x ^ z: Numbers of detector recoveries made by first model of bridge detector are indicated by +, second model of bridge detector by ^{x}, first model of induction detector by ^, and second model of induction detector by ^{z} .

Type of Detector	Seasons of Detector Operation																Approximate Average Efficiency
	1936 - 37	1937 - 38	1938 - 39	1939 - 40	1940 - 41	1941 - 42	1942 - 43	1943 - 44	1944 - 45	1945 - 46	1946 - 47	1947 - 48	1948 - 49	1949 - 50	1950 - 51	1951 - 52	
Bridge Type (Model 1)	90	90	70	50	70	80	90	90	90	90	90	90	55	70	80	75	80
Bridge Type (Model 2)	–	50	<10	<10	20	0	65	20	–	–	–	–	–	<10	50	0	25
Induction Type (Model 1)	–	–	–	–	–	–	–	–	–	70	40	75	45	70	60	80	65
Induction Type (Model 2)	–	–	–	–	–	–	–	–	–	–	0	<10	0	10	–	<10	5

Table III.

Percentage efficiency of tag detectors in recovering tags; underlined estimates are based on results of specific tests, whereas those not underlined are approximations.

Table IV.

Percentage of efficiency of plants in various years in recovering test tags, with numbers of individual tests indicated in parantheses.

Plants	Years of Tests							
	1939 - 40	1946 - 47	1947 - 48	1948 - 49	1949 - 50	1950 - 51	1952 - 53	Average
Kildonan	66(1)	74(3)	83(2)	84(2)	92(1)	88(2)	-	81(11)
Ecoole	-	33(3)	78(2)	90(1)	98(1)	90(1)	-	78(8)
Port Albion	100(2)	90(3)	94(2)	98(1)	93(2)	91(2)	-	94(12)
Nootka	88(5)	77(1)	58(2)	78(1)	68(2)	88(3)	82(1)	77(15)
Ceepeecee	24(3)	50(2)	76(2)	84(1)	-	68(1)	69(2)	62(11)
Hecate	-	56(1)	53(2)	79(1)	-	-	54(1)	60(5)
Imperial	82(1)	-	-	68(1)	80(2)	82(3)	86(7)	80(14)
Colonial	-	-	-	68(1)	74(2)	74(3)	83(3)	75(9)
Gulf of Georgia	-	-	-	99(2)	58(2)	50(3)	83(8)	72(15)
Phoenix	-	-	-	-	-	86(1)	94(5)	90(6)
North Shore	-	-	-	-	-	54(1)	97(3)	76(4)
Alert Bay	70(1)	-	-	-	-	-	78(1)	74(2)
Namu	68(2)	-	-	-	-	78(1)	91(2)	79(5)
Butedale	98(2)	-	-	-	-	-	86(1)	92(3)
Port Edward	90(2)	-	-	-	-	78(1)	94(3)	87(6)
Seal Cove	-	-	-	-	-	-	63(1)	63(1)
Tuck Inlet	95(2)	-	-	-	-	-	-	95(2)
Average	78(21)	63(13)	74(12)	83(11)	80(12)	77(22)	82(38)	78(129)

Table V.

Results of tests made in five different years to show the time lag in recovery of tags in various plants.

Fishing season	Name of plant tested	No. of tests	No. of tags used in Tests	Percentage of Recovered Tags, Recovered after				
				1 day	2 days	3 days	1 week	2 weeks
1939-40	Kildonan	1	50	0	0	0	91	91
	Port Albion	2	24	38	42	42	88	100
	Nootka	5	60	13	30	34	68	89
	Ceepeecee	3	45	18	18	18	45	91
	Imperial	1	50	100	100	100	100	100
	Alert Bay	1	20	100	100	100	100	100
	Namu	2	40	0	0	0	41	96
	Butedale	2	40	97	97	100	100	100
	Port Edward	2	40	58	78	89	92	92
	Tuck Inlet	2	40	89	100	100	100	100
	All Plants	21	409	51	56	58	82	96
1946-47	Kildonan	3	149	16	22	24	40	66
	Ecoole	3	143	0	2	13	40	77
	Port Albion	3	148	56	80	83	90	98
	Nootka	1	48	19	35	35	62	100
	Ceepeecee	2	99	26	38	56	90	100
	Hecate	1	50	93	96	100	100	100
	All Plants	13	637	35	46	52	70	90
1947-48	Kildonan	2	100	17	46	54	80	92
	Ecoole	2	98	0	7	7	12	12
	Port Albion	2	98	29	71	79	98	100
	Nootka	2	95	29	55	80	96	100
	Ceepeecee	2	100	0	55	55	92	96
	Hecate	2	97	2	6	45	75	84
	All Plants	12	588	13	40	53	76	91
1948-49	Kildonan	2	100	24	45	51	71	73
	Ecoole	1	50	0	84	84	87	98
	Port Albion	1	50	69	88	98	98	98
	Nootka	1	49	3	29	66	82	92
	Ceepeecee	1	50	60	60	74	88	90
	Hecate	1	48	0	8	8	11	11
	Imperial	1	50	24	65	91	100	100
	Gulf of Georgia	2	98	26	87	88	100	100
	Colonial	1	50	0	59	68	74	74
	All Plants	11	545	23	58	70	79	82
1949-50	Kildonan	1	50	89	89	96	100	100
	Ecoole	1	50	14	31	31	100	100
	Port Albion	2	100	95	95	95	100	100
	Nootka	2	100	49	59	60	60	98
	Imperial	2	98	15	24	28	71	96
	Gulf of Georgia	2	98	37	56	56	56	58
	Colonial	2	100	23	43	81	97	100
	Phoenix	1	50	0	0	0	0	0
	All Plants	13	646	40	50	56	73	82

Table VI.

