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Management Strategies for Northeast Arctic Saithe
- should predation on herring be taken into account?

by

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ABSTRACT

The Norwegian Directorate of Fisheries has suggested a management strategy for Northeast Arctic saithe. Based on the assumption that a maximum sustainable yield is achieved at a fishing mortality below Fpa, a strategy targeting an F about 0.05 below Fpa was proposed and sent for public hearing. A strategy targeting a fishing mortality below Fpa will imply that the expected spawning stock biomass will be above Bpa. Taking into account that saithe is an important predator on commercial valuable prey stocks, some stakeholders were concerned that an increased spawning stock biomass would have its costs in the form of lesser output from fisheries based on the saithe's prey species, especially Norwegian spring-spawning herring. Based on stomach samples of saithe, its consumption of herring was estimated. It was estimated what the herring consumed by saithe could have contributed to in the Norwegian herring fishery. Taking this into account, the long-term economic yield was estimated for different exploitation levels of saithe. The results indicate, viewing the combined economic output from the fisheries on saithe and herring, that there will be no economic loss in applying an F of about 0.05 below Fpa as a long time management target for the saithe fishery.

INTRODUCTION

The stock of Northeast Arctic saithe has increased over the last 15 years, partly due to extensive regulations, increased minimum landing size and possible favourable environmental conditions. The most important regulation measures have been a limitation of the total catch by quotas and an increase of the minimum landing size in 1999.

The International Council for the Exploration of the Sea (ICES) gives advice on annual TAC level based on the precautionary fishing mortality F_{pa}, which for saithe is 0.35. If the annual quotas are set according to this fishing mortality, the risk for stock collapse is low. Beyond that a TAC at this level does not imply any optimisation of neither biological nor economic yield from the stock. Evaluated as a natural resource, a fish stock should be managed to give the highest total economic yield for the society. This implies that one has to take into account a number of factors such as total yield for different stock sizes, prices, costs and the stocks effect on other fish stocks.

During autumn 2004 the Norwegian Directorate of Fisheries suggested a management strategy for the stock of Northeast Arctic saithe, which was sent for public hearing. Figure 1 shows the elements the Directorate of Fisheries meant was important to take into account when choosing a management strategy:

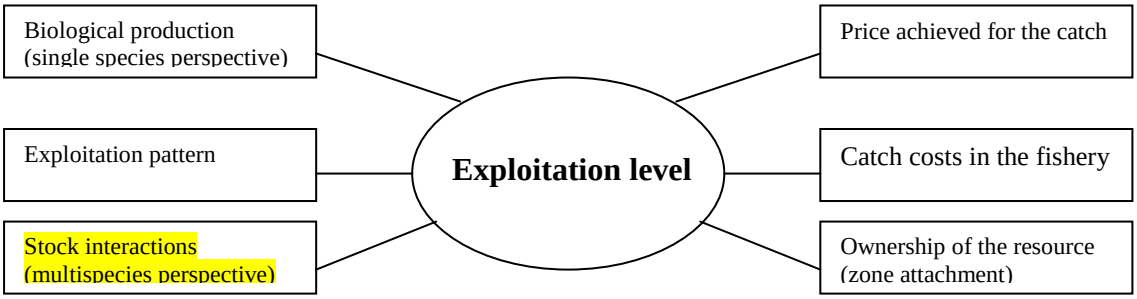


Figure 1 *Some factors the exploitation level of NEA saithe may affect, and therefore should be taken into account when deciding the exploitation level.*

Based on discussions and an over all evaluation of these factors the Directorate of Fisheries suggested an exploitation level somewhat lower than what would be biologically defensible. After a revision of the biological (precautionary approach) reference points for the stock spring 2005 the Directorate of Fisherie's suggestion implied a total fishing mortality of F=0.30. This is somewhat lower than what is regarded biologically safe (F_{pa} = 0.35).

The complete suggestion for a management strategy were as follows:

- At spawning stock levels above the precautionary approach level (B_{pa} = 220 000 tonnes), the TAC is based on the average of the TACs that a fishing mortality of 0.30 for reference ages 4-7 years would imply the next three years.
- The TAC should not be changed by more than +/- 10% from year to year

- If the spawning stock falls below Bpa the procedure for establishing TAC should be based on a fishing mortality that is linearly reduced from 0.30 at B_{pa} to F=0 at SSB equal to zero. At such low SSB-levels there should be no limitation on the year-to-year variation in TAC.

One reason for setting lower fishing mortality than what is biologically safe was to aim at a somewhat larger saithe stock that may produce a higher long time yield. The Directorate of Fisheries did not suggest an even lower fishing mortality due to the saithe's role as a predator in the ecosystem, or what is called "Stock interactions" in Figure 1. A larger saithe stock is expected to consume other fish stocks that may be valuable for Norwegian fishermen.

In the following public hearing the union of the fishing vessel owners focused on these stock interactions. It was stated that by having a large saithe stock, the costs in form of consumption of other fish species are considerable. With the knowledge we have about this to day, they found it unwise to suggest such a low exploitation level as the Directorate of Fisheries did.

Even if the Directorate of Fisheries took into account the predator costs in the suggested management strategy, the costs could of course legitimize a higher exploitation level. To evaluate this it is necessary to quantify the saiths stock's predation and what economic loss this predation implies in form of lost catch in other fisheries. One of the most important prey items for NEA saithe is young age groups of Norwegian spring spawning herring (Mehl, WD 7 2005), and in the present work we will estimate the costs of this predation. Such predator costs will also depend on how one manage/exploits the herring, but here we will apply the management strategy for Norwegian spring spawning herring that the coastal states adopted in 2001. This implies that herring consumed by saithe alternatively could have materialized as catch through the adopted management strategy, of which Norway would have received a fixed amount.

First the saithe stock's annual consumption of different age groups of herring is estimated. Then it is projected what the consumed herring could have produced in form of yield in the herring fishery if it not had been eaten by saithe. The costs of the saithe's consumption are estimated as what economic yield this herring could have given Norwegian herring fishers. Finally it is evaluated if these costs imply that the suggested management strategy should be changed.

There are large uncertainties connected to all the factors that enter the estimations. We do, however, carry out the estimations to get an indication of what the costs of the saithe's predation on herring could imply and how it could affect the choice of management strategy for saithe. We think that the estimations serve a purpose, but the absolute values of the estimates are very uncertain and should be treated thereafter.

