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INTERNAL TAGGING EXPERIMENTS OF MACKEREL IN THE SKAGERAK AND THE NORTH-EASTERN NORTH SEA

by

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INTRODUCTION

In 1965 the Norwegian purse seiners started to fish mackerel on a large scale in the Skagerak and the north-eastern North Sea. The bulk of the catch has been used for production of fish meal and oil, and this gave an opportunity to apply the internal tagging technique for stock size studies.

This paper deals with the various attempts made at the Institute of Marine Research in developing a suitable method for internal tagging of mackerel, and the results and experiences so far obtained.

THE TAGGING PROJECTS

The first internal tagging experiment on mackerel was carried out in 1966. From purse seine catches, 5708 tagged mackerel were released using the same type of tag and method as that for herring (Revheim 1966). This program was continued in 1967, releasing 2000 tagged mackerel. From these releases only three recoveries have been reported.

The very low number recovered made it obvious that the tagged mackerel could not have survived the handling it had been subjected to. From previous experiences in external tagging of mackerel, it was assumed that the fish had died either due to handling during the catching operation or by the tag itself. In order to check on the latter possibility a test experiment was carried out in the summer 1968. 100 internal tagged mackerel were kept in a large keep net for three weeks, together with a test group of 100 untagged fish. The sample was caught by beach seine, which previously had proved to procure fish in good condition for external tagging experiments.

The results of the test are summarized in Table 1. 18 tagged and 9 untagged fish died during the test period. The relatively high mortality of tagged fish at the third and fourth day after tagging was obviously due to damage of the skin of the belly of the fish. The reason for this, is most likely the frequent contact the fish have had with the netting of the keep net. This is also verified from experiments which shall be discussed later.

The examination of the fish as to the apparent causes of death gave the following results:

Tagged fish: 8 fish may have died due to the damage of the belly skin, 7 fish were badly injured by the tag and 3 fish showed no apparent cause of death.
Untagged fish: 2 fish had lost skin on the belly, 1 had a big wound on the back (probably attacked by a bird) and 6 fish showed no sign of injuries.

After 3 weeks in captivity the survivers were taken out of the net and their apparent condition was examined. Infection of the wound caused by the tag were noted in 12 cases and some 4-5 of those would most likely have died in the next few days. Some individuals, both tagged and untagged, had small wounds on the belly which seemed to be healing. The rest of the stock seemed to be in excelent condition.

It was further observed that if infection of the wou..d did occure, the tag had been inserted through the belly wall in front of anus and had penetrated internal organs.

Based on these observations it was concluded that some adjustments in the tagging technique could improve the results of further experiments. It was thus found that insertion of the tag slightly behind and to one side of anus would reduce the chance of hitting internal organs and this particular point has been selected for tag insertion in later experiments.

In previous projects the tagging gun described by Fridriksson and Aasen (1952) has been used for the insertion of tags. In order to hit precisely the point selected for tag insertion the Gundersen tagging pump (1961) furnished with a small knife (Figure 1) was prefered and has been used in all later experiments.

Although the test experiment indicates high mortality of mackerel kept in nets; the observed mortality rate could not alone explain the lack of recoveries from the experiments of 1966 and 1967. It was therefore assumed that the main causes of death of the tagged fish had to be sought in the handling of the fish prior to the tagging operation.

Internal tagged fish had been obtained from commercial catches. The best way of transfering fish from a seine to a keep net is by submersion of the corkline so that the fish can swim by themselves into the net. Due to various circumstances when handling a mackerel catch, the fishermen do not allow subersion of the corkline and the tagged fish had therefore to be brailed into the net. The brailing was done immediately after the catch was dried up. This is a rather rough way of handling fish for tagging, because the fish may be lethally wounded by the completion of the catching operation or by the brailing as well. It was therefore found necessary to try another way of transfering the fish from the seine to the keep net and for this purpose a new brailing net was constructed (Figure 2). This net is partly lined with canvas, so that the fish are kept in water when moved from the seine into the keep net. The brailing net is operated inside the seine as a chinese dip-net, catching the fish before their normal schooling behaviour is completely disrupted.

