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Marking and Recovery as a Means of Studying the Movements of Fish

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by

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Introduction

A fundamental characteristic of animals is that they move from place to place. Where, when, and why they migrate pose problems of urgent concern to biologists. In no field of study is this more important than in the study of fish, where movements are frequently extensive, but seldom directly observable. The purposes underlying the determination of fish migration are obvious. Fish migration is involved in life history studies, and studies of population dynamics, and hence knowledge of it is basic in the establishment of sound policies for fisheries management. The "why" behind the migrations of fish, which has been much studied and long debated, will not be dealt with in this paper. Rather it will be its purpose to outline through reference to available literature some of the considerable progress made in determining the "where" of migration--progress due largely to the development of the technique of marking fish, releasing them, and subsequently recapturing them.

When this procedure was first practiced, it cannot be stated with certainty, but probably first honors should go to Frederick II, Emperor of Germany, who (according to an editorial in Endeavour, January, 1948) "typified his love for experiment by ringing, in 1230, a pike which was long afterwards caught and presented to the Elector Palatine". In resent

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years Emperor Frederick's procedure has been employed more and more widely, and large amounts of data are available on the migrations of commerical and sport fish in many parts of the world.

Migrations of clupeid fishes

Considerable work has been done on the tagging of adult clupeids, especially on the Pacific coast of North America where large tagging programs have been carried out on pilchards and herring. The results relating to the migration of pilchards (California sardine) are given by Hart (1943) and Clark and Janssen (1945). The studies undertaken between 1935 and 1943 involved tagging with internal metal tags on fishing grounds from British Columbia to Magdalena bay, Mexico. Extensive movements along the coast were shown. Fish tagged in northern Mexican waters were taken as far north as San Francisco, while some fish tagged off British Columbia were captured in Californian waters. Marked fish appeared to disperse gradually over the range, and the rapidity of dispersal was correlated with size of fish, larger tagged fish migrating more rapidly than smaller fish. There was evidence that the southern limit of migration did not include the most southerly area of tagging at Magdalena bay in Mexico. Fish of the latter area were not recovered in the major fisheries. Vertebral data also suggested that these fish were an essentially discrete group. Hart pointed out that there were indications that although the main body of fish left British Columbia fishing grounds in autumn, some remained throughout the winter in the inlets, cut off from general migration by local conditions.

Tagging and recovery of herring in British Columbia waters was begun in 1936 and is still going on. Fish are tagged internally in the spring spawning season and are recovered in the subsequent fall and winter fisheries by means of tag-detectors and magnets in the reduction plants. Analysis of the recoveries has been published annually in the Reports of the British Columbia Fisheries Department. As a result of these studies the major herring populations of British Columbia have been fairly well delineated with respect to the area of their spawning migration. Intensive tagging on the populations of southern British Columbia in recent years has given rather precise data relating to movement within and between populations, and a program is now underway in the north to give more accurate information on the extent of the northern populations.

Much effort has been devoted to the study of the west coast of Vancouver island herring populations in recent years. Approximately 140,000 fish were tagged during the last five years in this population. Percentage recovery has varied from 1 to 8 per cent, the recovery from individual taggings of lots of 2,000 to 3,000 fish varying from nil to 13 percent. It was found that only a relatively small amount of intermingling occurred between fish of this population and fish of the other major populations which support fisheries along the lower, east coast of Vancouver island, Queen Charlotte strait, the central coastline, etc. The greatest intermingling occurred with herring of the lower east coast of Vancouver island population, but the data indicated that only about 5 per cent of the fish of each population

(on the average) were involved (Tester and Stevenson, 1947, 1948; Stevenson, 1950). There is evidence that most of the movement to and from the west coast population occurs at the southern extremity of the population range in the general vicinity of Barkley sound. The exceptionally great exploitation of this section of the population in 1949-50 might have been responsible for the apparently increased intermingling of west coast and lower east coast fish noted in that season (Stevenson and Lanigan, 1951).

