Fol. 4/ G

International Council for the Exploration of the Sea

C.M. 1979/G:56
Demersal Fish Committee

Some comments to the problem of adjusting TACs to mesh size changes

by

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1. Introduction.

Mesh assessments are usually carried out by calculating "short term losses" and "long term gains" expected from a change in the minimum legal mesh size, assuming no change in total fishing effort or its distribution by area and season (Gulland, 1961). At the time these methods were developed, minimum legal mesh- and/or landing sizes were the only regulatory measures applied on most demersal trawl fisheries. After the introduction of TACs one is faced with the problem of what effect a change in mesh size should have on the recommended TAC. Often this has been dealt with by simply calculating the catches corresponding to a range of fishing mortalities for the alternative mesh sizes and recommend TAC's corresponding to a certain value of the fishing mortality on the fully exploited age groups, identical for all mesh sizes. By this approach the "short term loss" is automatically transferred into the TAC, making the TAC for an increased mesh size smaller than the TAC for the present mesh size by an amount approximately equal to "short term losses". After a brief discussion of the assessment of short and long term effects of mesh size changes, this paper will mainly deal with the appro-

priateness or in-appropriateness of the usual methods applied for selecting TAC's and discuss alternatives.

2. Short term losses and long term gains.

By short term losses are usually meant the immediate decrease in total catches generated by a given fishing effort when the minimum legal mesh size is increased. In the usual estimation procedure it is assumed that the catch per unit of effort (cpue) of the length or age groups fully retained by the new net remain unchanged, and that the cpue of the smaller fish decreases as predicted by the estimated selection parameters for the two mesh sizes. It is further assumed that the pattern of fishing after the change in mesh size remains unchanged. Disregarding errors in the estimated selection parameters, short term losses may be overestimated for two reasons:

(i) The cpue of the larger fish may be higher for the new gear.

(ii) If the various size groups are partially separated by areas, a larger part of the fishing effort may be directed towards older fish when cpue of younger fish decreases as a result of the selectivety.

Under TAC regulations, the term "short term losses" is ambiguous. Fishermen and administrators are primarily interested in changes in TAC and cpue from one year to the next, and such changes depend on both the situation in the stock, such as strength of recruiting year classes, and on mesh size. The ratio between the TACs chosen for the different mesh sizes depends on the management strategy which the TAC's are based upon, and this question will be returned to in the next section. The traditional way of estimating short term losses has only relevance to the difference in catch rates between the various mesh sizes which may be expected. If there are strong variations in recruitment, and estimated "short term losses" are based upon an average situation, even estimated differences in cpue may be misleading.

The two sources of possible bias in the estimates of the short term losses mentioned above have one important concequence under a TAC regulation: The distribution of the fishing mortalities with age under the new mesh size may be different from the F-array estimated from the mesh assessment. Both (i) and (ii) will tend to decrease the fishing mortality on younger age groups compared to older age groups even more than predicted from the selection curves.

This will not only create difficulties in projecting the effects of a certain TAC on the stock when the mesh size is changed, but also later assessments of the state of the stock will be affected. For example, when estimating input F-values for a VPA some trial runs are usually carried out in order to estimate the exploitation pattern (distribution of F with age) in previous years, and then the same exploitation pattern is assumed for the last year in the final VPA. When the mesh size and therefore the exploitation pattern are changed, valid VPA estimates of the new exploitation pattern will usually not be available until several years after the change for the following two reasons: Firstly, one has to carry the VPA some years back to get efficient estimates. Secondly, the exploitation pattern will probably change from year to year during the period immediately following the mesh change until a new pattern is more or less stabilized.

While assessments of short term effects of mesh changes have an immediate effect on the calculations of catch composition and the fishing mortalities corresponding to a certain TAC, estimates of long term effects have no such immediate consequences although they of course should be considered when setting up a management strategy for the coming years. The primary aim of making estimates of the long term effects of a mesh change on yield and spawning stock is to see to what extent a change in mesh size will improve the situation in relation to rational utilization of the resource.

