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On Management of a Varying Shrimp Stock in the Davis Strait

by

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Abstract.

The optimal use of the shrimp (*Pandalus borealis*) resources in Greenland can be evaluated based on yield per recruit considerations. However since shrimp prices are very dependent on quality and size, the biological optimal level of exploitation may be quite different from an optimal level based on economic revenue.

The present paper presents a bioeconomic analysis determining the resource rent and optimal effort of the shrimp fishery of the Davis Strait.

The model simulates the expected yield and value applying a constant fishery on a varying shrimp stock.

Further, application of selective gears as a measurement to restrict overexploitation is discussed in both biological and economic terms.

Introduction

Fishery for shrimp (*Pandalus borealis*) on the offshore fishing grounds in the Davis Strait[1], Figure 1, has, since 1976, been assessed, first by the Scientific Councils of the International Commission for the Northwest Atlantic Fisheries and, after 1979, by the Northwest Atlantic Fisheries Organization (ICNAF and NAFO respectively). The total allowable catch (TAC) submitted annually is shared between Canada and Greenland, cf. Table 1.

As also shown in Table 1, the fishing fleet participating in the shrimp fishery of the Davis Strait is multinational. The major catches are taken by the vessels from Canada and Greenland but also vessels from Denmark, Faroe Islands, and France participate in the fishery.

Aging shrimps is an unsolved problem and, although much effort has been put into this work, aging difficulties has so far hindered application of analytical assessment models such as virtual population analysis (VPA) (Horsted, 1990). As a

1.i.e. the fishing grounds of NAFO subarea 0 and 1 more than 3 n.m. west of the Greenland archipelago.

consequence, the annual TACs have been based on logbook information on catches of the commercial fisheries and a survey series which began only in 1988. Recommended TACs are therefore reflections of trends in catch rates and yields of the fishery, rather than dynamic forecasts relating yield and effort.

In 1992, NAFO extended the assessment analysis also to include an index of catch per unit effort (CPUE) of large shrimp (> 8.5 gram). This index was based on 5 years commercial catches from 22 Greenlandic factory trawlers and was standardized with regard to area, month, year, and vessel (Carlsson and Lassen, 1991). The data, Figure 2, indicated a declining CPUE in the commercial fishery after 1987, but with the CPUE in 1990-1992 stabilized at the 1989 level. This decline is assumed to reflect an actual reduction in abundance of large shrimp in the stock, as discarding of these large shrimps is considered insignificant. The index is therefore not influenced by any changes in discard practice during the period.

In 1992, also length frequency data from survey samples were included in the assessment (Anon, 1992). From this data it became evident, that the 1985 year class constituted almost the entire catchable stock of shrimp in the Davis Strait, and that apart from the 1989 year class younger year classes are insignificant to the stock. On that basis NAFO recommended an immediate precautionary 20% reduction in the shrimp quota to secure future recruitment (Anon, 1992).

However, neither Greenland nor Canada implemented any restrictions on the shrimp fishery in 1992 which, surprisingly, turned out to be the best year ever recorded. Given the success of the 1992 fishery, the continous stability in the catch rates and in the biomass estimates, and an unexpected appearance of an apparently strong 1986 year class in the 1992 survey, the Scientific Council of NAFO, at its June meeting in 1993 (Anon, 1993), reconsidered this advice, and now stated that the TAC in both 1993 and 1994 should be kept at 50.000 tonnes.

The Greenland Fishery.

Three types of vessels paticipate in the Greenland offshore fishery. A major part of the fishing fleet is constituted by factory trawlers with processing plants on board. As a part of the licence conditions one subgroup of these factory trawlers is allowed to process 75% to 90% of the reported catch on board, whereas a second group is allowed to process 30% to 50% of the reported catch only. For both groups the remaining catch of shrimp larger than 2 grammes must be landed to the factories on shore. The third group of vessels participating in the offshore fishery is formed by minor boats not licensed to process. These boats are also allowed to fish on the inshore fishing grounds but the entire catch of this part of the fishing fleet must be landed to the factories on shore.

Three main products of shrimp are produced. At sea, frozen, unpeeled shrimps, which can be either raw or cooked, are produced. At the processing industry on shore, the shrimps are cooked and peeled. Beside the type of product, the sales prices also depend on the size of the shrimp. The commercial fleet operates commonly with 5 size categories: count[2] 50-70, count 70-90, count 90-120, count 120-150, and count 150+.

Christensen and Vestergaard (1993) estimated the resource rent of the shrimp fishery in the Davis Strait in 1991 at DKK 200-600 million, depending on the concept of costs, and demonstrated that the long term resource rent would increase by *reduction the effort*, c.f. Figure 3. The bioeconomic calculations of their study include a dynamic pool model of a population under constant annual recruitment. The size distribution of the catch estimated by their model was fitted to the size distribution of the commercial fishery in 1991 by tuning the selectivity parameters of the applied catch equation.

An alternative approach to achieve the observed size distribution of the 1991 catch would be to apply a constant selectivity parameter and multiply the number in each age group by appropriate figures minimizing

$$\min \sum_{l} (Y_l \,/\, Y - y_l \,/\, y)^2 \qquad (1)$$

where

Y is total estimated catch,

Y_l is total estimated catch of count group l,

y is total commercial catch,

y_l is the commercial catch of count l,

By this approach, also the relative age class composition of the population in 1991 is estimated. Extrapolating this size distribution, shown in Table 2, to 1992, the model predicts total landings at about 43,000 tonnes whereas the reported landings totaled more than 60,000 tonnes.

Apparently, the predictive value of catch and survey data is still low, with regard to the catches of future fisheries, and insufficient to fullfill the data requirements of standard analytical fishery models.

2.Count is defined as number of shrimps per kilogramme.

In this context, the present study suggests an alternative approach to simulate the variability in yield and value to be expected applying a constant fishery on a varying stock.

The Model

The objective function applied in the present study to calculate the resource rent, π, of the fishery can be expressed by the following equation:

$$\pi = TR(p_1, H_1) - TC(G_1, H_1, E) \qquad (2)$$

where

TR is total revenue of the fishery,

TC is total cost of the fishery,

E is total effort,

p_1 is average sales price per kilogramme liveweight of count 1,

H_1 is reported catch of count 1,

G_1 is gross revenue of reported catch of count 1.

The harvest function of the bioeconomic model (2) is specified by

$$H_1(E) = (Y_1(E) - D_1) \qquad (3)$$

where

Y_1 is the total catch of count 1

D_1 is the discard of count 1.

