

**FISHERIES RESEARCH BOARD  
OF CANADA**

MANUSCRIPT REPORTS OF THE BIOLOGICAL STATIONS

No. 448

**Title**

The Migrations of Herring \*

**Author**

S. K. Tibbo

\* A paper presented at Symposium on the Migrations of Marine Fishes held by Committee on Biological Investigations, Fisheries Research Board of Canada, Ottawa, Jan. 2nd, 1951.

## THE MIGRATIONS OF HERRING\*

by S. N. Tibbo

### INTRODUCTION

The problem of herring migrations is one which has occupied the attention of both fishermen and fisheries biologists for many years and although our knowledge of this intricate subject has been enormously increased there is still much to be learned. In the case of a fish such as the herring which has a wide distribution and is sought intensively in a relatively limited area, it is of prime importance to know whether the individuals move freely throughout the range or whether the population consists of two or more sub-populations each with its own distribution and each more or less independent of the others.

The great economic importance of herring, especially in western European countries and the extremely sporadic occurrence of the schools are the main reasons for the special attention which has been given to the species. During certain seasons of the year, herring may be found in enormous numbers in a given area while in other seasons they will disappear almost entirely. In other localities they may be caught all the year round but the quantities may vary tremendously from one season to the next. It is these variations which are attributed, mainly, to peculiarities in the migrations of the fish.

Up until the early 1930's the methods used for studying the migrations of herring were of an indirect nature. Very few marking experiments were attempted and investigators had to rely on data obtained from a study of variations in the morphological characteristics of the different spawning populations. Because of this, opinions and explanations of herring movements have been numerous and diverse which is probably to be expected in such circumstances where every theorist can point to a few facts which seem to prove his case.

The earliest accounts suggested that there was but a single body of herring in the North Atlantic and it was, therefore, credited with very extensive migrations. Roule (1933) wrote "The herring winter beneath the ice of the Arctic ocean, then in the spring move southwards and on their way break off in different directions, some towards the western coasts of Europe and others towards the eastern shores of the United States".

---

\* A paper presented at Symposium on the Migrations of Marine Fishes held by Committee on Biological Investigations, Fisheries Research Board of Canada. Ottawa, January 2nd, 1951.

In a later chapter of the same book, this author wrote "Today we know that this view has no foundation in fact. There is no such migration. The herring shoals are mating groups - making ready to spawn - which break up when that end has been accomplished. Each district, each fishing ground, has its own particular type of fish, proper to it, quite obviously belonging to it, fish which are not found elsewhere. The existence of most of them is passed within a limited area and there is no movement beyond its bounds".

Neither of these two extreme views is generally accepted today. We believe rather that the frequency of herring in a given area depends to a large extent on the survival rate of the various year classes but that migrations are mainly responsible for variations throughout a season.

## MIGRATIONS

### (a) Vertical

Although this paper is chiefly concerned with horizontal migrations of herring, some mention should be made of the vertical migrations since the two may be interrelated to some extent.

Plankton hauls at various depths and under different light conditions have shown that herring larvae are normally found in far greater numbers in the upper water layers at night than during the day. Undoubtedly the same applies for adult fish. During exploratory drift-net fishing in the Gulf of St. Lawrence in 1950 a day set on September 11th took only 11 herring whereas in a night set on September 13th at the same station more than 5000 pounds of herring were taken with the same gear. Whether such diurnal migrations are due to the phototaxis of the fish themselves or whether they are due to the fact that the pelagic organisms on which herring feed are also found in far greater numbers in the upper water layers at night has not been determined. However, these vertical diurnal migrations often bring the herring into water layers moving in different directions thus furthering the horizontal dispersion.

### (b) Horizontal

In considering the horizontal migrations of the herring, it is necessary to distinguish between the true active migrations in search of food or for spawning and the passive migrations where the herring are carried along by the ocean currents. In the case of the larval herring, it may be assumed that passive migrations are the more important, but when mature herring move towards the spawning grounds, they may follow a definite course quite apart from the direction of the currents.

As mentioned previously, herring frequently disappear altogether from a given locality during certain seasons of the year

and this is probably related to a scattering of the fish when as spents or recovering spents they go searching for food. They collect in shoals shortly before spawning and it is at this stage that the majority of commercial landings are made.

Although it can be shown when and where such migrations have taken place, in actual practice it is often impossible to determine the cause or the routes taken and, in fact, it is also impossible to determine which are active and which are passive migrations.