Using the new technique 6241 mackerel were tagged in 1969. Details appear from the table below:

Lib. no.		Number released	Date	Position of releases	Gear
I	A	750	30. May	57°38'N 4°43'E	purse sein..
	B	1000	1. - " -	57°39'N 4°32'E	"
II		304	1.-28. June	Off Farsund	hook & lin..
III		332	30. June - 17. July	57°15'N - 58°00'N 6°30'E - 10°00'E	"
IV		3855	7.-21. August	57°20'N - 58°00'N 5°00'E - 8°00'E	"

The hook and line caught fish were taken mostly by trolling. Liberation II was carried out from a commercial mackerel troller operating together with the trolling fleet close to the coast. Liberation III and liberation IV were both carried out from the research vessel "Peder Rønnestad" which operated in off shore waters and outside the area fished by the trollers.

RECOVERIES

The 1969 recoveries grouped according to the liberations in 1969, are summarized in Table 2. In Table 4 are shown the tag density in the mackerel catches by weeks for the liberation I and IV. The tag density is given as number of tags per 1000 tons of fish. The figures are calculated on the basis of tag recoveries per 1000 tons of mackerel reduced, the latter figure being adjusted according to the efficiency of the tag collecting equipment of the various plants. Reports from eight plants have been used for the study. These plants have reduced some 50% of the total Norwegian mackerel catch during the period concerned. The efficiency of magnets in these plants runs from 80-95%.

The fish tagged from purse seine catches (liberation I) were released in two batches, the recoveries from each of them appears from the bottom row of Table 3. The table shows moreover the tag returns for each 100 fish successively liberated from the keep net in which they were kept before tagging.

RESULTS AND DISCUSSION

The low percentage of returns from liberation II is probably due to high fishing intensity in the area the fish were released. The area was fished by trollers and their catches are used for human consumption.

The proportions of returns of liberation III show no significant differences from that of liberation IV. The tag returns are, however, so few that the statistical impact on the results by pooling the data of the two liberations is negligible.

With the exception of three returns from liberation I, in June-July, all the tagged fish have been recaught in the Skagerak and the north-eastern North Sea, south of 59°N. The three recaptures were reported from catches landed from the Tampen-Shetland area. Since most of the mackerel catch used for reduction is taken within the tagging area, and since the reported position of recaught internal tags always are rather uncertain, the experiments give little opportunity for migration studies. The further consideration of the data will therefore be concerned with stock size estimates only.

On the basis of the available knowledge of the life history, distribution and migration of mackerel in the north-eastern Atlantic and adjacent seas, it is assumed that the mackerel in the Skagerak and the North Sea is one unit stock. The stock may, however, exchange individuals with other stocks, particularly the stock which spawn south and south-west of the British Isles. This has been proved by external tagging, but no quantitative measure of mixing is so far available (Bolster 1969, Zijlstra & Posthuma 1968).

From September to April the North Sea mackerel congregate in large concentrations with a very high vulnarability to purse seiners. In autumn and spring the largest concentrations are found on the Reef from north-west of Egersund to south-east of Lindesnes. In winter when the schools migrate into deeper waters, the fish are found in Skagerak and in the north-western part of the Norwegian Channel.

From May to August the mackerel disperse over a very wide area and may be encountered all over the Skagerak, the Kattegat, the North Sea and the southern part of the Norwegian Sea. It is reasonable to believe that eventual intermingling with other stocks may take place during this period. With regard to the distribution of the tags according to the distribution area of the fish, the recoveries have been obtained in autumn when the adult stock is concentrated on the Reef. Although adult mackerel may be encountered in other parts of the distribution area during late autumn it is believed that the main part of the stock is found in the area covered by the Norwegian purse seine fleet.

The fish of liberation I have been in liberty during the whole summer, when the fish disperse and random distribution of recoveries according to catch should be expected. It is not possible to analyse the distribution of tag returns with respect to the individual catches (catch and recaptures can not be associated with certainty), but the tag density according to approximate time of recapture is available. These figures appear from Table 4.

It will be noted that the tag density does increase during the weeks 33-38. In the week 39 the tag density of liberation I drops close to the original value but starts to increase again and reaches a new maximum at the end of the season. It is also noted that the extreme high rate of returns according to catch is assosiated with the end of a period of good catch (high production in the plants).