MATERIAL AND METHODS

The saithe stock's annual consumption of herring

Since 1985 a Norwegian acoustic survey specially designed for saithe has been conducted annually in October-November (Nedreaas 1997). The survey covers the near coastal banks from the Varangerfjord close to the Russian border and southwards to 62° N. The whole area has been covered since 1992, and the major parts since 1988. The survey area is divided into four sub-areas. Autumn 1998 a three-year stomach-sampling program for Northeast Arctic saithe was initiated (Mehl, WD 7 2005).

Trawl hauls, both with bottom and pelagic trawl, are normally based on acoustic information. The purpose of the trawl hauls is to provide information about the species composition in the acoustic registrations and to do biological sampling of the target species. On every station with catch of saithe, 5 fish in each 5 cm length group is sampled for length, weight, age (otolits), sex, maturity and stomach content. The whole stomachs are frozen individually, and later analyzed in the laboratory at IMR. The methods applied are the same as in the North Sea stomach sampling programs (Anon. 1981, ICES 1991) and the joint Norwegian-Russian program in the Barents Sea (Mehl and Yaragina 1991).

Based on the average stomach content by predator age group and sub-area, the acoustic abundance estimate of saithe and average weight at age by sub-area and average temperature in 100 m depth by sub-area (Berg, Korsbrekke, Mehl and Nybakk, 2004), the acoustically measured saithe stock's consumption of main prey items in quarter 4 was estimated (Mehl, WD 7 2005). The gastric evacuation model applied for cod in the Barents Sea is also used for saithe, with the same prey specific constants (Bogstad and Mehl 1997, Bogstad, Haug and Mehl 2000).

It is further assumed that the diet of the saithe not covered by the survey in autumn is the same as for the part covered. For adult saithe not properly covered by the survey the predation on mature herring is perhaps larger than the stomach samples indicate. The "survey stock" of saithe in quarter 4 was for each age group scaled to the "XSA-stock" per 01.01 next year of the corresponding year class (next age group). Then the total consumption in tonnes of different length groups of herring in quarter 4 was calculated.

Applying the average weight of each length group of herring, the numbers of herring consumed was calculated. Finally the numbers consumed of different length groups of herring was converted to numbers consumed of different age groups by use of ALKs.

The distributions of saithe catches by quarter show a quite similar pattern throughout the year. It was therefore assumed that the different age groups of saithe on average have a similar distribution by sub area as in quarter 4. It was further assumed that the availability of immature 1-3 group herring is the same throughout the year and that the availability of 0-group herring is the same in quarter 3 as in quarter 4. In order to scale the quarter 4 consumption estimates to the whole year, the estimates of 1-3

group and 0-group herring were multiplied by 4 and 2, respectively. Table 1 shows the total annual consumption of herring applied in the further analyses.

Tabell 1. Northeast Arctic saithe's consumption of different age groups of herring (in millions) north of 62°N in 1998-2004.

	Age group of herring				
	0-group	1-group	2-group	3-group	Sum
1998	11272	5404	140	35	16851
1999	12417	6001	535	578	19531
2000	343	1194	1027	1087	3651
2001	0	760	906	204	1871
2002	704	580	778	0	2062
2003	13091	183	0	877	14151
2004	8301	2840	0	0	11141

The costs of the saithe's feeding on herring

The saithe mainly preys upon 0- and 1-group herring, and to some extent on 2 and 3 year olds. In order to estimate the costs of this predation we have to estimate the catch value of this herring if it had been allowed to grow and harvested in the herring fishery.

If the number of 0, 1, 2 or 3 group herring eaten by saithe is nominated N_a , this number would, if the herring had not been eaten by saithe, been reduced due to other natural mortality and fishery according to the equation:

$$N_{y+1,a+1} = N_{y,a} e^{-(M_y + F_y)} \quad (1)$$

where M_y and F_y are annual natural and fishing mortality, respectively. After the herring has recruited to the fishery, the number caught each (C) year is given by the equation:

$$C_{y,a} = \frac{F_{y,a} N_{y,a} (1 - e^{-(F_{y,a} + M_{y,a})})}{F_{y,a} + M_{y,a}} * N_{y,a} \quad (2)$$

If we sum up all the individuals that, if they not had been eaten by saithe, had been fished during their life span, and multiply by the average weight at the time of fishing ($W_{y,a}$), we get the total weight of herring that could have been available for the fishery.

$$Y = \sum_{y,a} C_{y,a} * W_{y,a} \quad (3)$$

To find the gross catch value, the catch is multiplied by a price, and to find the net catch value one substract variable catch costs. Since the catch accumulates over several years, and we want to estimate the value of all catch now, we find this value by discounting future catch incomes and catch costs:

$$NPV = \sum_{y} Y_y * (P - K) * (1 + r)^{-y} \quad (4)$$

where P and K are unit costs in the fishery, and r are the interest level in the society.

To do the estimates we have to know the biological and economic factors in equations (1) to (4).

Economic yield in the Norwegian fishery for Norwegian spring spawning herring

Norwegian fishermen exploit two herring stocks, North Sea herring and Norwegian spring spawning herring. The price achieved for Norwegian spring spawning herring depends on the total catch of the two stocks. The connection between real price of Norwegian spring spawning herring and the total catch of the two stocks is presented in Figure 2.

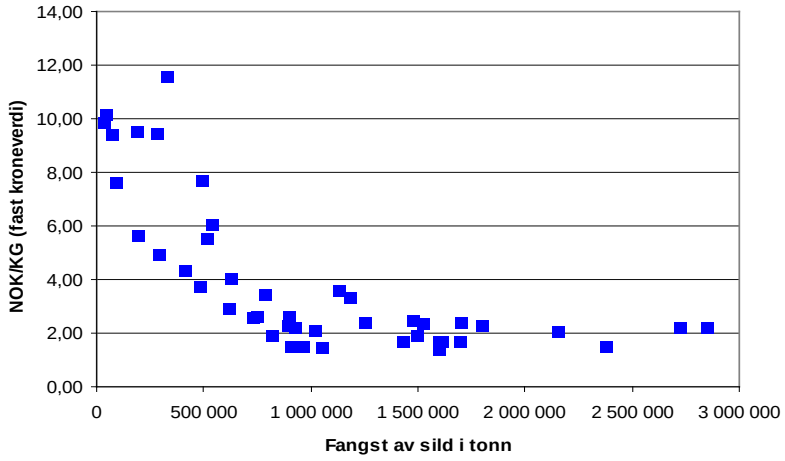


Figure 2 *Real price (NOK/kg) achieved for herring by Norwegian fishermen in relation to the total catch of North Sea herring and Norwegian spring spawning herring in 1960 – 2003.*