The catch at age, Y_a, and the total catch, Y, is calculated by the catch equation:

$$Y = \sum_a R_a \cdot (1 - \exp(-(Z_a))) \cdot F_a \cdot S_a / (Z_a) \cdot w_a \qquad (4)$$

where

R_a is recruitment at age a,

F_a is fishing mortality rate at age a,

Z_a is total mortality at age a,

w_a is weight at age a,

S_a is gear selection factor at age a,

M is natural mortality rate.

The total mortality at age, Z_a, is calculated by equation (5):

$$Z_a = S_a \cdot F_a + M \qquad (5)$$

where the age dependent gear selectivity parameter, S_a, is introduced by the logistic selection curve, i.e.

$$S_a = 1 / (1+ \exp(T1 - T2 \cdot a)) \tag{6}$$

where

$T1 = t_{50} \cdot \ln(3)/(t_{75} - t_{50})$

$T2 = \ln(3)/(t_{75} - t_{50})$

and

$t_{50} = t_0 - (1/k) \ln(1 - L_{50}/L_\infty)$

$t_{75} = t_0 - (1/k) \ln(1 - L_{75}/L_\infty)$

where a is age and t_0, k and L_∞ are the von Bertalanffy growth parameters (Hoydal, Rørvik and Sparre, 1982).

Variability is introduced into the model by generating the stock size by age, R_a, using random numbers. R_a is generated as a random variate from a distribution $F(\mu,...)$. In the simulations presented below this distribution is realized as a rectangular distribution.

The mean of the distribution *decreases with age*

$$\mu_a = \mu_{a-1} \cdot \exp(- Z_{a-1}) \tag{7}$$

The arithmetic mean of the distribution estimated by

$$AM = 0.5 \cdot (\mu \cdot \sqrt{f} + \mu / \sqrt{f}) \tag{8}$$

where

f is the ratio between the lower limit, α, and the upper limit, β, in the rectangular distribution

remains constant with varying f.

The rectangular distribution used in the simulations has an upper limit

$$\beta = \mu \cdot \sqrt{f} \tag{9}$$

and lower limit

$$\alpha = \mu / \sqrt{f} \tag{10}$$

The calculated catches at age, Y_a, are distributed on the different count groups, l, by equation (11):

$$Y_l = \sum_a Y_a \cdot k_{a,l} \tag{11}$$

where the matrix, $k_{a,l}$, shown in Table 3, is estimated by algoritms adopted from Sparre and Willmann (1992).

Subsequently the landing at count group l, H_l, and the discard at count group l, D_l, is estimated by

$$H_l = Y_l \cdot (1 - d_l) \qquad (12)$$

and

$$D_l = Y_l \cdot d_l \qquad (13)$$

where

d_l is discard ratio of count group l.

The total landing and discard is calculated as

$$H = \sum_l H_l \qquad (14)$$

and

$$D = \sum_l D_l \qquad (15)$$

respectively, and the total revenue is calculated by

$$TR = \sum_l H_l \cdot p_l \qquad (16).$$

Based on information from the accounts of the individual trawlers, Christensen and Vestergaard (1993) estimated the total cost, TC of the objective function (2), by

$$TC = \sum_l c(G_l) + c(H_l) + c(E) \qquad (17)$$

where

$c(G_l)$ is the costs depending on the value of the reported catch (sales provision and resource tax),
$c(H_l)$ is the cost depending on the volume of the reported catch (insurance, transport, salt, handeling and packageing materials),
$c(E)$ is the cost depending on effort (fuel, wages to the crew, and repair and maintenance of gear and vessel).

In all simulations of the present study, effort costs are assumed proportional to the fishing mortality rate.

Data and Material.

Carlsson et al (1993) submits estimates of the individual age classes in the period 1986-1991 indicating that the ratio at age 3 between the lower and the higher year class strength is about 9-10, c.f. Table 4. In the present study simulations are performed applying 3, 9, and 27 as estimates of f.

The average number of recruits at age 3, $\acute{R}_3$, determines the average catch level. The best estimate of the long term average catch, at fixed effort, may be the annual TAC recommended by the Scientific Council of NAFO. Therefore, $\acute{R}_3$ is tuned to a level generating an average annual landing about 50,000 tonnes.

Savard et al. (1989) analysed all available length at age data and obtained estimates of mean length at age, Table 5. Carlsson and Kanneworff (1993) found, that these estimates are still consistent with estimates based on data from the fishery.

In the present study, growth is assumed to follow the von Bertalanffy growth equation (Bertalanffy, 1938), estimating the length at age a, l_a, by

$$l_a = L_\infty(1 - \exp(-k(a - t_0))) \tag{18}$$

where
- L_∞ is the infinite length,
- k is the growth rate,
- t_0 is the age (negative) at which the size (here length) is zero.

Regressing the annual increment against the estimates of length at age, the parameter L_∞ of the growth equation (18) is estimated at 35.65 mm and k at 0.154 per year. Subsequently t_0 is estimated at -0.7 as decribed by Gulland (1983).

Weight at age a, w_a of (4), is subsequently estimated by

$$w_a = 0{,}000711 \cdot l_a^{\;2{,}93} \tag{19}$$

(Carlsson, 1993).

Surveys (REF) indicate that the 50% retention length, L_{50}, of commercial shrimp trawls is about 16-18mm. To obtain a discard close to the estimates of the commercial fishery (REF) 19.2 is applied as an estimate of L_{50} in the present study. This discrepance may be due to different fishing behaviour of scientific surveys (stratified random fishing) and commercial trawlers seaking out fishing grounds with larger shrimp.

The size distributions from surveys, Carlsson et al (1993) provided total mortality estimates between 0.24 - 1.05 per year. Based on initial simulations, a value around 0.70 per year for total mortality Z, which is close to the 4 years mean of age 6+, is found appropriate and applied in the present study.

In order to calculate the fishing mortality rate, F, of 1991 from the total mortality, Z, assumptions must be made with regard to the level of the natural mortality, M. No information is available in the literature on the level of the natural mortality of the shrimps in the Davis Strait. However, the Scientific Council of NAFO (Anon, 1977) suggests 0.2-0.3 as an estimate of the Icelandic shrimp stock, whereas the natural mortality rate of shrimps of Skagerrak and Fladen Ground in the North Sea is believed to be higher than 0.5 per year. Ronnow (1991) estimated a value of about 0.6 per year for shrimp in Disko Bay using data before 1960. Assuming that predation on the shrimp in the Davis Strait is reduced due to the current low cod abundance and assuming that the diversity of potential predators is low compared to Fladen Ground and Skagerrak, 0.35 is adopted in the present study as estimates of M. Accordingly, also F of the fully recruited size groups is estimated at 0,35 per year.

