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Management faced with
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The choice of TAC when faced with multiple objectives

by

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Abstract

The total allowable catch is a key instrument in fishery management, and advice on its level used to be based purely on biology. In 1991, ACFM stated that its objective was to provide the advice necessary to maintain viable fisheries within sustainable ecosystems, leaving the actual choice of management strategy and corresponding TAC for stocks within safe biological limits to managers. Usually there are several objectives for the fishery policy and the advice on the level of TAC must be based on analysis which quantifies the most important consequences. An outline of such advice on the level of TAC (when faced with multiple objectives) is given. Two transboundary stocks, Northeast Arctic cod and Norwegian spring spawning herring, serve as examples.

Key words:

Bioeconomic advice
Northeast Arctic cod
Management strategy
Norwegian spring spawning herring

1. Introduction

To reach the objectives of a fishery policy, a number of regulatory measures are applied. The most common are input regulations (licenses, participation rights, days at sea, etc.), output regulations (total allowable catch, vessel quota) and various technical regulations like minimum catching sizes, mesh sizes, closed areas or seasons. For each management issue it is the managers job to:

- identify the objectives for the fishery policy relevant for the management issue
- identify the necessary means to achieve these objectives
- enforce the chosen means

In this paper, the management issue of fixing the yearly level of total allowable catch (TAC) is discussed. Historically, the answer to this question was sought entirely from the profession of marine researchers, in the coastal countries of the Northeast Atlantic usually from the International Council for the Exploration of the Seas (ICES). For the most important fish stocks it was a tradition that ICES' Advisory Committee on Fisheries Management (ACFM) provided an advice on TAC. The basis for such advice was usually a maximum sustainable yield philosophy.

That process was altered when ACFM (1991) stated that its objective was to: *"provide the advice necessary to maintain viable fisheries within sustainable ecosystems"*. In order to reach such an objective, ACFM explained that *"for stocks which are below Minimum Biological Acceptable Level (MBAL) or expected to become so in the near future"* it would *"in so far as possible give advice on what measures are needed to rectify the situation"*. For *"stocks not in imminent danger of falling below the MBAL"* it *"would provide options together with impact statements for each option[1]"*.

Through this statement, ACFM pointed out that it would not provide specific advice on TAC for stocks within safe biological limits[2]. Under such circumstances, the choice of TAC should be based on objectives stated by the "owners" of the resource i.e. by the fishery managers.

To meet the position of ACFM, managers should have a way of analysing the consequences of different management strategies and corresponding levels of TAC on the most important objectives. In the following, an outline of our experience from giving advice on the level of TAC taking into account a fishery policy with conflicting objectives is given.

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1 In this paper, the phrase safe biological limit is used synonymous with the phrase Minimum Biological Acceptable Level (MBAL).

2 As an example, ACFM's management advice for Norwegian spring spawning herring for 1996 was: "ACFM advises that the fishery on this stock should be managed to ensure that the SSB is kept above the MBAL of 2.5 million t." (Anon 1996c).

2. Material and methods

As examples, the choice of TAC for two transboundary stocks, Northeast Arctic cod and Norwegian spring spawning herring, will be used. Relevant literature on the biology, assessment and management of the Northeast Arctic cod stock is given in Anon (1996a) and Jakobsen (1993). Literature on the Norwegian spring spawning herring is given in Anon (1996b) and Hamre (1989).

2.1 Management objective relevant for the choice of TAC

Multiple objectives are a common feature for the fishery policy of many nations. The objectives of the Norwegian fishery policy have been outlined in several white papers and are often formulated as follows:

*** The existing pattern of settlement shall be maintained**

*** Marine resources shall give sustainable yields**

*** People shall have secure and good jobs**

*** The value-added in the fisheries sector shall be increased**

For many management issues, these objectives are non-compatible. This can be illustrated by the following examples: A program to reduce overcapacity in the fishing fleet (input regulation) will be beneficial according to the 4th objective mentioned above, whereas it may not be beneficial to the 1st objective. Another example may be the distribution of a national quota to either a large or a small number of fishermen, which would stimulate the 1st and the 4th objective respectively.