The figure shows that average price of herring has varied considerably, from less than 2 to almost 12 NOK per kg. The price seems to be little dependent on the total catch at catch levels above about 800,000 tonnes. When the catch falls below this level, the price increases, but so do the variation. Therefore the costs of the saithe's consumption of herring will also vary according to the size of the herring stocks and the total catch of herring. If the stocks and TACs are at a low level, one may expect a higher price for the herring than for high TACs. If other factors are constant, this implies that the predator costs may be higher when the herring stock is low than when it is high.

The costs in the fishery can be devided into fixed and variable costs. The variable costs will depend on the vessel time used in the fishery, while the fixed costs will run independent of the activity in a single fishery. When evaluating the prifitability in one of several fisheries that a vessel participates in, one may evaluate the variable costs in this specific fishery. The connection between the activity in one fishery and how big share of the fixed costs that may be attributed this fishery, is more a matter of judgement. The fixed costs will also depend on how big the overcapacity is in each fleet group.

To get a picture of the prifitability in the herring fishery we will just look at the operating profit, or income minus variable costs. The fixed costs are not included in the analyses. The variable costs per ton catch in the herring fishery are estimated by Sandberg (2005). It was found that the costs were influenced by the size of the vessel quota and for two vessel groups also by the size of the herring stock. Our aim is to estimate the costs of the saithe stock's predation, and we need to know how profitable the herring fishery is. Neither price nor variable costs in the herring fishery are constant factors. They are expected to vary according to catch level and stock size. If the herring stock size is low, the variable unit costs will be higher than when the stock size is high, and if the vessel quotas are low the variable costs will increase.

We will run two scenarios (Table 3).

Table 2 *Firsthand value (price), variable catch costs and contribution margin per kg in two scenarios for prifitability in the fishery for Norwegian spring spawning herring.*

Scenario 1		**Scenario 2**	
Firsthand value per kg:	6 NOK	Firsthand value per kg:	2 NOK
Variable catch costs per kg:	2 NOK	Variable catch costs per kg:	1 NOK
Contribution margin per kg:	4 NOK	Contribution margin per kg:	1 NOK

Economic yield in the Norwegian fishery for Northeast Arctic saithe

Norwegian fishermen exploit two saithe stocks, North Sea saithe and Northeast Arctic saithe. We have compared the price Norwegian fishermen achieve for saithe to the total catch from the two stocks. Real price is found by adjusting by the consume price index.

Figure 3 shows that the real price has varied between 3 and 6 NOK per kg in the period 1967-2004. The figure also shows that there is little connection between total catch each year and the price achieved. For our purpose this implies that one may apply a constant price independent of the total catch the different management strategies generates. In addition one may estimate whether or not choice of management strategy is sensitive to high or low price.

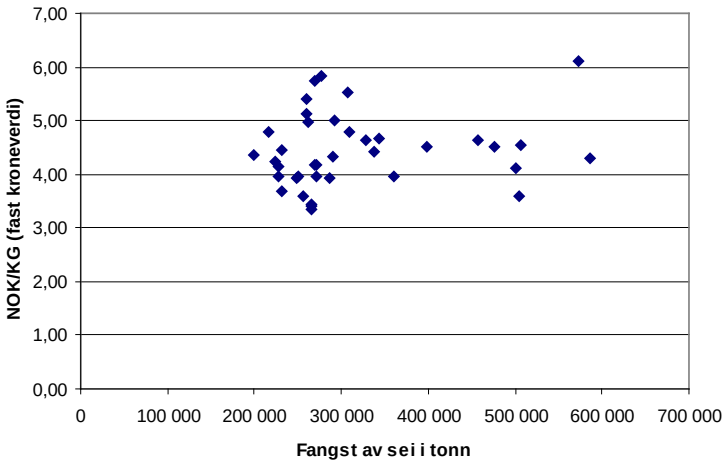


Figure 3 *Real price (2004-value) for saithe achieved by Norwegian fishermen in relation to the the total catch of* North Sea saithe and Northeast Arctic saithe in *1967 – 2004.*

Also for saithe we will just look at the operating profit, or income minus variable costs. When estimating optimal exploitation level in the saithe fishery, we will run two scenarios (Table 3).

Tabell 3 *Firsthand value (price), variable catch costs and contribution margin per kg in two scenarios for prifitability in the fishery for Northeast Arctic saithe.*

Scenario 1		**Scenario 2**	
Firsthand value per kg:	6 NOK	Firsthand value per kg:	4 NOK
Variable catch costs per kg:	4 NOK	Variable catch costs per kg:	3 NOK
Contribution margin per kg:	2 NOK	Contribution margin per kg:	1 NOK

RESULTS

Lost catch of herring due to predation by saithe

Figure 4 shows the annual consumption of herring in the period 1998 – 2004. There are large variations from year to year. The number of 0-group consumed is in three years between 11 and 13 billions, while in the three other years the number is less than 1 billion. In relation to the recruitment level estimated by ICES the consumption makes up between 0 and 7.7% of the annual recruitment. The number of 1-group consumed also varies considerable, while the consumption of 2 and 3-group is somewhat more stable from year to year.

