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REVIEW OF SCOTTISH HERRING TAGGING EXPERIMENTS 1948 - 1953

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Part I

Description of tagging methods

Introduction

So far as is known, scientists of the Fishery Board for Scotland made the first efforts at marking and tagging herring (Fulton 1893). The first method was to punch a triangular hole in the tail fin, but this experiment was unproductive and later a metal tag consisting of a barbed hook carrying a rigid numbered plate on the shaft was used, unfortunately also without success.

American scientists in 1927 experimented with external tags on Pacific herring without, however, achieving conspicuous success (Rounsefell 1930). They finally made the bold experiment of inserting a small numbered metal plate into the body cavity, which could be recovered magnetically during processing. This innovation has proved most successful both in North America and, since the war, in Norway and Iceland, where the bulk of the fish is converted into meal and oil.

Preliminary experiments 1948-1950.

When herring tagging experiments were again undertaken in Scotland in July 1948, most of the North Sea catch was prepared and sold for human consumption so that it was necessary to use an external tag which had a chance of being seen by fishermen or others engaged in the industry. The tags first used consisted of a strip of pliable green plastic, tapering at both ends and about eight to ten millimetres wide at the widest part, as shown in Figure 1. The tag was applied round the body of the fish immediately behind the pectoral fins and was secured by a small fastener of stainless steel, which bore a serial number. The herring used in these experiments were caught by drift net from the Scottish research vessel "Clupea". In 1948, 892 herring were tagged and one fish was recovered, and in 1949 out of a total of 1,124 fish tagged four were recaptured.

The application of this band tag was a slow and chilling process and by the end of 1950 experiments had been made with three other types of tags. They were as follows

1. Numbered rubber band (fixed immediately behind the pectoral fins).
2. Lea's hydrostatic tag (attached with the customary bridle immediately in front of the dorsal fin).
3. Plastic strip (Danish "flag" tag), attached by wire through the dorsal musculature in front of the dorsal fin.

All of the liberations with these tag types in the period 1948-1950 were made on the Scottish north-east coast and Shetland fishing grounds from drift net catches taken by F.R.S. "Clupea". A small fleet of 17 nets was worked in the customary manner, but facilities were provided on board to ensure that the herring were placed in running sea water immediately they were brought on board. Only the liveliest, undamaged herring were selected for tagging; these were tagged under water and liberated individually.

A total of about 7,000 herring was liberated in this manner in the three years, and 23 recaptures were recorded. Each of the tag types used was represented in the returns, but the numbers of records were too small to assess their relative merits effectively.

The most important result which emerged from these experiments was that reasonably long period recaptures could be obtained from herring caught by drift-net. It was evident, however, that, in order to increase the numbers of recaptures without increasing the scale and cost of the investigation greatly, it was necessary to devise a tagging technique which would provide a much larger number of liberations during the course of the fishing season.

It was evident that tagging mortality was only one of a number of important factors which resulted in the loss of recapture data; others such as tag-shedding, missed tags in catch, etc. were mostly independent of the condition of the fish at liberation.

In these circumstances it was decided to investigate the possibility of conducting large scale tagging experiments from commercial drift-net vessels. A preliminary experiment made by Mr. G. Bolster (then of the Scottish Home Department Marine Laboratory, now with the Ministry of Agriculture and Fisheries), on board a commercial drifter in 1950 had indicated the possibilities of success by this method. It was considered that if liberations could be increased four or five-fold with the same effort in scientific manpower, substantially greater numbers of recaptures might be obtained even if tagging mortality was increased as a result of less careful handling.

The first step in developing a method of tagging from commercial drifters was to devise a tag and a tagging technique which allowed the work to be carried out on the deck of the vessel without interfering seriously with the fishing operations. The technique had to be as simple as possible, and the number of operators on each vessel as small as possible, preferably one man.

Two fundamentally different methods of herring tagging, "internal" and "external" were possible, each appropriate to particular practical circumstances. Internal tagging is the most appropriate when the herring are bulk handled in reduction plants, and the possibilities of spotting the tags in the catch are very small; and external tagging is most appropriate when the fish are handled singly or in small quantities and where there is no easy method of recovering the tags mechanically. Norwegian workers have shown recently that both methods can be used together on the same fish. The choice of method is governed largely by the type of fisheries practised in and adjacent to the centres of tagging.

In the North Sea, the fisheries for adult herring are conducted mainly by trawl and drift-net by a number of countries and the catch is treated in a variety of ways. Large quantities are bulk handled in reduction plants and the remainder are treated in one way or another for human consumption. It would appear, therefore, that the most appropriate tagging technique for the North Sea herring investigations was one incorporating both "internal" and "external" methods. However, for this to be justified, tag separators would have to be installed in the main reduction plants in all the countries fishing in the North Sea. Under the circumstances, therefore, it was decided to continue to concentrate the Scottish effort on "external" tagging, and to rely for recaptures mostly on the fish which were treated for human consumption. So far as could be judged from the rather scanty information as to the disposal of the adult herring catches in the North Sea, this would not introduce any serious bias in the biological results which accrued.⁺⁾

^{+) Experiments were conducted in 1951 and 1952 on the possibilities of extracting the "external" tags from reduction plants, by incorporating a small numbered strip of thin steel (0.5" by 0.1") in the body of the tag. The results of these experiments showed that while the metal strips were recovered when they were distributed free amongst the mass of herring fed to the plant the tags containing the strips were not recovered. This was probably due to the bulkiness of the tag, after heating, preventing it being drawn through the mass of partly processed material passing over the magnetic separator. Its use was therefore discontinued in subsequent tagging experiments.}

The development of a "one-man" tag.

Attention was first given to developing a simple and rapid method of attaching the tag to the fish which could be worked by a single operator. After several trials a form of "toggle" attachment shown in Figure 2 A was adopted and this has been used in almost all the experiments conducted since 1950. Recently, however, further experiments have been made with a new form on one-man "bridle" attachment shown in Figure 2 B. The "toggle" attachment consists of a wire "anchor" which is attached to the tag by a loop of nylon thread. It was found that a cheap and effective "toggle" could be made by twisting two strands of nickel or stainless steel wire tightly together and feeding the nylon thread through the "toggle" during the twisting process; this eliminated any need for knotting the nylon at any stage in making the complete tag. A simple apparatus, shown in Figure 3, for making "toggles" in large numbers was designed by Mr. G. Davies (now with the Ministry of Agriculture and Fisheries), and with it they can be made at the rate of about 100 per hour. They are made in strings and are then out up into single toggles of any required length.

The development of a suitable tag was conditioned by demands for (a) availability in large numbers, (b) cheapness, (c) hydrostatic properties, and (d) conspicuousness on capture. The tag adopted is illustrated attached to the fish in Figure 2 C. It consists of two "boat-shaped" sections of a plastic "polystyrene" (Figure 2 A), cemented together and containing a numbered strip of paper which can be read through the material of the tag. One of the sections is marked with "Reward" and the address of the Laboratory. The specific gravity of the tag without a metal strip is approximately 0.81 which gives it a positive buoyancy in all sea waters. When a metal strip is incorporated in the tag the specific gravity is 1.05 which still gives it a positive buoyancy in "average" sea water. The sections of the tag are mass-produced and they are made up into the complete tags in the laboratory. The cost for each complete tag is approximately 6 d.

This, and small numbers of the "Lea" hydrostatic and "Danish flag" type tags have been used with the "toggle" attachment in all tagging experiments made since 1950.

The method of tagging.

The adoption of a "one-man" tag necessitated rapid handling of the fish to ensure the largest possible number of live liberations. Early trials showed that the whole tagging operation with the "toggle" attachment could be easily worked by a single operator; furthermore, it was soon found that with some experience it was possible to dispense with water containers for testing the liveliness of the herring before and after tagging.

The technique which had been adopted in the experiments since 1950 is as follows: the operator selects the liveliest herring as they drop from the nets on to the deck of the vessel, tags them quickly in air, and then immediately drops them back into the sea. Cloth bandoliers, each holding fifty or sixty tags, are worn round the waist of the operator to ensure a ready supply.

Experience has shown that the best method of handling is to hold the fish firmly in the cup of one hand, with the head pointing forward, and to insert the "toggle" in the mid-dorsal line and press it forwards and sideways through the flesh of the back so that it emerges in front of and to the side of the point of entry.

Tagging rate.

The number of herring which an operator can tag effectively with the "one-man" tag in the course of a single-drift-net haul will be determined by a number of factors. Chief amongst these are:

- (a) The availability of live herring.
- (b) The care taken in the selection of the fish for tagging.
- (c) The weather conditions; cold, state of sea, etc.
- (d) The skill of the operator.

A number of experiments have been performed to determine the maximum rate of tagging which an operator of average experience can attain under good conditions, i.e. a constant supply of live, undamaged fish and a calm sea. In these experiments the tagged herring were placed in a tank on board ship and were kept there under observation for an hour before being liberated. The numbers of herring which failed to swim away after being liberated were also noted. The results of these trials are given in Table 1.

Table 1.

Experiment	Number of herring tagged	Total time taken (mins.)	Average time taken per tagging (secs.)	Number of herring dying within 1 hr. of tagging	Number of herring failing to swim away on liberation
1	60	25	25.0	Nil.	Nil
2	43	21	29.3	Nil	Nil
3	66	30	27.2	Nil	Nil
4	75	32	25.5	Nil	Nil
Total	244	108	26.5	Nil	Nil

These data show that, given a constant supply of live herring under favourable conditions, an operator might tag between 400-600 herring during a drift-net haul lasting 3-4 hours. Furthermore, they demonstrate that the numbers of immediate deaths resulting from the handling technique should be negligible.

