

PLATE A.

Series of plaice, showing average yearly growth of the females during the first five years, in the Southern North Sea.

MARKING AND TRANSPLANTATION
EXPERIMENTS WITH PLAICE, AND SOME
NOTES ON THE NATURAL HISTORY
OF THAT FISH.

BY A NATURALIST.

Of the many branches of fishery investigation which have been inaugurated in recent years, few, perhaps, appeal so readily to the imagination as the labelling and setting out of living fishes. This has been done to a great extent by the different nations participating in the International Scheme, with the object of tracing the migration and growth of individual fishes so treated.*

That a flat fish bearing a numbered disc and set at liberty at a spot many miles from land, and perhaps with not a single fishing boat in sight should ever be found again can only seem a matter of wonder to the lay mind. But, when one fully realizes that of such fishes at least 20% or 30% are returned regularly by the fishermen in a year, wonder turns to consternation at the influence man has on this harvest of the sea.

It is proposed to give here a short survey of some of the results that have been attained in the experiments the International Investigations have already afforded. Many of these are not only of great interest to the naturalist—and each of us is in some degree such—but also of deeper economic portent.

However, before entering into this subject it is desirable to bring before the reader some elementary but fundamental facts regarding the biology of the fish with which it is proposed to deal.

* Proceedings of Suff. Inst. Arch., 1903, Vol. xi., pt. 3, p. 273.

The plaice spawns in winter, resorting for that purpose to water of desired depth and salinity. At Iceland, where the north and east coasts are chiefly under the influence of very cold water, marked plaice have been found to migrate halfway round the island to the south and west coasts to spawn in the warmer water coming from the Atlantic. The floating eggs develop whilst drifting with the genial current, and are transported long distances back to the coasts from which the parent fish came.

The route from Harwich to the Hook of Holland lies right across the chief spawning area in the North Sea.

Dutch investigators, with fine meshed nets have taken as many as 576 plaice eggs suspended in the column of water underlying a square metre of surface, whilst in other parts of the North Sea 100 are rarely found in a similar column.

These eggs are carried by a current coming through the Straits of Dover along the Dutch coast, and the little newly-hatched plaice, after passing through various stages, eventually settle on the bottom, on some shallow, sandy beach. Though the smallest dabs are found at various depths, no small plaice are found in deep water. Such eggs as may be carried out over too great a depth seem to inevitably perish. This is a regular occurrence off Norway, where the plaice at the best have but a narrow shelf to live on, between the rugged coast and the deep Norwegian Sea, and the surface currents are for the most part flowing out of the fiords.

In our own sea the set of the upper egg-bearing currents in winter are not favourable for the distribution of plaice eggs along the Suffolk coast, and there are, moreover, few sandy beaches such as are suitable for the young fish. These are in consequence poorly represented in comparison with the abundance found on the Continental beaches. The eggs require a longer or shorter period to hatch, according to the