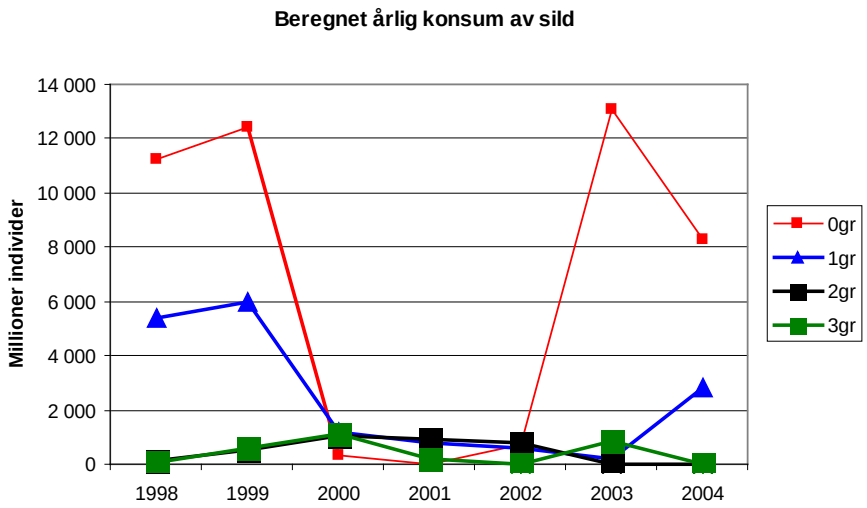


Figure 4 *Estimated annual consumption of herring (in billions) in 1998 - 2004*

If this herring had not been consumed by saithe and not by predators competing with saithe, it would have grown and materialized in the herring fishery. Both growth and other natural mortality will vary, but in relation to the annual recruitment, the saithe's consumption is relatively low. We have therefore applied the same values for weight at age and other natural mortality at age as applied by ICES (ICES, 2003). We have further applied the same exploitation level (F = 0.125) and exploitation pattern as in the ordinary herring fishery.

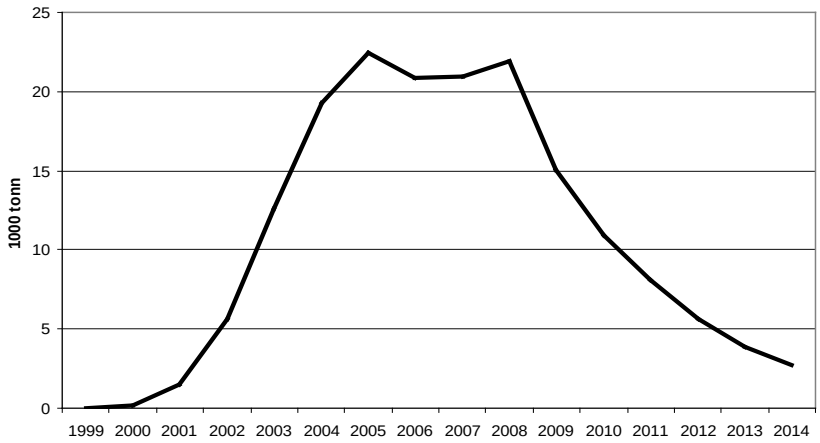


Figure 7 *Estimated lost catch in the herring fishery in the period 1999 – 2014 due to saithe's predation on herring in 1998. The lost catch reflects how the herring otherwise could have been caught in the fishery through it's lifespan.*

Figure 5 shows estimated lost catch in the herring fishery due to the predation by saithe in 1998. The figure is based on the numbers in Table 1/Figure 4 which show the saithe's consumption of age groups 0, 1, 2 and 3. For 1998 the saithe's consumption of these age groups was estimated to 16,851 million individuals. If these individuals had not been eaten they would collectively had a development determined by individual growth and natural mortality. In order to find what theses individuals would have contributed to the herring fishery we apply the management strategy and

present exploitation pattern for herring. The resulting estimated lost catch is presented in Figure 5.

The sum of the ”lost catch” in the herring fishery shown in Figure 5 is about 160 000 tonnes. This is estimated loss due to predation by saithe in 1998. If we make similar calculations for the other years with feeding data (1999-2004), lost catch due to saithe predation may be estimated for each year. Figure 6 presents the total losses.

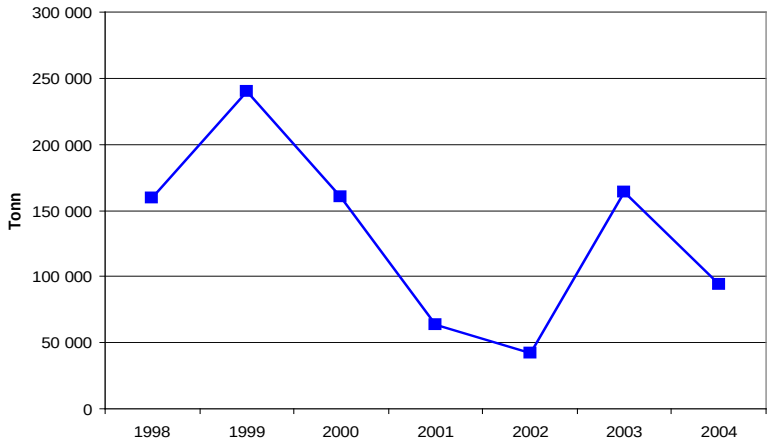


Figure 6 *Estimated lost catch in the herring fishery due to predation by saithe in 1998 – 2004.*

The figure shows large variations in lost catch, highest in 1999 (240 000 tonnes) and lowest in 2002 (42 000 tonnes). The highest loss is almost six times higher than the lowest.

The economic loss due to saithe predation

The economic loss due to saithe predation in one year runs over several years. If we use the predation in 1998 on age groups 0, 1, 2 og 3, and take into account that the herring otherwise could have lived up to 16 years, we may estimate the net value lost in the herring fishery in 1999 – 2014.

Figure 7 presents the estimated economic loss for Norwegian fishermen through 16 years due to the saithe’s predation on young herring in 1998. The loss increases when the herring recruits to the fishery at age 4-5.

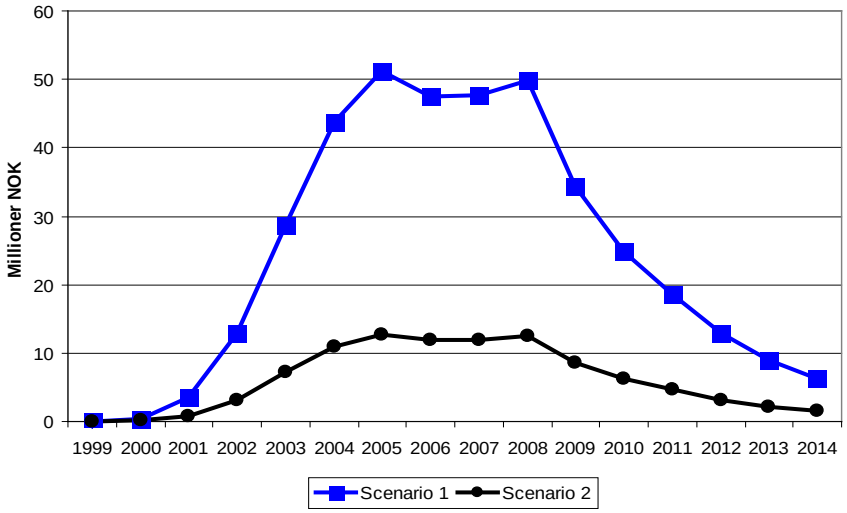


Figure 7 *Estimated running (nominal) economic loss in the herring fishery due to the saith'e predation of young herrring in 1998. In Scenario 1 the herring price is 6 NOK/kg and variable catch costs are 2 NOK/kg. . In Scenario 2 the herring price is 2 NOK/kg and variable catch costs are 1 NOK/kg. Norwegian share of the catches is set to 57%.*