Johansen (1927) has concluded that every race of herring has its own particular area of migrations which may be of enormous extent or confined within narrow bounds. He writes "The Norwegian spring herring may move from the southwestern coasts of Norway up to the north Cape and the Barents Sea and back again, whereas some races of herring spawning in the Kattegat and the Belt Sea never seem to leave these waters".

#### METHODS OF STUDYING MIGRATIONS

##### (a) Population Studies

It was recognized very early that herring were not of the same sort everywhere since fishermen in different localities caught fish which varied greatly in size and quality and this led scientists to conclude that there were many local groups or races each with its own spawning and feeding area.

Studies of the variations between groups have been going on for many years but it is mainly within the present century that this information has been used to determine the migrations of herring. For example, the summer herring on the North Coast of Iceland and the spring herring on the southwestern coast of Norway have long been known to differ only in length and age composition. However, it was not until 1944 that it was suggested that these Iceland herring were simply an older and more migratory part of a population which was spawned in Norway and that migrations between the two areas were of considerable extent (Fridriksson, 1944). This suggestion was subsequently confirmed by tagging.

Ever since the time of Linnaeus, students have been making observations on the peculiarities of the different groups of herring and have noted differences in body proportions, length and position of the fins, number of fin rays and gill rakers, number of vertebrae and keeled scales and other characteristics. Particular attention has been given to such characters as the number of vertebrae, fin rays and keeled scales which once formed are constant throughout the lifetime of the individual. Body proportions and the position of the fins change somewhat with seasons and in the course of development.

In studying these morphological peculiarities it has been found that herring spawning under different conditions of temperature and salinity also exhibit morphological differences. Sometimes these differences are very small and the characters subject to such wide variations that it is necessary, not only to make very extensive observations, but also to find some arithmetical expression to describe the differences.

Much attention has also been given to the structure of the scales and otoliths, the number of growth zones, the relative size of the nucleus and the distance between the different winter rings. Certain writers such as Lea, Storrow and Hodgson have based their investigations of the herring migrations almost exclusively on a study of the scales with appropriate calculations as to the growth of the fish.

Studies have been made of the position of spawning grounds and the physical properties of the water and observations taken as to where the larvae, young fish, fat herring, full herring, spent fish and recovering spents of one and the same race are to be found.

To illustrate the results of these studies a schematic presentation of the migrations of Norwegian herring is taken from Lea (1929) and given in figure 1.

This figure illustrates:-

A. The shoreward migration of spawning herring during the period January to April. These fish arrive at the spawning grounds in two groups; firstly, the repeaters and then the recruits - spawners.

B. The dispersal of larval and post-larval stages of herring of the year along the entire coast.

C. In their second year these herring remain in inshore areas.

D. In their third year the herring from the southern part of the area move seaward.

E. During the fourth year of life the herring from the northern part of the area also move seaward.

F. The oceanic stage. Duration from one to three years, age two to six, possibly seven years.

G. After sexual development the oceanic stage is abandoned by that part of the population which will become sexually mature during the next spawning season.