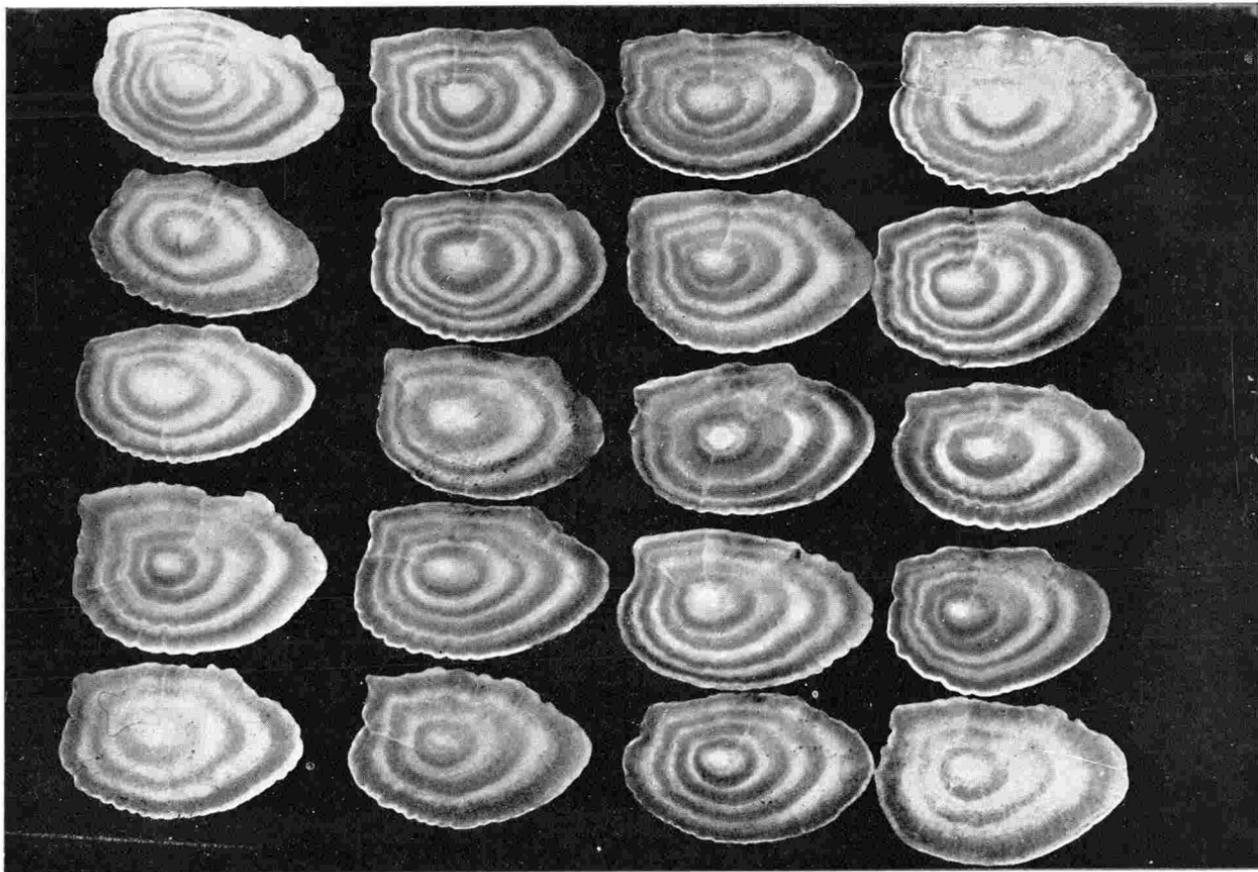


PLATE B.

Otoliths of 20 plaice, length $10\frac{1}{2}$ inches; mostly 4 years old. May, 1905.

temperature of the water, and it has experimentally been found to vary between $10\frac{1}{2}$ and $18\frac{1}{4}$ days at 12° C. and 6° C. respectively. The newly hatched fish or larvæ, which at this stage swim like the young of round fishes and have an eye at each side of the head, still require five or six weeks' life in the upper water layers before finally settling down on the bottom in the shallows; when this occurs one eye travels round the head in a most remarkable manner, and the fish assumes the form of a flat fish as we commonly know it.

From what has been said it can be easily understood that a young plaice, or any other fish derived from a floating egg, can be found many miles from where the egg was spawned.

The illustration (plate A) shows the rate of growth of female plaice for the first five years of life in the south part of the North Sea.

The length at the end of each year is approximately

1st year,	$2\frac{3}{4}$	inches.
2nd year,	$5\frac{1}{2}$	„
3rd year,	$8\frac{1}{4}$	„
4th year,	$10\frac{3}{4}$	„
5th year,	$13\frac{1}{4}$	„

The rate of growth is found to be practically the same along the Continental coast from Belgium to Denmark for the first three years averaging about $2\frac{3}{4}$ inches a year.