Future economic amounts have to be adjusted by a factor to express the present value. Such a factor is often called discount factor, and is based on the society's price for delaying incomes and costs. Today a factor of 4% is often used. If net catch value of herring in 1 year is 1 million NOK, the present value is 1 mill NOK /1.04 = 0.96 mill NOK.

If one adjusts the future losses in Figure 7 with a discount factor and summarizes all years one gets the present value of the lost catch that the saithe's consumption of young herring in 1998 caused. This is done for each of the years 1998 – 2004, and shown in Figure 8 for the two scenarios. The price of herring will also vary with individual size, but since we apply a constant exploitation pattern, prices based on individually size will not contribute anything to the analyses.

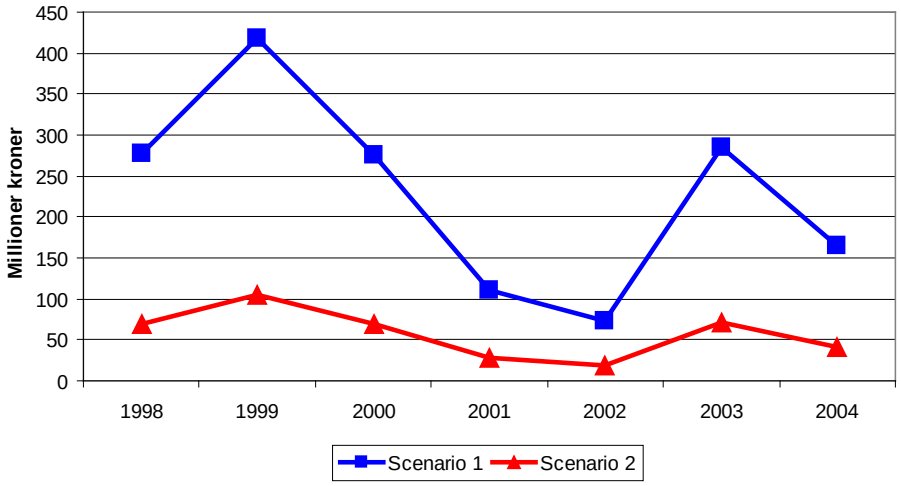


Figure 8 *Estimated Norwegian economic loss in the fishery for Norwegian spring spawning herring due predation by saithe in 1998 – 2004. In Scenario 1 the herring price is 6 NOK/kg and variable catch costs are 2 NOK/kg. In Scenario 2 the herring price is 2 NOK/kg and variable catch costs are 1 NOK/kg. Norwegian share of the catches is set to 57%.*

The economic losses will be distributed over the years the herring could have been caught. With a herring price of 6 NOK/kg and variable costs of 2 NOK/kg the total losses vary between 75 and 420 million NOK in the period 1998-2004.

Does the predation on herring affect the management strategy of saithe?

The choice of management strategy determines the annual TAC, and thereby the stock size one aims for. In a singe species perspective the choice of management strategy will be determined by the long time economic yield the different strategies give. Predator costs become relevant if there is any relation between the size of the predator stock and the predation pressure.

If the relation is mutual, the catch rules for both stocks may depend on each other (Flaaten, 1989). If the prey stock has high price and low catch costs, while the predator has low price and high catch costs, it may in some occasions be profitable for the society to reduce the predator stock to such an extent that the prey stock increases. This may become even more relevant if the unit costs in the fishery for the prey stock is reduced with increasing stock size.

A central question is therefore whether or not there is any relation between the stock size of saithe and the predation on herring. The stomach samples that are the basis for the consumption estimates are, however, limited in numbers and only cover the period 1998 – 2004. Figure 9 shows the total herring consumption in relation to the size of the saithe stock.

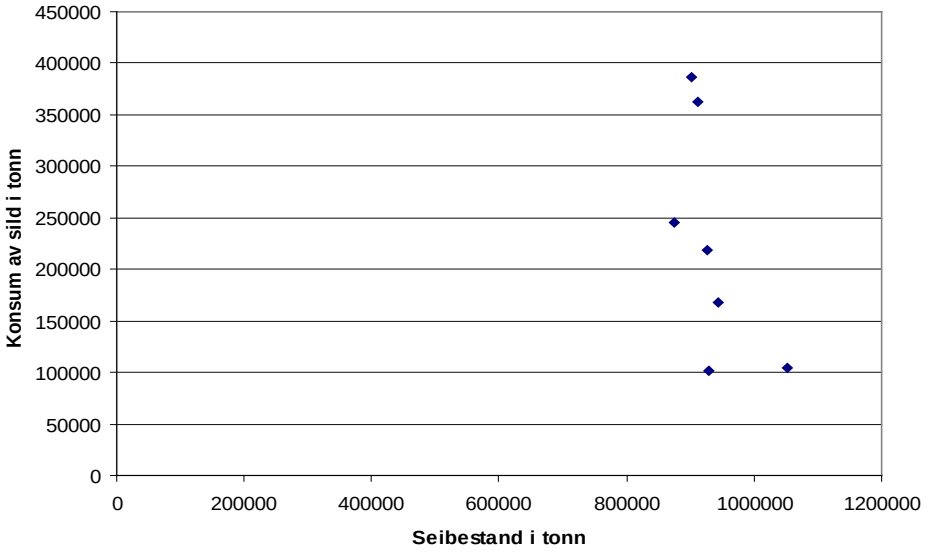


Figure 9 Estimated consumption of herring in relation to saithe stock size 1998-2004

The figure shows that the saithe stock has been at a relatively high level in the period with stomach sampling. The consumption of herring has varied a lot even if the saithe stock not has varied much. This indicates that also other factors than the size of the saithe stock influences the consumption of herring, e.g. the year class strength of

herring. We are therefore not able to quantitatively estimate how the amount consumed of herring depends on the saithe stock size.