The conditions encountered in the open sea drift-net fisheries are, of course, seldom suitable for this tagging rate to be accomplished. In some hauls most of the fish are dead when they are brought aboard, and in others they are too tightly meshed for them to be taken from the net in a completely undamaged state. The average rates actually accomplished in the experiments in the North Sea in 1951-1953 are presented in Table 2.

Table 2.

Tagging area	Year	Total No. of liberations	Number of hauls (one operator per haul)	Average No. of liberations per operator per haul
Scottish North-East Coast	1951	5714	55	105
	1952	8214	52	158
	1953	6811	35	195
	Total	20739	142	146
Shetland	1951	1867	22	85
	1952	2979	18	166
	1953	998	15	67
	Total	5844	55	106

These figures apply to all the hauls made with a tagging operator aboard, and include those in which no live herring were available. The greatest number of liberations during any one haul was made on the Scottish north-east coast grounds in 1953, when 1000 herring were liberated in a haul lasting approximately five hours.

On the basis of these figures an operator can be expected, under average conditions, to tag 600-800 herring by this method in a normal fishing week comprising five hauls. The tagging rate from commercial vessels has been approximately four times greater than that accomplished from the research vessel; it has afforded greater flexibility in the choice of tagging centres at any time, and has enabled the research vessel to undertake other work.

Cost of tagging operations.

The adoption of the "one-man" tagging technique on board commercial drifters not only resulted in a higher tagging rate per haul than was accomplished in the earlier experiments from the research vessels, but it also resulted in a reduction in the cost of each liberation.

Observations of tagged fish in captivity.

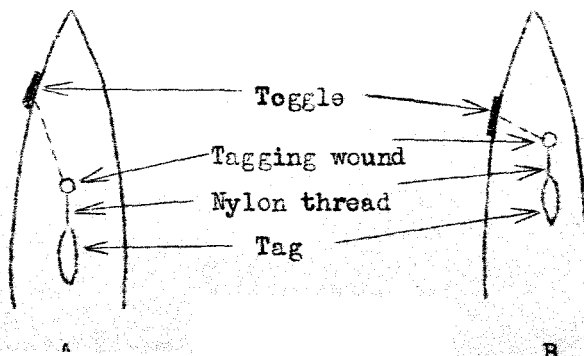
In the preliminary trials with the new technique only short term observations could be made on the fish after tagging and, as shown in Table 1, these indicated that mortality due to the handling technique was negligible up to one hour after the attachment of the tag. Nothing, however, was known of the magnitude of the mortality due to tagging, or the incidence of tag shedding after longer intervals. The magnitude of these sources of tag loss relative to other methods had in fact to be judged from the recapture data.

In October 1953, however, a small number of tagged and untagged herring were successfully established in aquarium tanks at the laboratory, and these have provided longer term data on the relative mortalities of tagged and untagged fish, the incidence of tag shedding, the course of the wound made during the attachment of the tag, and the general behaviour of the tagged fish.

Ten herring between 18-20 cms. in length, tagged in the normal way with the "Scottish" tag and toggle attachment and ten untagged herring of the same size range from a beach seine catch were placed in the aquarium tank on 26th October. Food was offered to the fish daily. After a period of about 12 days, during which neither the tagged nor untagged herring took food, regular feeding commenced by members of both groups and up to the time of writing no differences in their feeding habits and general behaviour have been detected.

Up to 15th May 1954, 200 days after introduction into the tank, 2 tagged and 1 untagged herring have died. In addition 3 tagged herring have shed their tags. In one instance the tag became detached from the toggle due to a faulty attachment, but in the remainder the tag with toggle attached was shed as a result of the nylon cutting through the flesh. The two tagged fish deaths took place the day after and 10 days after tagging respectively and the tags were shed after 72, 95 and 118 days respectively. The untagged fish died 10 days after introduction into the tank.

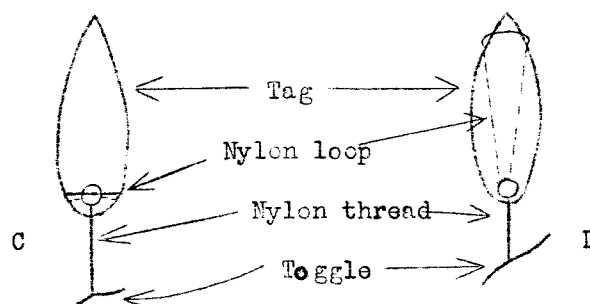
These results suggest that long term mortality due to the effect of the tag is probably not a serious source of tag loss, but they are of interest with regard to the incidence of tag shedding. It would appear that this may become a significant source of tag loss after periods of three to four months at liberty as the result of a gradual increase in size of the tagging wound by the movement of the nylon thread. Observations taken at intervals after tagging have shown that the increase in size of the wound may vary according to the angle of the nylon at the point of emergence from the back of the fish. The increase has been least in those instances where the nylon runs approximately anteroposteriorly, as in diagram A, and greatest when it makes a large angle with the longitudinal axis of the fish at the point of emergence, as in diagram B. In all instances the wound has remained open, but there has been no evidence of decay of the tissue.



In the light of these observations it is thought that tag shedding has been a substantial source of long term tag loss in the Scottish experiments since 1950. In support of this are 13 records of Scottish tags found stranded on the beach along the coasts of western Europe, after time intervals which have always been greater than two months from the time of liberation.

As mentioned earlier, a new design of bridle has been designed recently, and experiments will be conducted in 1954 in the aquarium and at sea, to determine whether with its use long term tag shedding can be reduced.

During the course of these experiments in the aquarium, a number of easily remedied defects of the complete tag assembly have been brought to light which may have contributed to tag shedding in experiments to date. These concern particularly the method of attaching the toggle to the tag and the use of adhesive material along the toggle to prevent the nylon pulling away from the twisted wire. Hitherto, the toggle has been attached to the tag by looping the nylon thread through the eye in the tag, as in diagram C; these experiments have shown that this form of attachment can come undone when long nylon loops are used as in Diagram D. The loss of the tag after 72 days was from this cause. This will be remedied in future by inserting a double loop at the point of attachment of the tag. It has also been found that the presence of an adhesive on the toggle after a long immersion in sea water results in a gradual decay and eventual breakage of the nylon at the point where it joins the wire toggle.



Recaptures from "one-man" tagging experiments and comparisons of tag types 1951 experiments.

The first experiment with the one-man tag was made in May 1951, and further experiments designed to study the migration of herring from the north-western North Sea were made at intervals between May and September on the north-east coast and Shetland drift-net grounds. Experiments were also made in the Minch in June, July and September.

Three types of tag were used in 1951, the "Lea" hydrostatic tag, the new "Scottish" hydrostatic tag and the plastic "flag" tag; all were used with the toggle attachment. The first deliveries of the "Scottish" tag were not made in time for the May experiment, when only "Lea" tags were used, but thereafter most of the liberations were made with the "Scottish" tag.

The recaptures reported to date from the 1951 liberations are given in Table 3, together with the percentage of each type of tag recaptured and the period of time after liberation within which the recaptures were made. +)

The corresponding information for the research vessel experiments in the North Sea in 1949 and 1950 are also given.

+) The returns repeated in this and all subsequent tables include only those which are known to have been recaptured during fishing operations.

Table 3.

Recaptures from Commercial Experiments in 1951

Area of Liberation	Type of Tag		Month of Liberation					Total
			May	June	July	Aug.	Sept.	
	Lea Hydro-static	No. Liberated	1440	-	-	-	-	1440
		No. Recaptured	51	-	-	-	-	51
		% Recaptured	3.54	-	-	-	-	3.54
		Times at liberty (Days)	1-263	-	-	-	-	1-263
Scottish North-east Coast	Scottish Hydro-static	No. Liberated	-	1293	1827	494	150	3764
		No. Recaptured	-	26	18	1	1	46
		% Recaptured	-	2.01	0.99	0.20	0.67	1.22
		Times at liberty (Days)	-	0-100	1-70	+	+	0-100 +)
	"Flag"	No. Liberated	-	410	-	-	-	410
		No. Recaptured	-	10	-	-	-	10
		% Recaptured	-	2.44	-	-	-	2.44
		Times at liberty (Days)	-	10-140	-	-	-	10-140
Shetland-Orkney	Scottish Hydro-static	No. Liberated	-	1247	720	-	-	1967
		No. Recaptured	-	12	6	-	-	18
		% Recaptured	-	0.96	0.83	-	-	0.92
		Times at Liberty (Days)	-	21-233	13-48	-	-	13-238
North Minch	Scottish Hydro-static	No. Liberated	-	299	200	-	-	499
		No. Recaptured	-	2	-	-	-	2
		% Recaptured	-	0.67	-	-	-	0.40
		Times at Liberty (Days)	-	1-53	-	-	-	1-53
All Liberations in 1951		No. Liberated	1440	3249	2747	494	150	8080
		No. Recaptured	51	50	24	1	1	127
		% Recaptured	3.54	1.54	0.87	0.20	0.67	1.57
		Times at Liberty (Days)	1-263	0-238	1-70	+	+	0.263
All Liberations in 1949 and 1950		No. Liberated	2335	1966	1406	329	-	6036
		No. Recaptured	7	10	3	2	-	22
		% Recaptured	0.30	0.51	0.21	0.61	-	0.36
		Times at Liberty (Days)	75-257	4-92	3-68	1-2	-	1-257

+) 2 fish liberated off Scottish N.E. coast in June and 1 in August and September recaptured on night of liberation in vicinity of tagging area.