The females from an early age grow faster than the males, and are also found to live to a greater age. Although up to five years males are more numerous than females, after that age females predominate, and the largest and oldest plaice are all females.

The valuable discovery by a German naturalist in 1899 that the age of plaice could be determined from the otoliths or earstones has helped to solve many problems connected with this species. These bones, some of which are figured in plate B, are situated

in the head and show rings of darker or lighter appearance according to the period they are deposited. These rings are similar in significance to those seen on a cross section of a tree trunk, viz., periodic growth.

The white ring on the otolith signifies the spring and early summer growth, the dark ring that of late summer and autumn. In winter plaice appear not to feed, and growth ceases.

Other bones, as the vertebræ and the bones of the gill cover, show similar rings, but for plaice which are not very old the otoliths are the simplest to investigate.

The illustration shows the otoliths of twenty plaice, one (of the two present) being taken from each fish, of $10\frac{1}{2}$ inches length. The fish were caught in May or just at the beginning of a plaice's year. Most of the bones show four white rings indicating the fish are for the most part just four years old.

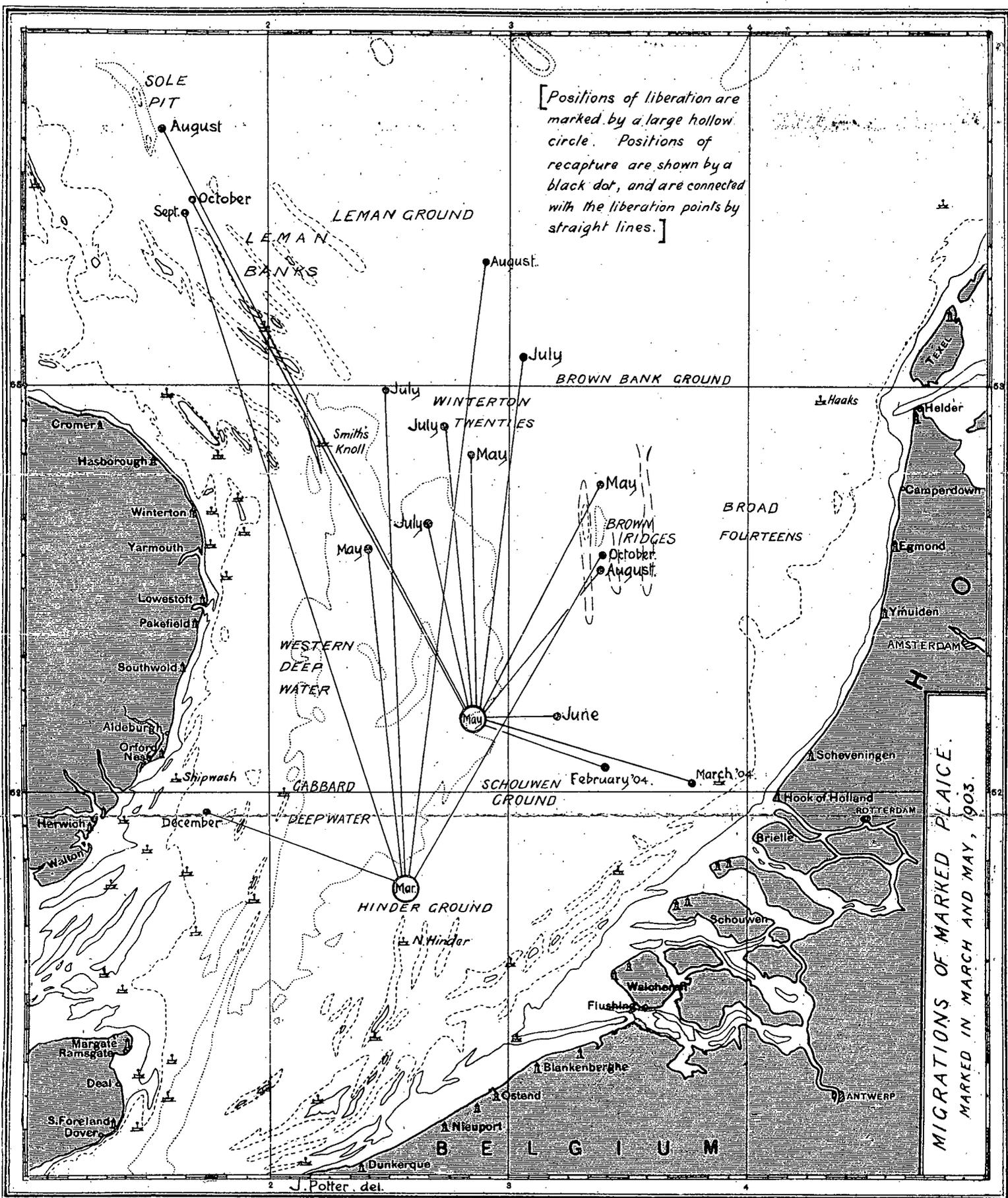
This method of age investigation by means of the bones has been very fully investigated in England and Germany, and gives some striking results.