Number of recoveries (plant and detector returns combined) and percentage recovery (in parantheses) from each season's tagging on the spawning grounds, showing the recovery in successive fishing seasons after tagging.

Year of Tagging	No. of fish tagged on spawning grounds	No. of recoveries (and percentage recovery)						Total
		1st fishing season	2nd fishing season	3rd fishing season	4th fishing season	5th fishing season	6th, 7th and 8th f. season	
1936-37	7590	34(0.45)	8(0.11)	0	0	0	0	42(0.56)
1937-38	12561	133(1.06)	98(0.78)	5(0.04)	1(0.01)	0	0	237(1.89)
1938-39	18222	402(2.21)	103(0.57)	12(0.07)	3(0.02)	0	0	520(2.87)
1939-40	25606	651(2.54)	160(0.62)	34(0.13)	20(0.08)	2(0.01)	0	867(3.38)
1940-41	23374	279(1.19)	110(0.47)	49(0.21)	10(0.04)	1 (+)	3(0.01)	452(1.92)
1941-42	22521	95(0.42)	130(0.58)	16(0.07)	23(0.10)	0	3(0.01)	267(1.18)
1942-43	30131	516(1.71)	76(0.25)	20(0.07)	5(0.02)	8(0.03)	0	625(2.08)
1943-44	45965	276(0.60)	72(0.16)	43(0.09)	22(0.05)	9(0.02)	4(0.01)	426(0.93)
1944-45	47579	525(1.10)	119(0.25)	127(0.27)	97(0.20)	20(0.04)	35(0.07)	923(1.93)
1945-46	51531	564(1.09)	285(0.55)	100(0.19)	17(0.03)	5(0.01)	7(0.01)	978(1.88)
1946-47	41551	1779(4.28)	765(1.84)	129(0.31)	26(0.06)	20(0.05)	–	2719(6.54)
1947-48	45577	2194(4.81)	287(0.63)	82(0.18)	67(0.15)	–	–	2630(5.77)
1948-49	34874	675(1.94)	261(0.75)	150(0.43)	–	–	–	1086(3.12)
1949-50	56435	1919(3.40)	1097(1.94)	–	–	–	–	3016(5.34)
1950-51	56834	3345(5.89)	–	–	–	–	–	3345(5.89)
All Years	520351	13387(2.57)	3571(0.77)	767(0.19)	291(0.08)	65(0.02)	52(0.02)	18133(3.65)

Table VII.

Detector recoveries (combined for all seasons of recoveries) according to sub-district and area of tagging; only recoveries from taggings on spawning grounds are included.

Sub-district and Area of Tagging		Sub-district and Area of Recovery															Total
		Northern	North Central	South Central		Upper E. Coast	Middle E. Coast		Lower E. Coast			South W. Coast		North W. Coast			
		5	6	7	8	12	13	14	17A	17B	18	23	24	25	26	27	
Northern	4	37									2	1					40
	5	8															8
North Central	6	7	27	2	1		1	.									38
South Central	7		2	68	51	2						1		1		1	126
South Central (inner part)	10			7	3	1	4										15
Upper East Coast	12		1		2	113	23	4	1		2	1		1			148
Middle East Coast	13				2	6	60	5	5		3			1			82
	14						16	22	9	4	26	2				1	79
	15					2	109	28	20	3	3						165
	16						10	46	25	2	6			1			90
Lower East Coast	17A						7	5	30	20	118	2		1			183
	17B							4	26	27	168	5					230
	18						1	8	11	17	86	5	1				129
	20									2	5	1					8
South West Coast	23						2	1	12	17	27	452		24	3		538
	24						1		5	1	10	119	8	50	1		195
North West Coast	25			1	1		1		2	2	6	47	3	168	7		238
	26			3	1							6		80	19		109
	27			7	1						1	1		7	7	3	27
TOTALS		52	30	88	62	124	234	123	146	95	463	643	12	334	37	5	2448

Table VIII.

Number of plant and detector recoveries, from 8,643 herring tagged in eight seasons in the Strait of Juan de Fuca (near Sooke - Area 20), according to sub-district of recovery.

	Sub-district of Recovery					
Method of Recovery	Middle E. Coast	Lower E. Coast	South W. Coast	North W. C.	Indeterminate	Total
	Recoveries taken in fishing season following tagging					
Plant	2	143	8	1	2	156
Detector	1	150	0	0	0	151
Total	3	293	8	1	2	307
	Recoveries taken in subsequent fishing seasons					
Plant	1	9	2	1	4	17
Detector	0	7	1	0	0	8
Total	1	16	3	1	4	25

Table IX.

