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A STOCK ASSESSMENT OF LOBSTER (HOMARUS GAMMARUS) ON THE NORWEGIAN SKAGERRAK COAST

by

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ABSTRACT

The lobster stock on the Norwegian Skagerrak coast has become gradually less abundant since early 1950'ies. This is shown by decreasing catch per unit of effort and decreasing numbers according to cohort analysis on length groups. A modified mesh assessment model is used to model the stock and the fishery. Predicted changes in yield per recruit are supported by tagging experiments. A relationship between spawning stock and subsequent recruitment is found and yield curves are constructed. The results indicate that the long term yield would be increased by about 200% if the present fishing effort is reduced by 50% and the minimum landing length is increased from 22 cm to 26 cm.

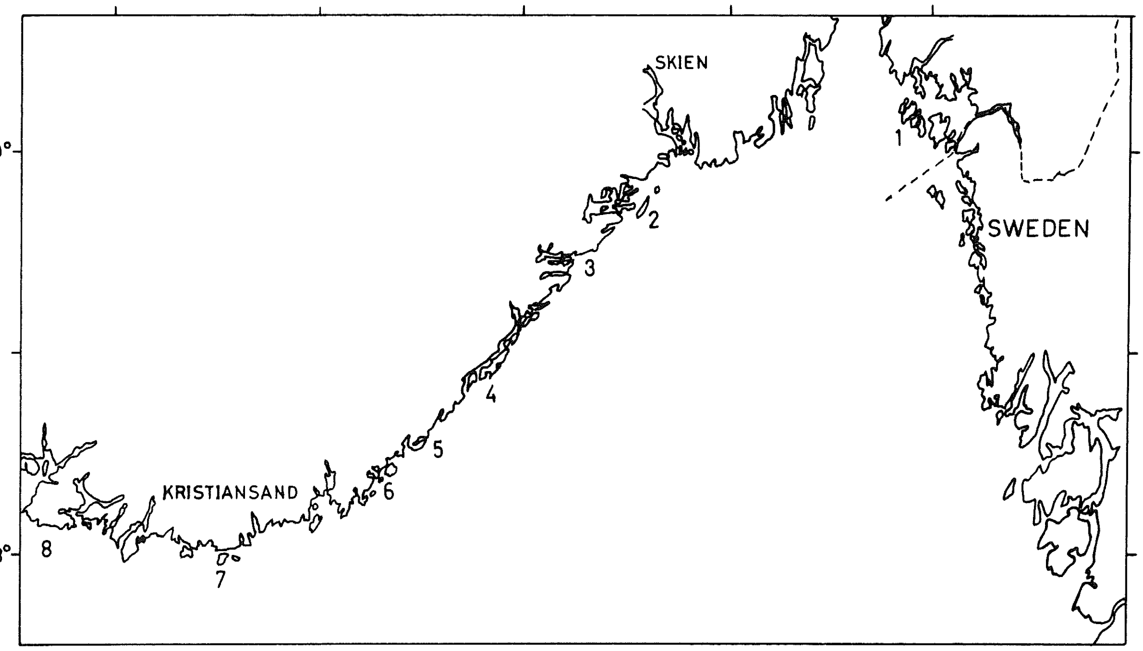

Fig. 1. Locations of areas considered. Length measurements performed annually from 1949 at 2 Kragerø, 4 Arendal, 6 Høvåg and 7 Mandal, from 1962 at 1 Hvaler.

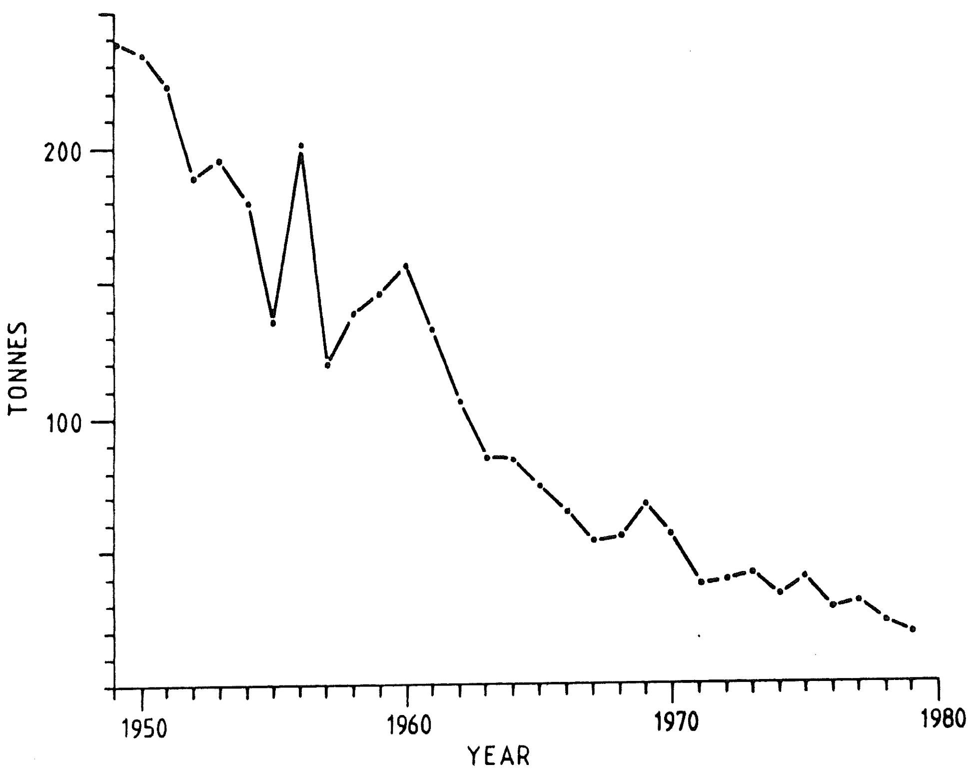

Fig. 2. Lobsters (H. gammarus) on the Norwegian Skagerrak coast. Total reported catch 1949-1979.