H. Annual migration of adult herring between spawning and feeding grounds.

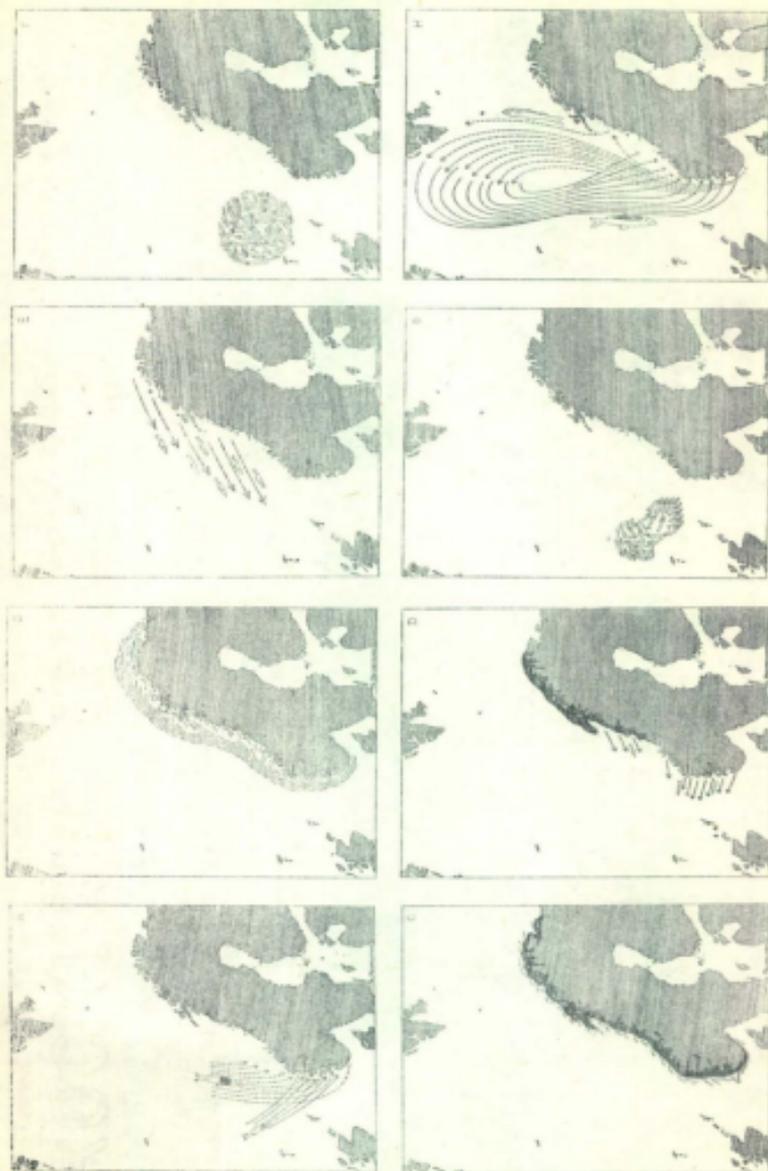


Figure 1 - Diagrammatic representation of the movements of herring along the coast of Norway (Laa, 1929).

(b) Tagging

Tagging fish is an extremely simple and useful way of finding out whether they move from one place to another and many types of tags have been used in many countries and for many species of fish. Valuable results can be obtained from this method of studying migrations provided that enough fish can be tagged in enough places; that the tags will remain in place for reasonably long periods; that the fish can be tagged without undue mortality and that there are adequate means of recovery.

Although migrations are considered to be the most important single factor in the study of the life history of herring little has been done in the way of a positive approach to finding a solution for this problem. It is quite probable that most investigators have considered herring to be unsuitable for tagging because of the difficulty of handling without injury and furthermore, the enormous quantities that were taken and the methods of handling catches in bulk rendered any known system of recovery an extremely arduous, if not impossible, task.

Apart from one or two unsuccessful attempts during the 1890's by Fulton of the Scottish Fisheries Board (Fulton, 1893) there appears to have been no real effort to find a suitable tag for herring until 1932 when Rounsefell and Dahlgren of the U.S. Bureau of Fisheries conducted some experiments in Puget Sound, Washington (Rounsefell and Dahlgren, 1933). They tried several types of tags including silk ribbons in the operculum and in the body, small monel metal strap tags attached to the caudal peduncle and to the operculum and internal monel metal tags. They concluded from these experiments that the strap tags attached to the operculum and the internal tags were both quite satisfactory and overcame the problem of recovery by an ingenious method of installing electro-magnets in the meal line of the reduction plants that were handling the catches. In 1933 they tagged approximately 4000 herring at Jamestown Bay in Alaska and subsequently recovered 4% of the internal tags and  $\frac{1}{4}$  of 1 per cent of the opercular tags. This clearly demonstrated the superiority of the internal tags and these were used exclusively for later taggings. In 1936 they developed an "electronic" or "induction" detector as a refinement of the recovery apparatus since with the electro-magnet only the tag could be recovered and after passing through a reduction plant there was often some doubt as to its origin.

Hart, Tester, and their associates have been using this internal tagging method of studying herring migrations since 1936 on the British Columbia coast and have made noteworthy contributions towards a better understanding of the composition of the shoals and the movements of herring in that area (Hart and Tester, 1937).

Their reports which have been published annually in the Report of the B. C. Fisheries Department contain a great deal of

information on the efficiency of the tagging method, the amount of mixing of schools which were previously believed to be discrete and the migration of herring throughout the fishing season.

It has been shown, for example, that the movement of herring between such areas as the lower east coast and the west coast of Vancouver Island is very small (from 2 to 5.8%) but that there is a considerable mixing of populations in adjacent areas on the west coast of Vancouver Island (Tester and Stevenson, 1948).

A very recent paper by Fridriksson and Aasen gives the results of tagging experiments in Norway and Iceland during the last three years (Fridriksson and Aasen, 1950). They have also adopted the internal method of tagging developed by Rounsefell and Dahlgren and have met with considerable success in their efforts.