Often calculations of short and long term effects are presented as a table giving the expected effects for the various fleets participating in the fishery, assuming continuation of the present level of both total effort and its various components,

even if the present F is far from any reasonable management objective for the mesh sizes considered. Such a table is often of little value and may even be misleading. Firstly, advisable changes in total effort are not taken into account. Secondly, the calculated effects for the various components of the trawler fleet may be completely misleading since a change in fishing pattern is not taken into account. Such a change could influence the effects for certain components to a very high extent, even if it has only a moderate effect on the total gain or loss.

The overall long term effects of a mesh change are usually best illustrated in a simple way by giving the yield and spawning stock per recruit curves for the alternative mesh sizes. In some cases it may, however, be required to give expected effects for individual fisheries, especially in cases where there are important fisheries with other gears than trawl. Since the total yield per recruit is the sum of the yield per recruit in the individual fisheries, one should in principle be able to calculate yield per recruit for each fishery. One then of course has to make assumptions about the proportion of the total effort generated by each main fishery, but such assumptions are implicitly made when assuming a certain exploitation pattern and calculating a total yield per recruit curve, and it would probably be an advantage to be forced to make such assumptions explicitly for the various levels of total effort. Therefore, if estimates of long term effects of various mesh sizes are required for individual fisheries, the most appropriate approach will be to calculate a yield per recruit curve for each main fishery (yield per recruit plotted against total F) instead of presenting this in the traditional way giving the effect only for the present level of overall fishing effort.

The main sources of errors in calculated biomass and yield per recruit curves are:

(i) Changes in the fishing pattern of the various fleets or changes in their relative contribution to the total effort when a new mesh size is enforced, resulting in a distri-

bution of fishing mortalities with age different from that estimated from the old fishing pattern and the selection parameters.

(ii) Uncertainties about the value of natural mortality and the growth rate, and possible changes in these parameters when stock biomass changes significantly. For calculations of spawning stock biomass the maturity ogive and its dependence on stock biomass is critical.

3. Management strategies when giving advice on TAC's corresponding to different mesh sizes.

This section will deal with the problem of advising on TAC's in situations where an increase in mesh size is recommended in order to increase the long term yield and spawning stock. It would be useful during this discussion to distinguish between the following situations:

Situation 1: The present fishing effort (fishing mortality) is far above any acceptable reference points as F_{max} or $F_{0.1}$ for the mesh sizes considered, and the spawning stock is in a strongly depleted state.

Situation 2: Fishing mortality is above the reference points F_{max} or $F_{0.1}$ for the mesh sizes considered, but there are no serious worries about the size of the spawning stock.

Situation 3: There is no need for any drastic changes in fishing effort, or the fishing effort may even be increased somewhat for the higher mesh sizes (which give higher F_{max} or $F_{0.1}$).

Unfortunately most of the major demersal fish stocks in North-East Atlantic are in Situation 1 or 2, and the discussion will concentrate on those cases, and especially on Situation 1 which causes the most difficult management problems.

In cases where fishing mortality is far above the advisable level, TAC recommendations combined with possible mesh size changes have often been formulated by aiming at certain percentage reduction in fishing mortality as a first step and calculate the TAC corresponding to this F for the present mesh size and for the recommended mesh size (see for example Report of the North Sea Roundfish Working Group, C.M. 1978/G:7). By this procedure the "short term losses" are transferred directly into the TAC. Although the lower mesh size generate higher removal of young fish from the sea, one is recommending the same removal of older fish for the two mesh sizes. The two TAC's implies rather different management strategies in terms of exploitable biomass or spawning biomass in coming years, a difference which easily could be modified by recommending a lower fishing effort (i.e. lower fishing mortality on the older age groups) for the lower mesh size. The implications of various management strategies are illustrated below for North-East Arctic cod. This stock was chosen since it is a typical Situation 1 stock and since the mesh assessments which have been carried out on this stock have been very thoroughly reported by the Arctic Fisheries Working Group.