INTRODUCTION

At the Biological Station in Flødevigen near Arendal, lobster has been one of the most important fields of research. Quite an extensive material has been collected. This material has partly been published before by DANNEVIG (1927, 1936, 1951) and TVEITE (1970, 1979). The present paper utilize some of this material as well as more recent observations.

MATERIAL AND METHODS

Lobsters from the area Kragerø to Lindesnes (Fig. 1) are treated as one stock, omitting the Hvaler area where the length frequencies and catch per trap per day have shown different development. Reported catch from this stock from 1949 to 1979 are shown in Fig. 2. The proportion of the total catch that is not reported has increased over the years and may now be in the range 50-75%.

Since 1928 about 30 fishermen on the Skagerrak coast have answered a questionary about lobster fishing (no. of traps, days fished, catch etc.) every year.

Length measurements have been performed annually since 1949 at four localities and from 1962 at five localities (Fig. 1). Two fishermen at each locality were given dispensation to keep the undersized lobsters untill they were measured by people from the Biological Station. Usually the total catch below the minimum size were measured, and at least 100 lobsters above the minimum size.

Marking experiments have been done occasionally since 1919 at different localities along the coast. From 1919 to 1966 the lobsters were marked by punching two holes in the tail fan (TRYBOM 1904). After 1966 only suture tags (BUTLER 1957, GUNDERSEN 1962, 1964) have been used. Stored lobsters were marked and released in the sea after the fishing season.

Since only lobsters around the minimum size have been tagged, the experiments are unsuitable for stock assessment. They are, however, useful for estimation of growth and mortality in the length range of the tagged animals.

The two models that are used in the present analysis are the cohort analysis on length (JONES 1974, 1979) and a modification of the mesh assessment model (HOYDAL, RØRVIK and SPARRE 1980, 1983). The cohort by length model is used to estimate the development of the stock since 1949. The mesh-assessment model with the modifications is used to model the stock and the fishery and to predict the consequences of changing the minimum legal size and the effort.

Both models involve the von Bertalanffy growth equation

$$L_t = l_\infty \ (1-\exp(-K(t-t_0))$$

and the natural mortality M. Before applying the models these parameters have to be estimated.

GROWTH

Length increments of crustaceans are stepwise, but here growth is considered to be a continous prosess.

Using one year increments the growth tends to be overestimated since molters are more actively searching for food than nonmolters which give molters higher catchability. Whereas when using two years increments there is a possibility of underestimation because the largest individuals are growing into a size where the catchability might be lower because the traps have their highest selectivity for the medium sized and more abundant lobsters. Moreover the larger individuals tends to have a lower activity due to less frequent molting.

Using the length distribution formulas given by POWELL (1979) the L_∞ is found to be around 32-33 cm with small differences between the sexes. However, this method may underestimate the L_∞ because of the lower catchability of the larger animals. Ford-Walford plots gives approximately L_∞=31 cm for females and 43 cm for males using one year increments.

Growth of lobsters kept in captivity are so much different from results of tagging experiments that these data are found completely unreliable. Thus all methods of estimating growth are unreliable to some extent.

If the L_∞ of 43 cm for males is used the K best fitting the annual increments from tagging experiments, would be 0.14. Since cohort analyses on length groups and the modified mesh assessment model require that L_∞ is bigger than the biggest sizegroup measured, L_∞ for females is chosen to be 35 cm, K will then be 0.22. The relevant results from the models applied are independent of t_0. Rather arbitrary t_0=0 is chosen for both sexes. It should also be noted as long as the combination of L_∞ and K describes the growth rate in the most relevant lengthgroups the actual values of L_∞ and K are of less importance.

NATURAL MORTALITY

Mortality rates can be estimated from tagging experiments. Possible errors using tagging experiments for survival calculations are:

1. Immediate loss of tags and deaths of tagged animal due to tagging.

2. Loss of tags throughout the experiment, extra mortality among tagged individual and emigration from the area.

3. Incomplete reporting.

The first one is quite negligible in these experiments according to GUNDERSEN (1964).

The second type of errors is probably negligible according to aquarium experiments (GUNDERSEN 1964). However, some lobsters had lost the external tag, as shown by extruding gut ends.

The third error is considerable in some of our experiments. However in other experiments this error is very small due to good information about the experiments to the few fishermen fishing in the area.

This leaves incomplete reporting as the main source of error for most of the experiments. In addition the rate of exploitation is appearantly decreasing with size as discussed below. Methods for calculation of mortalities using more than two years recaptures are therefore unreliable as it overestimates natural mortality.

The experiments which gave highest recapture percentage (around 80%), gives estimates of natural mortality between 0.08 and 0.15 without correcting for decreasing rate of exploitation or incomplete reporting. The total mortality is found by the ratio between the numbers recaptured the first and the second year after tagging. The rate of exploitation is calculated from the ratio: numbers recaptured/sum of lobsters present before the seasons involved. In the present paper a constant natural mortality of 0.1 is used.

MODELS AND RESULTS

Cohort analysis

JONES (1974) adapted the basic equations of cohort analysis for application to length composition data, thus avoiding the problem of aging the catch. The rate of exploitation of the largest length group has also to be given as input. From tagging experiments $F/Z=0.8$ seemed to be reasonable and fitted well to the values consequently calculated for the length groups next to the biggest. Cohort analysis based on average length distributions for the area Kragerø-Mandal from 1949 to 1979 were performed.