The most spectacular result of these experiments is that transoceanic migrations between Norway and Iceland are shown to take place to a considerable extent. This had been previously suspected by Fridriksson and supported by Rasmussen (1950) from studies of population characteristics in the two countries but the first direct evidence was from a tag which was liberated in Iceland on August 22nd, 1948, and found on February 9th, 1949, in a plant which was using herring taken from a fishing area just north of Bergen in Norway. During the 1949 fishing season in Iceland one tagged herring that had been liberated in Norway in 1948 was recaptured. During the last fishing season in Norway (1950) a total of 67 tags were recovered, 11 of which were from 5 different taggings in Iceland in 1948. The total returns from these taggings have been small, 149 out of 42,054 or ca. 1/3 of 1 per cent but it should be noted that the installation of recovery apparatus was going on at the same time as the tagging and is not yet complete for Norwegian factories and also that this group of herring which Johansen named Atlanto Scandian yields nearly 1,000,000 metric tons of fish annually.

Other results of these experiments indicate that the schooling of herring is a temporary phenomenon with the schools dispersing after awhile and the fish later forming into new groups which may be quite different from the previous ones. Evidence for this has come from tagged herring liberated as a small school and later recaptured over widely scattered areas and long periods of time. It is further indicated that the Norwegian winter and spring herring which were previously believed to be separate and distinct groups cannot continue to be regarded as such since tagging returns show that there is a definite mixing of these two groups.

There has been very little effort on the east coast of Canada to study herring migrations by the tagging method chiefly because the fishery there has not developed to the stage where large quantities of herring are handled in a single processing plant. In Newfoundland alone in 1948 there were 990 licenses issued to pack slightly less than 20,000 tons of herring. This is an average of ca. 20 tons per plant for the whole season, whereas a reduction

plant could process more than 10 times this amount in a single day.

In spite of this, however, it was thought that some tags might be recovered and 2375 herring were tagged and liberated in the Magdalen Islands area during the early part of June in 1948. Two types of internal tags were used viz. green celluloid and silver-plated steel. Nine out of the 1860 green celluloid tags were recovered within a few days of the actual tagging but only one since and it was recovered in May 1950 in the same area in which it had been released two years previously. None of the 515 silver-plated steel tags have been returned.

(c) Hydrographic Studies

In an attempt to throw further light on this problem of herring migrations some investigators have considered herring to be purely planktonic in their movements and have suggested that there is no active, purposeful, migration and that both larval and adult herring are carried passively by water currents.

Tester (1938) showed that there was an inverse relationship between tidal differences and the availability of herring as measured by the average catch per seine per day. He did not arrive at any definite conclusion to explain this correlation but mentions the following factors which might be related to it.

(a) the mechanical effect of the tidal current on the ease of manipulating purse seines and thus catching fish.

(b) the effect of tidal currents on the movements of herring to the fishing grounds.

(c) the amount of light from the moon and the reaction of herring to light of certain intensities.

Huntsman (1934) investigated the sardine fishery of the Passamaquoddy area in the Bay of Fundy and concluded that catches in the stationary weirs were determined mainly by the movements of water currents which were set up by winds or by fresh water inflow.

He points out that "weir catches indicate very definitely that the herring are shifted from place to place in the superficial movements set up by the wind" and further that "During freshets, water of low density in the middle of the bay passes to localities of deep mixing carrying herring to the so-called "spring weirs" irrespective of the time of the year - that during freshets the herring are carried away from the vicinity of estuaries; but with lessened outflow - particularly in the autumn, they are moved to the estuaries and the bay mouth to give large catches in the so-called "fall weirs".

## STUDIES IN CANADIAN ATLANTIC WATERS

Studies of herring on the Atlantic coast of Canada were first made during the Canadian Fisheries Expedition 1914-15 (Lea, 1919). The principal aim of this investigation was to determine if all of the fish on the coast belonged to a single population or if it was possible to distinguish several groups. Observations were made as to the length, weight, sex and state of maturity of the gonads, fat content, number of vertebrae, number of fin rays and number of keeled scales.

Very striking differences were observed in the data from various localities and it, therefore, became obvious that there were separate groups of herring which intermingled to a limited extent if at all.

Similar studies were begun by the Atlantic Herring Investigation Committee in 1944 and have been continued each year since to establish the geographical limits of the different populations and also to test the constancy of those characters which are different for each group. The results of these studies have been that it is now possible to distinguish six separate and distinct populations of herring on the Atlantic Coast. It is possible that further segregation could be made with much more intensive sampling but it does not seem worthwhile, particularly since it is not feasible at present to test the results by the direct tagging method.