Christensen and Vestergaard (1993) estimate the total volume of the size discard of 1991 at 13,197 tonnes equivalent to a discard rate of 8.1% of the catch of count 120-150 and of 69.1% of the catch of count 150+. These estimates are adopted as estimates of d_1 in (12) and (13).

The economic parameters, i.e. prices per kilogramme of the different count groups, p_1, and costs per fishing day, c.f. Table 6, as well as an estimate of the total effort, are adopted from Christensen and Vestergaard (1993), and the reader is refered to that paper for detailes about derivation. Based on the principle of opportunity costs, they estimated the total cost of one fishing day of a shrimp trawler to be between DKK 42.500 and DKK 80,000, depending on the underlying assumption about the level of opportunity cost for labour and the level of the rates of real interest of capital.

In the present study, assuming low opportunity costs for labour and low alternative rate of interest of capital, DKK 50,000 is applied as an estimate of costs per fishing day. As they estimate the total effort applied in 1991 at 12,215 standard fishing days, the total annual cost is estimated at about DKK 0.6 billion.

Results.

Table 7 shows simulated results from 1000 samples generated using the random number generator included in BORLAND TURBO PASCAL. Agegroups 3 to 12 were included in the simulations. The

Table (7) shows results from three levels of the ratio between the lower and upper limit on stock abundance 3, 9 and 27. The yield level is through the recruitment level adjusted to 50,000 tonnes annually for all three examples. The variabilities in average yield, average revenue and discards are due to these averaged the mean of 1000 realizations.

Figure 4 and 5 demonstrates, the effect of an increase of the recruitment factor with regard to the yield and revenue respectively. Figure 4 shows that, at an recruitment factor at 3, the probability to catch 60,000 tonnes or less is 95%. A recruitment factor at 9 or 27 decreses the probability to 85% and 80% respectively. Figure 5 shows, that the probability is about 97% to obtain a revenue at DKK 1.2 billion applying 3 as recruitment factor. With 9 and 27 as recruitment factor the probability decreases to 90% and 85% respectively.

Figure 6, which is based on Table 8, demonstrates, that increasing the mesh size from 43mm to 55mm, increases the probability only to catch 50.000 tonnes or less from 50% to about 60%, at a fixed effort level.

Figure 7, also based on Table 8, demonstrates that by the mesh size increase, the average revenue increases from about DKK 1, billion to about DKK 1.6 billion.

Figure 8 shows the average yields at different levels of fishing mortalities applying mesh sizes at 43mm and 55mm. The Figure (8) demonstrates, as does Figure 6, that if the minimum alowable mesh size is increased, the average long term yield decreases at fixed effort. The Figure (8) also demonstrates, that after a mesh size increase, a minor gain in yield may be obtained by increasing effort.

Figure 9 shows that, if the object is to maximize the revenue, the effort should be reduced from the present level, estimated at 12,215 days in 1991, to about 7,000 days, using 43mm mesh size. If the object is to maximize the resource rent, the effort should be reduced a little further.

Figure 10 shows that the present effort level, about 12,000 fishing days, is close to the effort which maximizes the revenue using 55mm mesh size. However, in order to maximize the resource rent the effort should be reduced to about 7-8,000 fishing days.

Discussion.

Assuming that the TAC reflects the expectations to the productivity of the shrimp stock, the average number of recruits, in all simulations of the present study, is tuned to generate average landings about that level. However, as the actual landings, during the past three years of fishery, have exceeded the TAC, apparently without overfishing, the average long term yield, at constant effort may be at a higher level.

The simulations indicates that the present fishery is around F_{max}. This is a result of the assumption of the natural morality $M = 0.35$ per year. Because of that assumption and that of $Z = 0.7$ per year the fishing mortality is fixed at approximately $F = M$ which in these models corresponds fairly close to F_{max}. The study should therefore be expanded with a more detailed study of the effect of the M and F assumptions.

As indicated in Table 7 and Figure 4 the variance does not increase proportionally to f. This is due to the fact that the the upper limit of the uniform distribution quite quickly approaches $2 \cdot AM$ and the lower limit 0. It is therefore not very relevant to make intensive studies for $f > 10$.

Assuming that the stock abundance is lognormal distributed the arithmetic mean AM is

$$AM = \exp(\mu + \sigma^2/2) \qquad (20)$$

Simulations were arranged so that the arithmetic mean remained constant with varying variance i.e.

$$\mu = \ln(AM) - \sigma^2/2 \qquad (21)$$

From Table 7, showing the output from 1000 simulations assuming that the stock abundance is lognormal distributed with $\sigma = 1.8$, demonstrates how this distribution induces a higher level of variability.

Table 8 and Figure 6-8 shows simulations with 43 and 55 mm mesh size. These simulations are made under the assumption that the selectivity is due to gear selection and that choice of fishing grounds under the historical known fishery with 43 mm have not changed L_{50} appreciably. Under these assumptions L_{50} change from 19.4 mm CL to 24.8 mm CL.

A mesh size increase is expected to increase gross revenue substantially from about DKK 1 billion to DKK 1.6 billion without a change in the total yield. Also discards should decrease substantially under such a strategy. The increase in value will only be realized after a new equilibrium i.e. increased recruitment have affected all age groups in the population. Such a period will be at least 5 years. Even so the simulations could be severely invalidated should the apparent selection in the fishery of to-day be doiminated by choice of fishing ground rather than gear selection. Selection studies Lehmann, Valdemarsen and Riget (1992) indicate a slightly lower selection factor around 0.4 than the 0.45 applied in this study. Should the 0.4 or even lower be more realistic the increase in gross revenue would be less.

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Table 1. TACs and offshore catches of shrimp (tonnes) in the Davis Strait (NAFO Sub-area 0+1).