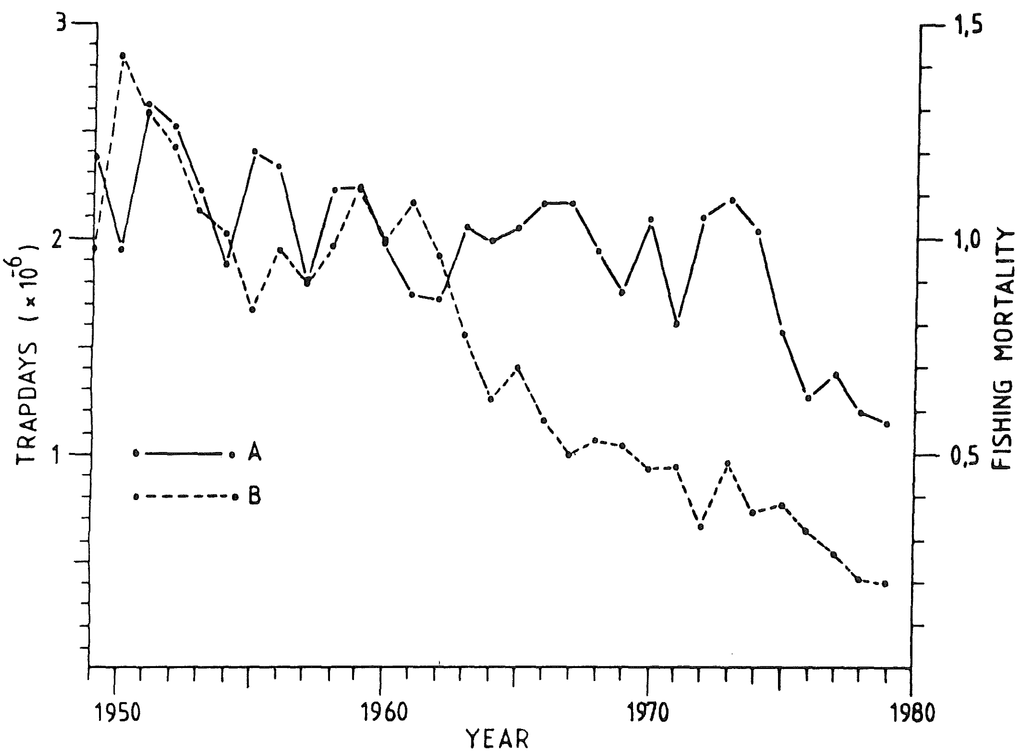

Fig. 3. Lobsters (H. gammarus) on the Norwegian Skagerrak coast.
A: Average annual fishing mortality for the length groups 23-26 cm both sexes according to cohort analysis on length groups.
B: Effort in million trapdays from cpue and reported catch.

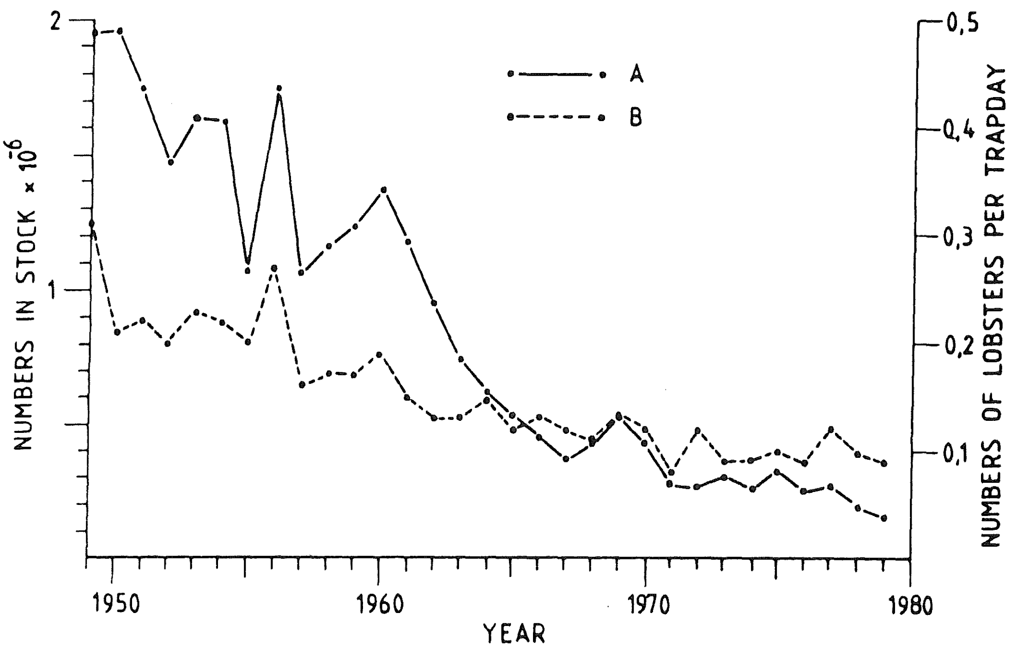

Fig. 4. Lobsters (H. gammarus) on the Norwegian Skagerrak coast.
A: Stock (≥22 cm) in millions according to cohort analysis.
B: Catch in numbers per trap per day from questionaries.

Fig. 3 shows the calculated annual F on the length interval from 23 to 26 cm together with the total effort. The estimated F on these lengthgroups depends little on the ratio F/Z on the largest lengthgroups. The length distribution of the catch in any year contains several yearclasses and the annual F can strictly not be calculated. However, the decreasing trend of F from 1949 to 1979 (Fig. 3) seems significant. Total effort in trap days are calculated from the total reported catch and the catch per trap day (cpue) as reported from about 30 fishermen each year. The calculated effort decrease at a faster rate than the calculated F. This is probably caused by a gradually increasing proportion of total catch beeing sold directly to consumers or taken by spare time fishermen and thus exempted from the official statistics.

The estimated stock and cpue are given in Fig. 4. The stock seemed to have been decreasing at a higher rate than the cpue series. The difference has the same reason as for Fig. 3, the cohort based stock assessment is dependent on the official catch statistics whereas the cpue data are independent. Of these two measures of the stock size, the cpue is probably the best one.