As will appear from Report of the Arctic Fisheries Working Group (ANON 1979) and Report of the ICES Advisory Committee on Fishery Management (ICES 1979), the North-East Arctic cod is in a strongly depleted state. Fishing mortality of 8-12 years old fish in 1978 was estimated to around 0.7 compared to $F_{max} = 0.25$ and $F_{0.1} = 0.15$ with the present exploitation pattern (120 mm legal mesh size). The spawning stock is expected to decline to the low level of 200 000 tonnes in 1980 compared to the previously recommended level of 800 000-1000 000 tonnes. The low spawning stock is the result of increased exploitation of immature cod, especially 3-4 years old cod, during the period 1973-1978, together with the maintenance of a high fishing mortality on older cod during the last two decades. At its last meeting the Working Group was asked to report on the effects of increases in mesh size in addition to assess TAC for 1980. The short and long term effects of increases in mesh size to 135 mm

or 150 mm were shown by the usual table of long term gains and short term losses by continuation of the mean fishing effort during the period 1967-1977. Yield and spawning stock per recruit curves clearly showed the long term gains in yield and spawning stock which could be achieved by increasing the mesh size and decreasing the fishing effort.

Catches in 1980 and spawning stock in 1981 were given for a range of fishing mortalities for each of the three mesh sizes considered. It should, however, be noted that spawning stock in 1981 depends only on F and not on mesh size in 1980 since all mature cod in 1981 will already in 1980 be above the selection range for the largest mesh size considered.

ACFM recommended an increase in mesh size to 155 mm, and assuming this to be effective in 1980, a TAC of 390 000 tonnes which corresponds to a decrease in F to 0.65 or 20% below the estimated 1979 level was recommended. TAC's corresponding to alternative mesh sizes were not specified. Instead a general statement was given, saying that the spawning stock biomass can only be expected to reach the desired long-term level if the pattern of exploitation is to be improved considerably, or if fishing mortality immediately is set at much lower levels, resulting in a lower TAC for the coming years.

The recommendation of ACFM was not based on any long term prognosis giving stock sizes for the mid 1980's which may be a critical period for the stock if recruitment remains poor, nor was any such prognosis carried out for the present exploitation pattern. The main problem by running such a prognosis is of course the assumptions which have to be made about recruitment. However, a prognosis carrying the stock several years forwards is the only way to really see the effect of various TACs for alternative mesh sizes, especially when one is conserned about the spawning biomass. For illustrative purposes, the author has therefore carried out such prognoses, assuming that recruitment remains at the moderately low level of 310 million fish as 3 years olds, as estimated for the 1976 and 1977 year classes by

the Working Group. 0-group indices indicate that the 1978 and 1979 year classes are poor. The spawning stock is estimated to be at a very low level during 1980-82, and the assumed recruitment is regarded as realistic, although conservative, also for these year classes. Year classes from 1983 onwards will not influence the catches before 1986, and they will not recruit the spawning stock in significant numbers before 1991.

The starting point for the calculations is the stock in number by age by 1 Jan. 1980 as adopted by ACFM. This stock differs somewhat from the Working Group estimates mainly because of an adjustment of the 1975 year class.

In Fig. 1 is illustrated the effect of adopting the usual procedure of giving TACs for alternative mesh sizes by applying F = 0.65 in 1980 both for the presently observed exploitation pattern (an effective mesh size substantially below the 120 mm legal mesh size) and a 150 mm effective mesh size. F in 1981 and future years has been decreased by 10% of the 1980 level each year until F_{max} is reached (F_{max} equal to 0.25 for the present exploitation pattern and 0.33 for an effective mesh size of 150 mm).

It is not before 1983 that a significant difference in the spawning stock (S) between the two alternative exploitation patterns appears with approximately 80 000 tonnes larger spawning stock for 150 mm mesh size. This year the originally strong but already in 1978-1979 heavily reduced 1975 year class is expected to spawn for the first time, and in 1980 a 150 mm mesh size will reduce F on this year class. From 1983 to 1986 the difference in S between the two alternatives gradually increases, but from 1987 onwards the two curves approach each other. If the prognosis had been carried further, S for the present exploitation pattern would have become the largest, as shown by the S/R curves given in the Working Group report with F = 0.25 and 0.33 for 120 mm and 150 mm mesh size respectively.