The apparent periodical variation in the tag density might be due to three factors: (1) The tags do not move through the production machinery of the plants with the same speed as the remnants of the fish. This has been observed when the efficiency of the magnets have been tested but has not been studied in details. (2) The factory workers may report the recoveries in batches without specifying time of recapture. (3) In most of the plants there are pockets which collect tags. These tags may be discovered when there is a brake in the production and the machinery is cleaned up.

These three factors do all contribute to an overestimate of the true density of tags at the end of a good catch period at the cost of a corresponding underestimation of the figures at the beginning of the period. The average tag density compiled on the basis of one catch period should therefore give a better estimate of the true density in the stock than any other unit based on time only. In the present case two such periods do occur. One covering the weeks 33-38, the other the weeks 39-45. The figures of average tag density for each of the periods and over all average are given in the three columns to the right of Table 4.

Founded on the above consideration it seems fair to conclude that the tagged fish from liberation I have been evenly distributed through out the whole season and that the estimated over all tag density of 0.66 tags per 1000 tons of fish is a good approximation to the true value of the stock available to the purse seine fleet.

The tagged fish of liberation IV were released according to the hooking rate and cover most of the area fished. The tagged fish should therefore be distributed in relation to the abundance of fish from the very beginning. Table 4 does, however, indicate that most of the tagged fish have not entered the large concentrations on which the purse seiners fished before the very end of the first catch period. During the whole second catch period, the data indicate full recruitment to the catchable stock also from the liberation IV. The tag density from liberation IV of 3.87 tags per 1000 tons of fish which is the average of the second catch period may therefore be considered as the best estimate of the true value of the stock.

Within the area fished by the seiners the frequency of catches is no doubt related to the abundance of fish. This together with the observed regularity in the rate of recaptures according to catch and time, form in the author's opinion a solid basis for accepting these data for stock size estimates as far as distribution of tagged fish is concerned. Since the time interval between releases and recoveries are relatively short the data are compiled for a direct estimate (single census).

The estimate of the stock size is based on the actual number of tagged fish present in the stock at a given time, excluding the number of tagged fish lost since the tagging took place. In the present case one has chosen the end of the week 38 (20. September) as a basic time for the estimates.

For liberation IV the time interval between release and the time of estimate is so short that the mortality due to natural causes may be neglected. The death of fish due to fishing is on the other side noticeable and is calculated as the average tag density of the first catch period of liberation IV (Table 4) multiplied by the total catch. The total Norwegian catch during the week 33 to 38 was 201 000 tons which makes the loss of tags due to fishing equal to $201 \cdot 0.79 = 159$ tagged fish. If $\underline{s}$ denotes the fraction surviving the tagging operation, the actual number of tagged fish from liberation IV present on the grounds at the end of the week 38 is $(3855 \cdot s - 159)$ tagged fish. The corresponding tag density is estimated to 3.87 tags per 1000 tons of fish. If $\underline{P}$ denotes the stock in 1000 tons we have:

$$P = 996 \cdot s - 41 \qquad (1)$$

This is the state of the stock on the 20. September 1969 (Figure 3). The only available measure of s in absolute terms is from the test experiment described previously. Disregarding the fish which showed obvious signs of net damage and taking into account the likely impact of the new technique on the frequency of tag injuries, it is felt that with the very careful handling of the fish tagged from hook and line the tagging mortality may not have exceeded 10%. Assuming 10% tagging mortality i.e. s = 0.9, P is close to 850 000 tons. Selecting 95% confidence the limits of the estimate are according to the formula given by Jones (1966):

$$P = 850\ (1 \pm \frac{2}{\sqrt{324}}) = (850 \pm 95) \text{ thousand tons}$$

A corresponding stock size estimate based on liberation I is more complicated due to apparent complexity in the tagging mortality of purse seine caught fish (Table 3) and the loss of tagged fish from natural causes including possible emigration during the summer months. With regard to the former problems there exists a significant difference between the percentage return of the two batches of liberation as well as between the fish liberated in the beginning and at the end of each batch. Although the first batch liberated (750 fish) show sign of introductional difficulties in the adjustment of the new method to the prevailing circumstances,it is not felt that this is the only reason for the difference in the number of recoveries between the two batches. Other factors may have caused a higher mortality in the first batch and these are probably associated with the catching operation and thus out of our control.