The most important result from the 1951 experiments was the large increase in the number of recaptures over the two previous years. These were approximately five times greater than the combined recaptures from the 1949 and 1950 liberations; the percentage recaptured was also much greater. While the recovery of tags was promoted by a growing interest in the experiments, it is not possible to ascertain whether the great increase in tag recoveries in 1951 was due entirely to the differences between the tags or tagging techniques employed in the two periods, since no comparable research vessel experiments were conducted during that year, but the results, particularly from the North Sea experiments, indicated that the new technique was much more effective than the one hitherto in use.

Of the three types of tag used, "Lea"s tag gave the highest and the "Scottish" tag the lowest recapture percentage. However, on only one occasion, in June on the Scottish north-east coast grounds, were two or more of the types used together in the

same experiment. The percentages recaptured from the two sets of liberations of "Scottish" and "flag" tags on this occasion were not significantly different. Thus, it was not possible from these experiments to assess reliably the relative merits of all the tag types, but it was evident from the recaptures from the North Sea liberations in May and June that all three gave worth while results. Experiments designed to test the relative efficiencies of the two main types, the "Lea" and "Scottish" hydrostatic tags were subsequently conducted in 1952.

The 1952 experiments.

Because of the relatively encouraging results obtained following the introduction of the one-man tagging technique in 1951, it was again employed in 1952 on a more extensive scale. Once more, the main objective was to study the migrations of herring from the summer drift-net grounds in the North Sea, and tagging was carried out in this area in each of the months from May to August. A small number of liberations was also made in this area from F.R.S. "Clupea" in April and May. The tagging effort on the west coast grounds was also increased, and tagging was undertaken for the first time in the north-eastern North Sea in April, in the vicinity of the Coral Bank.

A small scale experiment was also conducted on the "halflin" stock in the upper reaches of the Firth of Forth in January and March 1952. The objective was to trace the subsequent movements of these herring (in their 3rd year) from the nursery area to the open sea grounds. A total of 529 liberations was made and 20 recaptures (3.78%) were reported, but all came from the vicinity of the tagging area. No returns were made from the open sea grounds.

In addition to these general tagging operations experiments were also made in 1952 to compare (a) the results from liberations made by the new Scottish technique and those made by the much more meticulous technique used by Swedish workers in the Bohuslän area; (b) the relative efficiencies of different types and colours of tags when used with the Scottish toggle attachment. The first of these comparisons was made possible by the kind invitation to one of the authors by Dr. Höglund of the Swedish Fishery Board to take part in the spring tagging experiments along the Bohuslän coast. The second set of experiments was conducted during the course of the main summer tagging experiments in the North Sea, when two different types of tag and a number of different colour versions of the Scottish tag were used in liberations from the same hauls.

The total (and percentage) recaptures from all the open sea experiments made in 1952, exclusive of those obtained from "Clupea" liberations and those from the Bohuslän coast experiment, are given in Table 4 (see page 8). They include recaptures from the experiments designed to compare tag types and colours.

The number of liberations made in 1952 and the numbers of recaptures reported were both over twice as large as in 1951; percentage recaptures were also larger, particularly for the main North Sea summer experiments from which all but 30 of the recaptures were obtained.

Again, as in 1951, there were marked differences between the percentage recaptures from liberations made in different areas and months. Recoveries from the North Sea summer liberations were once more relatively very much greater than from the west coast experiments, from which the percentage recaptured was only slightly than in 1951 despite a large increase in the number of tagging stations. The results from the north-western North Sea experiments showed the same general time differences as in 1951; recaptures from liberations made in August were again relatively very much smaller than those from liberations made in the earlier months.

An overall difference in recoveries of the two main types of tag used in the experiments is also shown in Table 4. The "Lea" tag, used throughout with the "toggle" attachment gave a higher recapture percentage than the Scottish tag for liberations made with the two types in all areas, but especially for those made in the north-east coast region. Here the Lea tag gave over twice the recapture percentage of the Scottish tag for all liberations.

Table 4.
Recaptures from Commercial Experiments
in 1952

Area of Liberation	Type of Tag		Month of Liberation						Total
			Feb.	April	May	June	July	Aug.	
Scottish North-east Coast	Lea Hydro-static	No. Liberated	-	-	330	331	133	-	794
		No. Recaptured	-	-	10	24	5	-	39
		% Recaptured	-	-	3.03	6.25	3.76	-	4.91 ^{+))}
		Times at Liberty (Days)	-	-	67-399	0-25	0-130	-	0-399 ^{+))}
Scottish North-east Coast	Scot-tish Hydro-static	No. Liberated	-	-	1649	2756	1797	1218	7420
		No. Recaptured	-	-	35	80	42	7	164
		% Recaptured	-	-	2.12	2.90	2.34	0.57	2.21 ⁺⁺⁾
		Times at Liberty (Days)	-	-	36-161	1-397	1-95	0.25	0-397 ⁺⁺⁾
Shetland	Lea Hydro-static	No. Liberated	-	-	45	258	115	100	518
		No. Recaptured	-	-	2	6	1	2	11
		% Recaptured	-	-	4.44	2.33	0.87	2.00	2.12
		Times at Liberty (Days)	-	-	43-63	39-218	18	5-149	5-218
Shetland	Scot-tish Hydro-static	No. Liberated	-	-	226	1287	749	199	2461
		No. Recaptured	-	-	3	35	5	-	43
		% Recaptured	-	-	1.33	2.72	0.67	-	1.75
		Times at Liberty (Days)	-	-	35-77	2-148	6-50	-	2-148
North Eastern North Sea	Scot-tish Hydro-static	No. Liberated	-	1308	-	-	-	-	1308
		No. Recaptured	-	6	-	-	-	-	6
		% Recaptured	-	0.46	-	-	-	-	0.46
		Times at Liberty (Days)	-	40-134	-	-	-	-	40-134
North and South Minch	Lea Hydro-static	No. Liberated	200	-	-	-	175	249	624
		No. Recaptured	2	-	-	-	2	1	5
		% Recaptured	1.00	-	-	-	1.14	0.40	0.80 ⁺⁺⁺⁾
		Times at Liberty (Days)	1-44	-	-	-	?-416	0	0-416 ⁺⁺⁺⁾
North and South Minch	Scot-tish Hydro-static	No. Liberated	689	200	-	156	468	1747	3260
		No. Recaptured	3	-	-	2	3	11	19
		% Recaptured	0.44	-	-	1.28	0.64	0.63	0.58
		Times at Liberty (Days)	4-27	-	-	47	48-195	22-181	4-195
All open sea "commercial" liberations in 1952		No. Liberated	889	1508	2250	4788	3437	3513	16385
		No. Recaptured	5	6	50	147	58	21	287
		% Recaptured	0.56	0.40	2.22	3.07	1.69	0.60	1.75
		Times at Liberty (Days)	1-44	40-206	35-399	0-397	0-416	0-181	0-416

- ^{+))} 1 herring in June and 1 in July recaptured on night of liberation in vicinity of tagging area.
⁺⁺⁾ 2 herring in August recaptured on night of liberation in vicinity of tagging area
⁺⁺⁺⁾ Recapture in August made on night of liberation in vicinity of tagging area.

The numbers of liberations, however, with the two types of tags were very different each month, and "Lea" tags were not used at all tagging stations; a better assessment of the relative merits of the two types is obtained from the results of the comparative experiments when the two types of tag were used on the same night.

Comparison between tag types and colours.

Experiments in which "Lea" and "Scottish" tags were used in approximately equal numbers on herring tagged from the same haul, were undertaken on commercial vessels in the north-western North Sea in May and June, when a total of 5,173 herring were liberated. In these experiments a number of different colours of "Scottish" tag were used. In 1951, when the "Scottish" tag was first produced, only red tags were used, but in 1952 tags of different colours were employed. The colour types were, (1) Red, (2) Bright yellow, (3) Dull yellow (amber), (4) One section red, one section bright yellow, (5) One section blue, one section bright yellow. On all occasions the tags were used with the "toggle" attachment.

To ensure a random distribution of tag types amongst the herring liberated from each haul, bandoliers, each holding equal numbers of the various tag types distributed along them at random, were worn by the tagging operators.

The data from these experiments are summarised in Table 5. This gives the numbers of recaptures of each tag and colour type at successive time intervals after liberation.

Table 5.