It should here be noted that the figures given in both the Working Group and ACFM report for the long term effects on the spawning stock of applying various mesh sizes to the average 1967-1977 situation hardly give any useful information at all about future development since that depends on the management strategy chosen for each mesh size. A continuation of the fishing effort exerted on the stock during the recent years should definitely not be seriously considered as an option.

Figure 1 clearly illustrates that adopting the same fishing mortality for two alternative mesh sizes could lead to an unacceptable management strategy for one of the mesh sizes. The management strategy corresponding to the present exploitation pattern in Figure 1 is unacceptable for two reasons: Firstly, the recruitment of the 1975 year class to the spawning stock in 1983 increases the spawning biomass to only about 420 000 tonnes while the Working Group regarded 500 000 tonnes as the minimum level to reduce the probability of recruitment failure. This level would not be reached before 1987, and in 1984-85 the spawning stock would even decrease below 400 000 tonnes. Secondly, the drastic drop in catches in future years down to a level of about 240 000 tonnes in 1986 would certainly not be acceptable when alternative management strategies show that this can be avoided. For these reasons, only management strategies adopting a value of F significantly below 0.65 in 1980 should be seriously considered if the present exploitation pattern is continued.

The management strategy corresponding to 150 mm mesh size in Fig. 1 is attractive from pure spawning stock considerations if a low level of the spawning stock in 1981-82 is accepted in order to avoid unessessary hardship for the fishing industry during 1980-1981. However, also this alternative leads to catches in 1983-87 below the recommended level of 390 000 tonnes for 1980 and could for that reason be regarded as little satisfactory. This leads us finally to what all TAC recommendations for a strongly depleted stock should start with whatever mesh size it is fished with:

1. Define some minimum requirements for spawning stock biomass.

2. Define your strategy conserning year to year variation in catches and/or fishing mortalities under these requirements, taking into consideration whether several alternative strategies should be outlined leaving the final choise to the management bodies.

As an example, for the North-East Arctic cod this could be done as follows:

1. The spawning stock should not be allowed to fall below the 1980 level (200 000 tonnes) in 1981 and 1982. It should increase to at least 500 000 tonnes in 1983 and should thereafter gradually increase towards the target level of at least 800 000 tonnes.

2. Fishing mortality should gradually decrease towards F_{max}. The recommended catches for 1980 should be sustainable in order to avoid further drastic declines in TACs.

In Fig. 2-3 are shown spawning stock biomasses and fishing mortalities corresponding to constant TACs of 360, 390, 420 and 450 thousand tonnes, for both the present exploitation pattern (Fig. 2) and an effective mesh size of 150 mm (Fig. 3).

For both mesh sizes a TAC of 420 000 tonnes or higher violates the constraints specified above for both spawning stock sizes and fishing mortalities. A TAC of 390 000 tonnes satisfies the constraints if fished with a 150 mm mesh size. By continuation with the present exploitation pattern this TAC would not meet the requirements of gradually decreasing F towards F_{max} or gradually increasing S after 1983, although the spawning stock during the first coming years would be higher than if the TAC was fished with a 150 mm mesh size, and in 1983 would be appreciably above the minimum level of 500 000 tonnes.

If a TAC of 390 000 tonnes is taken with a mesh size of 150 mm, there is a danger that the spawning stock in 1981-1982 may

decrease below the defined critical level of 200 000 tonnes if the exploitation pattern is changed towards older age groups even more than predicted by the Working Group. The complicated nature of the problem is illustrated by the fact that this does not depend only, or perhaps not even primarily, on how the pattern of fishing of the various fishing fleets changes as a result of a mesh size change. The drastic decline in TAC compared to earlier years may also cause changes in the relative proportion of the catch taken by the trawler fleet compared to that taken by other gears in coastal fisheries of which the fishery on the spawning stock is an important part. Such changes are not predictable since they depend primarily on internal regulations in a country which in previous years has taken nearly half of the total TAC. In such a situation the best thing a Working Group can do is to specify the assumptions underlying the estimated exploitation pattern and briefly describe the effects if these assumptions are altered in one way or another.