The decreasing rate of returns according to released numbers in both batches demonstrate increased frequency of injured fish in the keep net in the course of the tagging operation. Judging from the test experiment this is probably due to skin damage caused by frequent contact with the walls of the keep net, and also with the dip net used for catching the individuals for tagging.

An estimate of the average survival of the whole liberation I may be obtained by choosing the survival of the first 700 fish released from batch B as a standard. Out of this standard group 90 tags are reported (Table 3).

Since the survivals of the various batches should have been subjected to the same mortality rate, the following sample relation does exist:

$$\frac{160}{1750 \cdot s_1} = \frac{90}{700 \cdot s_o}$$

or rearranged :

$$s_1 = 0.71 \cdot s_o \qquad (2)$$

where s_1 is the fraction surviving from liberation I as a whole and s_o that of the standard group. The effective number of tagged fish (N_o) is therefore in terms of the standard unit:

$$N_o = 1750 \cdot 0.71 \cdot s_o = 1243 \cdot s_o$$

From the end of May to 20. September N_o is reduced due to mortality caused by fishing and mortality due to natural caused including emigration. If N_1 denotes the number available at the end of the considered period, then we have according to the law of probability:

$$N_o - N_1 = N_o\ (m + f - m \cdot f) \qquad (3)$$

where f is the fraction which has died due to fishing and m the fraction which has been lost due to other causes.

Since $N_o \cdot f = C \cdot d$, where C is the catch during the considered period and d the tag density a solution of N_1 from equation (3) may be expressed as follows:

$$N_1 = N_o(1 - m) - C \cdot d(1 - m)$$

The corresonding estimate of the stock size in 1000 tons (P_1) is therefore:

$$P_1 = \frac{N_1}{d} = \frac{N_o}{d}(1 - m) - C(1 - m) \qquad (4)$$

The Norwegian catch from 1. June to 20. September was 235000 tons. d is estimated to 0.66 tags per 1000 tons (Table 4). Using this value and substituting for N_o, the following expression for P_1 is obtained:

$$P_1 = (1883 \cdot s_o - 235)(1 - m)$$

or in terms of instantaneous measurements:

$$P_1 = (1883 \cdot s_o - 235)\, e^{-0.3 \cdot M} \qquad (5)$$

where M is the instantaneous rate of mortality due to other causes than Norwegian fishing. M has been acting over a period of 0.3 years.

The estimated stock size P_1 as a function of M for the various values of s_o are illustrated in Figure 3.

Postuma (1969) concludes that prior to 1965 the mortality in the mackerel stock has been low and suggested 0.2 as a likely value for the instantaneous natural mortality rate.

On the basis of age composition data Aasen (1969) estimated the annual survival rate of mackerel to be 0.784 and concluded that his estimate approached the natural survival rate for the North Sea mackerel stock. This corresponds to an instantaneous mortality coefficient of 0.24 .

Unless a very large emigration for tagged fish out of the area fished by the Norwegian seiners has taken place during the summer of 1969 one may read from Figure 3 that s_o has been less than 0.7 . The fish were tagged under excelent weather conditions and it is therefore assumed that even with the new method and releasing small batches from each catch, the survival of purse seine caught fish may under all circumstances be expected to be low compared with hook and line caught fish. Since the survival of tagged fish also may vary according to unknown circumstances associated with the catching operation, purse seine caught mackerel has been found unfit for tagging when the experiment is intended to be used for stock size studies.

SUMMARY AND CONCLUSIONS

1. The paper deals with methodical problems in tagging mackerel with internal tags. Two groups of tagged fish are studied. One group is tagged from purse seine catches, the other was caught with hook and line.

2. Comparing the percentage of returns within and between samples, purse seine caught fish is found unfit for tagging experiments.

3. A test experiment on mortality of tagged fish was carried out in the summer of 1968. On the basis of the results, some improvements in the previously used tagging technique are suggested (Figure 1 and 2). The tagging mortality of hook and line caught fish is found to be close to 10%.

4. On the basis of 3855 tagged fish from hook and line, the stock size available to the Norwegian purse seine fleet is estimated to be with 95% confidence limits, 850 ± 95 thousand tons. The estimate applies to the state of the stock at 20. September 1969.