Plaice in the North Sea have been found up to 25 and 29 years of age, whilst those in northern regions growing more slowly probably live to even greater ages.*

As the range of the species extends from the coast of France to the coast of Lapland and to Iceland, over twenty degrees of latitude, it would be expected that some variation should occur in the rate of growth in different regions. This is being investigated by means of otoliths and other bones, as is also the age at which plaice spawn for the first time. In the English Channel female plaice spawn when four years old, off the Dutch coast they spawn when five years old, and in the neighbourhood of the Dogger Bank the majority are six years old when they arrive at maturity.

In the North Sea the fishermen's catches consist for the most part of fish two to six years old. On the

* On March 11th, 1910 the writer received a very thin plaice 27 inches in length, which had been taken by a Lowestoft smack off the Dutch coast. It had recently spawned, and the examination of the bones showed the age to be 23 years.



MIGRATIONS OF MARKED PLAICE.
 MARKED IN MARCH AND MAY, 1903.

PLATE C.

central grounds, as for instance the Dogger Bank, five and six years old fish are chiefly caught, because, as mentioned before, none of the very young plaice are found out at sea, and such as are on the Dogger have arrived there by their own efforts after several years migration.

Otolith investigation also throws light on the migration of plaice. It is found for instance, that in certain places off the Dutch coast the average size of the fish is smaller in autumn than earlier in the year. This apparent paradox is explained on examining the otoliths. The fish of the later period are found to be of a younger brood and have moved from the shore during the summer, replacing the fish which were formerly there; and these, in their turn, have moved further seawards.

This fact is of considerable importance in explaining a misconception held by many East Coast fishermen. They maintain that the "Easterly plaice are a class which never grow any bigger," because on the same grounds they find them about the same size all the year round. They thus overlook the fact that as each year's brood does grow bigger it disappears from the fishing ground it occupied one year, and a younger brood coming from the coast takes its place.

In passing from this question it may be said that what the study of scales is doing in solving the problems of the salmon, so is that of the otoliths with regard to the plaice; and had scientific men earlier been in a position to acquaint themselves with the records of age which each of these fish carry on their bodies, it is not unlikely that many an erroneous theory and bitter controversy would have been avoided.

MARKING EXPERIMENTS.

The first marking of plaice was carried out in Denmark in 1887; in Scotland experiments were made in the early nineties, but it was not until the commence-

ment of the International Investigations that it has been possible to mark fish in thousands on the chief fishing grounds of the North Sea.

Besides England, other nations engaged in this marking work in the North Sea have been Denmark, Germany and Holland, and in consequence much light has been thrown on the movements of the fish and the amount of fishing which occurs.

Of 6,605 plaice marked by German investigators since September, 1902, 1,269 specimens, or 19·2%, were retaken by fishermen up to November 1st, 1906.