	Advised TAC	Effective TAC Green-land	Effective TAC Canada	Catch Greenland	Catch Canada	Catch Others	Total Catch
1976				2,478		40,288	42,766
1977	40,000	36,000		7,081		27,219	34,300
1978	40,000	40,000		5,531		21,338	26,869
1979	29,500	29,500		12,676	245	14,166	27,087
1980	29,500	29,500		28,316	649	7,687	36,652
1981	29,500	30,000	5,000	28,282	1,590	17,428	37,300
1982	29,500	29,800	5,000	32,024	858	3,945	36,827
1983	29,500	29,625	5,000	30,929	2,030	6,308	39,267
1984	29,500	29,925	5,000	32,131	448	3,304	35,883
1985	36,000	36,000	6,120	39,137	233	2,817	42,187
1986	36,000	36,000	6,120	40,668	126	3,790	44,584
1987	36,000	34,000	6,120	37,998	3,252	4,910	46,160
1988	36,000	34,000	6,120	35,947	6,087	1,615	43,649
1989	44,000	32,600	7,520	40,961	7,235	1,735	49,931
1990	50,000	37,455	7,520	45,620	6,177	976	52,773
1991	50,000	37,725	8,500	49,938	6,788	606	57,332
1992	50,000	35,700	8,500	53,217			62,958
1993	50,000						

Source: Anon 1986, Anon 1992, and Anon 1993.

Table 2. Trawlable biomass estimates and estimated landings.

Count	Biomass ('000 tonnes)		Landings ('000 tonnes)	
	1991	1992	1991	1992
50-70	6.9	5.5	1.9	1.4
70-90	29.2	25.9	10.4	9.2
90-120	65.2	37.3	22.9	13.2
120-150	46.5	24.9	14.1	8.6
150-300	50.6	42.4	6.8	10.0
300+	0.7	1.9	0.1	0.6
Total	199.1	141.9	56.2	43.0

Table 3. Ratio of age group a belonging to count group j, $k_{a,j}$.

Age	50-70	70-90	90-120	120-150	150-300	300+
3	0	0	0	0	0.16	0.84
4	0	0	0	0	1	0
5	0	0	0	0.12	0.88	0
6	0	0	0.15	0.85	0	0
7	0	0	1	0	0	0
8	0	0.48	0.52	0	0	0
9	0	1	0	0	0	0
10	0.34	0.66	0	0	0	0
11	1	0	0	0	0	0
12	1	0	0	0	0	0

Table 4. Abundance of shrimp ($x10^{-6}$) at age and total mortality rates (Z) estimated from Greenland trawl surveys, 1988-1992.

Year / Age (yr)	1988	1989	1990	1991	1992
2	549	461	852	182	846
3	1122	4775	1076	726	2932
4	4534	16499	3227	1970	3753
5	9354	7212	11967	2529	6736
6	8304	3985	5289	8564	10610
7+	9970	6398	8146	5257	6459
Total	33832	39331	30556	19228	31336
Z(5+)		0.98	0.27	0.61	-0.04
Z(6+)		1.05	0.24	0.94	0.76

Source: Carlsson et. al. (1993).

Table 5. Summary of age and growth data for samples of northern shrimp from the Davis Strait, 1983-87, combined.

Age (yr)	Min - Max length (mm)	Mean length (mm)
1	7.4 - 9.8	8.4
2	10.9 - 13.1	12.3
3	14.5 - 16.6	15.7
4	17.6 - 19.4	18.5
5	19.1 - 22.1	20.6
6	21.3 - 23.8	22.7
7	23.0 - 26.6	24.9
8	24.4 - 28.0	26.3

Source: Savard, Parson and Carlsson (1989)

Table 6. Economic input parameters.

Count	50-70	70-90	90-120	120-150	150-300	300+
Price	89.2	34.69	21.19	9.86	5.43	0

Cost per fishing day: DKK 50.000.

Source: Christensen and Vestergaard (1993)

Table 7. Average yield, discard and revenue at different assumption about the recruitment factor β_3 / α_3. Results from 1000 samples.

Rectangular distribution:			
RecFac	Average yield '000 tonnes	Average revenue million DKK	Discard '000 tonnes
3	49 CV. = 12.6	993 CV. = 11.1	21
9	50 CV. = 19.6	997 CV. = 17.5	21
27	50 CV. = 23.3	993 CV. = 20.6	21
Lognormal distribution:			
σ = 1.8	49 CV. = 237	975 CV. = 190	21

Table 8. Average yield, discard and revenue at different mesh sizes. Results from 1000 samples using rectuangular distribution for simulating stock composition.

Mesh size, mm	Average yield '000 tonnes	Average revenue million DKK	Discard '000 tonnes
43	49 CV. = 12.6	993 CV. = 11.1	21
55	48 CV. = 12.9	1611 CV. = 11.9	1

Table 9. Average yield, discard and revenue at different levels of fishing mortalities.

Fishing mortality	Average yield '000 tonnes	Average revenue million DKK	Discard '000 tonnes
0.2	47 CV. = 11.8	1174 CV. = 10.7	14
0.35	49 CV. = 12.6	993 CV. = 11.1	21
0.5	45 CV. = 13.1	747 11.7	25