	Lea Tag	Scottish Tag						Total all Tags
		Red	Dull Yellow (Amber)	Bright Yellow	Red Bright Yellow	Blue Bright Yellow	Total	
Number tagged	863	864	862	861	861	862	4310	5173
Number recaptured	No. %	No. %	No. %	No. %	No. %	No. %	No. %	No. %
within 30 days	2 0.23	3 0.35	3 0.35	4 0.46	3 0.35	4 0.46	17 0.39	19 0.37
Between 31-61 days	10 1.16	5 0.58	5 0.58	12 1.39	12 1.39	8 0.93	42 0.97	52 1.01
" 62-91 "	11 1.27	9 1.04	2 0.23	7 0.81	9 1.04	8 0.93	35 0.81	46 0.89
" 92-183 "	6 0.70	5 0.58	2 0.23	2 0.23	3 0.35	2 0.23	14 0.32	20 0.39
" 184-365 "	1 0.12				1 0.12		1 0.02	2 0.02
After 365 days	1 0.12		1 0.12				1 0.02	2 0.02
Unknown	3 0.35	2 0.23	2 0.23	3 0.35	7 0.81	2 0.23	16 0.37	19 0.37
Totals	34 3.94	24 2.78	15 1.74	28 3.25	35 4.07	24 2.78	126 2.92	160 3.09
		2.26%		3.37%				

The most striking difference between tag types was that between tags with and without a bright yellow component. Statistical analysis of the complete data shows no significant difference between the percentage recaptures of the Lea tag and the Scottish tags with a bright yellow component but both of these give significantly greater values than the average for the other colour types of the Scottish tags.

Thus it would appear that colour plays a large part in determining the relative efficiencies of two basically similar designs such as the Lea and Scottish tags. No very marked differences are shown between the recovery times for the two tag types, but the number of recoveries of both types after six months at liberty was too small for reliable conclusions to be drawn regarding their relative "long-term" merits. It is probable, however, that the provision in the Lea tag of detailed instructions to the finder in more than one language makes it more efficient than the Scottish tag when used in regions fished by a number of different countries.

While it is not possible to say to what extent the differences in efficiency of the colour types is attributable to difference in conspicuousness to predator species or in conspicuousness amongst the mass of fish after recapture, it is thought that conspicuousness on recapture is perhaps the more important factor. This is borne

out by the marked difference in recapture percentage between the "bright yellow" and "amber" tags. The absorption spectra of these colours are very similar, but experiments on board ship have shown the bright yellow tag to be much more conspicuous and much more easily picked out amongst a mass of herring.

Further data of the relative efficiencies of different tag types and colours are available from the experiments made off the Swedish coast in April 1952. The same colour types of the Scottish tag were used as in the North Sea experiments, and these and Lea tags were distributed in equal numbers amongst the fish tagged. The results from these liberations are contained in Table 6.

Table 6.

Tag Type	Colour	Number tagged	Number Recaptured	Percentage Recaptured
Lea	Blue and bright yellow	57	-	-
Scottish	Red	56	3	5.36)
	Dull yellow(amber)	57	3	5.26)
	Bright yellow	57	6	10.53)
	Red-Bright yellow	57	11	19.30)
	Blue-Bright yellow	57	4	7.00)
Total all Scottish		284	27	9.50
Total all Types		341	27	7.92

Apart from the absence of returns of the Lea tag, these results show the same general features as those from the North Sea experiments. Tags with a bright yellow component provided the greatest numbers of recaptures for the various colour types of the Scottish tag, and the red-yellow combination again gave the highest number of any one type. The practical significance of the greater efficiency of the red-yellow combination is obscure. The absence of recaptures of the Lea is very surprising considering that this tag is the one used in the Swedish experiments and is familiar to the fishermen operating in the Skagerrak, from which all recaptures from these experiments were obtained.

Comparison of tagging methods.

The Swedish experiments also provided information on the relative merits of the Scottish method of tagging and the Swedish technique used by Dr. H. Höglund. Approximately equal numbers of herring caught by pound-net were tagged on each of several days by each method and the two batches of herring were liberated together. Unfortunately, the quantities of herring caught during the course of the experiment were very small, and the number of comparable liberations made by the Swedish and Scottish methods was restricted to 237 and 238 respectively (The difference between the total for Scottish liberations given here and those stated in Table 6 is due to additional liberations, contained in Table 6 but not in Table 7, being made after the comparative experiments had ceased.).

The herring tagged by each method were placed in the same water container, and were liberated together. Observations taken at the time of the experiment showed no differences in the liveliness of the herring tagged by the two methods, and gave no indication of a difference in short term tagging mortality between the two methods.

The numbers (and percentage) of recaptures from the two sets of liberations are presented in Table 7. (see p.11).

+) The reader is referred to Dr. Höglund's contribution for details of the tagging technique employed in the Swedish experiments, and for a more detailed analysis of the recapture data.

Table 7.

	No. Recaptured		Percentage	
	Swedish	Scottish	Swedish	Scottish
After 1 month	13	5	5.5	2.1 (2.2) ⁺
" 3 months	21	12	8.9	5.1 (5.4)
" 6 "	27	17	11.4	7.1 (7.6)
" 8 "	33	18	13.9	7.6 (8.1)
" 12 "	42	18	17.7	7.6 (8.1)

⁺) Figures in brackets are percentages recaptured of Scottish tag, excluding the "Lea" tag.

These results show a higher recapture percentage of Swedish tags than Scottish ones for all periods at liberty, but in particular they indicate a much more rapid fall off in the numbers of recaptures of Scottish tags after three months. Whereas returns of the Swedish tag continued to be made one year after the experiments, no recaptures of Scottish tags have been reported after six months. These results are of particular interest in the light of those obtained subsequently with the herring kept in the aquarium, and point to a relatively high incidence of shedding of the Scottish tag. It is considered therefore that the difference in numbers of recaptures from the two sets of liberations are mainly due to differences in efficiency of the methods of attachment used rather than in the handling methods.

However, these results must be viewed in the light of differences in the tagging rate with the two methods. On average, four herring were tagged with the Scottish method by a single operator during the time taken by a team of three scientists to tag one by the Swedish method. Thus, given a constant supply of herring a team of three operators would liberate much larger numbers by the Scottish than by the Swedish method, and at smaller cost. The greater tagging potential of the Scottish method more than compensates for the smaller recapture percentage at least up to six months after liberation.

One feature of the technique used in the Swedish experiments is the collection of length data and scale samples from all herring tagged. This has not been undertaken in the Scottish experiments; instead these data are only taken at the time of recapture. This inevitably results in a substantial loss of such information since with a large number of returns only the tags are received. Steps are being taken in the Scottish experiments to investigate the possibility of collecting scales at the time of liberation. It is clear, however, that the technique to be adopted will depend on the main objectives of the investigations, the resources available and on local fishing circumstances.

The 1953 experiments.

The open sea tagging experiments in 1953 followed the same general lines as in 1952. The "commercial" technique was employed throughout, and either "Scottish" or "Lea" tags were used with the toggle attachment. Small numbers of liberations were also made with the one-man bridle shown in Figure 2C. All Scottish tags used in 1953 possessed a yellow component.

The total numbers of liberations and recaptures to date, including those made with the bridle attachment, for each of the open sea experiments in 1953 are given in Table 7 A (see p.12).

Table 7 A.

Recaptures from Commercial Experiments in 1953.

Area of Liberation	Type of Tag		Month of Liberation					Total
			April	May	June	July	August	
Scottish North-east Coast	Scottish Hydro-static	No.Liberated	-	3995	1418	1229	169	6811
		No.Recaptured	-	41	7	19	1	68
		% Recaptured	-	1.03	0.49	1.55	0.59	1.00
		Times at Liberty (Days)	-	0-157	1-203	1-202	16	0-203 +)
Shetland	Scottish Hydro-static	No.Liberated	-	338	565	85	-	988
		No.Recaptured	-	9	9	1	-	19
		%Recaptured	-	2.66	1.59	1.18	-	1.92
		Times at Liberty (Days)	-	59-252	1-70	16	-	1-252
North of Fladen (approx. 58° 45' N 1° 00' E)	Scottish Hydro-static	No.Liberated	200	400	-	-	-	600
		No.Recaptured	5	4	-	-	-	9
		%Recaptured	2.50	1.00	-	-	-	1.50
		Times at Liberty (Days)	143-179	83-136	-	-	-	83-179
North Minch	Lea Hydro-static	No.Liberated	-	-	-	120	880	1000
		No.Recaptured	-	-	-	0	2	2
		% Recaptured	-	-	-	0	0.23	0.20
		Times at Liberty (Days)	-	-	-	-	4-118	4-118
North Minch	Scottish Hydro-static	No.Liberated	-	-	-	769	1389	2158
		No.Recaptured	-	-	-	2	5	7
		% Recaptured	-	-	-	0.26	0.36	0.32
		Times at Liberty (Days)	-	-	-	79-193	3-138	3-193
All Liberations in 1953		No.Liberated	200	4733	1983	2203	2438	11.557
		No.Recaptured	5	54	16	22	8	105
		% Recaptured	2.50	1.14	0.81	1.00	0.33	0.91
		Times at Liberty (Days)	143-179	0-252	1-203	1-202	3-138	0-252

+) 1 herring in May recaptured on night of liberation in vicinity of the tagging area.

The percentages recaptured from the 1953 liberations were appreciably lower than in 1951 and 1952 except for the experiments in the north-eastern North Sea. The most marked drop in recoveries was from liberations made off the north-east coast of Scotland in May and June; whereas recoveries from liberations made in these months in 1952 averaged 2.8% those from the 1953 experiments averaged only 0.9%. While further returns from those experiments may yet be received, it is unlikely that they will be in sufficient numbers to increase this percentage appreciably. The reason for this decrease in returns is not known, but it is believed that it may be, in part at least, the result of a general increase in 1953 in the proportion of the total European herring catch which was bulk handled in reduction plants. It is not possible to assess alternatively to what extent this drop in recoveries might be related to an overall decrease in effort and catch in 1953 since no effort statistics for the total European herring fisheries in the North Sea are available.