The estimated number of tags (based on plant and detector returns) according to sub-district of tagging, in the sub-district catches, showing (1) the distribution, expressed in percentages, of each sub-district's taggings among the various sub-district catches (in parentheses), and (2) the proportions, expressed in percentages of the tags of each sub-district catch that were derived from various sub-district taggings (underlined); only recoveries from taggings on the spawning grounds were considered in the calculations.

b-district of gging	Sub-district of Recovery: East Coast, Queen Charlotte Is.	Northern	North Central	South Central	South C. (inner part)	Upper E. Coast	Middle E. Coast	Lower E. Coast	South W. Coast	North W. Coast	Totals
st Coast Queen arlotte Is.	8(100.0) 80.0										8(100.0)
rthern	2(0.2) 20.0	677(77.4) 67.2	155(17.7) 7.0	26(3.0) 0.7		3(0.3) 0.3	1(0.1) 0.1	4(0.5) 0.2	1(0.1) +	6(0.7) 0.1	875(100.0)
rth Central		243(11.8) 24.1	1566(76.3) 70.7	212(10.3) 6.0	1(+) 2.6	7(0.3) 0.6	6(0.3) 0.7	4(0.2) 0.2		13(0.6) 0.2	2052(99.8)
th Central		62(1.8) 6.2	412(12.1) 18.6	2790(82.1) 78.5	8(0.2) 21.1	35(1.0) 3.0	17(0.5) 2.1	26(0.8) 1.4	8(0.2) 0.1	41(1.2) 0.7	3399(99.9)
th Central ner part)		8(3.3) 0.8	19(7.8) 0.9	159(64.9) 4.5	24(9.8) 63.2	15(6.1) 1.3	9(3.7) 1.1	4(1.6) 0.2	1(0.4) +	6(2.4) 0.1	245(100.0)
er East Coast		1(0.1) 0.1	12(1.0) 0.5	134(10.8) 3.8	4(0.3) 10.5	1020(82.5) 86.9	46(3.7) 5.6	3(0.2) 0.2	4(0.3) 0.1	12(1.0) 0.2	1236(99.9)
dle East ast		2(0.2) 0.2	11(1.0) 0.5	58(5.3) 1.6	1(0.1) 2.6	84(7.7) 7.2	593(54.5) 71.7	300(27.6) 16.5	20(1.8) 0.4	19(1.7) 0.3	1088(99.9)
er East ast		1(0.1) 0.1	1(0.1) +	8(0.6) 0.2		3(0.2) 0.3	86(6.7) 10.4	1068(83.6) 58.9	84(6.6) 1.5	27(2.1) 0.5	1278(100.0)
th West Coast		1(+) 0.1	6(0.1) 0.3	15(0.3) 0.4		3(0.1) 0.3	39(0.7) 4.7	279(5.3) 15.4	3759(71.5) 68.1	1156(22.0) 20.0	5258(100.0)
rth West Coast		12(0.2) 1.2	33(0.5) 1.5	152(2.3) 4.3		4(0.1) 0.3	30(0.5) 3.6	125(1.9) 6.9	1644(25.3) 29.8	4495(69.2) 77.9	6495(100.0)
TOTALS	10 100.0	1007 100.0	2215 100.0	3554 100.0	38 100.0	1174 100.2	827 100.0	1813 99.9	5521 100.0	5775 100.0	21934

Table X.

Estimated number and percentage of tags in catches for taggings in each sub-district; calculations are based on plant and detector returns from spawning ground taggings for all seasons.

Sub-district of Tagging	No. of fish tagged on sp. grounds	Estimated number of Tags in catches	Estimated Percentage of Tags in catches	Combined catch of all seasons in tons[1] (x 10^3)	No. of tags per ton of catch
Northern	21174	875	4.13	293	0.003
North Central	18440	2052	11.13	187	0.011
South Central	36081	3399	9.42	274	0.012
South Central (inner part)	11929	245	2.05	16	0.015
Upper East Coast	34231	1236	3.61	80	0.015
Middle East Coast	89615	1088	1.21	123	0.009
Lower East Coast	108365	1278	1.18	569	0.002
South West Coast	104171	5258	5.05	243	0.022
North West Coast	96345	6495	6.74	188	0.035
All Sub-districts	520351	21926	4.21	1973	0.011

1) Total catch, in tons, for fishing seasons 1937-38 to 1951-52, both inclusive.

Table XI

The number of recoveries (plant and detector returns combined for all seasons) from upper east coast taggings in upper east coast catches and in catches made in areas outside the upper east coast.

Population Tagged	No. of Fish Tagged	No. of Recoveries: Upper East Coast Populations +)											% Recov.
		A	B	C	D	E	F	Total A-F	Indeterminate	Total	Outside popul.	++) Total	
C	1,976	0	3	11	1	29	0	44	5	49	9	58	2.9
D	20,304	0	21	14	51	99	0	185	40	225	64	289	1.4
E	11,951	0	7	5	15	427	0	454	37	491	72	563	4.7
Total	34,231	0	31	30	67	555	0	683	82	765	145	910	2.7

+) The "indeterminate" recoveries are plant returns from upper east coast catches, for which information was not sufficiently precise to permit assignment to any specific upper east coast locality.