The Danes set out near their coast in April, 1903, 1,220 marked plaice and up to September 30th, 1906, 397 or 32·5% had been reported. In February, 1904, they marked 210 more fish, and of these 41·0% had been caught again up to September 30th, 1906.

As regards the Dutch contribution to this work 1,052 plaice were labelled from July, 1903, to the end of 1905, and of these 110 or 10·5% had been retaken to the end of the latter year.

In the English report it is stated that out of 855 plaice over 8 inches in length which had been marked, 21% were caught again in twelve months, whilst of bigger plaice marked on the Dogger Bank in the spring of 1904 more than 40% were returned in less than a year.

Such results are very striking and clearly indicate the great amount of trawling to which the North Sea grounds are subjected.

Only the broader aspects of the migration of this species as shown by marking experiments will be entered into here, and a few instances given indicating that the movements which do occur are of a much more extensive nature than was believed by the naturalists of years ago. A Danish naturalist in 1843 stated that the fishermen on those coasts found that the plaice migrated to the deeper water twice a year—in warmest summer and coldest winter. This view has been confirmed by the marking experiments

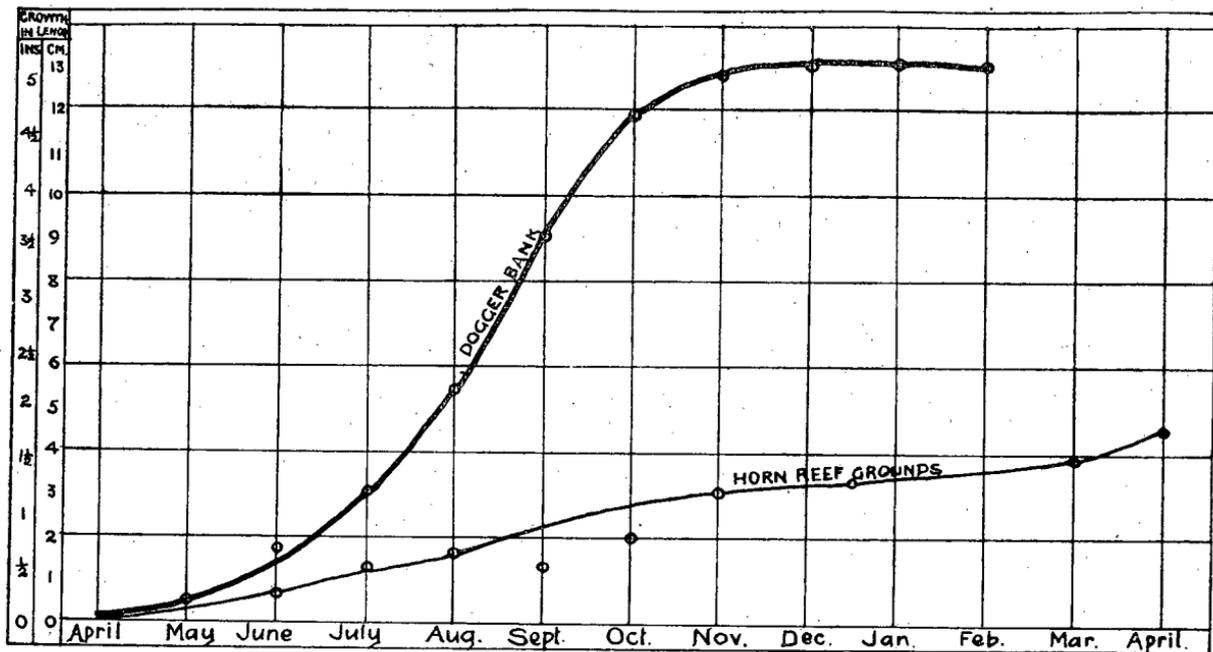


Diagram showing the relative rates of growth of small marked plaice on the Danish Coast compared with small plaice similarly marked and transplanted by the English investigation steamer "Huxley" to the Dogger Bank. The fish on the coast grew on an average less than 2 inches in a year, whilst those taken to the Dogger grew more than 5 inches.

of recent years. The gradual working of young plaice to the off-shore grounds is also shown by these experiments, and this may be said to resolve itself into a feeding migration.