Concerning the management issue discussed in <u>this</u> paper, a small TAC will be negative to 3 of the 4 objectives stated in the short run. However, it is obvious that in order to be able to pursue the four goals in the *long run*, protection of the fish stocks against overfishing and stock decline is of vital importance. For several of the economic most important fish stocks in Norway, priority had to be given to the objective of a stable, high and sustainable yield knowing that an increase in yield was necessary in order to be able to pursue the other three goals. Therefore, a management objective in compliance with the overall objectives of the fishery policy is:

The level of TAC should aim at giving a stable and highest possible sustainable economic yield.

Such an objective is still multi-faceted in so far as the TAC should aim at **stability** (not too large variations from year to year), **highest possible economic yield** (which in many instances are synonymous with a high TAC) and **sustainability** (which imply that the catch should not press the stock below MBAL).

As advisers to the managers one must accept multiple objectives. In order to give an advice on the level of TAC under such circumstances, it is necessary to:

a) quantify the consequences of different management strategies and corresponding levels of TAC (or fishing mortality) on the different objectives as stability, economic yield and sustainability
b) make a choice of TAC based on the outlined consequences.
c) give an advice to managers on levels of TAC and clarify its consequences.

For transboundary stocks, the actual decision on the level of TAC is taken as an integral part of fishery negotiations between the parties concerned. As each party may have different objectives for their fishery policy, it should not come as a surprise that they may differ in opinions regarding the level of TAC. However, the advisory process described above may clarify which consequences alternative TACs will have for the fulfilment of each party's objectives, and as such be instrumental to reach a compromise solution.

To carry out analysis of this kind it is important to keep in mind the status which ICES possess as a neutral biological adviser to all management authorities in the region of the Northeast Atlantic. This fact implies that bioeconomic analysis undertaken to outline different consequences must be compatible with ICES stock assessment and prognosis. When giving advice on the level of TAC under such conditions, it is our experience that a co-operation between economists working in the management, in the universities and biologists with up-to-date knowledge of ICES' stock assessments has been rewarding.

A description of biological and economic models and data applied to describe the consequences of different levels of TAC for the two stocks follows below.

2.2 Length of the forecast

Although the decision on the level of TAC is a yearly event, it has long term consequences. For Northeast Arctic cod we have calculated consequences for a period of 5 years. For Norwegian spring spawning herring, consequences for a 10 year period were calculated. The longer time horizon applied for herring was caused by the recruitment pattern of this stock (see section 2.5.3).

2.3 Biological model

The usual VPA-type age-structured population model is used:

$$N_{y+1,a+1} = N_{y,a}e^{-Z_{y,a}}$$

$$Z_{y,a} = F_{y,a} + M_{y,a}$$

$$C_{y,a} = \frac{F_{y,a}N_{y,a}(1 - e^{-(F_{y,a}+M_{y,a})})}{F_{y,a} + M_{y,a}}$$

where

y: year

a: age (years)

$N_{y,a}$: Number of fish of age a at the start of year y.

$F_{y,a}$: Fishing mortality rate

$M_{y,a}$: Natural mortality rate

$Z_{y,a}$: Total mortality rate

$C_{y,a}$: Catch in numbers.

The total catch in weight (TAC) in year y is then given by

$$TAC_y = \sum_a C_{y,a} WC_{y,a}$$

Spawning stock biomass is given by:

$$SSB_y = \sum_a N_{y,a} WS_{y,a} O_{y,a}$$

where

$WC_{y,a}$: Weight of fish at age a in the catch in year y

$WS_{y,a}$: Weight of fish at age a in the stock in year y

$O_{y,a}$: Maturity ogive (proportion of fish at age a which is mature in year y)

In order to separate the effect of the selection pattern from the effect of the overall fishing pressure, we define

$$F_{y,a} = f_y S_{y,a}$$

where

$S_{y,a}$: Selection pattern

f_y : reference fishing mortality

The selection pattern is usually scaled in such a way that

$$\frac{\sum_{a=a1}^{a2} S_{y,a}}{a2 - a1 - 1} = 1$$

The reference fishing mortality is then equal to:

$$F_{y,a1\text{-}a2} = \frac{1}{a2-a1-1} \sum_{a=a1}^{a2} F_{y,a} = \frac{1}{a2-a1-1} \sum_{a=a1}^{a=a2} f_y S_{y,a} = f_y$$

This is denoted by F later in the paper. For cod, an age range (a_1-a_2) from 5-10 is used for the reference mortality, while for herring, age 5-13 is used.

2.4 Economic models

As the specification of harvesting costs generally differ between a demersal and a pelagic fishery, different economic models were applied for Northeast Arctic cod and Norwegian spring spawning herring.