++) An additional 101 plant recoveries, for which information concerning area of capture was lacking, are not included in the tabulation.

Table XII.

Tag recovery in catches on the southwest and northwest coasts of Vancouver Island from taggings of eight west coast herring runs, according to (1) unadjusted plant and detector returns (combining data from all seasons of recovery), and (2) estimated number of tags in the catches based on detector returns in the seasons from 1946-47 to 1951-52; percentage recovery in the two west coast sub-districts shown in paranthese.

Area of Tagging		Sub-district of Recovery: Southwest Coast (Areas 23 and 24)	Sub-district of Recovery: Northwest Coast (Areas 25,26 and 27)	Total
Southwest Coast 23A(south-east portion of Barkley Sound)	1	483(98.8)	6(1.2)	489
	2	476(98.6)	7(1.4)	483
23B(north-west portion of Barkley Sound)	1	1111(88.7)	141(11.3)	1252
	2	2926(90.2)	317(9.8)	3243
24A(Clayoquot Sound)	1	179(79.6)	46(20.4)	225
	2	314(75.3)	103(24.7)	417
24B(Sydney Inlet and Refuge Cove)	1	236(51.1)	226(48.9)	462
	2	610(51.8)	567(48.2)	1177
Northwest Coast 25A(Nootka Sound)	1	127(22.7)	432(77.3)	559
	2	271(21.9)	964(78.1)	1235
25B(Esperanza Inlet)	1	65(11.8)	488(88.2)	553
	2	113(8.1)	1279(91.9)	1392
26(Kyuquot Sound and Cheslesit Bay)	1	35(6.2)	529(93.8)	564
	2	55(3.2)	1653(96.8)	1708
27(Quatsino Sound)	1	3(1.5)	194(98.5)	197
	2	12(5.2)	219(94.8)	231

Table XIII.

Comparison of number of tags recovered (unadjusted returns) in lower east coast and west coast catches and in northern-central and west coast catches from taggings of various west coast runs; percentage recovery shown in paranthese.

Area of Tagging	Sub-district of Recovery					
	Lower East Coast(Areas 17A,17B and 18)	West Coast (Areas 23 to 27)	Totals	Northern and Central(Areas 4 to 10)	West Coast (Areas 23 to 27)	Totals
South West Coast						
23A	60(8.7)	633(91.3)	693			
23B	126(5.6)	2140(94.4)	2266	8(0.2)	3884(99.8)	3892
24	34(3.0)	1111(97.0)	1145			
North West Coast						
25				18(0.9)	2060(99.1)	2078
26	48(1.4)	3470(98.6)	3518	25(2.3)	1067(97.7)	1092
27				79(18.7)	343(81.3)	422

Table XIV.

Comparison of number of tags recovered (unadjusted returns) in west coast and lower east coast catches and in middle east coast and lower east coast catches from taggings of various lower east coast runs; percentage recovery shown in paranthese.

Area of Tagging	Sub-district of Recovery					
	West Coast (Areas 23 to 27)	Lower East Coast(Areas 17A,17B and 18)	Totals	Middle East Coast(Areas 13 and 14)	Lower East Coast (Areas 17A,17B and 18)	Totals
17A	22(6.4)	321(93.6)	343	23(6.7)	32(93.3)	344
17B	24(7.2)	311(92.8)	335	7(2.2)	311(97.8)	318
18	17(8.3)	188(91.7)	205	12(6.0)	188(94.0)	200

Table XV.

Comparison of number of tags recovered (unadjusted returns) in lower east coast and middle east coast catches and in northern-central-upper east coast and lower east coast catches from taggings of various middle east coast runs; percentage recovery shown in paranthese.

Area of Tagging	Sub-district of Recovery					
	Lower East Coast (Areas 17A,17B and 18)	Middle East Coast(Areas 13 and 14)	Totals	Northern,Central and Upper East Coast(A.4 to 12)	Middle East Coast(Areas 13 and 14)	Total
13	8(9.5)	76(90.5)	84	56(42.4)	76(57.6)	132
14	31(34.4)	59(65.6)	90	35(37.2)	59(62.8)	94
15	49(16.4)	250(83.6)	299	32(11.3)	250(88.7)	282
16	62(45.6)	74(54.4)	136	0	74(100.0	74

Tablo XVI.

Compar'son of number of tags (unadjusted returns) in central and northern catchos from two northern taggings and two north central taggings, one tagging of each pair being located more northorly within the sub-district than the other; percentage recovery shown in parantheso.