It is, however, amongst the larger and older plaice that the most striking migrations occur. These are the spawning migrations. Most fish when ready to spawn require and seek out rather definite conditions of temperature, salinity and depth. It has already been mentioned that at Iceland the plaice leave the cold water on the north and east coasts and make for the south and west coasts to spawn in the warm Atlantic water. In the North Sea such simple hydrographic conditions do not occur as Atlantic water enters this shallow sea not only through the Straits of Dover but also round the North of Scotland.

The migrations are similarly complicated, but the water from the Channel appears to have a predominant influence on the plaice of many of the fishing grounds south of the Dogger Bank.

The statistics of the English Fishery Board show great accumulations of plaice in winter in the "deep water" off the Suffolk coast, which agrees with the finding of the Dutch scientists that in this region occurs the greatest abundance of eggs.

Whence come these fish, and where do they go to after the spawning season is over? Marking experiments have thrown some light on both these questions.

Some Lowestoft fishermen think they come from the Channel, but there is little to support such a theory, and on the other hand there have been taken on the grounds worked by Lowestoft vessels many marked specimens which have come long distances from the north, north-west, and north-east.

In the report on the English marking experiments plaice were noted to have left the north coast of Holland in winter and to have come to this south part of the North Sea. Several plaice marked by the Germans near Heligoland have been observed to make

their way 200 miles and more to these same grounds, and it is noteworthy that flounders, which go out to sea to spawn, have been labelled in the Elbe, and some of them appear to have been similarly attracted towards the area between the East Anglian and the Dutch coasts.

An English marked plaice liberated on the Leman ground off the Norfolk coast passed into the Channel and was caught in Rye Bay, Sussex, at least 175 miles from where it was set out. A plaice marked on board the Dutch investigation steamer on the north part of the Dogger Bank was caught again by a Lowestoft smack off the Hook of Holland, and a very similar migration to this was demonstrated by a fish bearing a German label, which, marked in the same region as the fish just mentioned, was taken off the mouth of the Thames, having travelled 215 miles in 655 days.

Such are the indications of the sources from which the winter plaice stock of the Lowestoft and Ramsgate trawlers is derived.

After the spawning season the fishermen find that the plaice "take off" as they term it. English and Dutch experiments are available which throw light on this phenomenon. The fish appear to return to the north, probably in search of better feeding grounds. This tendency has been illustrated by a chart of two English experiments made in March and May, 1903.

The fish were caught and labelled off Harwich and Southwold on the Dutch side of the deep channel which lies off this coast. Following up the lines drawn from the points of liberation to the localities where individual fish were caught again in the months indicated, it can be seen that all the fish reported had moved northwards during spring and summer. (See Chart, plate c).

TRANSPLANTATION OF PLAICE.

In the remarks made above regarding the marking of plaice no mention has been made of the growth shown by the fish thus treated. This seems to agree very closely with the results obtained by comparing the average size of a number of fish of one age with the average size of fish a year younger or older, as determined by the examination of the otoliths. The latter method is naturally more reliable, since so much greater numbers can be dealt with at a given time, and marked fishes are only available at irregular intervals, as these happen to come into the fishermen's nets.

Both methods of investigation have shown that plaice in different parts grow at different rates. A natural consequence of such a discovery is to lead the investigator to enquire if it will not be practicable to turn it to practical advantage.

The striking absence of small plaice from the Dogger Bank in spite of favourable depths and evidence of abundant food, led the English naturalists to try the experiment of transplanting small plaice thither from the nursery grounds.

This has already been done with success in Denmark, small fish being taken from the Jutland coast to the Limfiord, a large shallow salt water broad with an outlet to the North Sea. It had been found by labelling plaice here that they grew much more rapidly than on the coast from which such plaice as were in the fiord naturally come.