<u>Modified mesh-assessment model</u>

HOYDAL, RØRVIK and SPARRE (1980, 1983) describe a model of a stock exploited by several fisheries that is used to estimate the effective mesh sizes. Logistic curves are used to describe the recruitment of the fish to the fishing grounds, the selective properties of the gears and the discard practise. By changing the length at 50% selection the model fits with the help of a minimisation routine the simulated length (or age) distributions to observed length (or age) distributions. The goodness of fit between the two distributions are given by the object function (OBJ) which is the sum of the squared differences between the simulated and the observed frequencies. With two modifications this model has been applied.

Firstly it is assumed that the whole catch of undersized lobsters

is discarded, and that the discards do not suffer from extra natural mortality. Secondly the following emperical relations between weight W (in kg) and total length L (in cm) are used:
for males,

$$W = -\ 3.82 \cdot 10^{-1} + 6.56 \cdot 10^{-2}\ L - 3.85 \cdot 10^{-3}\ L^2 + 1.05 \cdot 10^{-4}\ L^3$$

and for females,

$$W = +\ 3.00 \cdot 10^{-1} - 4.50 \cdot 10^{-2}\ L + 2.05 \cdot 10^{-3}\ L^2$$

The model was calibrated against the average length distribution of females caught in the seasons 1949-1963 when the minimum landing size was 21 cm. The length distribution of the catch since 1964 has been treated seperately since the minimum landing size was increased by 1 cm in 1964. The length distribution used include the discards.

From the cohort analysis on length groups an effective $F \simeq 1.3$ (1949-1963) was found for the length interval 23-26 cm (Fig. 3). The total F in the model was taken to be 1.80 so that the effective F's simulated on these length groups become about 1.3. The simulated F's tends to be smaller than the input total F since the simulated F's of a given length is the product of input total F the proportion recruited, the selection ratio of the traps and the proportion retained in the discard practise.

The recruitment curve was chosen so that 50% and 75% recruitment occured at 15 cm and 20 cm respectively. The recruitment curve was not assumed to decrease for the larger animals.

The selection curve is the product of two curves, an increasing selection of the smaller animals and a decreasing selection for the larger lobsters. Let L_{75} and L_{50} be the lengths at 75% and 50% selection of the traps. For the left increasing part of the selection curve it was found that a L_{75}/L_{50} ratio =1.10 gave a reasonable steepness of the estimated length frequency. The deselection of the larger animals are caused by the opening of the traps, and posssibly by less mobility of the larger ones. This was accounted for by setting the 75% and 50% selection at 27.5 cm

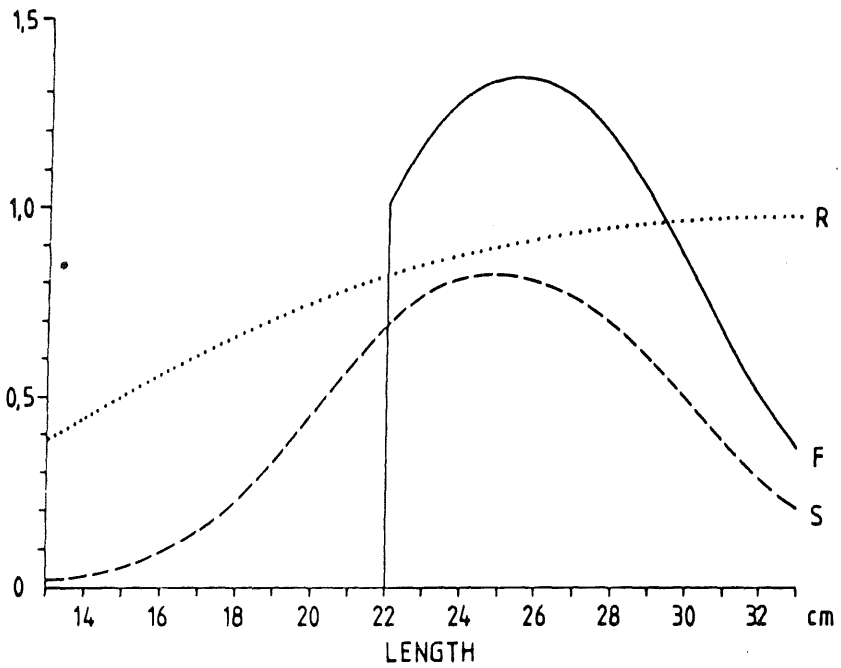

Fig. 5. Lobsters (H. gammarus) on the Norwegian Skagerrak coast. R: Proportion recruited S: Selection, F: Fishing mortality arrived at for female lobsters, 1949-1963, using the modified mesh assessment model.

and 30 cm respectively which was found to give a reasonable good fit between the observed and simulated length frequencies for the larger length groups.

Given these parameters, M=0.10, K=0.22, t_0=0, L_∞=35 cm and the length frequency of the females caught from 1949 to 1963, L_{50}=20.4 cm minimized the object function. The observed and simulated length distribution are shown in Fig. 6 (OBJ=13.51). The recruitment curve (constant), the resulting selection curve as given by L_{50}=20.4 cm and L_{75}/L_{50}=1.10 and the implied landing (fishing) mortality are shown in Fig. 5.

In fitting the length distribution of males caught in 1949-1963 the same parameters were used, except for K (=0.14) and L_∞ (=43). The result is shown in Fig. 7. L_{50} is estimated to be 20.2 cm, close to that for females, although the fit between the two curves (OBJ=21.16) is somewhat weaker than for females.

Using data from the periode 1964-1979 the change in minimum landing size from 21 cm to 22 cm was accounted for. Except for F, all the other parameters remain the same as used for the first period. The input total F (=1.10) was chosen so that the effective F on the lengthgroups 23-26 cm become about 0.8 which is close to the cohort average for this period (Fig. 3).