It is, however, reasonable to assume that if the saithe stock is reduced to a considerable lower level, the predation on herring also will be reduced. In lack of data we will in the further analyses assume a proportional relationship between predator stock size and consumption level.

Optimal exploitation level for saithe – a calculation example

In the calculation example we present below we apply the average predator costs for the years 1998 – 2004, and assume a proportional relationship between saithe stock size and consumption of herring.

We further apply ICES data on how ”yield per recruit” and ”spawning stock biomass per recruit” depend on fishing mortality (ICES 2005). By multiplying with the annual recruitment one may estimate the biological long time yield and spawning stock biomass of saithe.

The recruitment of Northeast Arctic saithe varies from year to year (ICES 2005), but the variations are relatively independent of spawning stock size (Figure 10).

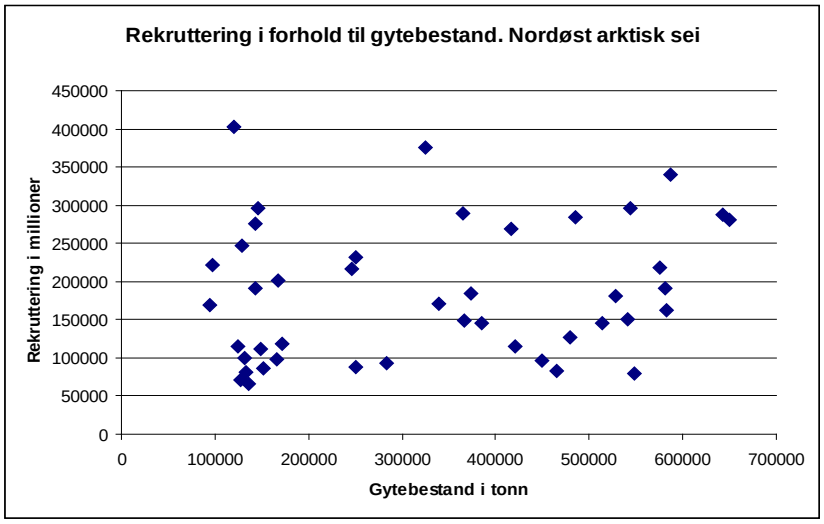


Figure 10 *Recruitment of Northeast Arctic saithe in relation to Spawning stock biomass*

It is estimated that at SSB above the precautionary approach level (220 000 tonnes), the recruitment is on average 173 million individuals (3 year olds). By applying this recruitment level we can estimate how long time yield and spawning stock biomass depends on fishing mortality (Figure 11).

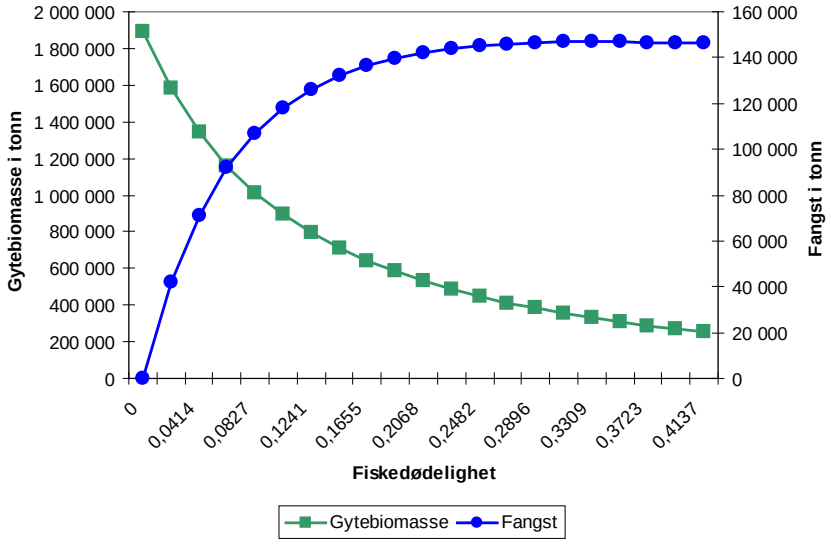


Figure 11 Estimated long time yield and spawning stock size for different levels of fishing mortality

The figure shows that the expected long time yield reaches a top at about F = 0.30 (Fmax = 0.33 at present), while the SSB is reduced considerably relative to a "not exploited" stock. For the choice of management strategy this implies;

- The biological yield does not increase much for fishing mortalities above 0.30.
- At F = 0.30 the spawning stock biomass of saithe, and thereby the predation on herring, are considerably reduced relative to what it would have been for an unexploited saithe stock. It is limited how much the predation can be further reduced by increasing the fishing mortality.

By including the prices and costs of saithe and herring catches, and assuming a proportional relationship between saithe stock size and consumption of herring, we may then includes economy to the curves in Figure 11.

Optimal exploitation level in relation to first hand value

In the first example we will look at how expected spawning stock, gross catch value in the saithe fishery, predator costs and total catch value (gross catch value in the saithe fishery minus predator costs) changes with increasing fishing mortality. 3 figures are presented, in the first we assume the price of both saithe and herring to be high (6 NOK/kg for both). In the second we assume the price of saithe to be high (6 NOK/kg), while the price of herring is low (2 NOK/kg). In the last we assume the price of saithe to be low (4 NOK/kg), while the price of herring is high (6 NOK/kg).

Figure 12 shows how the spawning stock of saithe and the economic yield varies in relation to fishing mortality. At a fishing mortality of 0.35 (PA level), the long time spawning stock biomass is about 300 000 tonnes, which is somewhat above the PA level of 220 000 tonnes.

Det total economic yield following the management strategy for saithe is the sum of yield in the saithe fishery and the predator costs. By increasing the fishing mortality the total yield increases more than in the saithe fishery alone. The reason for this is

that through increased exploitation level, income in the saithe fishery is increased and the predator costs are reduced.