Features of the 1951 and 1952 recapture data which are again illustrated in the 1953 figures are,

- 1) The much smaller recovery of tags from the Minch experiments than in the North Sea.
- 2) The smaller percentage recapture from liberations in the North Sea in August compared with the earlier months.

Comparison between toggle and bridle attachments.

Experiments in which the bridle and toggle attachments were used together were made on the north-east coast grounds in June, and on the Minch grounds in July. In addition, liberations with both types of attachment were made on the "halfin" fishing grounds in the upper reaches of the Moray Firth in December and again in March 1954.

The numbers of liberations and recaptures from these experiments are given in Table 8.

Table 8.

		Number Liberated	Number Recaptured	Percentage Recaptured	Times at Liberty(Days)
Scottish North-East Coast	Toggle	100	0	0	-
	Bridle	199	5	2.51	1-203
Shetland	Toggle	60	0	0	-
	Bridle	120	2	1.67	79-193
Upper Moray Firth	Toggle	130	2		+)
	Bridle	251	6	2.39	5-67

+) Both fish caught on night of liberation in tagging area.

On the basis of these rather limited data it would seem that better returns would result from the adoption of the bridle attachment possibly as the result of a reduction in the incidence of tag shedding. Larger scale experiments to test the relative merits of these two attachments will be made in 1954, both in the aquarium and in the field.

Discussion.

The recaptures obtained from the experiments in the years 1951 to 1953 provide adequate material from which to assess the respective merits and shortcomings of the one-man tagging technique from commercial drift-net vessels, on which almost the whole of the Scottish contribution to the European herring tagging programme has been based.

It is evident from the data which have accumulated since 1951 that this technique has satisfied the initial demands of much greater numbers of liberations and recaptures per unit cost than hitherto, and has at the same time allowed the rather limited resources of one research vessel to be used entirely for other important investigations. These, it is considered, are considerations of very great importance, which can be over-ruled only if the technique is failing to provide some essential data which would be forthcoming from the adoption of an alternative, more expensive technique.

The least satisfactory feature of the results to date is the absence of substantial numbers of long-term recaptures, especially after periods at liberty exceeding one year. This is shown by the data contained in Table 9 (see p.14), which gives the numbers of recaptures after successive three monthly intervals from all the North Sea experiments made in the period 1951 to 1953.

Table 9.

Time at liberty	Number of Recaptures	%
Up to 3 months	376	81.9
3-6 "	72	15.7
6-9 "	9	2.0
9-12 "	-	-
12-15 "	2	0.4
15-18 "	-	-
Over 18 "	-	-

Since the herring fished in the north-western North Sea in the summer months are mainly an indigenous stock of autumn spawning herring which are probably fished intensively throughout the greater part of the year, the most likely explanation of the absence of the long-term recaptures must be sought amongst the various sources of tag loss, collectively termed "tagging mortality". The two most likely sources are (1) deaths of tagged fish due either to the direct effect on the fish of the tag itself or its attraction of predators, and (2) the shedding of tags after long periods at liberty. The second of these sources is considered to be the more important and it was in an attempt to reduce this loss that experiments with a further bridle attachment were undertaken in 1953. It will not be possible, however, to assess the relative merits of the two attachments and to determine whether the numbers of long-term recaptures can be increased substantially by the use of the bridle attachment until further field and aquarium trials have been made. The alternative possibility that liberated drift-net caught herring, whether tagged or not, suffer a relatively high mortality after several months at liberty cannot be ruled out.

It is thought that the poor returns from the Minch experiments are associated with the absence of areas of shoal concentration, such as are found on the Fladen Ground and in the region of the Dogger, where the shoals are much more effectively exploited by trawl than by drift net. Recently, there has been a marked increase in the proportion of the Minch catch which is bulk handled in reduction plants, and in 1953 it comprised 68% of the total catch. Steps are being taken, therefore, to install magnetic tag separators at the main reduction plants in this area with a view to the introduction of internal tagging in the Minch.

At the present time it is not considered possible to change from the basic method of external tagging in the North Sea because of the lack of tag separators in the reduction plants of most European countries. In view, however, of the present trends in the disposal of the European catch from the North Sea it is becoming increasingly important that, in order to maintain an effective herring tagging programme in the North Sea, steps should be taken to effect their installation. Not until this is accomplished on a large scale will a major change in the North Sea tagging technique be justified. It is considered that future developments in herring tagging in the North Sea should be towards "combination" external tags which can be magnetically from reduction plants as well as readily spotted on the fish treated for human consumption. The experiments with the Scottish tag containing a metal strip, although unsuccessful in themselves, provided information which pointed to the possibility of developing an effective "combination" tag. Trials with a new design of such a tag will be made in the Scottish experiments in 1954.

* / separated

PART II.

Biological Results from Scottish Tagging
Experiments.

This part of the paper deals with the more important biological features of the results from the Scottish tagging experiments. Preliminary reports of some of these have already been submitted at the Council's meetings in 1951 and 1952 (e.g. Wood 1951, McPherson 1952) and further summaries of each year's recaptures are contained in Annales Biologiques, volumes VI to IX.

Area distribution of recaptures.

The areas in which recaptures have been made from all experiments since 1948, excluding those on the juvenile stocks in the Moray Firth and Firth of Forth, and that off the Swedish coast (see report by Dr. H. Höglund), are listed in Tables 10-13 (at the end of the text). These give the numbers of recaptures made in each main fishing region from liberations made each month in each tagging locality; only those records for which there is complete information as to time and place of recapture are included. The numbers of records, which were unusable due to the absence of this information, was small, but for completeness they are recorded under "unusable" records in the tables. Most of the data are also reproduced in Charts 1-10.

Before any biological interpretation of these results can be made, it is necessary to consider the more important factors which may influence the numbers of recaptures in different areas and which, if not fully recognised, may lead to faulty biological interpretation. The most important of such possible factors are:

1. The distribution and amount of fishing effort.

It is an obvious limitation of all such tagging experiments that recaptures can only come from areas in which fisheries operate. Furthermore, the chances of recaptures being made in each fishery will be a function of the amount and kind of fishing effort to which the population of tagged fish is subjected after liberation.

2. The influence of the gear on tag loss at recapture.

Unrepresentative numbers of recaptures will be made in different fisheries if there are differences in the incidence of tag loss at recapture due to the mode of action of the gears. This factor is possibly important in the present enquiry since tag loss on recapture by drift net is thought to be higher than by trawl.

3. Differences in the chances of the tags being spotted in the catches taken by different gears and in different handling processes on board ship and ashore.

4. Differences in the awareness of fishermen and other operatives in different areas to the tagging experiment.

The composition of the herring fisheries in the North Sea is such that all of these factors are important in the present enquiry. It is evident that a full quantitative appraisal of the recapture data cannot be made without complete details of the distribution of fishing effort by each type of gear in the North Sea and its approaches. Unfortunately, these are not available for any of the years in which liberations have been made, and in consequence it is not possible to make deductions as to the magnitude of any migration from one area to another. The problem is further complicated by the suspected relatively high (but unknown) increase in the incidence of tag shedding after periods at liberty exceeding four months (see Part I, p.6).

For these reasons deductions from the recapture data must be to a large extent tentative and qualitative. Nevertheless they provide some important and interesting pointers to the migrations undertaken by the herring populations which inhabit

the north-western North Sea in the summer months. Many of these support deductions made from other biological data, while some point to possible channels of future investigation.

North Sea Experiments.

Shetland and Scottish north-east coast liberations.

The most noticeable features of the recapture data from these experiments, shown in Tables 10-13, are:

1. The absence of recoveries from areas outwith the North Sea or its near approaches.
2. The wide spread of the recoveries within the North Sea boundaries.
3. The high incidence of recaptures from the Fladen ground.
4. The relatively small numbers of recaptures from the areas in which tagged fish were liberated.

Each of these features has important biological interpretations.

(1) It is now generally accepted by European ^{herring} workers that the main North Sea autumn spawning stock, on which most of the Scottish taggings have been made, lives within the boundaries of the North Sea and that ~~this~~ is largely independent of herring populations in adjacent areas, although there might be some mixing of these populations at the boundaries. Tags from North Sea liberations have been returned from the Skagerak and the Straits of Dover, but none from the West Coast of Scotland, the west of Norway or from the English Channel west of Dover. The absence of recaptures from the Minch grounds is of particular interest. Fisheries based on autumn spawning herring, with similar characters to the North Sea stock, are at present conducted in the Minch during the greater part of the year. The absence of recaptures from North Sea liberations in this area, or indeed in the reverse direction, points to geographical independence of the population in the two regions. It must be admitted that the chances of getting recoveries from some areas are greatly reduced by the nature of the fisheries. This is particularly so for the Norwegian coast where most of the herring are bulk handled in reduction plants. On the west coast of Scotland the herring fishery is carried on mainly by drift-nets, which probably gives rise to a much higher tag loss at recapture than the trawl.

The recoveries from the northern Skagerak have all been made during the course of the winter fishery for recovering autumn spawning herring, which takes place off the Behuslän coast of Sweden and northwards from the Skaw. None has been made in the inner reaches of Skagerak and further south. It would appear that the northern Skagerak marks the limit of extension of the North Sea autumn spawning stock into the Transition Area.

The absence of recoveries from the Norwegian coast also points to the existence of an eastern boundary in the northern North Sea at the edge of the deep water channel off the Norwegian coast. However, this must be regarded tentatively since the external tags used in the Scottish experiments are not recoverable from the Norwegian meal factories at which the greater part of the Norwegian catch is processed.