The extent of dispersal of tags from tagging areas to other areas within the range of the west coast of Vancouver island population is rather great, involving on the average about 45 per cent of the fish (Tester, 1948). The greatest mixture is found to occur between runs of adjacent areas. Thus although each of the runs to the five areas on the west coast of Vancouver island shows a certain relatively small degree of independence, they are considered to be essentially a series of intergrading units within the major population.

Muzinic (1948-49, 1950) reports on initial tagging studies on the sardine on the Dalmatian coast of Yugoslavia. He aims to determine whether sardines caught on the eastern coast of the Adriatic constitute a homogeneous population or whether the intermingling of distinct populations is involved. In the summers of 1948 and 1949, he tagged 31,000 fish using strap tags attached to the opercle, and he obtained a recovery of about 1 per cent. His studies indicated that movement was greater during late May and early June than at any other time during the summer. At that time movement of sardines was

generally from the offshore islands towards the mainland shore. Because there was a considerable loss of tags caused by wearing off of the tissue, recoveries could not be obtained in following years. No recoveries were taken outside the mid-Dalmatian region where the tagging was carried on.

In the St. Lawrence from 1945 to 1948, Vladykov (1948) carried out tagging experiments on another clupeid species, the shad. He found that after spendings five or six winter months in the Atlantic, the shad in May approaches Canso strait and enters the gulf of St. Lawrence. The return to the sea takes place in late summer.

Migrations of the Pacific halibut

Tagging of the Pacific halibut in the 1920's gave pertinent information on the movement and delineation of halibut stocks (Thompson and Herrington, 1930). In all, about 12,000 fish were tagged with opercular tags. It was found that cape Spencer, near Juneau, Alaska, separated two groups of halibut which were practically independent of each other. Only 5 per cent of the fish tagged north and west of cape Spencer (in the area referred to as the West Banks) were recaptured south of cape Spencer (the South Banks). Movement in the reverse direction was practically negligible.

On the South Banks migration was slight, averaging 22 miles, greatest in spring and fall, and showed no definite movement in any one direction. In one area there was a tendency towards concentration, the migrations being opposed in net direction from the extremes to the

centre. On the other hand, migration was rather extensive on the West Banks, averaging 209 miles. There, the movement was decidedly westward, and the dispersion was greater in the summer than in the spring and fall. It was concluded that there was a free interchange of mature stocks for all or most of the halibut on the West Banks.

Migrations of the Pacific mackerel

Fry and Roedel (1949) reported the results of tagging studies on the Pacific mackerel which supports an intensive fishery off southern California. Between 1935 and 1943, 76,000 mackerel were marked off central and southern California, and in Mexican waters. In addition, a small number (eleven) were marked off the Oregon coast. In several respects, the returns gave results similar to those related previously for the pilchard. An extensive north-south interchange of fish was demonstrated. Mackerel from as far north as Oregon and as far south as the central part of lower California, Mexico, entered the south Californian fishery. There were indications of a gradual dispersal over a period of years from the points of tagging. The small number of returns from the central part of lower California suggested that that area contributed little to the south California fishery. It was considered that the main body of fish which enters the fishery moves southerly during the period of the year that the fishery is not in progress. The need for further tagging in Mexican waters to determine the southern limits of the main population was pointed out. There was some evidence of a differential southerly movement with respect to size in fish tagged in central California and recovered in

southern California. Large sizes of fish tended to be recovered first.

Migrations of the striped bass

Turning to the Atlantic, the work on the striped bass (Merriman, 1941) is noteworthy. From April, 1936 to June, 1938, about 4,000 striped bass, including some young, were marked with external disc tags or internal belly tags. Taggings were carried out from Connecticut to North Carolina. Returns (which averaged about 20 per cent) showed that there was a mass migration to the north in the spring, and to the south in the fall, and that the population in the northern waters was stationary in the summer. It was concluded that these migrations took place chiefly between Massachusetts and Virginia, and that the greatest intensity of migration was along the southern New England and Long Island shores. It was also found that not all of the fish migrate since some were caught throughout the summer in southern waters and in the winter in northern waters. Coastal migrations were not undertaken by bass less than two years old. Tagging in North Carolina showed that bass from that region contributed directly only a small percentage to the population in the more northerly waters. In contrast to this situation in the striped bass of the Atlantic, Clark (1936) reported that the introduced population in California waters showed by tagging experiments to undertake "no definite migrations, but simply a diffusion from the localities in which they were tagged".