This procedure gave L_{50}=20.9 cm for females and L_{50}=20.6 cm for males. The fit between observed and simulated distributions were in both cases relatively good (Fig. 8 (OBJ=6.87), and Fig. 9 (OBJ=9.39)). If F had not been changed the fit between the two distributions would have been significantly impaired, and the estimates of L_{50} would increase by about 2 cm and become 22.7 cm for females (OBJ=28.63) and 22.3 cm for males (OBJ=28.72).

However, with the adopted procedure the four estimates of length at 50% selection of the traps (L_{50}) varies between 20.2 cm and 20.9 cm. It seems to us that the parameters used describes a fairly consistent model of the population and the fishery. It may

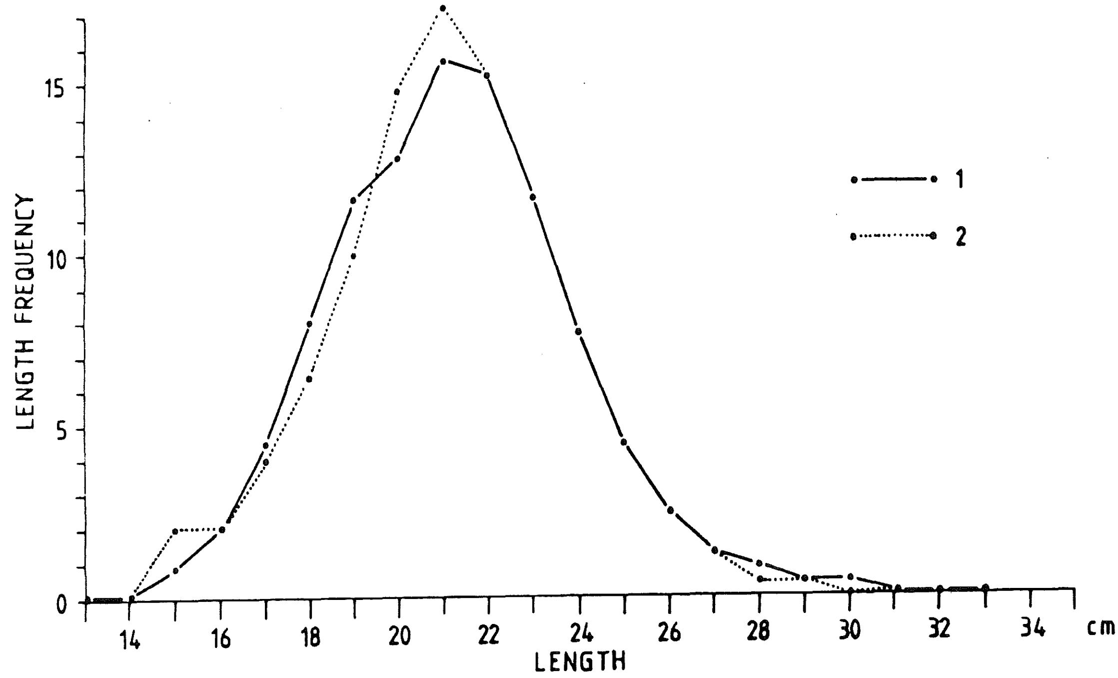

Fig. 6. Lobsters (H. gammarus) on the Norwegian Skagerrak coast. Observed 1) and simulated 2) length frequencies in percent including discards for female lobsters 1949-1963. OBJ=13.5.

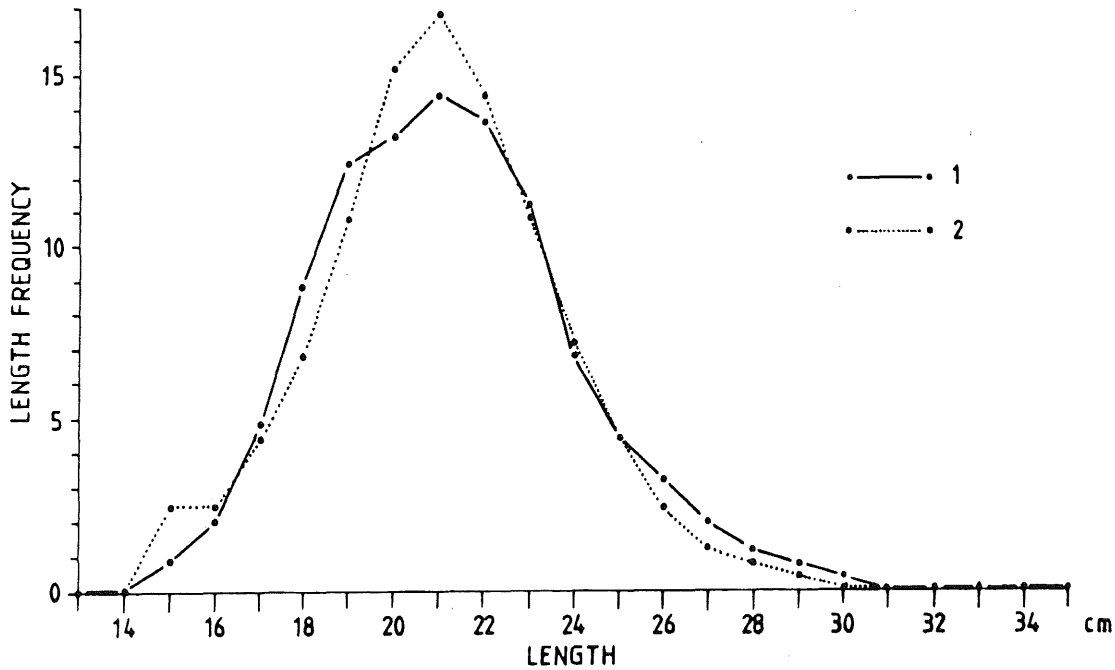

Fig. 7. Lobsters (H. gammarus) on the Norwegian Skagerrak coast. Observed 1) and simulated 2) length frequencies in percent including discards for male lobsters 1949-1963. OBJ=21.2.