(2) The data contained in the tables and charts show that one or more recaptures have been made from all of the regions of the North Sea in which major fisheries for adult autumn spawners operate. Thus, on the assumption that the movements of tagged and untagged herring are approximately the same, it is evident that at least part of the herring stock which inhabits the north western North Sea in the summer months subsequently spreads over a wide area. The movements suggested by the recapture data are predominantly southwards and eastwards, and while such a movement pattern would necessarily be accentuated by the seasonal shifts of the

fisheries through the different areas, it is clear that the disposition of the herring fisheries corresponds closely with the disposition of the herring shoals. It is clear also that fish which are constituents of the north-western North Sea population during summer later invade the fishing grounds at Fladen, the Gut, the Dogger, off the north-east coast of England, East Anglia, the eastern part of the English Channel and the northern Skagerrak.

It is not possible to gauge the magnitude of the migration to each of these areas for reasons already given, nor is it possible to trace the routes followed by the fish in arriving at each locality, but it is very probable that herring moving southwards from the north-western North Sea to the central North Sea (Dogger and Tyne) and East Anglian areas make up a quite substantial part of the adult stocks which are fished in these regions, in the period September to November.

The ages of the herring recaptured in these southern areas are of particular interest in that fish between 3 and 8 years of age have been included in the recaptures. Unfortunately, however, the numbers of returns for which ages could be determined have been disappointingly few. The maturities of the recaptured fish from these areas have ranged between stages I (one specimen) and VII. Those from the Dogger grounds have mostly been in stages V-VII and those from East Anglia in stages IV-V. It is most probable, therefore, that the immigrants to these areas leave the more northerly grounds at the end of the summer period of active feeding and when maturation of the gonads is in progress.

(3) Of the grounds from which recoveries of tags liberated in the north-western North Sea have been obtained, the Fladen has provided by far the greatest number each year. The numbers of recoveries from all liberations made on the north-east coast and Shetland grounds since 1948 are shown in Table 14 and 15 at the end of the text. Those from the Fladen Ground constituted about 84% of all recoveries from Shetland liberations and 60% of all north-east coast liberations. Furthermore, it will be seen from Tables 10-13 that the proportion of the total recoveries from this area has increased appreciably between 1950 and 1953. Factors which undoubtedly contribute to the relatively much higher number of recaptures from this area than elsewhere are:

- a) The proximity of the Fladen ground to the tagging centres.
- b) The high intensity of fishing by trawl in this area.
- c) The relatively short time interval between liberation and the commencement of fishing at Fladen.

Despite the presence of these factors, the data show quite clearly that a large proportion of the autumn spawning stocks which are fished off the north-east coast of Scotland and at Shetland move from these regions to the deep water basin at Fladen. It would appear that this movement takes place continuously between June and September. It is as yet impossible to say whether the movement is a random one within a relatively wide summer boundary which includes the Fladen Ground, or a directional movement of a stock which is continuously replenished from another source.

The composition of the herring stock on the Fladen Ground undergoes a marked change following the spawning season on the neighbouring coastal banks. Whereas in the period prior to the main spawning time the composition of the autumn spawning stock there is similar to that on the grounds to the north and west (Shetland and N.E. coast grounds), consisting of fish in maturity stages III-V, after spawning season the composition is made up largely of newly spent fish (Annales Biologiques, Vol. VIII and Vol. IX). This change is also shown by the maturities of recaptured tagged fish for which complete data have been obtained. Thus, it is probable that the recaptures at Fladen between June and October are successively made up of:

- 1) Herring which have moved eastwards from the north-east grounds and southwards from Shetland, and which will subsequently return to spawn on these grounds (Probably very few of the recaptures from Shetland liberations are of this type).

- II) Herring which have spent the summer in the north-western North Sea but which proceed via the Fladen and Gut to other grounds before the onset of spawning. (Their probable destinations are the spawning grounds in the central southern North Sea).
- III) Spent herring from the neighbouring spawning grounds. These have an increasing dominance in the catches from about mid-September.

It is not clear at present whether I) and II) represent different spawning communities (races) of herring or whether they are members of the same community which has an extended spawning season over a wide area.

It is hoped that further information on the movements of the herring from the Fladen Ground will be obtained from large-scale tagging experiments there, particularly in August and September. Some attempts have been made to tag trawl-caught herring in this area without marked success, but further efforts will be made in the next two or three years.

(4) An unusual feature of the records from the north-western North Sea liberations is the relatively small number of recaptures in the region of the tagging places; only 2% of the recaptures from Shetland liberations and 16% from north-east coast liberations have come from fisheries in these regions. However, both of these fisheries are conducted by drift-net, and it is likely that the small number of recaptures from them may be due, partly at least, to a high incidence of tag loss on recapture by this gear⁺. If this is indeed true, biological interpretation of the data becomes very difficult. For example, any tendency to migration between the more or less coastal shoals fished by drift-net would be masked by the relatively unsuccessful recovery of tags from these fisheries. By the same token, the relatively few recaptures to the south of the Fladen Ground should be weighted considerably in any assessment, both for this reason and because of the tendency for tags to become detached with the passage of time. They do suggest, however, that the herring stock in the north-western North Sea during the summer undergoes fairly rapid movements into and away from the areas fished by the Scottish drifter fleets; as stated earlier, it is not yet known whether these movements are mainly at random or directional, but the evidence tends to support the latter view.

It will be seen from charts 1-10 that while the movements of fish tagged on the north-east coast during the summer months have taken place in a number of directions, no herring from this source have been recaptured on the Shetland grounds in the same year. Also, all but one of the recoveries from Shetland liberations show a southerly movement. It is probable, therefore, that there is little recruitment of herring to the Shetland grounds from those further south after the main invasion of the north-western North Sea has taken place each summer; recruits of autumn spawners to the Shetland grounds probably come from the same source and at the same time as those on the north-east coast grounds. Evidence of a common source is provided by one recapture on the Shetland grounds one year after liberation on the north-east coast grounds (see Chart 5).

Skagerak Recoveries.

Two interesting series of recaptures were made in the Skagerak or within Danish waters, one from a tagging experiment made in the region of the Coral Bank on 4th April 1952, the other from experiments made off Shetland and off north-east Scotland during May and June. In the case of the experiment carried out near the Coral Bank in April 1952 the recoveries from near the Danish coast were made between 13th May and 8th July of the same year, and four of the five recoveries were made from the Skagerak in the region of the Skaw between 27th June and 8th July (see Chart 5). On the other hand the seven recoveries from the tagging experiments in the north-western North Sea were made between 15th January and 12th February. All of them were in condition of recovering after spawning. It is interesting to note that the Skagerak recoveries in January and February were derived from fish tagged in May and June, which also yielded the majority of the recaptures made in the

+)

Less than 25% of the recaptures from the North Sea have been taken by drift net.

Dogger area. There is therefore a reasonable possibility that the spent fish, which were recovered in Danish waters in January and February, had spawned on the Dogger or its neighbourhood during the autumn.

It is evident from the results of sampling surveys in the Coral Bank area in the spring that the stock fished there is a mixed one of spring and autumn spawning herring. It is probable that the recoveries of Coral Bank liberations between May and July were members of a spring spawning population which inhabits the Skagerak and eastern North Sea throughout most of the year, while those taken in the winter were members of the North Sea autumn spawning stock. These recoveries certainly suggest that at least part of the stock which inhabits the north-western North Sea in the summer travels via the northern Skagerak in the course of its annual migration.

West Coast Investigations.

The numbers of recaptures of herring tagged in the Minch grounds have been disappointingly few and some possible reasons for this have been given in our earlier section. However, there are features of the recovery data worthy of mention. These are:

- (1) The absence of recoveries from areas outwith the Minch.

This has been mentioned already (p.16) in relation to the possible interchange of herring between the west coast of Scotland and the North Sea. The recapture data from both area have so far produced no evidence of intermixing of the two autumn spawning stocks in these areas. There is no evidence either of movements of Minch herring to Irish Sea grounds (Isle of Man) where seasonal fisheries for autumn spawning herring take place.

- (2) Records of recaptures in the southern part of the Minch from liberations made in its northern regions.

These records suggest that the autumn spawning herring fished throughout the Minch constitute a common stock, and there is a circulation of them within its boundaries.

- (3) Two recoveries from Minch liberations are of special interest. The first is of a herring liberated off the island of South Uist in July 1952, which was recaptured in the same area in August 1953, and the second is of a herring liberated off the coast of Lewis in February 1952 and recaptured off the Scottish mainland at about the same latitude in February 1954. This is the only Scottish record of a two year interval between liberation and recapture.

Tagging of "halflin" Herring.

In 1952 and 1953 tagging experiments were conducted on the adolescent "halflin" herring stocks which inhabit the upper reaches of the Firth of Forth and the Moray Firth. Fisheries for these herring, which are mostly in their third year of life, are conducted by small meshed drift and ring net in the winter months between November and March, after which the fish migrate from the areas. The objective of these tagging experiment was to trace the movement of these emigrants, after they left the nursery areas.

While a number of tagged fish were recaptured within the estuaries during the tagging season, none has been recaptured so far in the open sea.+) More extensive experiments have been planned for the winter of 1954.