Migrations of the cod in the Atlantic

A considerable amount of study has been devoted to the study of cod migration on both sides of the Atlantic. This review will be limited to the work done on the western Atlantic coast by Schroeder (1930), McKenzie (1938 and 1940), and Thompson (1943). Schroeder tagged over 40,000 fish in the period 1923 to 1929 from north of cape Cod to the New Jersey coast. From the returns, which amounted to about 3 per cent, he concluded that the stock of cod living on Nantucket Shoals was for the most part distinct from that found to the north and east of southern Massachusetts (cape Cod). He further found that a large part of the Nantucket Shoals cod population makes a fall migration to the Rhodes island-North Carolina region, but that only a relatively small number of iish north and east of cape Cod makes this same migration. The return movement takes place in the spring.

In the spring of 1937 Mackenzie (1938) tagged cod on the banks off Nova Scotia. Tag returns obtained from June to September showed considerable movement of fish, recoveries having been taken on the Grand Bank, off the south shore of Newfoundland, and towards the gulf of St. Lawrence as far as Gaspé. By fall most of the recoveries were obtained near the banks in the vicinity of tagging, suggesting a return migration. No tags were recovered west or south west of the tagging area. Results from tagging cod in inshore waters off Halifax in 1925 and 1934 showed that the majority of the spring and summer cod of that area were "usually native resident fish" (McKenzie, 1940).

Thompson's study (1943) of the cod of the Newfoundland area from 1933 to 1937 suggested that prior to maturity there was insufficient movement to cause significant intermingling of stocks, but that there was increased migration when maturity was reached. Movement was found to be greater for fish tagged offshore than for those tagged inshore. No great degree of interchange of cod between the banks and coastal areas was demonstrated, but in certain cases some movement occurred, as for instance from Grand Banks and from St. Pierre Bank to the coast. Some interchange was found between these two banks, and also between the Newfoundland banks and the Nova Scotian banks. Thompson tagged a total of 8,700 fish and received a return of about 11 per cent.

Migrations of salmonid fishes

There seems to be no doubt that the salmonids have been subjected to more marking than any other group of fishes. An extensive literature has been built up on the results of such studies in various parts of the world. As examples of the work done on the Atlantic salmon there is the tagging of salmon of the Margaree river on cape Breton island (Huntsman, 1938), and to the tagging experiments carried out on Norwegian salmon (Dahl, 1938).

The Margaree study involved the tagging in the fall of about 3,500 salmon which were spent and ready to return to sea. The program extended from 1913 to 1936, and resulted in the recapture of about 6 per cent of the marked fish. It was found that 70 per cent of the recoveries were taken in the general Margaree river area in the first and

second years after tagging, and that the remaining 30 per cent, most of which were recaptured in the second year after tagging, had spread from as far south as Pictou, N.S. to as far north as the Labrador coast. The migration to Newfoundland differed considerably from year to year, and bore no relationship to the number of fish tagged. Migration to all three Newfoundland coasts was observed, but in 1934 no returns were received from any of the three coasts. In 1930 all six Newfoundland recoveries were taken on the east coast of the island, and the three returns in 1935 came from the Belle Isle strait area.

Dahl (1938) reports on the results from the tagging of 1,500 salmon at four major tagging stations along the outer Norwegian coast during 1935, 1936, and 1937. The average recovery from these experiments was exceptionally high, over 40 per cent. Most of the returns were taken in the general area of tagging, but many recaptures showed that the salmon undertake great migrations in northern European waters. The data proved for the first time that salmon cross the Skagerak and Kattegat from Norway to Sweden, and the North Sea from Norway to the British Isles. Dahl refers also to a record of Menzies (1937) in which a fish tagged off Scotland was recaptured off Norway (the early scale growth strongly suggested that this fish had come originally from Norway). The extreme range of salmon tagged on the Norwegian coast was from England to the river Petchora in Soviet Russia, which is considered to be the eastern limit of the species. The great speed of migration was noted, as much as 1,100 kilometres in eleven days. On two occasions a fish was marked at one station, retaken, and re-marked at another station, and subsequently caught again. Both instances proved that migrating fish

do not necessarily take the shortest route between place of tagging and place of recapture. The direction of migration was found to be reversed after the fish were liberated a second time.