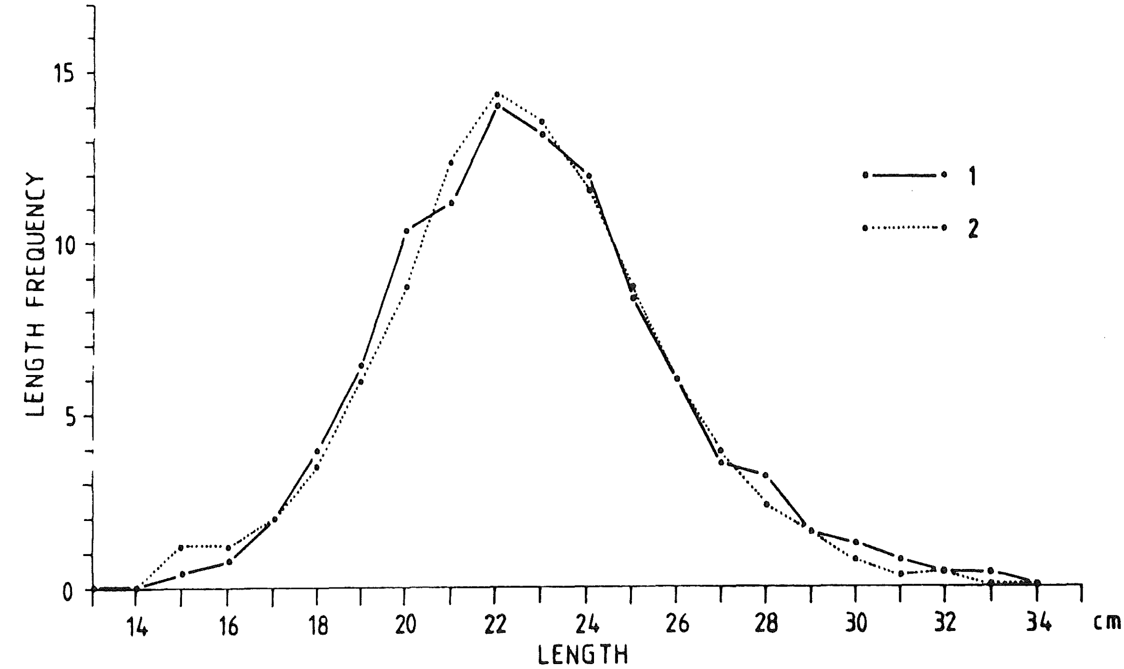

Fig. 8. Lobsters (H. gammarus) on the Norwegian Skagerrak coast. Observed 1) and simulated 2) length frequencies in percent including discards for female lobsters 1964-1979. OBJ=6.9.

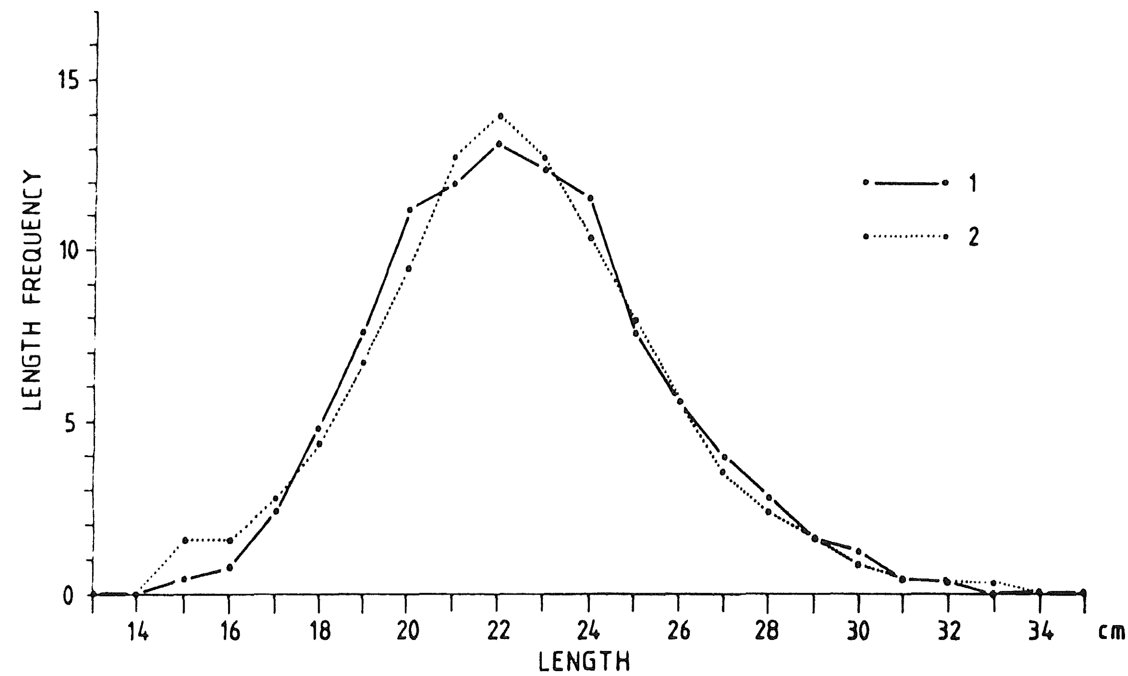

Fig. 9. Lobsters (H. gammarus) on the Norwegian Skagerrak coast. Observed 1) and simulated 2) length frequencies in percent including discards for male lobsters 1964-1979. OBJ=9.4.

Table 1. Shortterm effect on yield per recruit of different minimum legal length and fishing mortality, compared to longterm effect on yield per recruit and egg production.