Northeast Arctic cod

Price is given as average price per kg, whereas costs are given as a function of fishing mortality:

$$C(F) = \alpha + \beta F$$

where:

C :variable costs per fishing mortality

α :constant

β :coefficient

Norwegian spring spawning herring

Costs are given as an average cost per kg, whereas prices are given as a function of quantity landed.

$$P = p_{min} + e^{\alpha} * TAC^{-\beta}$$

where:

P :price per kg catch

p_{min} :minimum price

α :constant

$-\beta$:coefficient

2.5 Biological data

Both the stock size for the initial year and the fishing pattern, growth, natural mortality, maturation and recruitment (not for herring) in the years to come were taken from the last ICES Working Group reports (Table 3.23 in Anon, 1996a for cod and Table 3.5.12 in Anon, 1996b for herring).

2.5.1 Fishing pattern

For herring, a fishing pattern giving full recruitment to the fishery at age 5 is used. For cod, the average selection pattern for 1992-1994 is used in the predictions. This pattern implies that the cod is fully recruited to the fishery at about age 6.

2.5.2 Growth

The growth of Northeast Arctic cod is very variable and this has caused problem for the management of this stock (Mehl, 1991). The growth is closely correlated with the variations in abundance of capelin, the most important prey for cod. The weight at age from 1996 onwards is assumed to be equal to the average of the period 1987-1990, when the capelin stock was at a very low level. The capelin stock is currently at a similar low level and is expected to remain at such a level at least until 1998.

The Norwegian spring spawning herring is feeding on plankton and weight at age will generally not differ as much as for cod. In the prognosis, the average weight at age for the 1960s was used for 1997 onwards.

2.5.3 Recruitment at age 3

In the biological model, age of recruitment to the stock is usually defined as the age at which the fishery starts (currently age 3 is used for both Northeast Arctic cod and Norwegian Spring-Spawning Herring).

A long term analysis of biological and economic consequences of different levels of exploitation will to a great extent depend on the size of the recruiting year classes. The approach taken when giving a prognosis on recruitment was to investigate:

- time series of recruitment
- the recruitment's dependence on spawning stock
- prognosis on predation on fish not yet recruited to the fishable stock
- prognosis on oceanographic conditions relevant to recruitment

Time series of recruitment show high variability for both stocks. For Northeast Arctic cod, the recruitment was set equal to the average of the 1943-1991 year classes. For Norwegian spring-spawning herring, the stock development depend very strongly upon a few strong year classes. There seem to be typically 8-10 years between strong year classes. Several models for stock-recruitment relationship have been proposed and are under investigation by the ICES Atlanto-Scandian Herring, Capelin and Blue Whiting Working Group (Anon 1996b).

In order to illustrate the consequences of at what time the next strong year class occur in a simpler way than through a risk analysis, simulations were run with a high recruitment (24 billion, equal to the 1992 year class), occurring either in year 1998 or in year 2000. For the other years, the recruitment was assumed to be low (845 million, equal to the 1994 year class).

2.5.4 Natural mortality , age 3 and older

For Northeast Arctic cod M was set to 0.2 for all ages and years, whereas for Norwegian Spring Spawning Herring, M was set to 0.13.

2.5.5 Maturity ogive

For Northeast Arctic cod, a maturity ogive equal to the average for the period 1993-1995 was used. For Norwegian spring-spawning herring, a maturity ogive equal to the average for 1960-1968 was used for 1997 onwards. The ogive indicate that herring on average recruit to the spawning stock at age 5 and cod at age 7.

2.6 Economic data

In the fishery for cod, trawlers and vessels fishing with nets, long line and Danish seine participate. Data on costs representative for these vessel groups were drawn from the Norwegian profitability analysis (Fiskeridirektoratet, 1995a), whereas data on earnings were drawn from the Norwegian fishery statistics. In the fishery for herring, purse seine and trawl are the most common gear. Data on costs were drawn from the vessel group landing the majority of the catch, the licensed purse seiners (Fiskeridirektoratet, 1995b).

When calculating the economic benefits from fisheries, one should ideally obtain estimates of the value of the final cod products consumed by the population of Norway or exported, as well as the costs of fishing, transporting and processing of the catch. Net economic benefits would then accrue as total revenue less all costs involved.