Sub district, Area and Locality of Tagging	Sub-district of Recovery North Central (Areas 6,7 and 8)	Northern (Areas 4 and 5)	Total
Northern (Area 5)			
Anger Island (more northerly)	33(66.0)	17(34.0)	50
Union Passage (more southerly)	48(88.9)	6(11.1)	54
North Central(Area 6)			
Racey Inlet(more northerly)	210(83.3)	42(16.7)	252
Parsons Anchorage(more southerly)	583(95.1)	30(4.9)	613

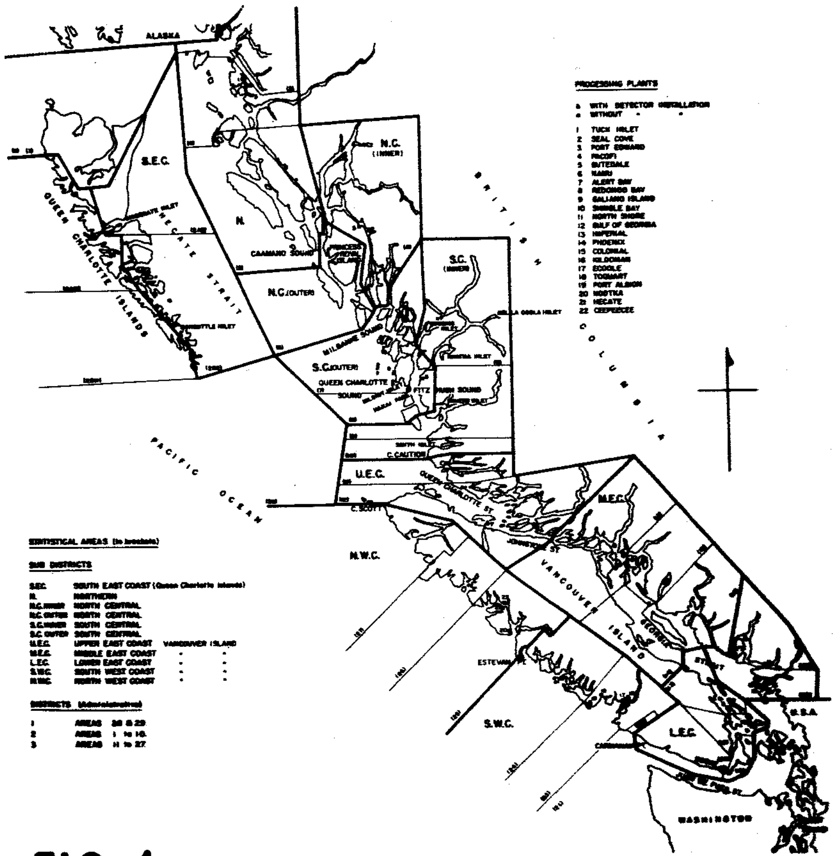
ALASKA
S.E.C.
N.
N.C. (INNER)
N.C.(OUTER)
S.C. (INNER)
S.C.(OUTER)
U.E.C.
M.E.C.
N.W.C.
S.W.C.
L.E.C.
PACIFIC OCEAN
BRITISH COLUMBIA
VANCOUVER ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE STRAIT
QUEEN CHARLOTTE SOUND
C. SCOTT
WASHINGTON
U.S.A.

FIG: 1

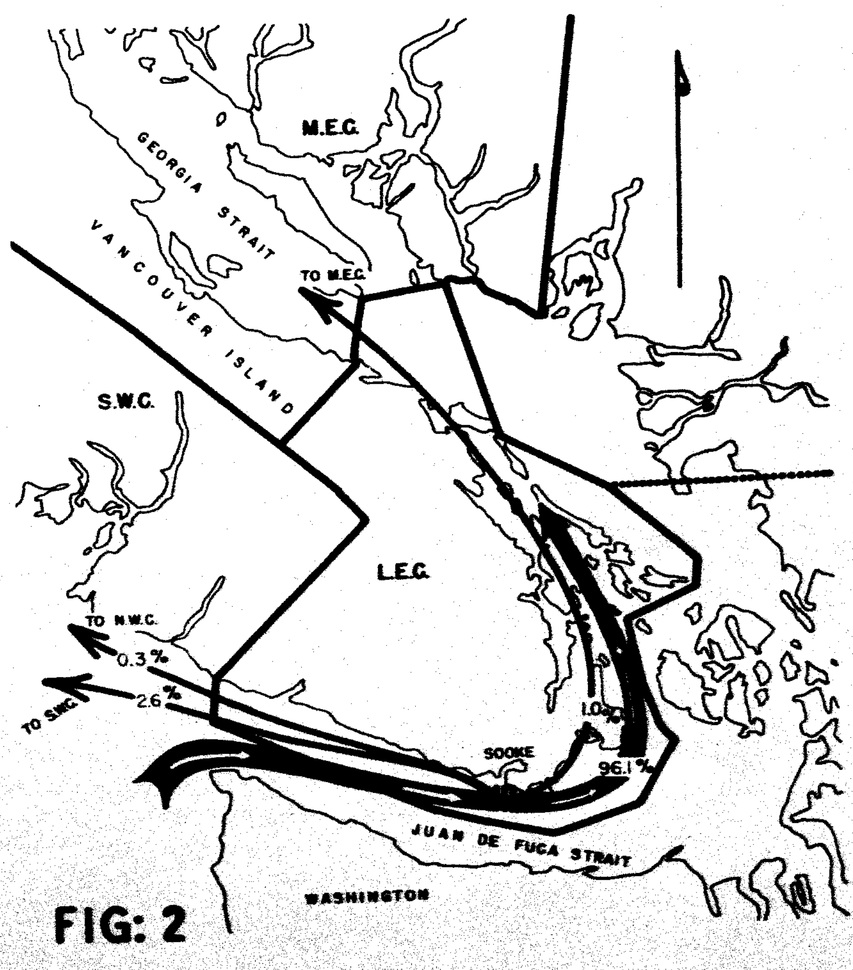
M.E.C.
GEORGIA STRAIT
VANCOUVER ISLAND
TO M.E.C.
S.W.C.
L.E.C.
TO N.W.C.
0.3%
2.6%
TO S.W.C.
1.0%
SOOKE
96.1%
JUAN DE FUCA STRAIT
WASHINGTON