Minimum length in cm	% change in F	% change in Y/R after 1 year	3 years	5 years	7 years	Long term effects Y/R	Egg spawned % change
	-75	-67	-54	-47	-44	-40	280
	-50	-37	-26	-22	-20	-18	109
0	0	-15	1	-8	-10	-12	-26
	50	-57	5	-11	-15	-18	-69
	100	92	2	-17	-21	-24	-84
	300	176	-24	-36	-37	-38	-98
	-75	-68	-58	-47	-44	-39	291
	-50	-40	-27	-21	-19	-16	121
20	0	10	1	-4	-6	-7	-17
	50	50	8	-4	-8	-10	-62
	100	83	6	-9	-13	-15	-80
	300	164	-13	-23	-25	-26	-97
	-75	-71	-57	-49	-45	-40	310
	-50	-45	-29	-20	-18	-14	143
22	0	0	0	0	0	0	0
	50	37	10	3	1	-2	-50
	100	67	11	0	-3	-5	-71
	300	141	-3	-11	-13	-15	-93
	-75	-77	-61	-50	-48	-39	344
	-50	-56	-35	-23	-18	-19	184
24	0	-20	-3	3	6	7	37
	50	10	10	11	10	10	-20
	100	35	16	11	10	8	-47
	300	99	13	3	2	1	-79
	-75	-85	-69	-58	-53	-46	395
	-50	-70	-46	-30	-23	-16	254
26	0	-45	-15	2	7	12	108
	50	-24	5	15	17	20	46
	100	-5	14	21	21	21	12
	300	46	24	20	19	18	-29

be that some of the deselection of the larger animals should be attributed to the behaviour (less movements of the larger animals) and therefore accounted for by the recruitment curve. A similar transfer between the selection and recruitment of the smaller animals may also have been argued for. However, in terms of the prognosis done later, what matters is the product between recruitment and the selection curve. As long as this product is unchanged it does not affect the estimates of what would happen if the effort and the minimum legal size are changed.

Before using this modified mesh assessment model for prediction, the input fishing mortality was changed so that effective F on the 23-26 cm become close to 0.50 (F_{tot}=0.70). This was done in accordance with Fig. 3 in order to let the model represent the present (late 1970's) situation. L_{50} as estimated for the periode 1964-1979 was used, all the other parameters in the model were left unchanged.

The estimated long term and short term effects on yield per recruitt due to changes in minimum landing size and fishing mortalities are given in Table 1.

Tagging

Tagging experiments have shown that if lobsters between 22 cm (the present minimum size) and 23 cm are released one will after three to four years recapture up to 122% in weight (Table 2). On an average this size group makes 15 kg of a 100 kg catch, by discarding these animals one will loose the 15 kg but after some years get back 18.3 kg i.e. 3.3% weigth increase for the same number of recruits. This is minimum figures since no allowance has been made for unreported recaptures or lost tags. Fishermen have reported that they have had tagged lobsters in their catch, but after storing, the tags have either been lost or the lobster sold without noticing the tags. In one experiment of 100 lobsters, six of the 82 recaptured had lost their external tag, but were recogniced on the extruding gut ends. Since they could not be

Table 2. Marking (1919-1966) and tagging (1966-1973) experiments. Numbers tagged (N) and percent recaptured by weight.

Year	Total length in cm 20.0-20.9		21.0-21.9		22.0-22.9	
	N	%	N	%	N	%
1919-1925	244	83	177	83	90	74
1962-1930	23	122	226	91	208	84
1932-1938	508	62				
1941-1946	69	37				
1954-1958	210	50	69	80	65	51
1960-1962	339	84	364	73	60	64
1966 marked	76	104	84	72	82	62
1966 tagged	80	128	95	116	76	122
1968-1973	135	128	217	106	451	103

identified to group, they have not been included in any figures. These experiments have also shown that discarded lobsters have great survival potentials.

DICUSSION

Table 1 shows that in the long run the yield per recruit would benefit from an increased minimum landing size, keeping the fishing mortality at or above the present level. With the present fishing mortality and a new minimum legal landing size of 24 cm compared to 22 cm at present, an increment in yield per recruit of 7% is indicated (Table 1). This compares well with the tagging experiments which indicated a 3,3% increase for one cm higher minimum landing size. For the present minimum length the present fishing mortality seems close to the MSY Level.

For all minimum lengths there are short term losses in Y/R when the fishing mortality is reduced. When fishing mortality is increased the first years gain is reduced through time.

Applying the Y/R results for management advice requires, strictly speaking, that the recruitment stays constant. The associated longterm changes in the eggproduction (Table 1) are not taken into account. Tveite (1979) shows that poor recruitment is one of the main reasons for the reduction of the stock since the early 1950's (Fig. 4).

Table 3. Correlation coefficients between catch per trap per day and number of recruits according to cohort analysis with 0 to 7 years lag.

Lag	0	1	2	3	4	5	6	7
r	0.895	0.800	0.846	0.763	0.876	0.909	0.815	0.839

In Table 3 the correlation coefficient between the weight per trapday according to fishermens information, and number of recruits (22-23 cm) according to the cohort analysis on length groups, is given for 0 to 7 years lag. It is seen that the correlation is relatively high for all combinations, most likely due to the general falling trend of both curves (Fig. 4). However, the best correlation is for 5 years lag which corresponds well with the expected age of lobsters 22-23 cm long. This indicates a relationship between the spawning stock and the subsequent recruitment as seen in Fig. 10.