Some results of the studies of herring stocks in Canadian Atlantic waters are given in figures 2 to 6. Figures 2a and 2b give the mean monthly catches of herring for the period 1933 to 1949. The catches during the fall and winter months (October to March) are small and have been combined in two sections of the figures. For the west coast of Newfoundland only annual catches are available and the mean monthly catches have been calculated on the basis of records kept during an investigation of the herring fishery in the area during the 1942-43 and 1943-44 seasons. The figures show that except for the Bay of Fundy area which has a year-round fishery for sardines the largest part of the total catch is taken in the southwestern section of the Gulf of St. Lawrence during the month of May. Large catches are also made along the outer coast of Nova Scotia during July, August and September.

Figure 3 shows the mean vertebral counts of samples taken from the commercial catches and also the principal spawning areas which are indicated by the heavy black lines. The spawning schools which are the basis of these commercial fisheries have all individuals with ripe or nearly ripe gonads which collect on the shores for the purpose of spawning and then disappear again. In some cases, for example, the Magdalen Islands area, this spawning migration lasts for from four to six weeks while in other, such as the Bay of Islands on the west coast of Newfoundland, the nearly ripe herring move in-

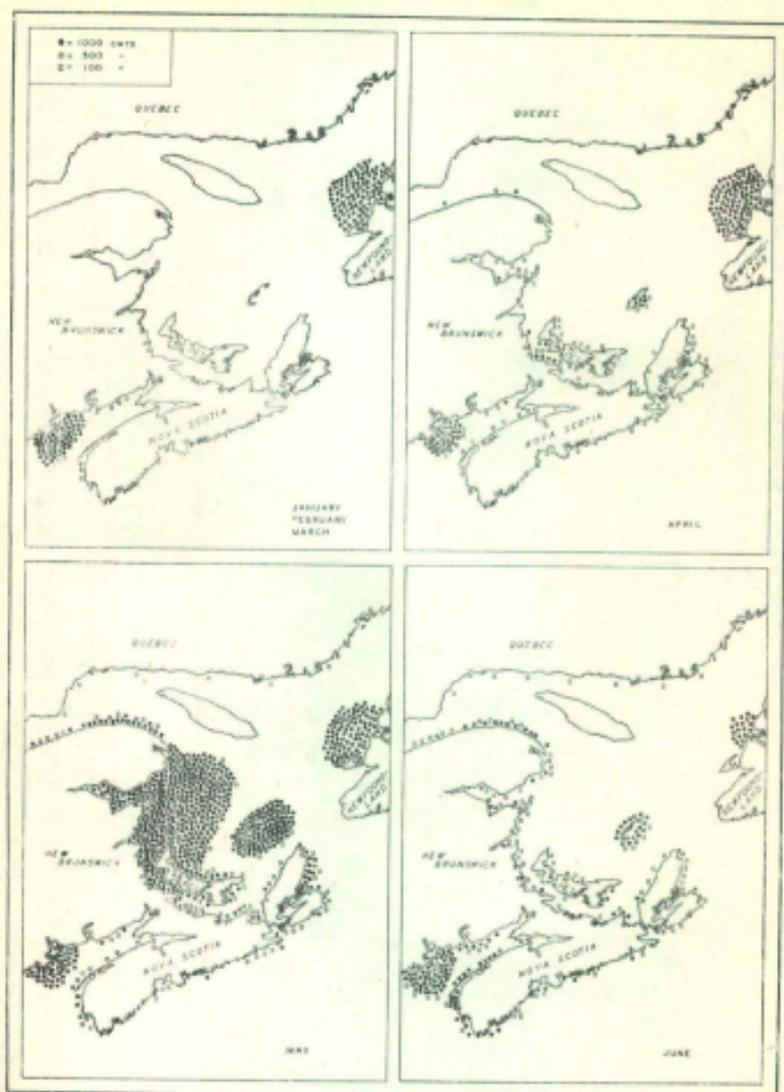


Figure 2(a) - Mean monthly catches of herring 1933-1949 (January-June).