So far, calculations have been carried out to establish revenues and costs in the processing of cod (Fiskeridirektoratet 1995a) and herring (Fiskeridirektoratet 1995b). However, these estimates of revenues and costs in the processing industry have yet not been found to be representative enough to use them in a bioeconomic analysis of this kind. Consequently, our approach hitherto has not reached a level where the net economic benefits to the Norwegian society could be calculated. Instead we have focused upon the economic benefits at the level of the Norwegian fishing fleet, and in the following we will sketch out how this benefit has been calculated.

2.6.1 Revenues

Revenues, or income, have been found as the share of the TAC which accrue to Norwegian fishermen times price obtained for the fish. Time series were analysed in order to find a long term trend in prices or whether prices correlated with the size of the Norwegian catch. For Northeast Arctic cod no trend during years or correlation between price or the size of the Norwegian catch was found (Fiskeridirektoratet, 1995a). As a prognosis for future price, the average price for the period 1989 - 1994 was used (Fiskeridirektoratet, 1995a).

For Norwegian spring spawning herring, a relationship between total catch and price was estimated using data from the period 1980-1993 (Bogstad et al, 1994 and Fiskeridirektoratet, 1995b).

2.6.2 Costs of fishing

Data on costs and earnings were taken from the profitability survey of Norwegian fishing vessels in 1994 (Budsjettnemnda 1994). Total costs of fishing were divided into fixed and variable. These have been treated as follows:

Fixed costs

Fixed costs are costs occurring irrespective of the activity or the catch level of the vessels. Concerning the question of fixing the level of TAC and the consequences of different levels of TAC during a period, the fixed costs are necessary for determining the economic benefit or profitability of the fishery. However, as the fixed costs occur irrespective of the size of the TAC, they are not relevant when calculating which TAC yields maximum economic benefit, unless there exists a relationship between the size of TAC and investment in the fishing fleet[3].

As we have not yet found any empirical relationship between the size of the TAC and investment, our approach has been to exclude fixed costs from the analysis. This implies that the economic benefit we calculate is equal to the contribution margin, that is revenue less variable costs.

Variable costs

In demersal fisheries, it is common to assume that some of the variable costs depend upon the size of the fishable part of the stock. The underlying logic for such assumption is that when the stock is small, a larger effort will be needed to catch a given quantity of fish than when the stock is large (Clark, 1976).

This assumption is not made in pelagic fisheries, as most pelagic fish are "schooling", targeted by sonar equipment. This implies that effort needed to catch a given quantity of fish may not be significantly higher when the stock is small than when the stock is large.

Consequently, for the Northeast Arctic cod, variable costs (ex labour costs) are à priori assumed to depend upon the stock size. Costs components classified to be variable were taken from profitability survey for Norwegian fishing vessels in 1994 (Budsjettnemnda 1994). In the profitability survey these constitutes labour costs, fuel, product tax and expenditure to cooling, salting and packing the catch, and are labelled R.2.01-R.2.04 and R.2.10 in the profitability analysis. In the profitability analysis, these costs are given as average costs per vessel. The cost per fishing mortality were simply found by multiplying the cost per vessel with the number of vessels needed to exercise a certain level of fishing mortality. A further discussion of the method can be found in Nakken et al (1994) and Steinshamn (1993).

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3 In the long run, it is reasonable to believe that investment in the fishing fleet will depend upon the level of TAC. Rational investors will adjust the investment in order to achieve as high a profit as possible, and a higher level of TAC may therefore also give higher investment and fixed costs in the long run.

For the Norwegian spring spawning herring, variable costs are only assumed to depend upon the catch level. The same cost components were taken from the most important vessel group (the licensed purse seiners) and using data from the period 1982-1992, a relation between quantity and price was found (Bogstad et al, 1994).

2.6.3 Discount rate

This year's TAC have a larger value than future TAC's since net revenue from catches this year can be invested and give a rate of return. To adjust for this we reduce the net revenue from future TAC by a factor that reflects the rate of return in the market, i.e. the discount rate. When discounting we use a rate of 5%.

The decision on the yearly level of TAC is a decision of how much of a resource should be used now versus in the future. According to an objective of sustainability, one might ask whether discounting can be justified. In the results, we therefore calculate both discounted and undiscounted revenues.