FIG: 2

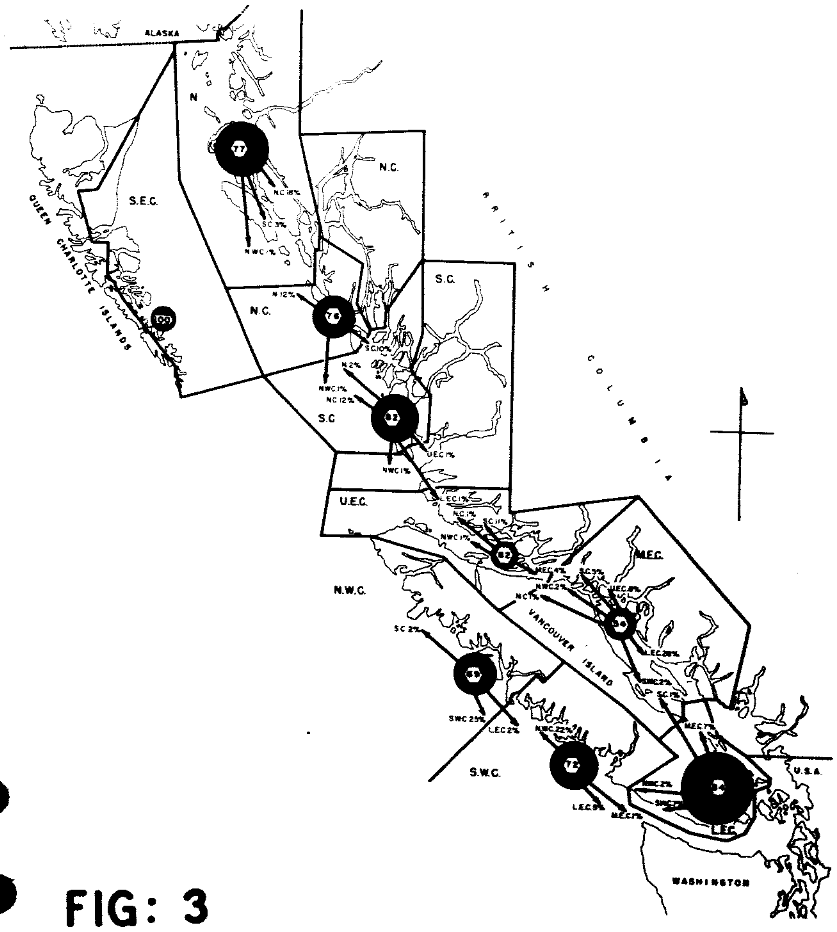

FIG: 3

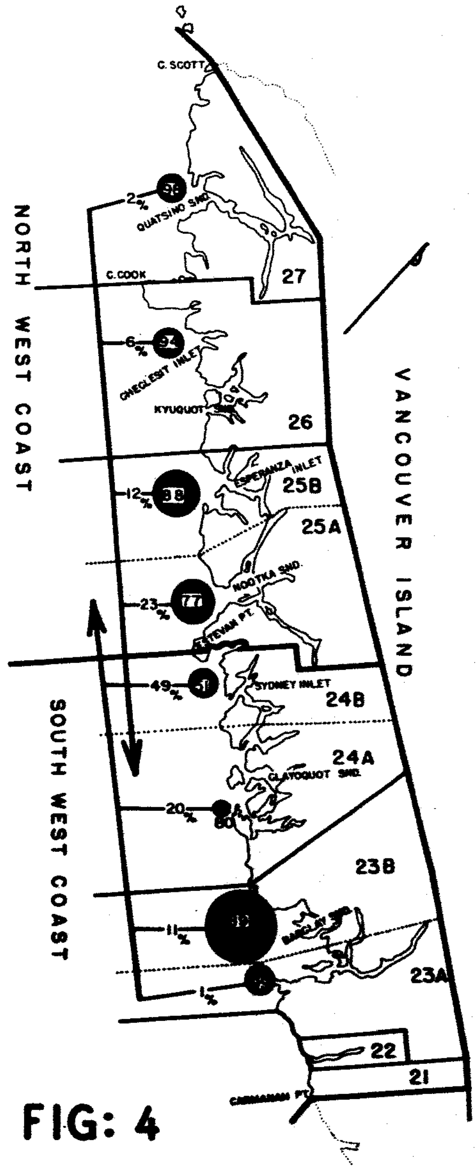

FIG: 4

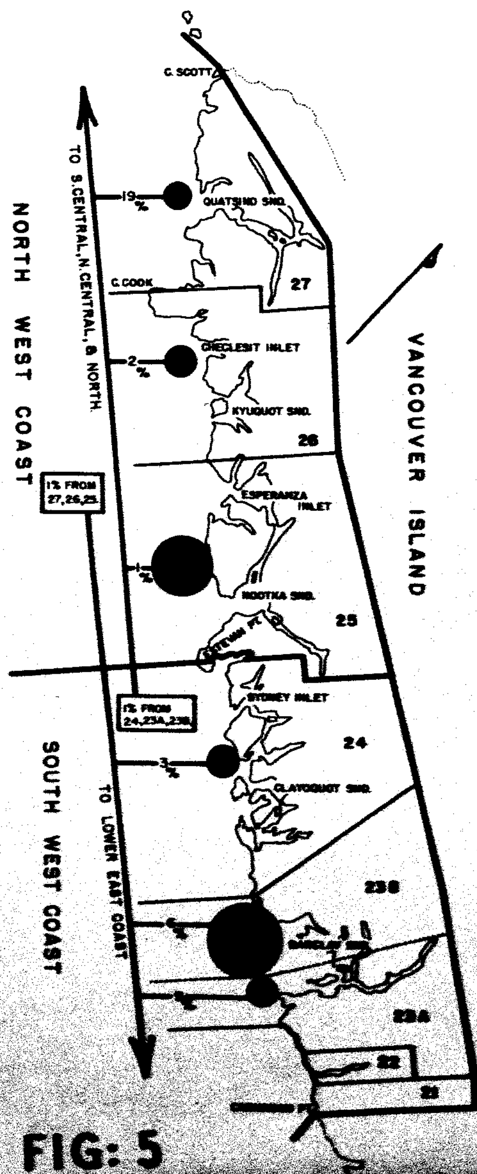

FIG: 5

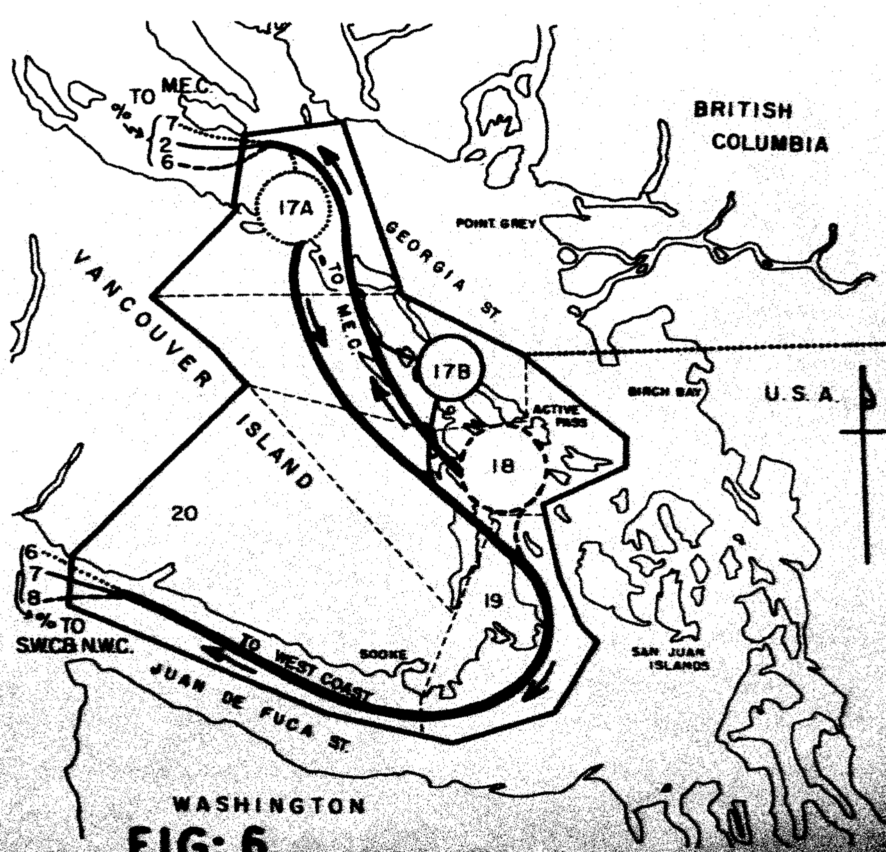