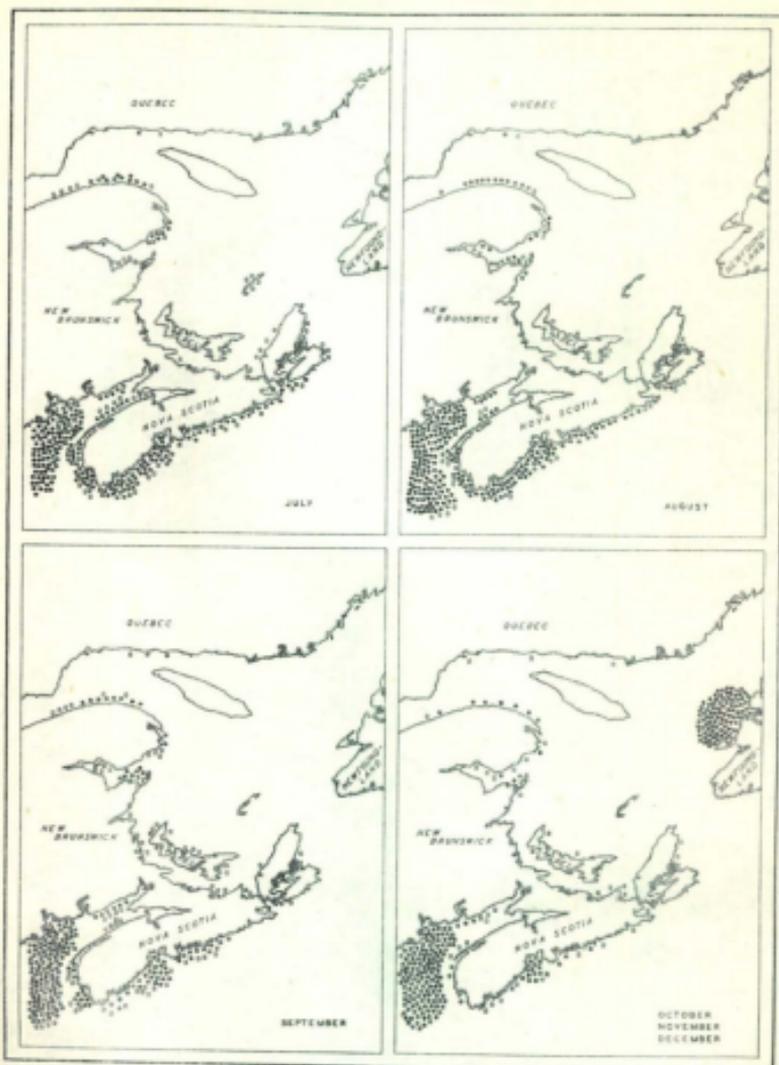


Figure D(b) - Mean monthly catches of herring 1933-1949 (July-December).

shore in November and do not spawn until the following May. Mean vertebral counts are higher in the estuary of the St. Lawrence and lowest on the northeast coast of Newfoundland. Areas which have been shown to have separate and distinct populations of herring are enclosed by broken lines. Vertebral counts are not sufficient in themselves to distinguish populations as shown by the counts from the Nova Scotian coast 55.54 and the ones from Prince Edward Island 55.56. Although these counts are almost identical differing by only 0.02 vertebrae, the populations are distinct as shown by growth rates, year class composition and spawning times. One is a spring and the other a fall spawning population.



Figure 3 - Mean vertebral counts and principal spawning areas.

Figure 4 shows the length and age composition of herring samples taken at six of the localities which are considered to have separate and distinct populations. It may be noted that these samples contain a mixture of many year classes sometimes as many as 15 or 16 different year classes being represented. This clearly demonstrates a considerable amount of mixing within an area of adult fish which are the products of different spawnings.

With regard to the immature herring in the Gulf of St. Lawrence we have very little information but the results of sampling

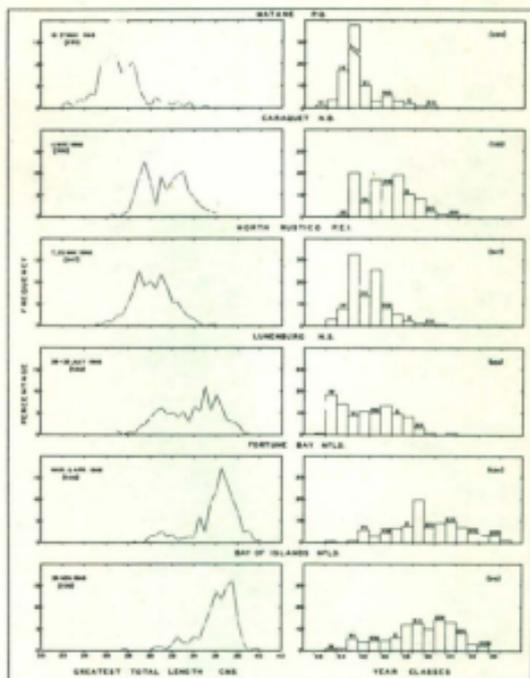


Figure 4. Length and age composition of herring samples.

on the Gaspé coast, during the summer months when there is a small fishery for virgin fish indicate that these herring are grouped according to size rather than age. It appears that the larger individuals of one year class mix with the smaller individuals of an older year class rather than with the smaller individuals of the same year class.