Based on the differences between the two curves in Fig. 3 and Fig. 4, the official statistics, somewhat arbitrary, is supposed to give the total catch landed until 1963, but gradually decreases to one third of the landings in 1979. One would then get a re-

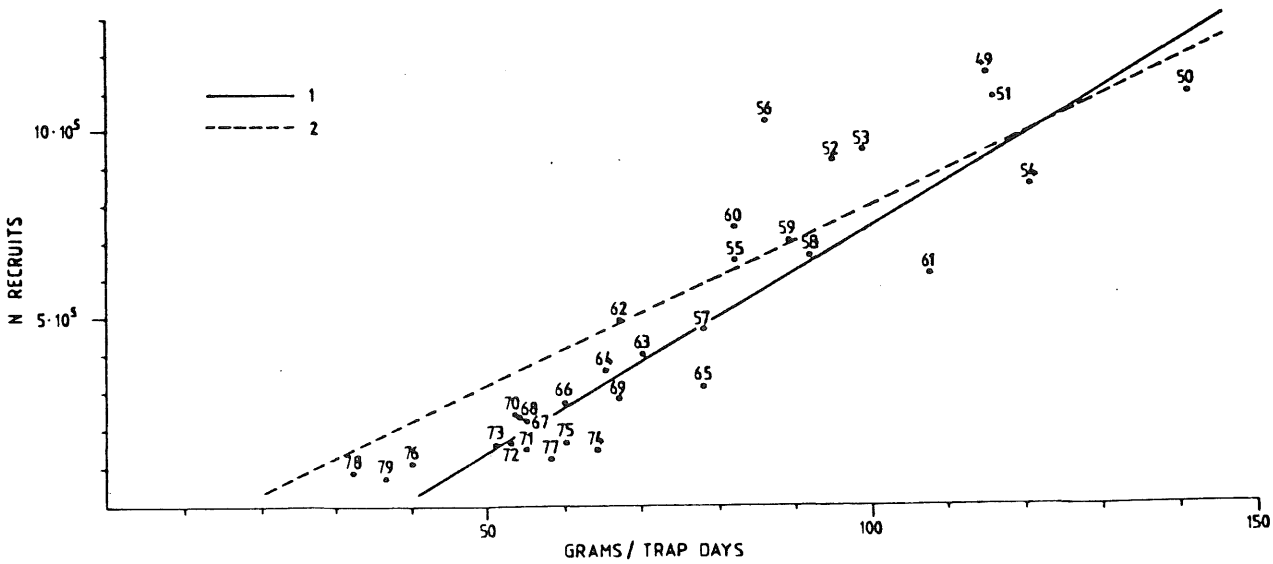

Fig. 10. Lobsters (H. gammarus) on the Norwegian Skagerrak coast. Stock as grams/trapdays and recruitment in numbers of lobsters 22-23 cm for the years 1949 (1944 yearclass) to 1979 with five years lag as calculated from official catch statistics

1) Regression line for official catch statistics

2) Regression line for adjusted catch statistics (see text).

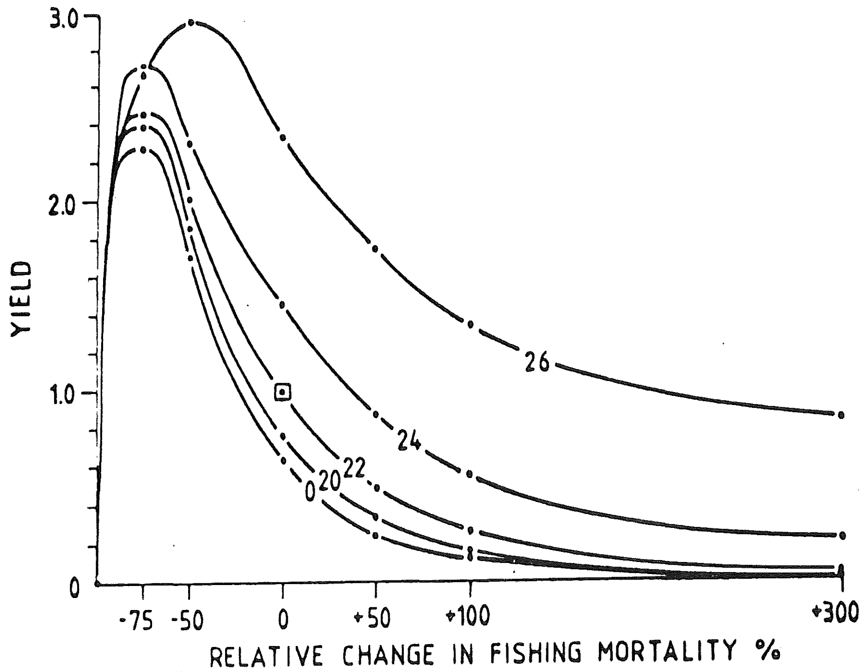

Fig. 11. Lobsters (H. gammarus) on the Norwegian Skagerrak coast. Long term yield for different fishing mortalities and minimum landing lengths relative to the present situation (F=0.5; M.l.l.=22 cm; Marked with a square).

gression line, like the stippled one in Fig. 10. This intersects the X-axis closer to origo as would be expected from theoretical considerations.

Taking the recruitment to be proportional to the egg production the long term yield (LY) relative to the present situation has been calculated from the formula: LY=(1+YR).(1+ES), where YR is the long term change in yield per recruit and ES is the change in eggs spawned. LY and ES is given in the last two columns of Table 1 as percentages. Fig. 11 shows the results for different combinations of fishing mortalities and minimum landing sizes.

It is estimated that reducing the effort by 50% but keeping the present minimum size, would double the long term catch. A similar increase in long term yield could be achieved by increasing the minimum landing size to 25-26 cm while leaving the fishing effort unchanged. If the minimum size is increased to 26 cm and the fishing mortality is reduced by 50% the long term yield would be three times the present, while yield per recruit is reduced by 16% (Table 1). Judged from the yield per recruit calculations (Table 1) and given the present minimum landing size, the present fishing mortality may be adviceable since it is close to the F_{MSY}.

Uncertainties about M effect the Y/R calculations (Table 1) and LY calculations (Fig. 11) equally. It is, however, reasonable that the relationship between spawning stock and subsequent recruitment shown in Fig. 10, should be considered in giving management advice especially at the present low stock level. It may thus be concluded that the yield per recruit model (Table 1) probably gives misleading results in terms of the probable effects on the catches from changes in minimum landing size and fishing mortality, and that Fig. 11 is a better basis for management advice.

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