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Table 1. Mortality of mackerel in number by days in captivity of two test groups of 100 individuals each.

Days in captivity	Tagged	Untagged
1 - 2	1	0
3 - 4	8	2
5 - 6	2	2
7 - 8	2	1
9 - 10	2	1
11 - 12	1	1
13 - 14	0	1
15 - 16	1	1
17 - 18	0	0
19 - 20	0	0
21	1	0
Sum	18	9

Table 2. Recoveries on internal tagged mackerel (in 1969) in number (N) and percent of number released (%), by liberations and months. U denotes recoveries not specified to months.

	June		July		August		Sept.		Okt.		Nov.		U		Sum	
Lib.	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
I	2	0.11	1	0.05	27	1.54	39	2.22	78	4.45	1	0.05	12	0.68	160	9.14
II	0	-	0	-	1	0.32	1	0.32	6	1.97	1	0.32	1	0.32	10	3.28
III	0	-	1	0.30	3	0.90	7	2.10	31	9.30	2	0.60	3	0.90	47	14.15
IV	0	-	0	-	11	0.28	88	2.28	400	10.37	21	0.54	50	1.29	570	14.78

Table 3. Recoveries of tagged mackerel from purse seine catches (liberation I) for each 100 fish released.

Batch A Release no.	N	Batch B Release no.	N	Sum A + B
1 - 100	4	1 - 100	18	22
101 - 200	11	101 - 200	12	23
201 - 300	11	201 - 300	11	21
301 - 400	9	301 - 400	10	19
401 - 500	3	401 - 500	12	15
501 - 600	4	501 - 600	15	19
601 - 700	5	601 - 700	12	17
701 - 800	2	701 - 800	8	10
		801 - 900	6	6
		901 - 1000	7	7
Sum	49		111	160
% recovered	6.5		11.1	9.1

Table 4. Recoveries of tagged mackerel (N) and corrected quantities of reduced mackerel (Q) in 1000 tons according to efficiency of magnets in 8 Norwegian plants by week and liberation number. "d" denotes number of tags reported per 1000 tons produced $(\frac{N}{Q})$.

		Period 1						Period 2								
Week no.	33	34	35	36	37	38	39	40	41	42	43	44	45	Per. 1	Per. 2	Total
Q	7.30	20.15	15.02	11.58	21.40	3.00	6.24	17.35	25.51	15.64	17.38		1.62	78.45	83.74	162.19
Lib. I N	3	7	10	6	14	9	3	9	17	12	16		1	49	58	107
d	0.41	0.35	0.67	0.52	0.65	3.00	0.48	0.52	0.67	0.77	0.92		0.62	0.62	0.69	0.66
Lib. IV N	1	2	5	1	40	13	16	37	98	63	85	8	17	62	324	386
d	0.14	0.10	0.33	0.09	1.87	4.33	2.56	2.13	3.84	4.03	4.89	∞	10.50	0.79	3.87	2.38