There are many papers dealing with the results of tagging and fin-clipping experiments on the Pacific salmons. Clemens, Foerster, and Pritchard (1939) concluded that there was a definite tendency for fin-clipped spring, pink and sockeye of British Columbia to return to their natal stream. They pointed out that spring salmon travelled long distances in the sea, and for this species they postulated a north-west feeding migration and a south-east spawning migration on the way back to the natal Columbia river. Further tagging experiments in 1949 and 1950 (Milne, 1951) suggest that in recent years the spring salmon population off the west coast of Vancouver island has changed, possibly containing a smaller proportion of Columbia fish at the present time. Studies have shown that coho tend to become more dispersed and undertake less extensive migrations than spring salmon.

In 1943 and 1945 tagging operations were carried out on pink salmon along the southern British Columbia coast and in Washington waters (Pritchard and De Lacy, 1944; De Lacy and Neave, 1947). Returns varied from 19 to 51 per cent in individual tagging (De Lacy and Neave, 1947). The studies showed a wide dispersal of tagged fish except in the case of those released in Puget sound. Fish tagged offshore at Swiftsure Bank moved through the strait of Juan de Fuca to all important fishing areas of Puget sound and southern Washington.

Tagging was used by Milne (1950) to show the effect of Moricetown Falls in hampering the migration of salmon up the Skeena river, B.C. He found that sockeye, coho, pink, and spring salmon were effected, and that pinks were most severely hindered.

In northern California from 1931 to 1937 fin-clipping and tagging studies were conducted on steelhead trout and silver (coho) salmon (Taft and Shapovalov, 1938). These studies were carried out in two coastal streams (Waddell and Scott creeks), and in certain tributaries of a large river system, the Klamath. It was found that about 98 per cent of the tagged and fin-clipped steelheads returned to the area of marking, only very few wandering from one coastal stream to the other or from one tributary of the Klamath to another. The degree of wandering of the fin-clipped silver salmon from one coastal stream to the other (about 20 per cent) was somewhat greater than in the case of the steelhead trout. It was concluded that even within a large drainage basin, such as that of the Klamath, the amount of straying among sea-run steelheads was not much greater than between small coastal streams.

Calhoun (1944) used fin clipping to show that in 1941 a significant portion of the black-spotted trout (Salimo clarkii henshawi) in Blue lake, California, did not migrate into the streams during the spawning period. This was done by marking all the spawning run each year and examining fish caught in the lake during the spawning period. It was expected that in 1941, as in 1940, the number of unmarked ripe fish caught in the lake would become negligible by the end of spawning, but actually after spawning was complete 16 per cent of the fish

caught in the lake were ripe unmarked fish, i.e. mature fish which had not ascended the river. No spawning was found in the lake.

Migrations of fish in the Great Lakes

Some of the more important marking and recovery studies on fresh-water fishes have been carried out in the Great Lakes. In lake Erie in 1938,1939, and 1940, Doan (1942) tagged nearly 3,800 fish of various species and recovered slightly over 2 per cent. He found that most of the marked fish did not travel very far in the first two weeks after release, the most active species, the small-mouth bass, travelling an average minimum distance of nine miles. The average distances of movement increased up to six months after release, and decreased between six months and a year. The decrease was considered to be a result of the yellow pickerel (Stizostedion vitreum vitreum) and blue pike (Stizostedion vitreum glaucum) returning to the localities they visited at the time of tagging. It was found that the blue pike tended to move westward from central lake Erie in autumn and winter, shoreward in spring, and to deep water in summer--apparently in response to temperature changes. From the west central part of the lake the movement was eastward in spring and summer. Yellow pickerel tended to remain in western lake Erie, suggesting that they were more tolerant of warmer water. Other species of fish were less intensively tagged than these two, but some general information was obtained on movements.