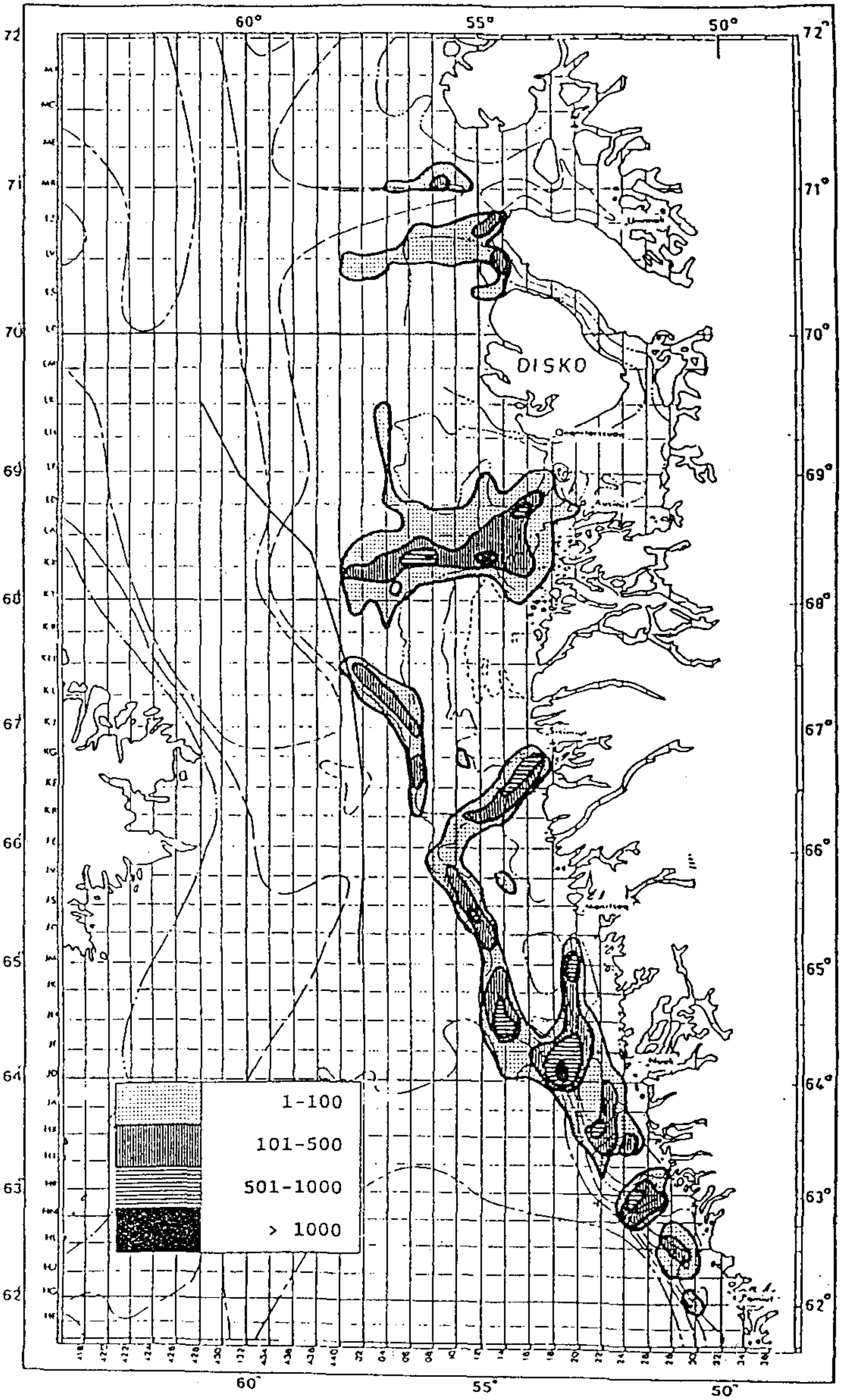

Figure 1. Distribution of total catches of shrimp (tons per statistical unit) in 1991 in NAFO Subarea 1 between 62°N and 72°N, based on logbooks from the Greenland trawlers. Source: Carlsson and Kanneworff (1992).

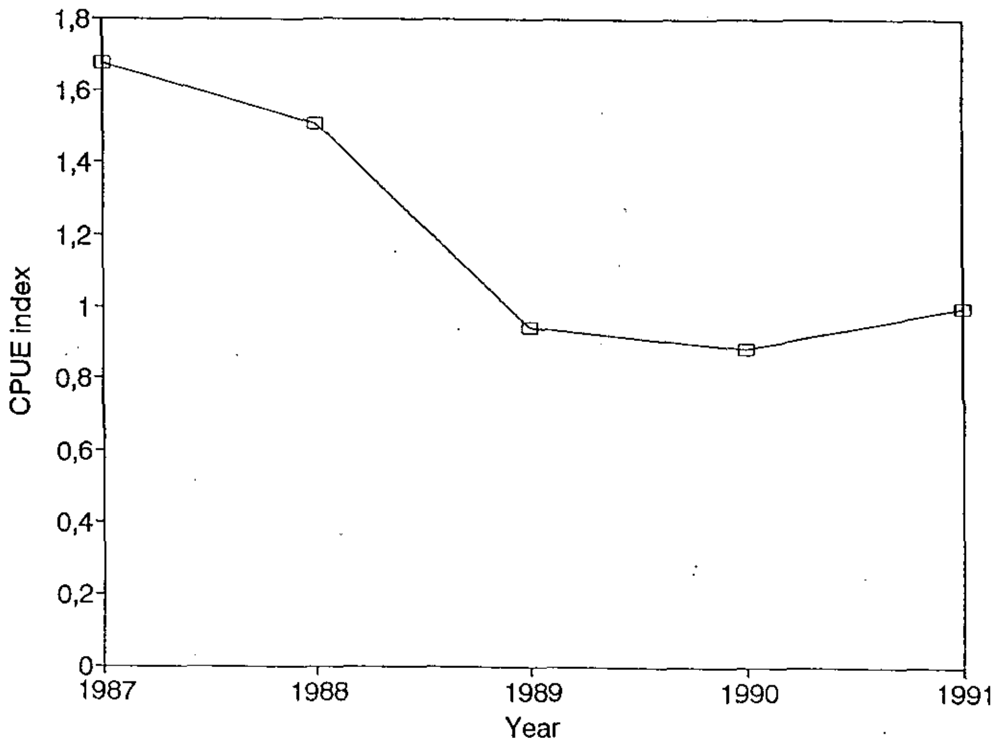

Figure 2. Yearly CPUE indices calculated for shrimp > 8.5 g. Source Carlsson and Lassen (1991).