+))

Since this report was prepared one recovery has been reported from the drift-net grounds off the Scottish north-east coast. The tagged fish was liberated in the upper reaches of the Moray Firth in March 1954, and was recaptured 35 miles east from Peterhead on 21.7.1954.

SUMMARY.

Part I of this paper deals with the methods used since 1948 in the Scottish tagging experiments, and discusses the relative merits of the different tag types and tagging techniques which have been used. Part II summarises the biological data which have resulted from these experiments.

Summary of Part I.

In the years 1948-1950, tagging experiments were conducted in the North Sea from catches made by drift net aboard F.R.S. "Clupea". A number of external tag types were used, which included a plastic band tag, a plastic "flag" tag, a coloured rubber band and Lea's hydrostatic tag. About 7000 liberations were made in different parts of the northern North Sea in the three years and twenty-three recaptures were recorded. These showed that selected herring could survive capture by drift net and subsequent tagging.

This method of tagging was costly and time consuming, and in 1951 trials were first made with a "one-man" tag on board commercial drifters. A much larger number of herring were tagged much more cheaply by this method, and a larger number of recaptures were reported than in the previous three years. This method has been adopted in all subsequent experiments.

Aquarium observations of herring tagged with the one-man tag show that tag shedding may be substantial after periods at liberty greater than four months. This might be a main contributory cause of a marked fall off in the numbers of recaptures after periods exceeding four months at liberty.

Comparisons between tag types and colours showed that the "Scottish" tag possessing a bright yellow component and the "Lea" tag were about equally effective when used with the "one-man" technique. Scottish tags without a bright yellow component proved less effective than the "Lea" tag. Conspicuousness on recapture is thought to be the major reason for the greater effectiveness of the bright yellow tag.

Comparative experiments between the meticulous Swedish tagging technique, in which "Lea" tags were used, and the one-man Scottish technique show a higher percentage recapture from the Swedish methods, particularly after intervals exceeding three months. It is thought that the main reason for this difference was the higher incidence of tag shedding of the Scottish tags. To reduce this, trials have been made with a new form of one-man bridle attachment which will be used in the Scottish experiments in 1954.

The limitations of external tagging in the North Sea and Scottish west coast experiments are discussed and because of a progressive increase in bulk handling of the catch the need for a combination external tag which is both magnetic and conspicuous is stressed. It is further recommended that steps be taken to effect the installation of magnetic separators in all European reduction factories.

Summary of Part II.

The main objectives of the Scottish tagging experiments have been to trace the movements of herring from the summer concentrations of autumn spawners in the north-western North Sea and from the summer and winter concentrations in the North and South Minch. Experiments have also been made on the adolescent "halflin" stocks of the Moray Firth and Firth of Forth to trace their offshore movements.

No herring tagged inside the North Sea have been recaptured outside its immediate approaches, but recoveries have come from widely separated localities within its boundaries.

The greatest numbers of recaptures from liberations in the north-western North Sea have been made on the Fladen ground, and others have come from central

and southern North Sea fisheries including those on the Gut, the Dogger Bank, off the English north-east coast, at East Anglia and in the eastern Channel. It is evident that a substantial part of the autumn spawning stock which frequents the northern North Sea in summer subsequently moves to the south in late summer and autumn, probably via the Fladen Ground and the Gut, and that probably a reverse migration takes place in the eastern North Sea in winter and spring when some of the fish penetrate the northern Skagerak.

The small number of recaptures from liberations made in the Minch show no migrations outside its boundaries, but point to a free circulation of herring within its limits. The only Scottish record of a two-year interval between liberations and recapture was reported in February 1954 from the North Minch, about 50 miles from the point of liberation.

All recaptures of taggings of "halflin" herring have been taken on the nursery grounds. Larger scale experiments on these stocks are planned.

ACKNOWLEDGEMENTS

The Scottish tagging programme has been carried out by a team of workers, all of whom have contributed to the development of the tags and tagging methods used and have taken part in the experiments at sea. Acknowledgement is made of the important part played by Mr. G. Davies +) in the development of the "toggle" attachment and in the first experiments on commercial drifters in 1951, to our colleagues, Messrs. Baxter, Bruce, Grierson, Robinson and Sinclair, who have undertaken much of the work at sea, and to Mr. J.H.S. Blaxter who has supervised the aquarium experiments.

Our sincere thanks are also expressed to Dr. H. Höglund of the Swedish Fishery Board for his kind invitation to one of the authors to take part in the Swedish tagging experiments in 1952.

+)(Now with the Ministry of Agriculture and Fisheries).

Table 10.

Records of recaptures of herring tagged in the years 1948, 1949 and 1950

Area of Liberation and Number Tagged	Area of Recapture	Month of Tagging				Total	%
		May	June	July	August		
Shetland-Orkney May = 70 June = 1263 July = 105	Fladen	1	6	Nil	-	7	100.00
Scottish N.E.Coast May = 2265 June = 960 July = 1482 August = 1040	Scottish N.E.Coast	1	2	Nil	3	6	37.50
	Fladen	1	2	2	Nil	5	31.25
	Gut	1	Nil	Nil	Nil	1	6.25
	English N.E. Coast	1	Nil	Nil	Nil	1	6.25
	Dogger	1	Nil	1	Nil	2	12.50
	Skagerak	1	Nil	Nil	Nil	1	6.25
	Total	6	4	3	3	16	100.00

Table 11.

Records of recaptures of herring tagged in 1951

Area of Liberation and Number tagged	Area of Recapture	Month of Tagging					Total	%
		May	June	July	Aug.	Sep.		
Shetland-Orkney June = 1247 July = 720 <u>1967</u>	Shetland	-	1	Nil	-	-	1	5.6
	Scottish N.E.Coast	-	1	Nil	-	-	1	5.6
	Fladen	-	8	6	-	-	14	77.6
	Dogger	-	1	Nil	-	-	1	5.6
	Skagerak	-	1	Nil	-	-	1	5.6
	Total	-	12	6	-	-	18	
	Unusable records	-	Nil	Nil	-	-	Nil	
Scottish N.E.Coast Apr. = 28 +) May = 1458 ++) June = 1703 July = 1827 Aug. = 494 Sep. = 150	Scottish N.E.Coast	13	6	5	1	1	26	27.4
	Fladen	16	20	9	Nil	Nil	45	47.4
	Gut	4	1	2	Nil	Nil	7	7.4
	English N.E.Coast	4	Nil	Nil	Nil	Nil	4	4.2
	Dogger	7	3	Nil	Nil	Nil	10	10.4
	East Anglia	2	Nil	Nil	Nil	Nil	2	2.1
	Skagerak	1	Nil	Nil	Nil	Nil	1	1.1
	Total	47	30	16	1	1	95	
	Unusable records	4	6	2	Nil	Nil	12	
North Minch June = 299 July = 200 +) Sept. = 359 +) Oct. = 51 +) Dec. = 24 +)	North Minch	-	2	Nil	-	1	3	75.0
	South Minch	-	Nil	Nil	-	1	1	25.0
	Total	-	Nil	Nil	-	2	4	
	Unusable records	-	Nil	Nil	-	Nil	Nil	

+)
Liberations made from F.R.S. "Clupea") Liberations and recaptures
++) Includes 18 liberations from F.R.S. "Clupea") not included in Table 3.

Table 12.

Records of recapture of herring tagged in 1952

Area of Liberation and Number Tagged	Area of Recapture	Month of Tagging						Total	%
		Febr.	Apr.	May	June	July	Aug.		
N.E. North Sea (Coral Bank) April = 1308	Gut	-	1	-	-	-	-	1	16.7
	Skagorak	-	5	-	-	-	-	5	83.3
	Total	-	6	-	-	-	-	6	
	Unusable records	-	Nil	-	-	-	-	Nil	-
Shetland May = 271 June = 1545 July = 864 Aug. = 299	Shetland	-	-	Nil	2	Nil	Nil	2	4.3
	Scottish N.E. Coast	-	-	1	Nil	Nil	Nil	1	2.1
	Fladen	-	-	4	30	5	2	41	87.2
	Dogger	-	-	Nil	2	Nil	Nil	2	4.3
	Skagerak	-	-	Nil	1	Nil	Nil	1	2.1
Total	-	-	5	35	5	2	47		
	Unusable records	-	-	Nil	6	1	Nil	7	
Scottish N.E. Coast April = 121 ⁺ May = 2764 ⁺⁺ June = 3087 July = 1930 Aug. = 1218	Shetland	-	-	1	Nil	Nil	Nil	1	0.6
	Scottish N.E. Coast	-	-	1	11	5	6	23	13.2
	Fladen	-	-	24	58	35	1	118	67.8
	Gut	-	-	1	6	2	Nil	9	5.3
	English N.E. Coast	-	-	3	4	1	Nil	8	4.6
	Dogger	-	-	6	4	1	Nil	11	6.3
	East Anglia	-	-	Nil	2	1	Nil	3	1.7
	Skagerak	-	1	Nil	Nil	Nil	Nil	1	0.6
Total	-	1	36	85	45	7	174		
	Unusable records	-	Nil	13	19	2	Nil	34	
North Minch Febr. = 889 Mar. = 200 July = 300 Aug. = 1996	North Minch	Febr. 6	Mar. Nil	June -	July 2	Aug. 6	Nov. -	14	77.8
	South Minch	Nil	Nil	-	Nil	4	-	4	22.2
	Total	6	Nil	-	2	10	-	18	
	Unusable records	Nil	Nil	-	Nil	2		2	
South Minch June = 156 July = 343 Nov. = 150 ⁺	North Minch	-	-	Nil	Nil	-	Nil	Nil	
	South Minch	-	-	1	1	-	1	3	100.0
	Total	-	-	1	1	-	1	3	
	Unusable records	-	-	1	2	-	Nil	3	

+) Liberations made from F.R.S. "Clupea".
 ++) 785 Liberations made from F.R.S. "Clupea", giving 4 recaptures.) Liberations and recaptures not included in Table 4.