It may be argued that the effect of a TAC of 390 000 tonnes will be very sensitive to small changes in the assumed recruitment for both mesh sizes and that stock sizes and fishing mortalities projected as far ahead as in Fig. 2-3 have little significance at all. This is of course true, and the only purpose of the figures is to see whether a certain TAC is sustainable under the assumptions made and indicate expected trends in F's and S's under those assumption. The conclusion of the exercise would then be that in order to meet the requirements specified above, TAC could be as high as 390 000 tonnes for a 150 mm mesh size but should preferably be set somewhat lower with a 120 mm mesh size, in contrast to the usual prosedure of recommending a lower TACs for the higher mesh size to adjust for "short term losses". Of course management strategies could be constructed which gave a higher TAC in 1980 for the 120 mm mesh size and still met the requirements conserning spawning stock and fishing mortalities. All such strategies would, however, have in common that a further decrease in TAC (below 390 000 tonnes) would be necessary in the near future if recruitment does not improve.

In this example both short and long term objectives concerning spawning stock size are spesified. If only the short term objectives (S in 1981-1983) had been taken into account, TAC for the present exploitation pattern could have been set as high as 450 000 tonnes while the TAC for a 150 mm mesh size still would have to be as low as 390 000 tonnes. This illustrates a general truth: The lowest mesh size allows you to take a higher catch in the immediate future if most emphasis is placed on the short term objectives for the spawning stock (assuming that length at maturity is within or above the selection range of the lower mesh size), while the larger mesh size may allow you to take the highest catch if the long term objectives are regarded as equally or more important. The most extreme unbalance between short and long term objectives is achieved by simply calculating for the two mesh sizes the TAC corresponding to a more or less arbitrary value of F and not looking ahead at all.

For stocks which suffer from growth overfishing (i.e. $F > F_{max}$) but where spawning stock size is not regarded to be critically low, the usual procedure of recommending the same stepwise reduction in F towards F_{max} or $F_{0.1}$ irrespective of mesh size may be appropriate when the fishing mortality one is aiming at is at approximately the same level for the mesh sizes considered. However, if there are considerable differences between F_{max} (or $F_{0.1}$) for the various mesh sizes, a more appropriate strategy may be to aim at reaching the reference point in the same number of steps leading to a slower reduction in F for the larger mesh size and thus modify "short term losses". The possibility of recommending a slower reduction in F for the larger mesh size should also be considered even if the F one is ultimately aiming at is not significantly different for the alternative mesh sizes. This would mean that the long term gains by both increasing the mesh size and decreasing the fishing mortality are attained more gradually, in order to modify the short term losses which may be considerable when both mesh size and fishing mortality are changed. If "short term losses" cause difficulties in getting the mesh size increased, the author can see no serious objections against such an approach compared to the alternative

of automatically apply a strategy in terms of F's for one mesh size even if this strategy originally was developed for another mesh size.

4. Conclusions

Mesh assessments and TAC recommendations should be combined as follows:

(i) Assumptions made about pattern of fishing when estimating the exploitation pattern under a new mesh size should be spesified.

(ii) Short term effects of mesh size changes on catch rates for the various components of the fleet may be calculated along traditional lines, but effects of possible changes in the assumed pattern of fishing should be indicated for those components where such changes are likely to occur. In situations with strongly varying recruitment, estimates of short term effects on cpue should if possible take into account the actual strength of the year classes within the selection range. Yield and spawning stock per recruit curves should be constructed for each mesh size considered, showing the long term effects (per recruit) of the various combinations of mesh size and fishing mortality. If one wants to see the long term effects for various components of the fleet, this could be done by calculating yield per recruit curves for each main fishery.

(iii) A management strategy should be outlined for each option of mesh size, spesifying both short and long term objectives. TAC recommendations should be based on such strategies and not on simple adjustments for "short term losses". Effects on the stock of likely deviations from the assumed pattern of fishing, both changes within each component of the fleet and changes in the proportion of the total fishing effort generated by the various components, should be described.