At port Washington on the mid-western shore of lake Michigan, Smith and Van Oosten (1940) tagged 2,900 fish of various species from 1929 to 1931, and obtained a 13 percent recovery. Most of the returns,

about 80 per cent, were taken within a radius of twenty-five miles from the point of tagging. It was found that lake trout, rainbow trout, and sturgeon migrated more extensively than lake herring, whitefish, chubs, pilots, and perhaps perch. Lake trout, herring, and whitefish tended to move in a northerly direction, perch southerly, and rainbow trout easterly towards the opposite or Michigan shore of the lake. Sturgeon appeared to roam all over the lake. It was found to take three years for the trout to become fairly well scattered through the lake.

In studies conducted at South Bay in lake Huron, Fry (1947) found that movements of small mouth bass during July and August were not extensive.

Migrations of fish in streams and small lakes

Dequine and Hall (1950) give the results of their studies on the movement of Florida largemouth bass in six connected lakes in central Florida. From their tagging of over 1,600 bass in late 1947 and early 1948 they received a return of 23 per cent. Considerable movement of bass was shown between the more closely connected lakes but no definite pattern or direction of migration was discernible.

Manges (1950) provides information on the migration of fish in Tennessee Valley Authority reservoirs. Over 5,000 fish were tagged from 1947 to 1949 in four reservoirs and one mainstream impoundment on the Tennessee river, and 13 per cent of the marked fish were recovered. It was shown that walleyes (Stizostedion v. vitreum) and saugers (Stizostedion canadense) moved more extensively than the basses and crappies. Furthermore, it was found that the sauger and walleye moved most extensively in late winter and early spring. It was not known whether this movement was directly associated with spawning.

The movement of walleyes in the Wolf river, Wisconsin, was given attention by Herman (1947). Approximately 3,700 walleyes from the spawning runs were tagged in the springs of 1944, 1945, and 1946. By the time of writing in 1947 partial returns had amounted to about 9 per cent. The data indicated that the majority of walleyes returned almost immediately to lake Winnebago after spawning, but a smaller number moved further upstream. Several of the fish arrived at the lake, a distance of fifty to sixty miles downstream, in ten days.

Bangham and Bennington (1938) tagged 487 fish of various species in the summer of 1937 at three stations located on two Ohio streams. Periodic seining at the stations was employed to capture fish for tagging and to recapture fish tagged in previous seinings. Fishermen also recaptured a few of the tagged fish. Movement was generally small. No marked fish were taken except near the station where the tagging was carried out. At each station more recaptures were made within two weeks after tagging than in later seining trips, but a few fish tagged early in the season were recovered late in the summer in the same mile of stream. The results of this study did not agree with those of Wickliff (1938) which indicated that returns of marked fish planted in Ohio streams showed decided downstream migration. Since two of the stations in Bangham and Bennington's experiment were on the same stream, one lower down than the other, an extensive migration would have been noted if it had occurred. Smith (1941) who tagged planted brook trout in the Salmon Trout river in northern Michigan concluded that migration of planted fish was limited in extent, but showed a slight downstream tendency.

Discussion

From these examples of marking and recovery experiments it is evident that a great deal of valuable information has been contributed to the study of fish migration, most of which could not have been obtained by other methods of study. In many of the great ocean fisheries the general degree of discreteness of the various populations has been fairly well established by marking studies, and much pertinent information has been amassed on the movement of fresh water commercial and games fishes. Without doubt this knowledge has permitted a closer approach to the ultimate goal of effective fisheries management.

Nevertheless the amount of data available on fish migration is for most fish still far from complete. Major problems of migration remain unsolved in many fisheries, while in others information is required on a large number of details of movement. Frequently little is known of the location of the fish between the time of marking and the time of recovery. Unfortunately, it is usually necessary to undertake large, costly marking and recovery programs and to continue them for a period of several years to obtain reasonably conclusive results. Also, there are involved in the technique various technical and theoretical deficiencies which are difficult to overcome. But, in spite of the difficulties it appears that the marking and tagging of fish has a bright outlook. The method will be improved, will have still wider application, and will produce more data for the advancement of fisheries knowledge--which perhaps will constitute suitable tribute to the "love of experiment" displayed by Emperor Frederick when he long ago marked and recovered a solitary pike.

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