Table 13.

Records of recaptures of herring tagged in 1953

Area of Liberation and Number Tagged	Area of Recapture	Month of Tagging					Total	%
		Apr.	May	June	July	Aug.		
Shetland May = 338 June = 565 July = 85	Shetland	-	Nil	1	Nil	-	1	5.3
	Fladen	-	6	8	1	-	15	79.0
	Dogger	-	1	Nil	Nil	-	1	5.3
	Skagerak	-	2	Nil	Nil	-	2	10.4
	Total	-	9	9	1	-	19	
	Unusable records	-	Nil	Nil	Nil	-	Nil	
North of Fladen (58°45'N 01°00'E) Apr. = 200 May = 400	Scottish N.E.Coast	Nil	1	-	-	-	1	14.3
	Fladen	Nil	1	-	-	-	1	14.3
	Dogger	4	1	-	-	-	5	71.4
	Total	4	3	-	-	-	7	
	Unusable records	1	1	-	-	-	2	
Scottish N.E.Coast May = 3995 June = 1418 July = 1229 Aug. = 169	Scottish N.E.Coast	-	6	2	4	Nil	12	19.4
	Fladen	-	22	2	11	Nil	35	56.5
	Gut	-	2	Nil	1	Nil	3	4.8
	English N.E.Coast	-	2	1	Nil	1	4	6.4
	Dogger	-	3	1	1	Nil	5	8.1
	East Anglia	-	Nil	Nil	1	Nil	1	1.6
	Skagerak	-	Nil	1	1	Nil	2	3.2
	Total	-	35	7	19	1	62	
	Unusable records	-	6	Nil	Nil	Nil	6	
North Minch July = 889 Aug. = 2269	North Minch	-	-	-	1	4	5	71.4
	South Minch	-	-	-	1	1	2	28.6
	Total	-	-	-	2	5	7	
	Unusable records	-	-	-	Nil	2	2	

Table 14.

Recaptures of herring tagged at Shetland 1948-53.

Area of recapture	Month of Tagging				Totals	%
	May	June	July	August		
Shetland	-	4	-	-	4	4.4
Scottish N.E.Coast	1	1	-	-	2	2.2
Fladen	11	52	12	2	77	84.6
Dogger	1	3			4	4.4
Skagerak	2	2			4	4.4
	15	62	12	2	91	100.0

Table 15.

Recaptures of herring tagged off Scottish N.E.Coast
1948-1953

Area of recapture	Month of Tagging						Totals	%
	Apr.	May	June	July	Aug.	Sept.		
Shetland		1					1	0.3
Scottish N.E.Coast		21	21	14	10	1	67	19.3
Fladen		63	82	57	1		203	58.5
Gut		8	7	5			20	5.8
English N.E.Coast		10	5	1	1		17	4.9
Dogger		17	8	3			28	8.1
East Anglia		2	2	2			6	1.7
Skagerak	1	2	1	1			5	1.4
	1	124	126	83	12	1	347	100.0



FIGURE 1

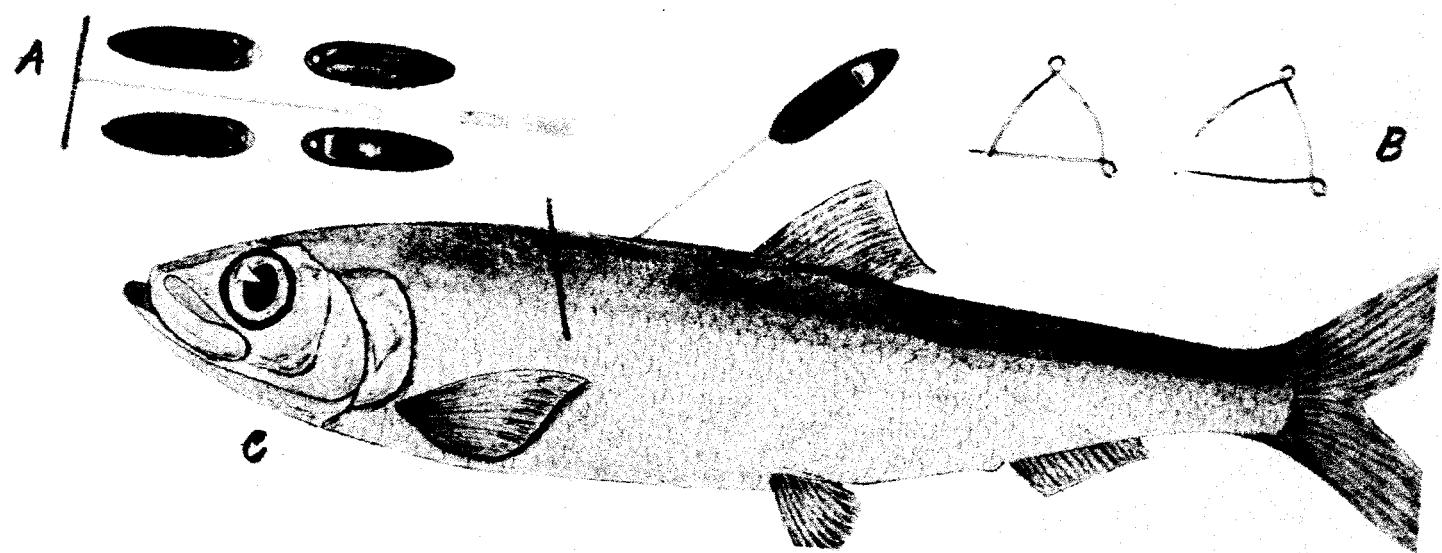


FIGURE 2

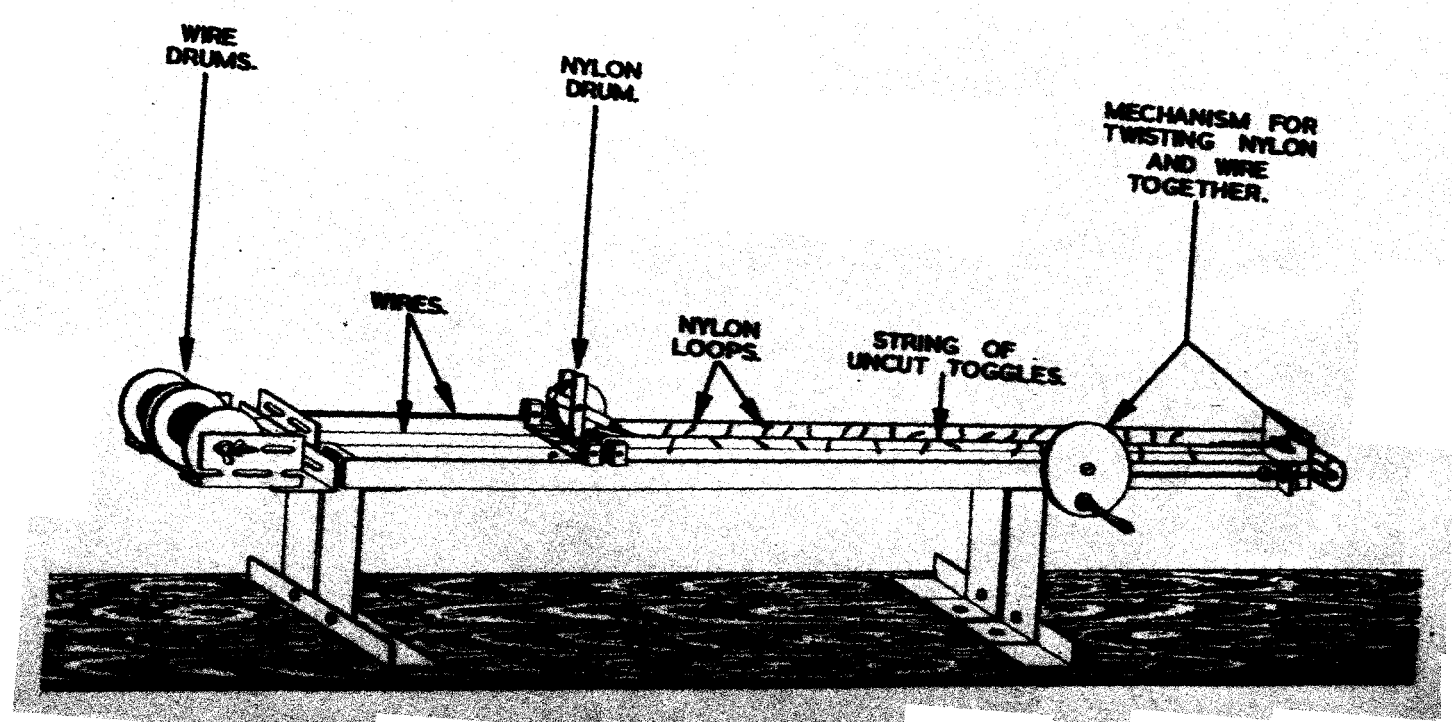


FIGURE 3