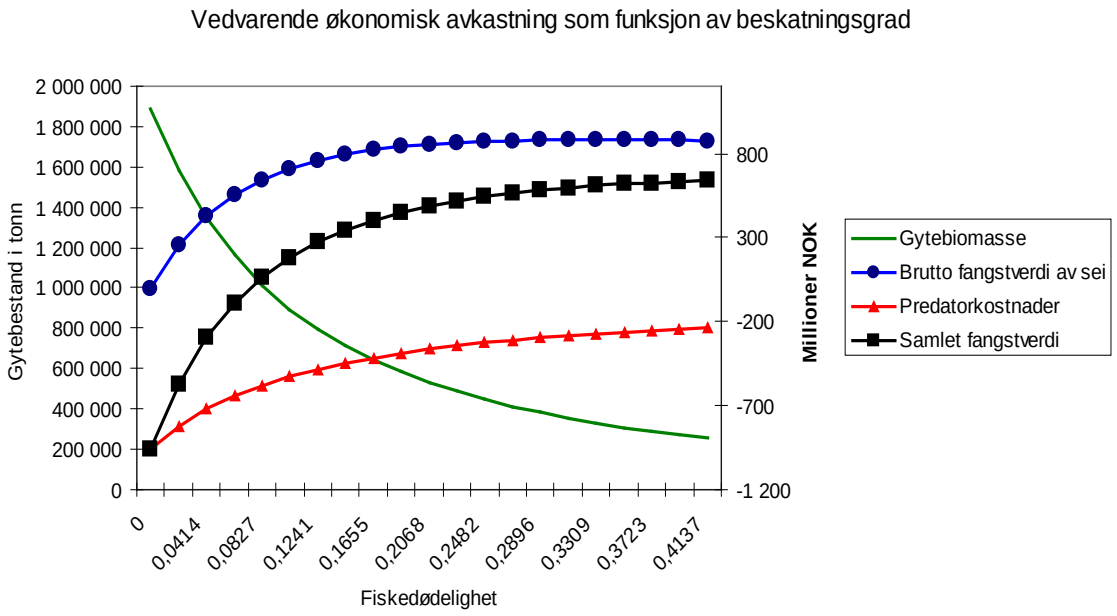
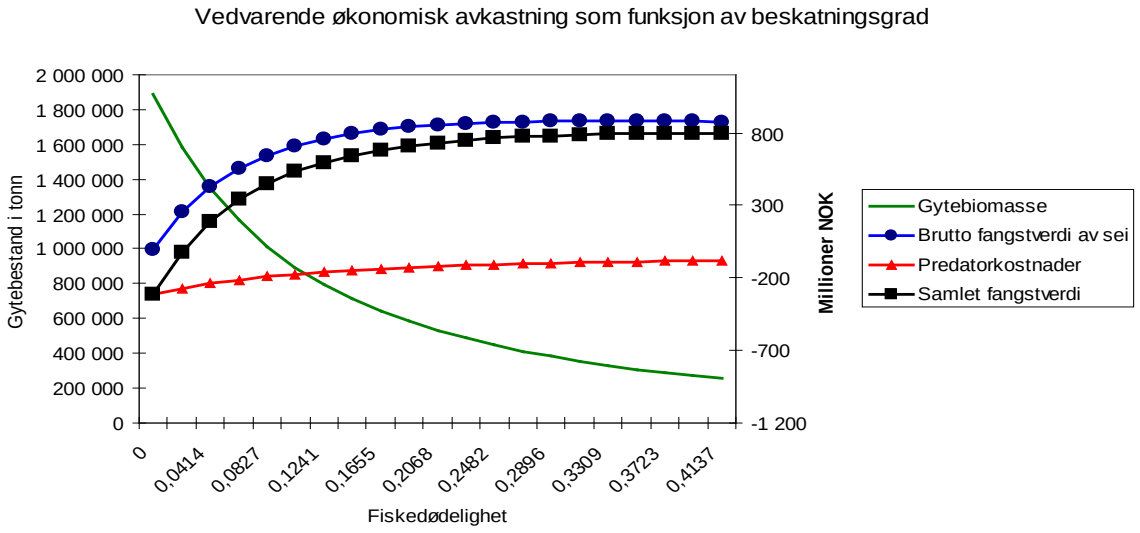


Figure 12 *Spawning stock biomass, gross first hand value of saithe, predator costs and total catch value in relation to fishing mortality. First hand value of saithe is 6 NOK/kg., first hand value of herring is 6 NOK/kg.*

With a first hand price for saithe of 6 NOK/kg, gross catch value increases with increasing exploitation level up to F=0.31. The long time yield of 147 000 tonnes has a value of 880 million NOK. Predator costs are reduced with increasing fishing mortality because the stock size of saithe is reduced. The predator costs imply that the total catch value increases with increasing fishing mortality for the presented intervals of F. The increase is, however, relatively small for fishing mortalities above 0.31.



Figuer 13 *Spawning stock biomass, gross first hand value of saithe, predator costs and total catch value in relation to fishing mortality. First hand value of saithe is 6 NOK/kg., first hand value of herring is 2 NOK/kg.*

Figure 13 presents corresponding indicators as in Figure 12, but the price of herring in the latter is reduced from 6 NOK/kg to 2 NOK/kg. This reduces the predator costs significantly, and total catch value is close to the gross catch value in the saithe fishery. Also in this case total catch value increases with increasing fishing mortality for the presented intervals of F, but the increase is marginal above F=0.31.

In Figure 14 the price of saithe is 4 NOK/kg and the price of herring 6 NOK/kg. This reduces the gross catch value in the saithe fishery, while the predator costs are high.