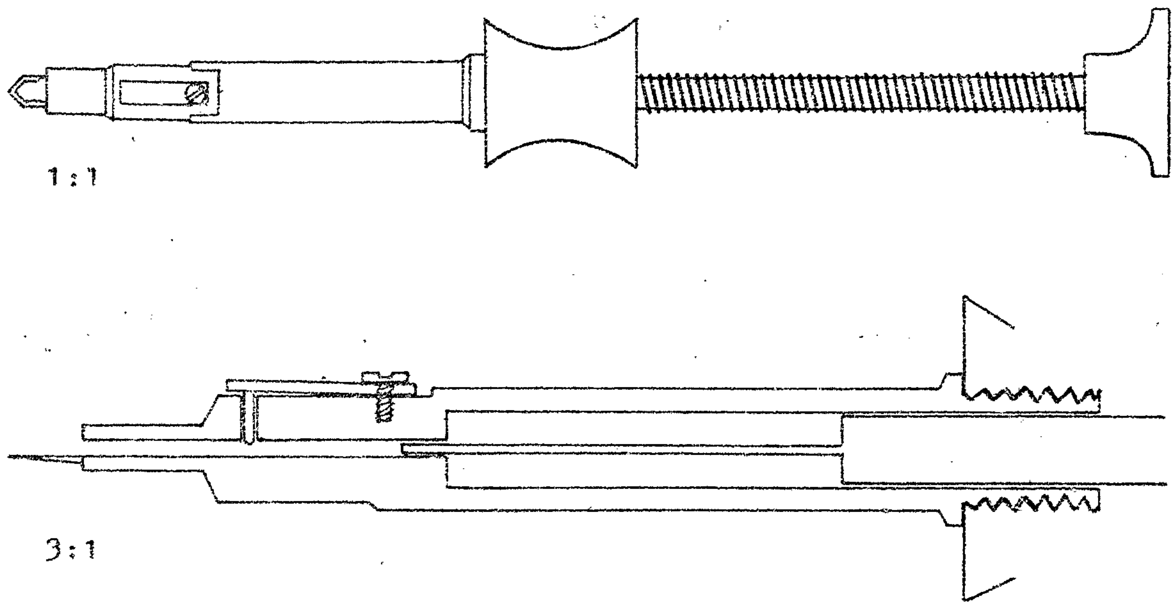

Fig. 1. The Gundersen's tagging pump.

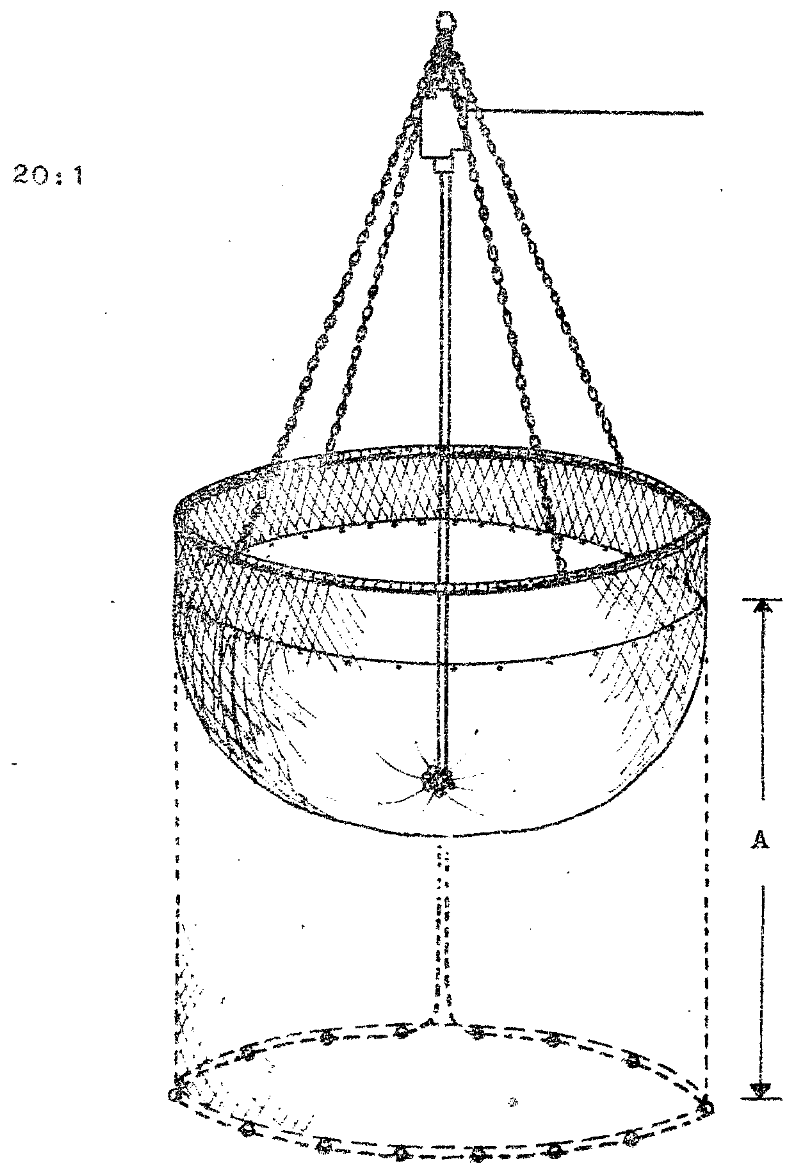

Fig. 2. Brailing net. (A) The portion lined with canvas.