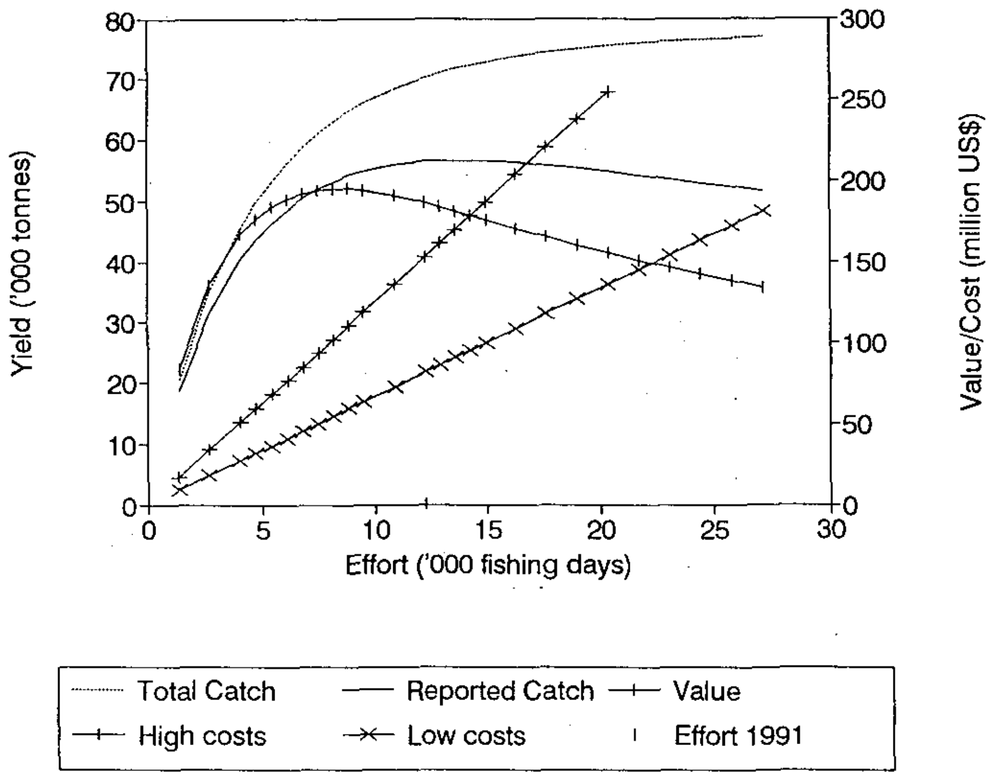

Figure 3. Estimated yield and cost curves applying 0.3 as the level of natural mortality rate. Source: Christensen and Vestergaard (1993).

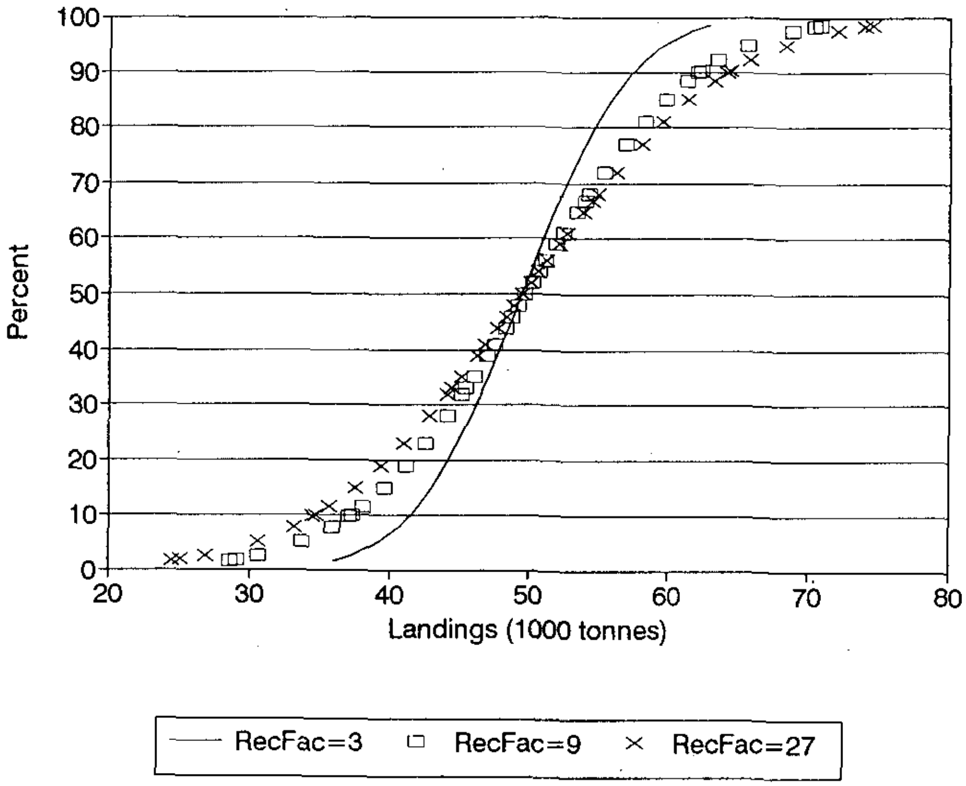

Figure 4. Probability distribution of yield at tree levels of the ratio between the lower and upper limit on stock abundance (RecFac).

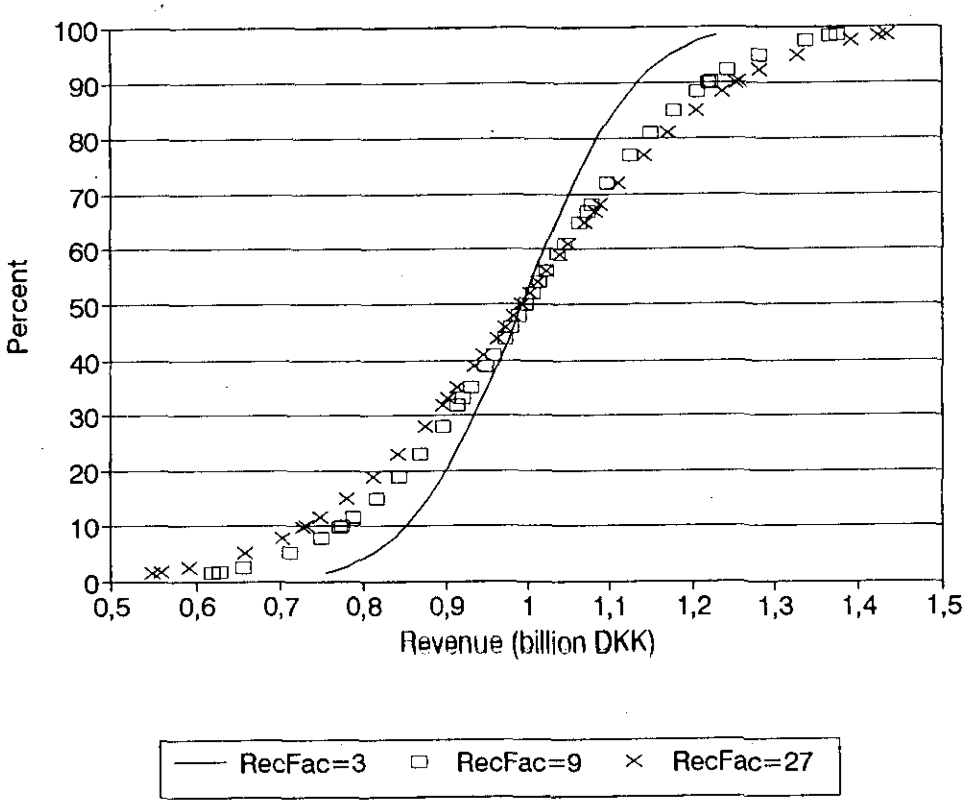

Figure 5. Probability distribution of revenue at tree levels of the ratio between the lower and upper limit on stock abundance (RecFac).