It may be argued that this opinion has no foundation in fact since the samples which provided the data for the conclusion

were obtained from fishing gear which is very selective in its action and will only take fish of a particular size group. However, fishermen have learned from long experience what gear to use for a particular area and hence their catches are probably representative of the population present. This mixing of young herring according to size groups may be decided by the activity of the fish, its ability to swim and the special sort of food it seeks.

Figure 5 shows the drift of surface water in the Canadian Atlantic area and figure 6 shows the relative sizes of combined catches of herring and mackerel during exploratory drift-net fishing in the Gulf of St. Lawrence during the summer of 1950. This investigation was carried on from the first of June until the end of September when there is a well defined surface layer of water in the area.

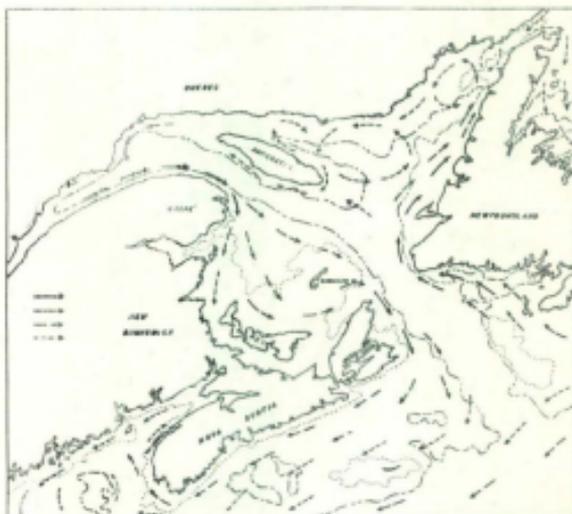


Figure 5 - Surface drift in Canadian Atlantic area.

Practically all of the fishing was done within this surface layer and the quantities taken indicate that there were large numbers of herring present. There does not seem to be,

however, any particular relationship between the distribution of herring and the movements of the surface water. There is some suggestion that the adult spring herring immediately after spawning move for the most part in the direction of the current since our best catches in June were made in the southwestern part of the Gulf but later in the season much larger quantities were taken in the northwestern part.

It might also be mentioned that there appears to be a definite relationship between the abundance of plankton and the quantities of herring captured and this was particularly evident during the last two weeks in July when Calanus were very abundant and were the principal constituent of the plankton hauls. For example at Station HDN 8 there were 310 c.c. of plankton taken in a 10-minute, horizontal tow with a meter net about 10 feet below the surface and 5000 lbs. of herring taken in the gill-nets. At

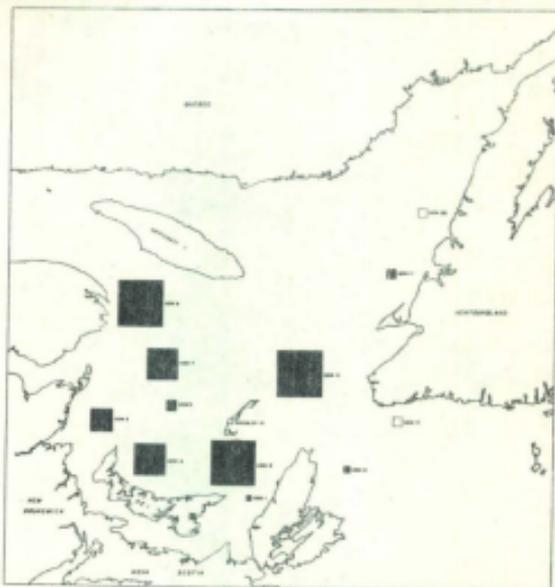


Figure 6 - Combined catches of herring and mackerel, 1950.

Station HDN 2 there were 220 c.c. of plankton and 2200 lbs. of fish; at Station HDN 5, 130 c.c. of plankton and 550 lbs. of fish and at Station HDN 1, 35 c.c. of plankton and 120 lbs. of fish.