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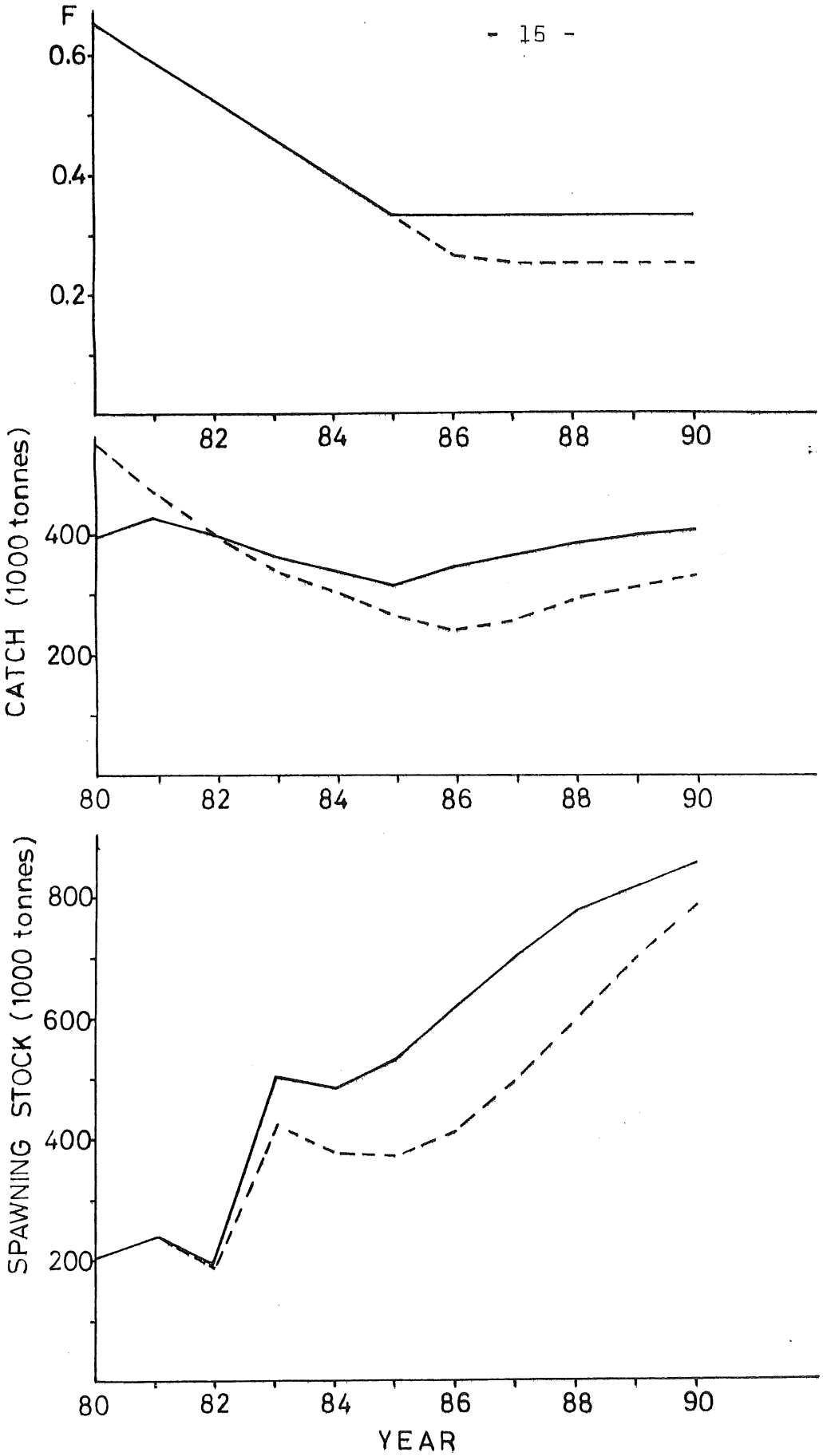

Figure 1. North-East Arctic cod. Fishing mortality (F), catch and spawning stock plotted against year under a management strategy aiming at F= 0.65 in in 1980 and thereafter a gradual decrease (10% of 1979 level) each year until F_{max} is reached. Whole line: 150 mm effective mesh size. Broken line: Present exploitation pattern.