The experiment of bringing the young fish into the fiord by artificial means having proved a success, the development of the fishery on these lines is becoming year by year of greater importance.

In 1902 over a quarter of a million fishes were brought to the fiord and liberated at a cost of about £156, or, in other words, over eighty fish were dealt

with for a shilling. The profit due to the improved growth and enhanced value of the fish was estimated at over £1,600.

In 1908 about 1,392,000 plaice were transplanted and the profit was estimated to amount to between £5,000 and £8,000.

These figures will serve to show the importance which plaice culture is assuming in Denmark.

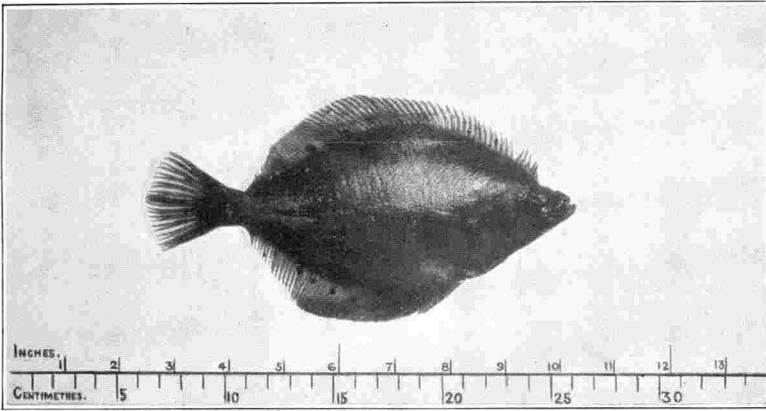
To transplant plaice to the Dogger Bank was a somewhat bolder step, as it involved an open sea journey of some 200 miles from the Danish coast, and about 100 miles from the English coast.

This was nevertheless undertaken by the English investigation steamer "Huxley" in the spring of 1904, fish being taken to the Bank from both coasts.

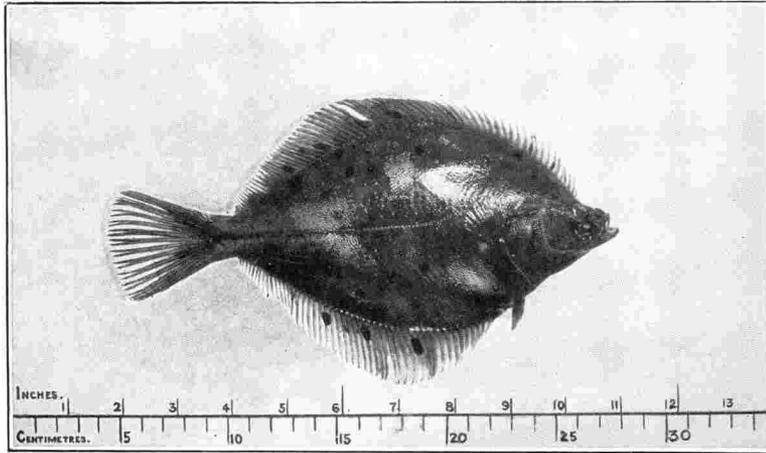
Some remarkable features resulted from these two experiments. The growth was found not only to exceed that of the coastal grounds from which the fish were taken, but it also exceeded any growth previously observed for plaice. A full year's length increment was found on the average to amount to six inches which is very striking compared with the average of $2\frac{3}{4}$ inches quoted on a previous page. From April to mid-winter the growths on the Danish coast and Dogger compare as follows. The overcrowded inshore fish increased 16% in length and 59% in weight, whilst similar fish transplanted to the Dogger increased by no less than 60% in length and 331% in weight. That is to say these little fish made such good use of the food available on the Bank as to grow nearly six times the normal rate.