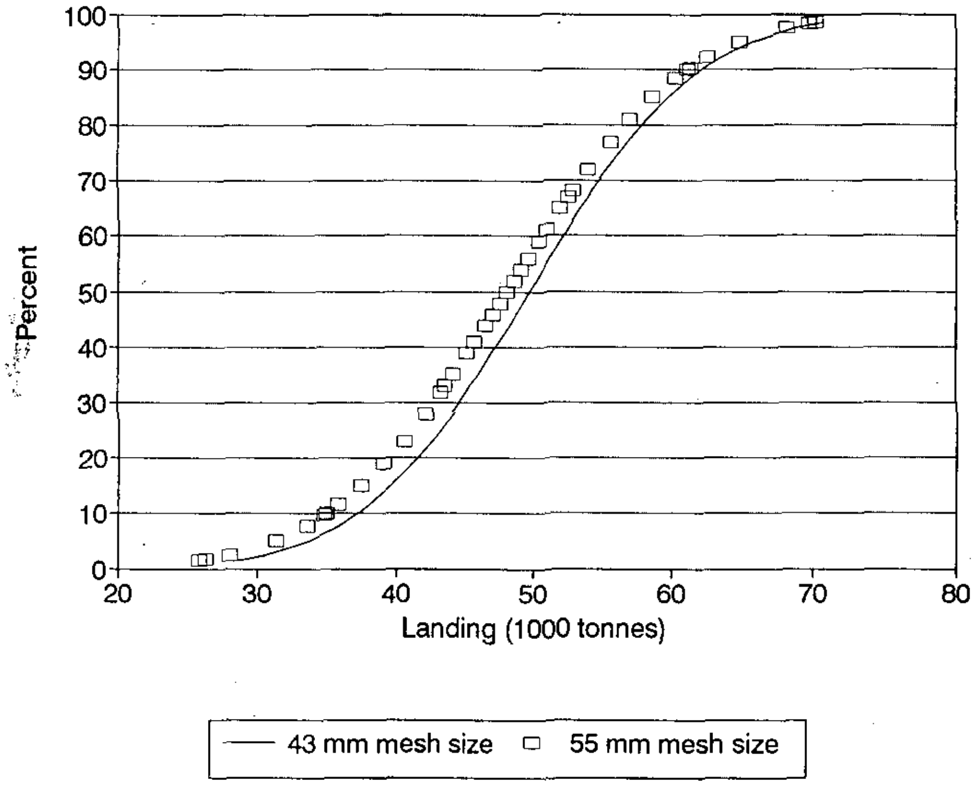

Figure 6. Probability distribution of yield at two different mesh sizes.

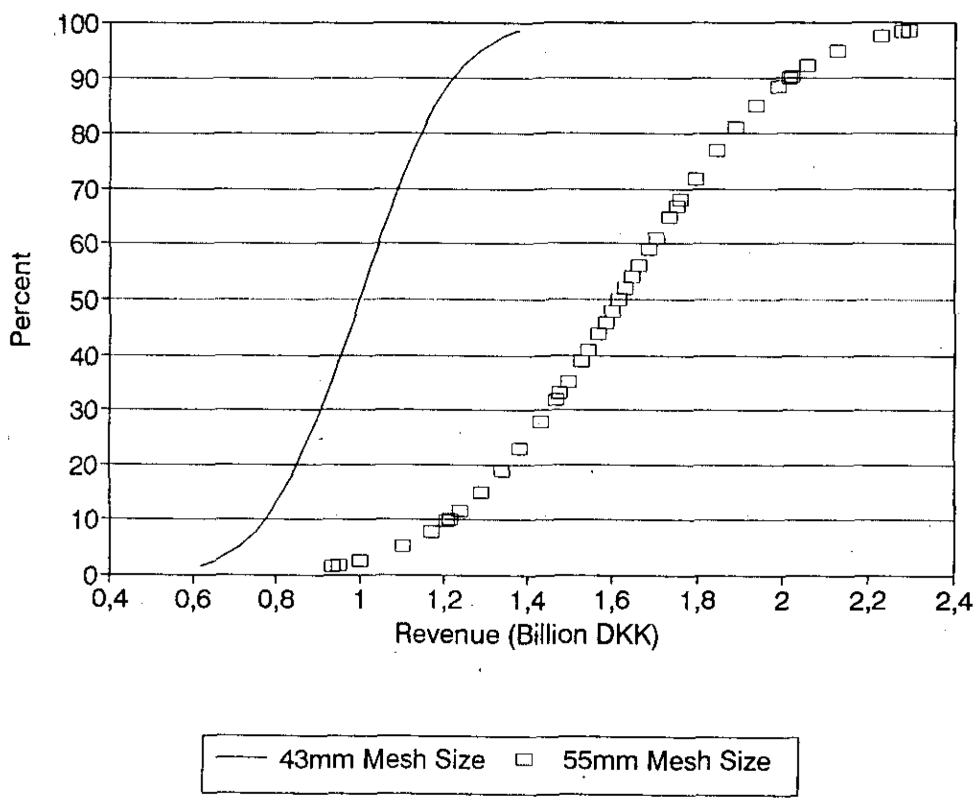

Figure 7. Probability distribution of revenue at two different mesh sizes.