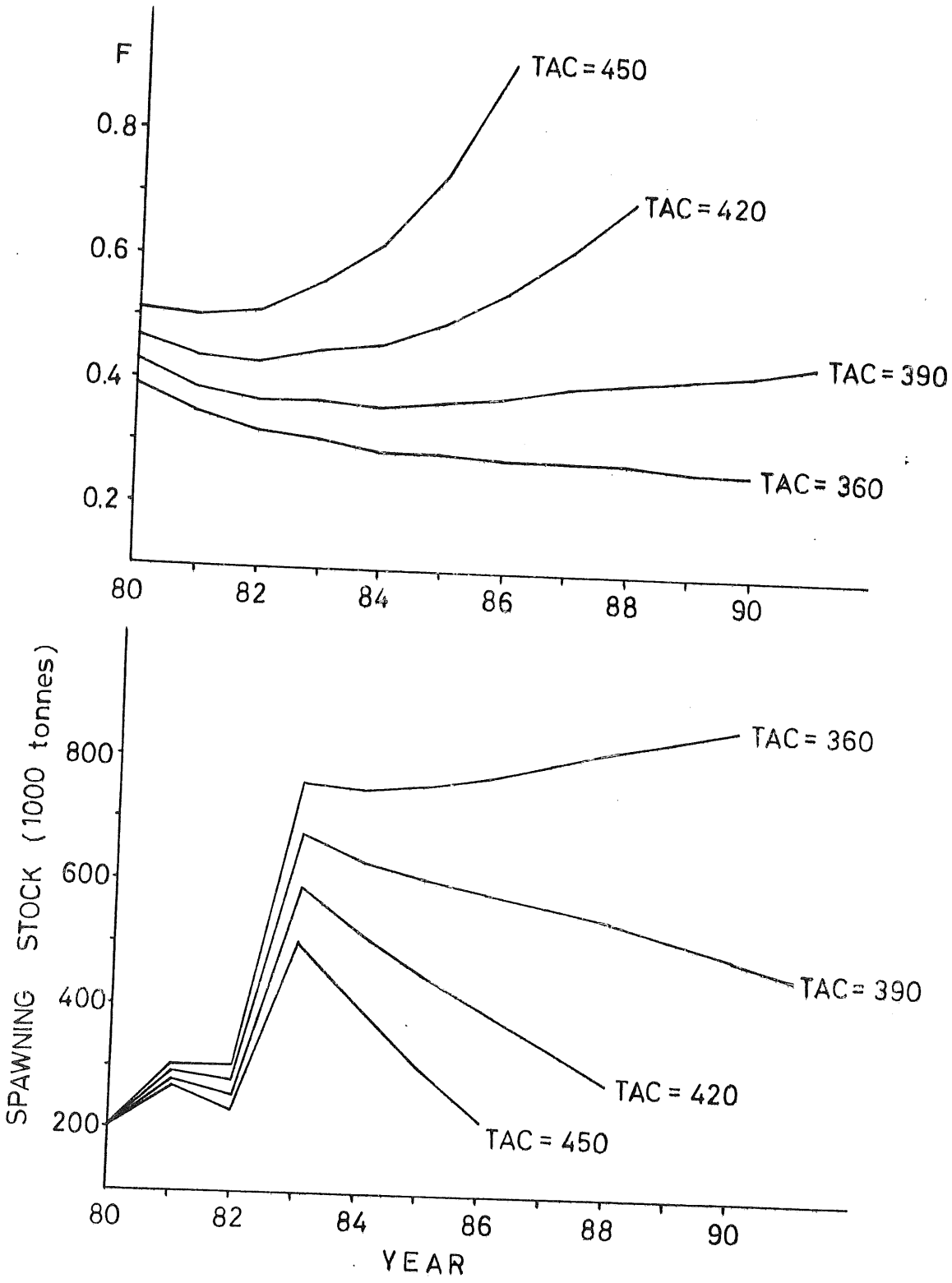

Figure 2. North-East Arctic cod. Fishing mortality (F) and spawning stock plotted against year for various constant TACs. Present exploitation pattern.