FIG: 6

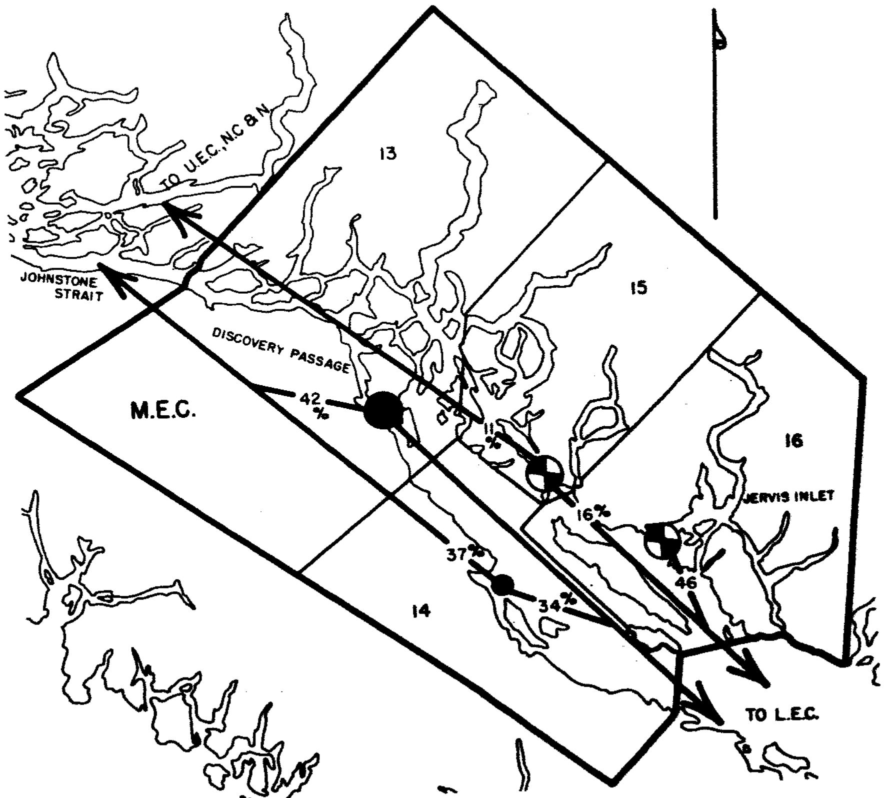
TO U.E.C, N.C & N.
13
JOHNSTONE STRAIT
15
DISCOVERY PASSAGE
16
M.E.C.
42 %
16%
JERVIS INLET
37%
46
34%
14
TO L.E.C.

FIG: 7