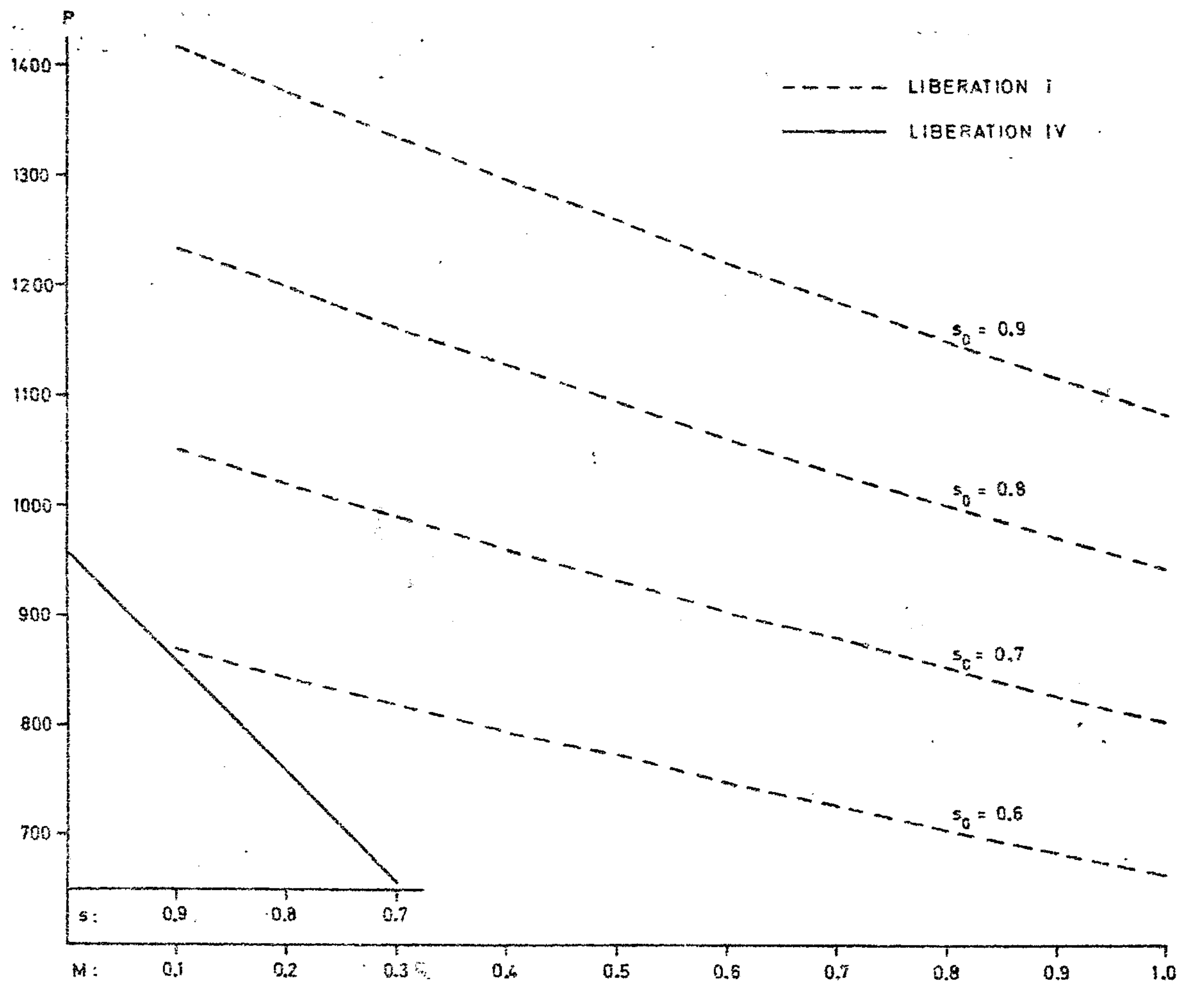

Fig. 3. Estimated stock size (P) in 1000 tons of North Sea mackerel. The solid line shows estimates of P based on fish tagged from hook and line as a function of the survival rate of tagged fish (s). The broken lines show estimates of P as a function of the natural instantaneous mortality rate (M) for various values of survival rate of fish tagged from purse seine catches (s_o).