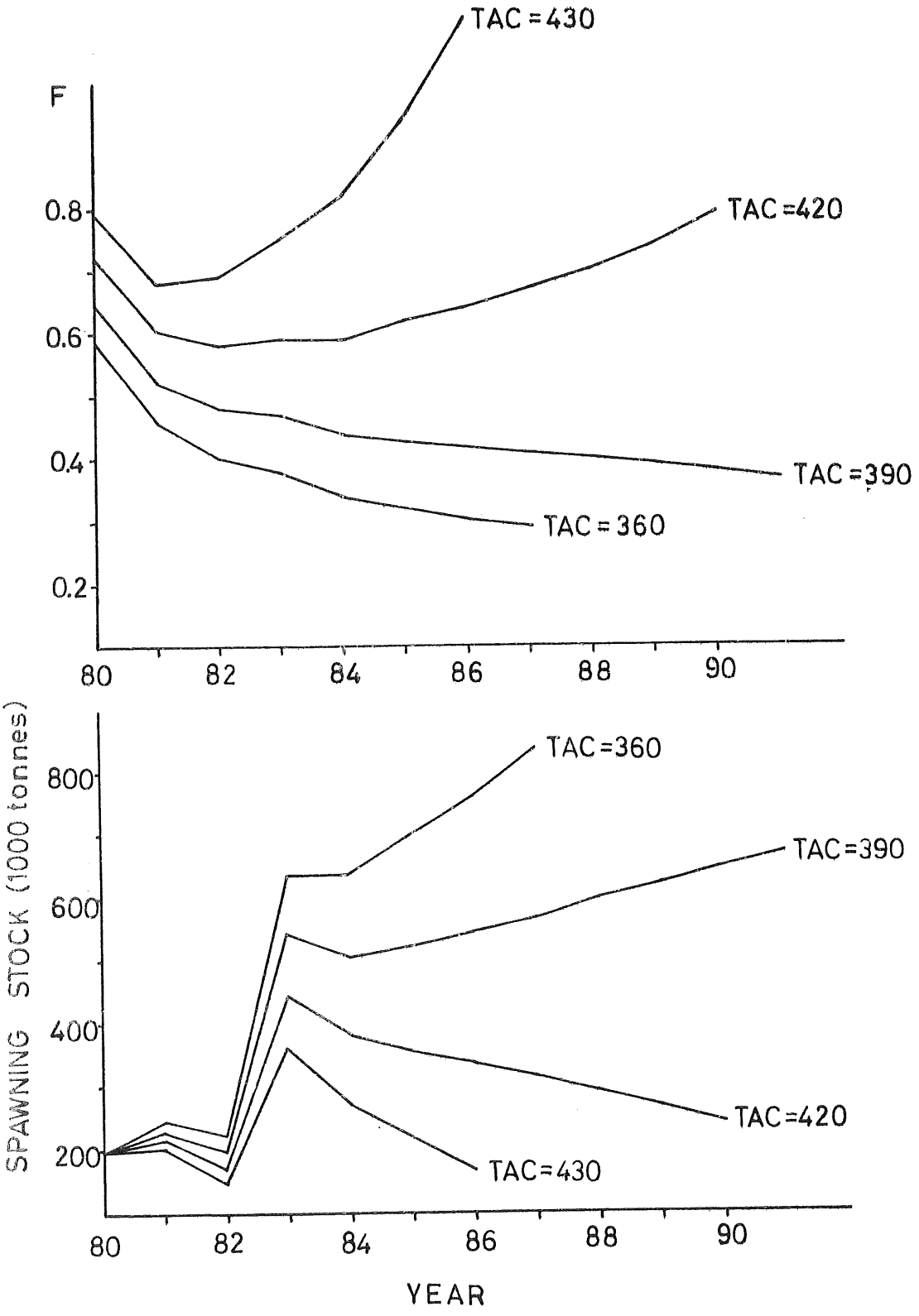

Figure 3. North-East Arctic cod. Fishing mortality (F) and spawning stock plotted against year for various constant TACs. 150 mm effective mesh size.