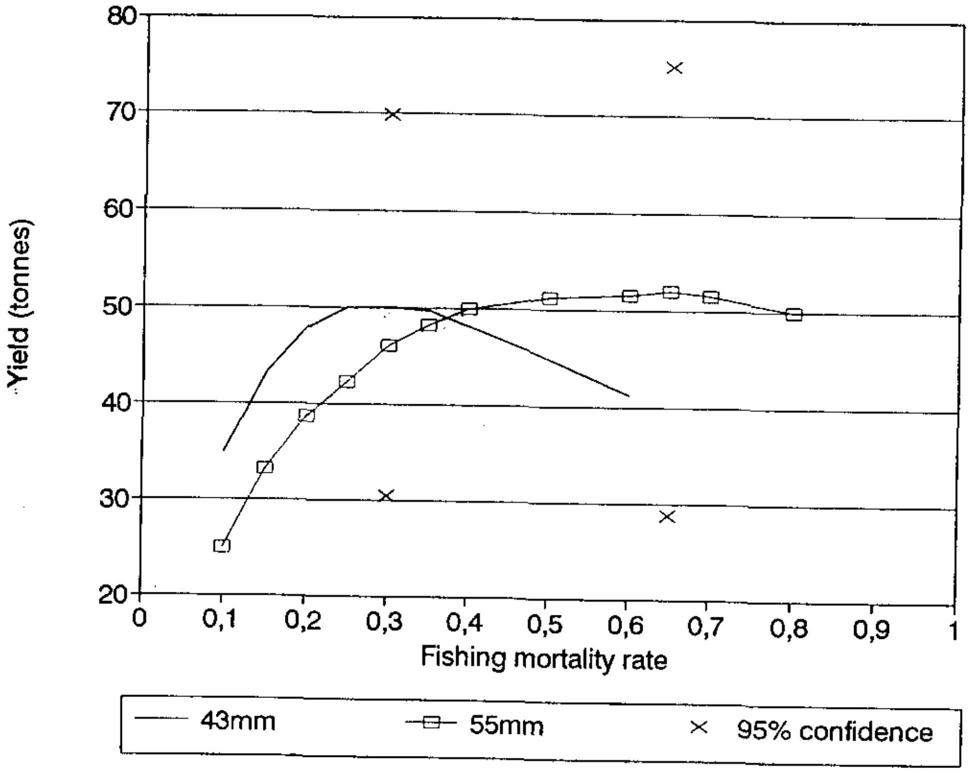

Figure 8. Average yields at two different mesh sizes as function of fishery mortality rate. 95% confidence intervals are applied at MSY.

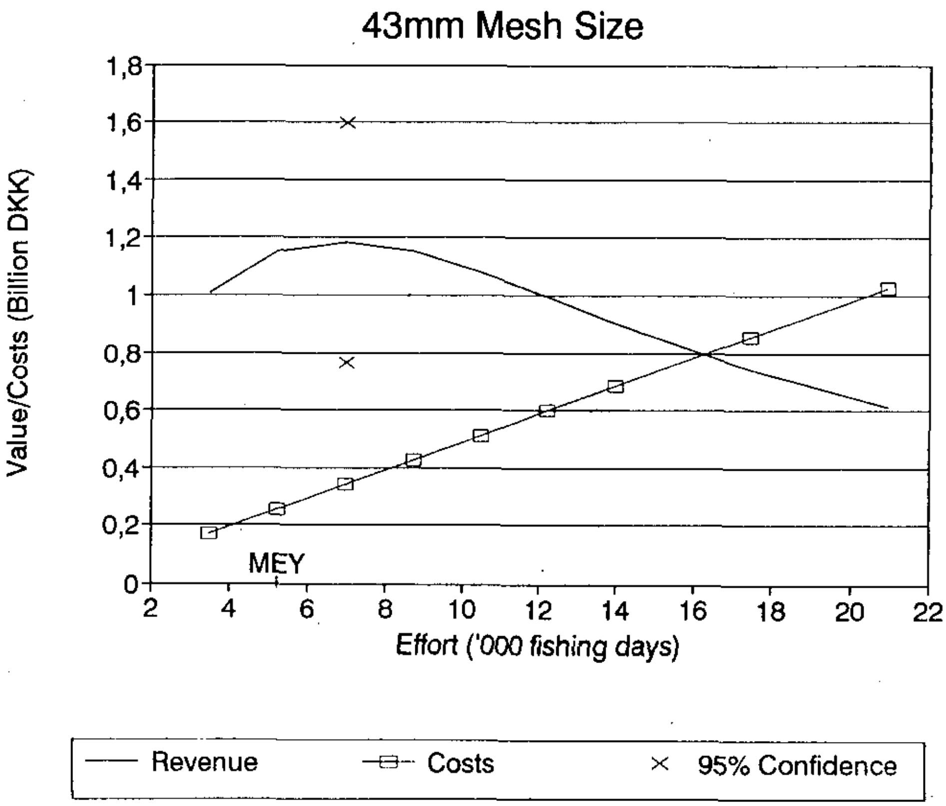

Figure 9. Average revenue and costs as function of effort applying 43 mm mesh size. 95% confidence interval is applied at MSR (maximum sustainable revenue).

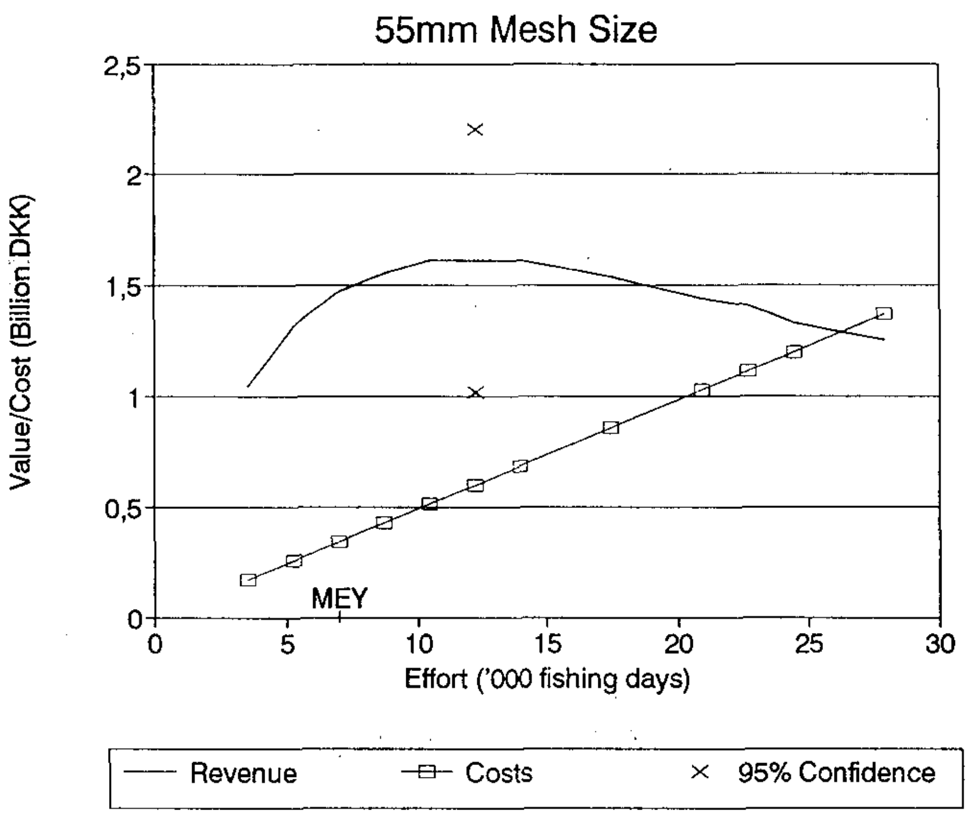

Figure 10. Average revenue and costs as function of effort applying 55 mm mesh size. 95% confidence interval is applied at MSR (maximum sustainable revenue)