2.7 Uncertainty

Data applied will be subject to various levels of uncertainty. Consequences of different management strategies and corresponding levels of TAC should therefore in principle only be presented according to a certain level of probability. An example of a risk analysis for Norwegian spring spawning herring undertaken by Anon (1996b) is described under section 3.2.

In order to combine economic and biological data, a simplified approach was used. The management advices described in this paper was therefore based on a deterministic approach. As a consequence, uncertainty inherent in data were not dealt with.

3. Results

The model and data as specified above were used for the two stocks mentioned, and tables 1-4 show the results. For Northeast Arctic cod different levels of fishing mortality during a five year period were analysed. For Norwegian spring spawning herring, scenarios were run to compare a fixed TAC-strategy with a fixed F-strategy. After finding that a fixed TAC-strategy, according to the objectives of the fishery policy, was better than a fixed F-strategy, different levels of fixed TACs were run.

As our objective was that the level of TAC should be fixed in order to give a stable, sustainable and highest possible economic yield, we calculated the consequences which different levels of fishing mortality or TAC had on spawning stock and on economic parameters as average gross and net revenues as well as the net present value of catch during a period.

3.1 Northeast Arctic cod

Tables 1 and 2 below show the biological and economic consequences of different levels of fishing mortalities.

Table 1. Biological consequences of different levels of fixed fishing mortalities during the period 1996-2000. Biomass and catches given in thousand tonnes.

Management strategy for the period 1996 - 2000	TAC for 1996	Average TAC	Minimum level of spawning stock	Spawning stock year 2001
F = 0,55	797	672	518	552
F = 0,46	694	640	683	733
F = 0,40	620	612	697	893
F = 0,37	580	594	697	996
F = 0,32	517	561	697	1 179

The TAC for Northeast Arctic cod for 1995 was 700 000 tonnes. The objective calling for **stability**, indicated that the TAC for 1996 should not deviate too much from that level.

Both Jakobsen (1993) and Nakken et al (1994) argues that a spawning stock of 500 000 tonnes should be seen as a limit reference point, beneath which managers should attempt not to bring the stock. Table 1 shows that the minimum level of spawning stock is far above this level for fishing mortalities in the range from 0.32 to 0.46, but very close when a fishing mortality of 0.55 is exercised. Furthermore, a lower fishing mortality will yield a higher spawning stock at the end of the period (year 2001).

In order to achieve a **sustainable** harvest, the stock should not be brought close to its limit reference point. Consequently, a fishing mortality of 0.55 should be ruled out. A fishing mortality of 0.40 would harvest the stock more conservatively than a fishing mortality of 0.46 as the spawning stock in the end of the period is forecast to be 160 000 tonnes higher. However, such a reduction would also imply a lower average TAC. Table 2 shows the economic consequences of that.

Table 2. Economic consequences of different levels of fixed fishing mortalities during the period 1996-2000. Catches given in thousand tonnes. Values based on a Norwegian share of the TAC at 45% and is given in million NOK. Discount rate = 5%.

Management strategy for the period 1996 - 2000	Average TAC	Average gross revenue for Norwegian fishing fleet	Average net revenue for Norwegian fishing fleet	Net present value of catch from the whole period (discounted)
F = 0,55	672	2 123	826	3 780
F = 0,46	640	2 023	832	3 788
F = 0,40	612	1 934	823	3 732
F = 0,37	594	1 876	812	3 676
F = 0,32	561	1 773	786	3 549

Not surprisingly, the average gross revenue is higher the higher fishing mortality. Due to the density-dependent harvesting costs, the average net revenue is lower when the fishing mortality is increased from 0.46 to 0.55. There is therefore no economic rationale in choosing the highest fishing mortality. Concerning the objective of **highest possible economic yield**, Table 2 shows that this will be almost identical for fishing mortalities in the range 0.32-0.55.

Taking account of the three objectives discussed above, our advice was that a fishing mortality of 0.40 during the period 1996 - 2000 would be beneficial. Such a fishing mortality would yield a TAC of 620 000 tonnes in 1996.