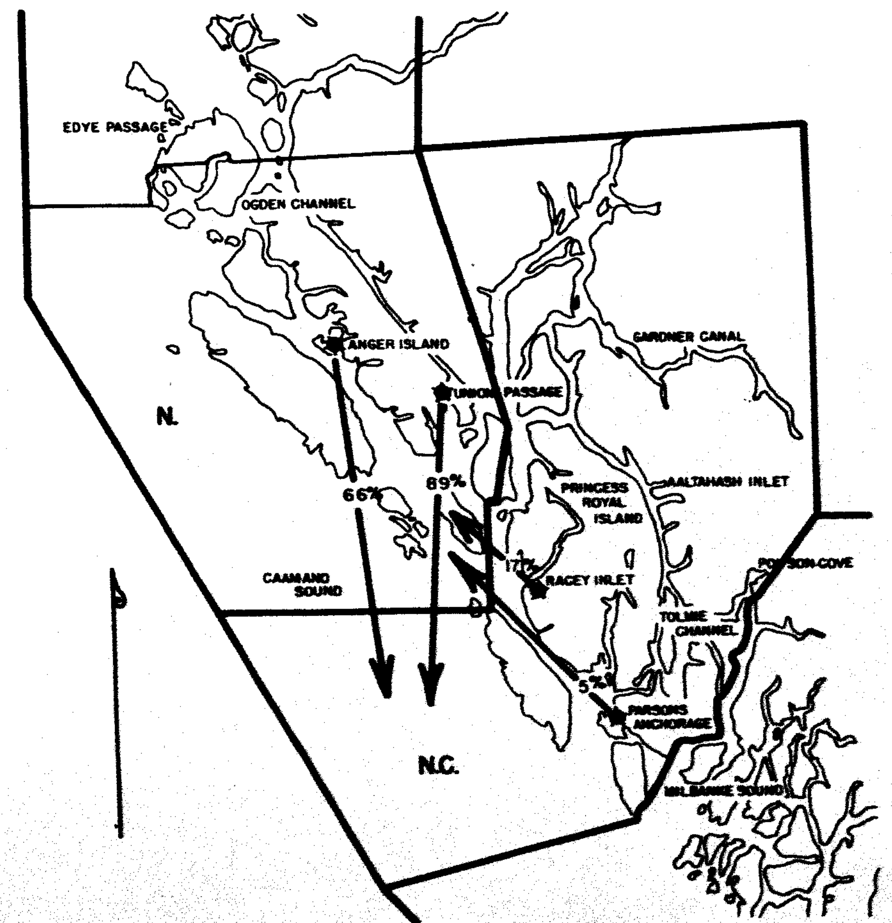
EDYE PASSAGE
OGDEN CHANNEL
GARDNER CANAL
N.
66%
89%
PRINCESS ROYAL ISLAND
CAAMANO SOUND
RACEY INLET
TOLMIE CHANNEL
PARSONS ANCHORAGE
N.C.
MILBANKE SOUND

FIG: 8