These comparative growths are shown by means of a diagram (plate D). From this it can be seen that the fish grew rapidly month by month until the autumn, and had in four months already surpassed a whole year's growth of the fish inshore.

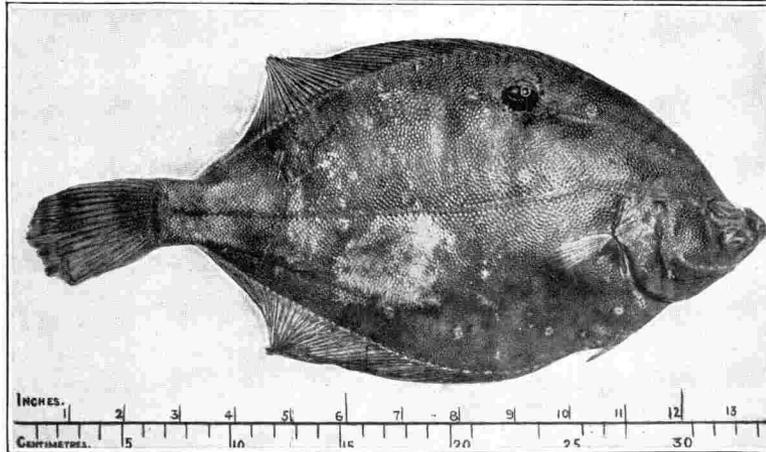
Photographs given in the report on these transplantation experiments, as conducted by the staff of the Lowestoft Laboratory, are reproduced in



No. 1



No. 2



No. 3

PLATE E.

- (1) Original size of fishes (2) and (3). ($7\frac{3}{8}$ ins. $2\frac{1}{2}$ ozs.)
- (2) Average size of (1) after seven months, growth on coastal grounds. ($9\frac{1}{8}$ ins. $4\frac{3}{8}$ ozs.)
- (3) Size of (1) after transplantation to the Dogger. Seven months, growth ($13\frac{3}{8}$ ins. 15 ozs.)

plate E. No. 1 shows the original size ($7\frac{3}{4}$ inches) of plaice such as were transplanted by the "Huxley." No. 2 shows the size No. 1 would have attained in the normal way in seven months on the coastal grounds. No. 3 depicts an actual specimen, the same size originally as 1 and 2, retaken seven months after having been transplanted to the Dogger.

Of 95 fish recaptured from these experiments no fewer than 87, or 92%, were taken by English fishermen and only 8 by all other nations combined, thus indicating that if this undertaking was carried out on a large scale, by far the greatest share of the profit would fall to English fishermen.

Such an important matter naturally calls for fuller investigation, and this report mentions that transplantation to other grounds is being tried with prospects of satisfactory results. These will be awaited with interest, and if the promises of the first experiments are borne out, it would seem only natural that we in England should make efforts to turn transplantation to practical advantage, as is being done in Denmark to-day.

With varying success, but never with that which has attended the above experiments, other transplantation experiments have been made on the Danish and German coasts.*

The German steamer brought a number of Baltic plaice to the North Sea through the Kiel Canal, but the fish did not grow. In conclusion it may be mentioned that German fish culturists are achieving success in another kind of transplantation, viz., that of eels. Numbers of elvers have been purchased on the Severn and successfully carried from England and set out in the German streams, and the undertaking seems likely to prove profitable.

* Since the above was written the Marine Biological Association has published in its Journal an account of a transplantation experiment with plaice to the North Sea from the new White Sea trawling grounds. Twenty-three fish were transported 1,540 miles on a Hull trawler, and set out near the Dogger Bank.

The water in which they were liberated was 24° F. warmer than that near the Russian coast where they were originally caught. The fish, however, appear not only to have survived, thirteen having been caught again, but they improved in condition and grew very much faster than North Sea plaice of corresponding sizes.

The foregoing short notes have been summarised from reports on plaice which have appeared in recent years. Further study of any of these reports, and others to which they refer, will amply repay any naturalist interested in the life history of one of our most valuable food fishes.

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