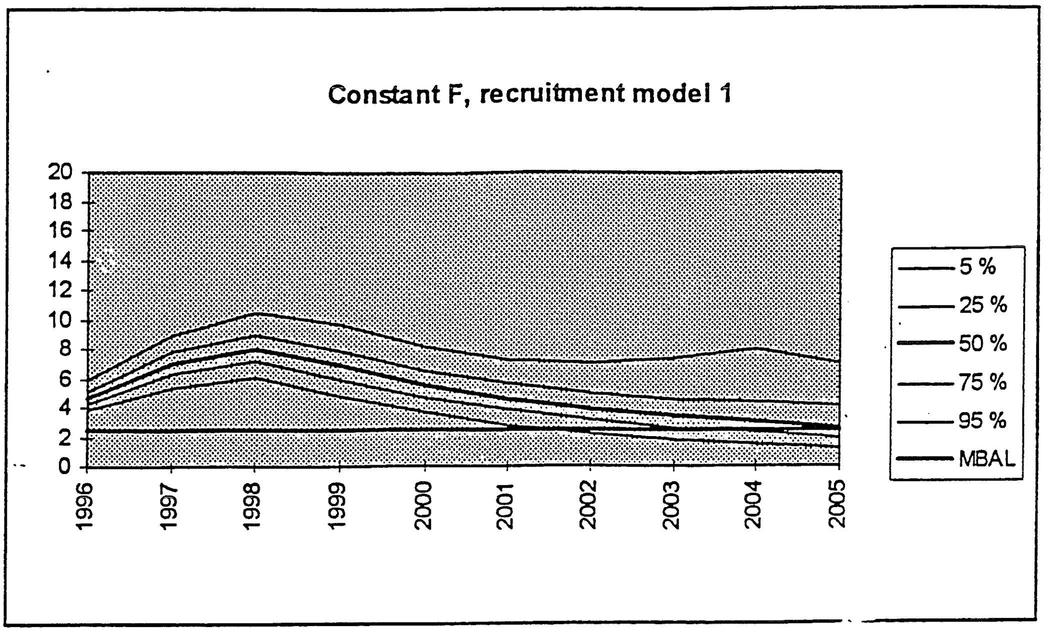
The actual TAC for 1996 was fixed at 700 000 tonnes.

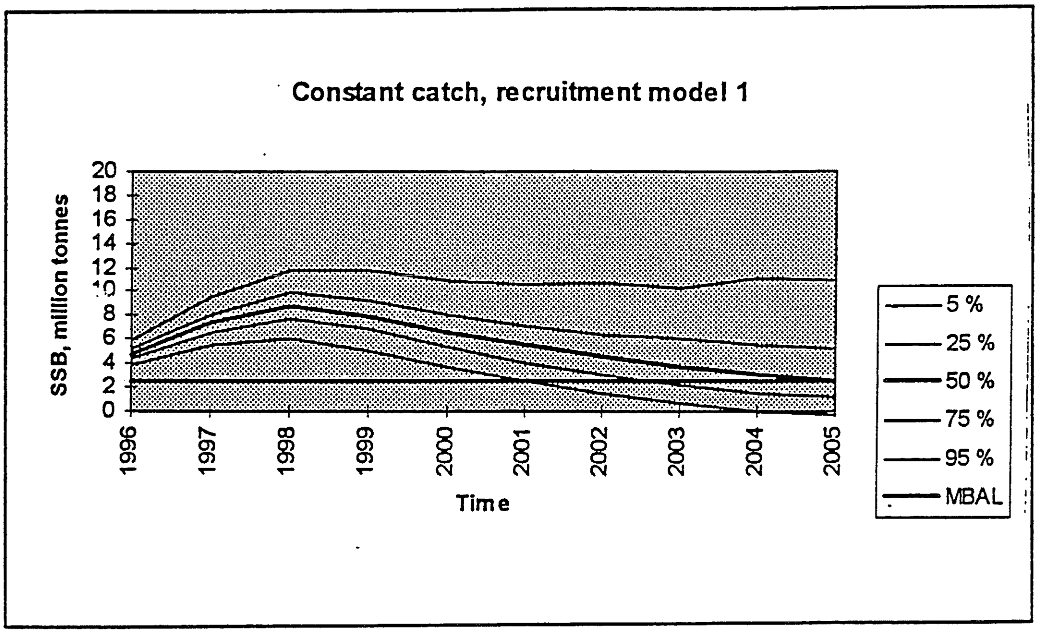
3.2 Norwegian spring spawning herring

Since the collapse of this stock in the 1960s, the stock has been managed in order to achieve a limit reference point of 2.5 million tonnes. The spawning stock biomass is now well above that level.