This relationship between herring catches and the presence in varying amounts of certain planktonic organisms is in conformity with the results of similar studies in the North Sea where commercial fishermen are now using a plankton indicator in connection with drift-netting.

## SUMMARY AND CONCLUSIONS

There are still many unsolved problems connected with the distribution and the relationships of the various groups of herring but perhaps enough is known to warrant some general conclusions about their migrations. The Norwegian investigators have shown that the newly hatched larvae are carried by the water currents from the spawning areas in the southwest part of Norway northwards along the coast and into the fjords. Here they remain for two or three years when they move off shore to the edges of the continental shelf where they form the basis of the fat-herring industry. When these herring become mature, they migrate southwards and shorewards where they then mix with the spawning shoals of the older year classes. After spawning the spent fish migrate northwards along the coast of Norway and out to sea. Some portion of the shoals migrate as far as the north coast of Iceland where they form the basis of a large summer fishery for recovering spents.

How far the results of a particular investigation can be applied generally is a question, the answer to which is very much in doubt. It may be as Johansen has suggested that each race has its own particular area of migrations which would mean that although basic principles may be applied each group has to be investigated separately.

As a general rule herring disappear for a greater or lesser portion of the year and this disappearance is undoubtedly often related to an extensive scattering of the fish at certain periods of their life. It is the adult fish which are thus dispersed when as spents or recovering spents they go hunting for food in a more pronounced degree than otherwise. The herring collect in shoals for the most part at the following stages of life:

- (a) as spawning fish
- (b) as young herring
- (c) as full herring shortly before spawning
- (d) as spent herring - a short time after spawning has taken place.

There are places where recovering spents are also caught in great numbers, as, for instance, on the north coast of Iceland in the summer and in the eastern Skagerak during winter.

During the period after spawning the herring are found feeding voraciously on the copepod, Calanus which is presumably transported mainly by the currents and the herring probably follow the movements of this and perhaps other food organisms. Whether this movement of herring is of an active or passive character we do not know and it is perhaps not particularly important. It may be sufficient to have a complete understanding of the factors affecting the production and distribution of the organisms on which herring feed in order to be able to describe this phase of their migrations.

It is perhaps important to appreciate the fact that since the larval stages of herring cannot be marked and their life history followed it is, therefore, impossible to produce direct evidence as to the place of origin of any school. However good the biometrical analyses may be there will always be some doubt as to whether any two samples come from the same spawning or whether they belong to different spawnings, the products of which have similar characters.

REFERENCES

- Fridriksson, A. and Olav Aasen. 1950. The Norwegian -- Icelandic Herring Tagging Experiments. Rept. on Norw. Fish. & Mar. Invest., IX, 11.
- Fulton, T. W. 1893. An experimental Investigation on the Migrations and Rate of Growth of the Food Fishes. 11th Ann. Rept. Fish. Bd. for Scotland.
- Hart, J. L. and A. L. Tester. 1937. The Tagging of Herring (*Clupea pallasii*) in British Columbia: Methods, Apparatus, Insertions and Recoveries during 1936-37. Ann. Rept. Prov. Dept. Fish., British Columbia, 55-67.
- Huntsman, A. G. 1934. Herring and Water Movements. James Johnstone Memorial Volume. Univ. of Liverpool.
- Johansen, A. C. 1927. On the Migrations of the Herring. J. Conseil, II, 1.
- Lea, Einar. 1919. Report on "Age and Growth of the Herring in Canadian Waters". Can. Fish. Exped., 1914-15, 75-164.
- Lea, Einar. 1929. The Oceanic Stage in the Life History of the Norwegian Herring. J. Conseil, IV, 1.
- Rasmussen, Thorolov. 1950. Is the Icelandic "Nordurlandssild" Identical with the Norwegian Winter Herring. Rept. Norw. Fish. & Mar. Invest., IX, 7.
- Roule, Louis. 1933. FISHES Their Journeys and Migrations. W. W. Norton & Co., Inc., New York.
- Rounsefell, G. A. and E. H. Dahlgren. 1933. Tagging Experiments on the Pacific Herring (*Clupea pallasii*). J. Conseil, VIII, 3.
- Tester, A. L. 1938. Herring, the Tide, and the Moon. Fish. Res. Bd. Can., Pac. Prog. Rept., No. 38, 10-14.
- Tester, A. L. and J. C. Stevenson. 1948. Results of the West coast of Vancouver Island Herring Investigation 1947-48. Ann. Rept. Prov. Dept. Fish., British Columbia, 41-86.