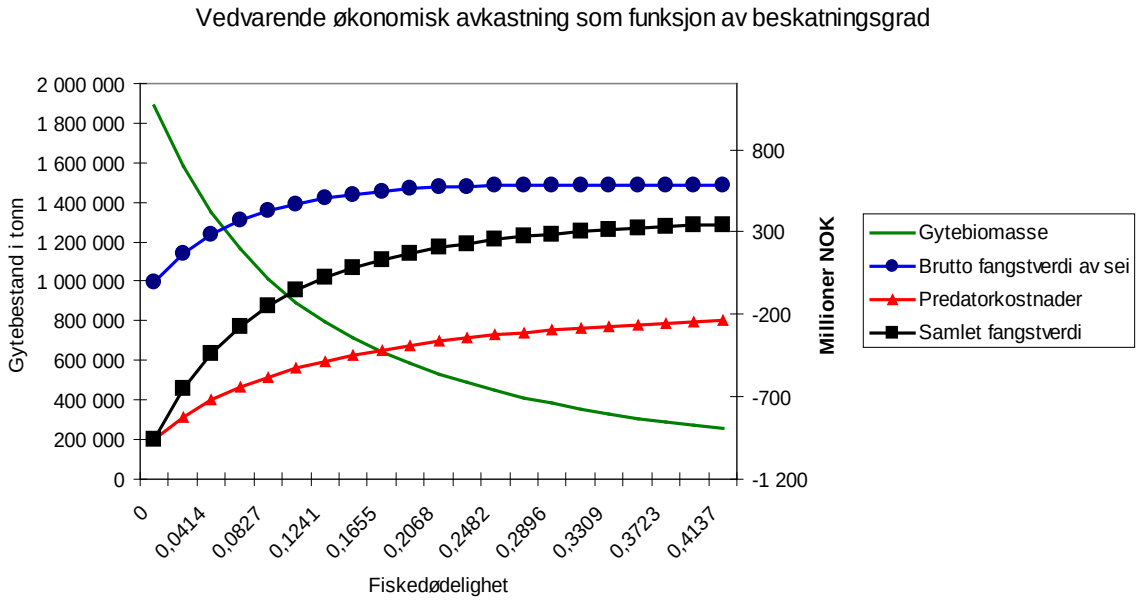


Figure 14 *Spawning stock biomass, gross first hand value of saithe, predator costs and total catch value in relation to fishing mortality. First hand value of saithe is 4 NOK/kg, first hand value of herring is 6 NOK/kg.*

In this scenario the predator costs are more important for the choice of optimal exploitation level then in the two former scenarios. There is a considerable increase in total catch value also above F = 0.31.

Optimal exploitation level in relation to contribution margin

If optimal exploitation level is evaluated in regard to long time contribution margin, one should take account of catch costs. In Figure 15 we have assumed a price of saithe of 4 NOK/kg and catch costs of 2 NOK/kg, while the price of herring is set to 2 NOK/kg and catch costs to 1 NOK/kg. This results in a contribution margin of 2 NOK/kg for saithe and 1 NOK/kg for herring.

Also when operating costs are accounted for the economic yield is highest for the highest fishing mortality in the interval we consider, but the increase is marginal for Fs above 0.27.

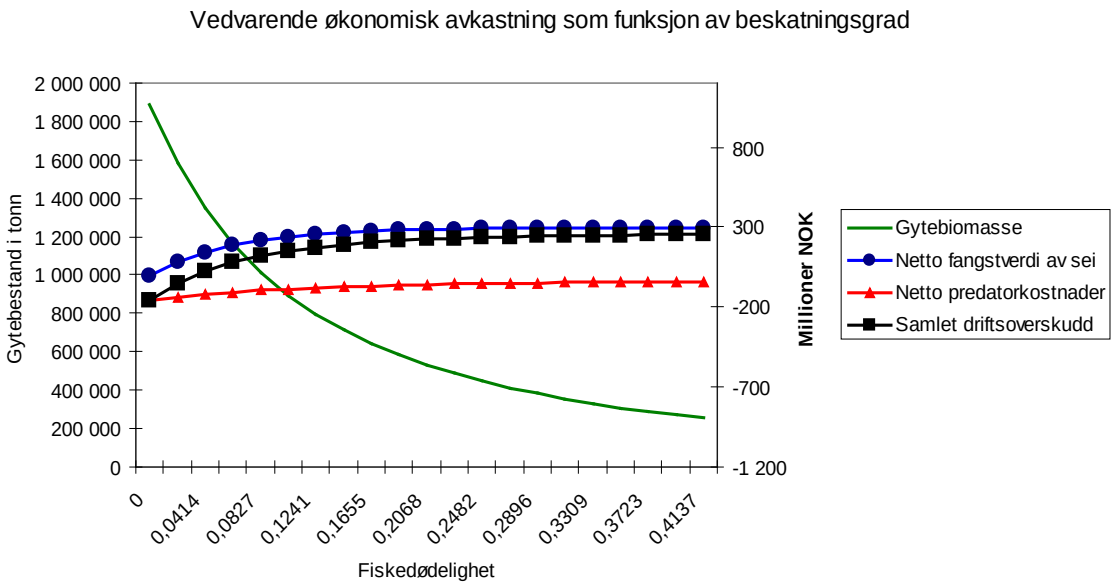


Figure 15 *Spawning stock biomass, gross first hand value of saithe, predator costs and contribution margine in relation to fishing mortality. Contribution margine of saithe is 2 NOK/kg., contribution margine of herring is 1 NOK/kg.*

If the economic yield in the saithe fishery is high while it is low in the herring fishery, the predator costs are not very important when chosing optimal management strategy (Figure 13). In the opposite situation, low economic yield in the saithe fishery and high in the herring fishery, the predator costs are important when chosing optimal management strategy (Figure 14). Still the economic yields in both scenarios are highest for the highest fishing mortality of saithe, at least within the precautionary approach level. This result is to a large extent given by the relatively flat shape of the yield curve for saithe over a large interval of fishing mortalities (Figure 11). Better knowledge about what affects recruitment and individual growth may improve the precision of theses estimates.

CONCLUSIONS

Based on the estimates presented in Figures 12-15 the following is concluded:

- The saithe's predation on herring reduces the economic yield in the herring fishery
- When the price of saithe increases relative to the price of herring, the costs of predation are of less importance for the total economic yield in the saithe and herring fisheries.
- If the predation on herring is reduced proportionally with a reduction in saithe stock size, the total economic yield will increase with increasing fishing mortality in the saithe fishery in the whole interval we have considered (0-0.41), but the increase is marginal for Fs above 0.30.

Depending on the assumptions made, these analyses indicate that the exploitation level of Northeast Arctic saithe should be in the interval 0.30 – 0.35. The total economic yield in the saithe and herring fisheries will, however, not increase significantly if the fishing mortality of saithe is increased from 0.30 to 0.35, while the expected spawning stock biomass of saithe is somewhat reduced. Considering the uncertainties in all data and stock assessment and the need for stability in quotas from year to year, one should consider carefully if such a marginal increase in expected economic yield is preferred.

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