A risk analysis, focusing on the uncertainty in recruitment of herring, and the effects of different harvesting strategies were carried out by Anon (1996b). Figure 1 is drawn from that analysis, and shows the results of the simulations giving the development of SSB during a 10-year period according to different levels of probabilities. In the upper frame, this development is shown for a constant F-strategy and in the lower frame it is shown for a constant TAC strategy. Both strategies yield total catch of approximately 10 million tonnes during the whole period.

Figure 1. Simulated development of SSB according to different levels of probability. The upper frame shows a constant F-strategy and the lower frame a constant TAC-strategy. Drawn from Anon (1996b).

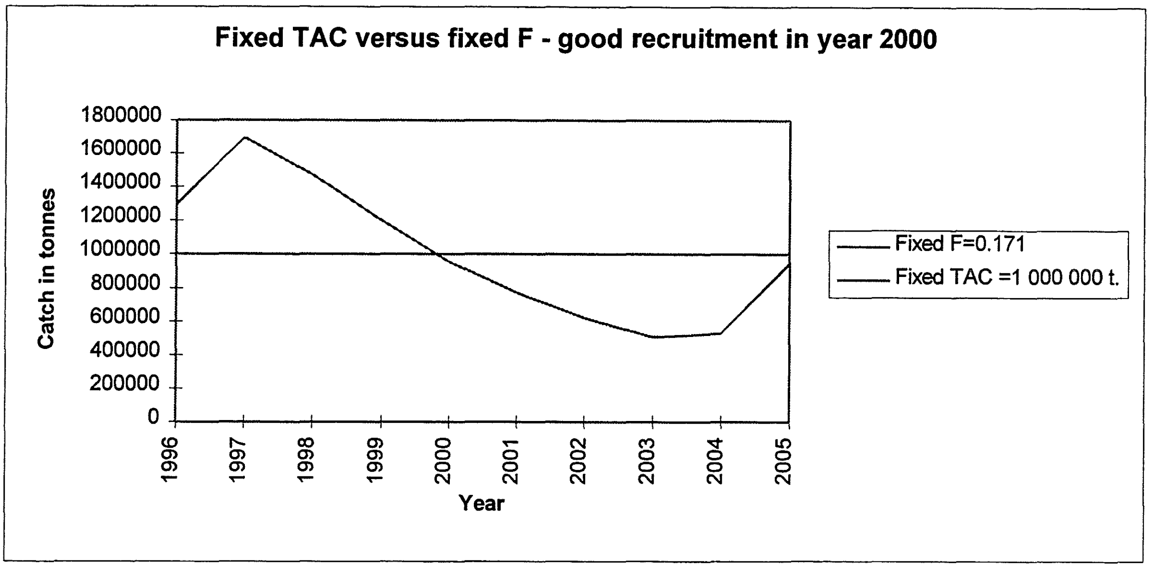




In general the constant catch option seems to give smaller probabilities of maintaining the spawning stock above 2.5 million tonnes. The reason seems to be that a constant F-strategy will tend to be more conservative in a declining stock situation.

According to a precautionary approach, a constant F-strategy would therefore be preferable to a constant TAC-strategy. However, according to the objective of stability in yield (see section 2.1), a constant TAC-strategy would be preferable to a constant F-strategy, see Figure 2.

Figure 2. A fixed TAC versus a simulated development of TAC according to a fixed F-strategy



Analysis carried out by Fiskeridirektoratet (1995b) showed that the difference in economic consequences of the two different strategies were very small. The objective of stability in yield therefore implied that a constant TAC-strategy was recommended.

Having established that a fixed TAC strategy was preferable to a fixed F strategy, we evaluated the level of a fixed TAC which could be recommended, using a deterministic model. Table 3 and 4 shows the most important consequences of different levels of TAC, according to different assumptions on the timing of next strong year class.

Table 3 Economic and biological consequences of different levels of TAC if the next strong year class (equal to the 1992-cohort) occur in year 2000. Biomass and catches given in thousand tonnes. Values based on a Norwegian share of 100% of the TAC and given in million NOK. Discount rate = 5%. Prices in 1992 NOK/kg

Yearly level of TAC for the period 1996 - 2005	Average price NOK/kg	Average gross revenue	Average net revenue	Net present value of catch from the whole period (discounted)	Year when spawning stock fall below 2.5 million tonnes	Lowest level of spawning stock
600	1,26	753	344	2 788	-	4 800
700	1,23	859	381	3 097	-	4 300
800	1,21	964	419	3 400	-	3 800
900	1,19	1 069	456	3 700	-	3 300
1 000	1,17	1 174	493	3 995	-	2 700
1 100	1,16	1 278	529	4 288	2004	2 200
1 200	1,15	1 381	565	4 579	2003	1 700

Table 4 Economic and biological consequences of different levels of TAC if the next strong year class (equal to the 1992-cohort) occur in year 1998. Biomass and catches given in thousand tonnes. . Values based on a Norwegian share of 100% of the TAC and given in million NOK. Discount rate = 5%. Prices in 1992 NOK/kg

Yearly level of TAC for the period 1996 - 2005	Average price NOK/kg	Average gross revenue	Average net revenue	Net present value of catch from the whole period (discounted)	Year when spawning stock fall below 2.5 million tonnes	Lowest level of spawning stock
600	1,26	753	344	2 788	-	6 700
700	1,23	859	381	3 097	-	6 300
800	1,21	964	419	3 400	-	5 800
900	1,19	1 069	456	3 700	-	5 400
1 000	1,17	1 174	493	3 995	-	4 900
1 100	1,16	1 278	529	4 288	-	4 400
1 200	1,15	1 381	565	4 579	-	3 800
1 300	1,14	1 486	600	4 868	-	3 200
1 400	1,14	1 589	636	5 155	-	2 600

Table 3 shows that if the next good recruitment comes in year 2000, it is possible to keep a constant TAC at 1 million tonnes during the period 1996-2005 without bringing the stock down to its limit reference point. However, if the next good recruitment comes as early as in year 1998 (Table 4), it is possible to keep a constant TAC at 1.4 million tonnes without bringing the stock down to its limit reference point.

As these are results of a deterministic model which do not explicitly state the probability, a precautionary approach would suggest lower levels of TAC than stated above.

As mentioned earlier, no density dependent harvesting cost are applied when calculating the net economic benefit for a pelagic species as herring. A high TAC will therefore satisfy the objective of a **highest possible economic** yield, only modified slightly by a lower price.

According to the objective of **stability**, we have advocated a strategy based on constant TAC for a number of years. Taking also account that such a level of TAC should be compatible with the objective of **sustainability**, the TAC could not be too high.

Taking account of the three objectives mentioned above, and the uncertainty of when the next strong year class will occur, our advice was that managers should adopt a management strategy of a fixed TAC at about 800 000 - 1 000 000 tonnes per year. A TAC in the lower region of this interval would be more precautionary than a TAC in the upper level.

Four coastal nations decided upon a TAC at approximately 1.1 million tonnes for 1996. As the stock is available for catch in international waters the actual catch may be higher than this.

4. Discussion

ACFM's 1991-statement of its objectives implies that managers must consider non-biological arguments when choosing levels of TAC and management strategies for different stocks. When multiple objectives characterise the fishery policy, it is also the managers job to identify which objective will be most affected by different choice of management strategy, and thereafter work towards a management strategy that accomplishes the given objectives in the best way possible.

Our experience so far indicate that:

1. Multiple objectives cannot be reduced to one objective.

2. Advice on the level of TAC when faced with multiple objective must be based on a quantification of the consequences which that TAC has on the different objectives.

3. For transboundary stocks, bioeconomic analysis leading to advice on the level of TAC to one of the management authorities should be based on stock assessment and prognosis provided by ICES and controlled by ACFM.

The process of communicating the associated risk with management strategies and levels of TAC is in its early stages and presents considerable challenges to both fishery scientists, economists and managers (Caddy and Mahon, 1995).

In Norway, this process of giving advice on the level of TAC has just started. Future work to improve the quality of these analysis include - inter alia - investigations on gear selectivity, multispecies analysis, further work on price-quantity relationships, estimation of processing costs and how harvesting costs depend upon the size of the various fish stocks.

Furthermore, the consequences of uncertainty in various parameters should be given treatment. The managers should stimulate the process of applying risk analysis which shows the potential cost of a management strategy which brings a stock below the MBAL level, as well as focus on analysis showing the consequences which arise when the national share of a TAC vary according to the size of a fish stock.

To meet the challenge by ACFM, such work should be an integral part of each nations fishery administration. If funding of such work is not given priority, it should be considered whether ACFM should return to its former practice of giving firm advice on the level of TAC, irrespective of the biological status of the stocks.

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