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Impacts of Increased Codend Mesh Size on the Catches and Fishery of Herring in the Northern Baltic Sea - Uncertainties from the Ecosystem and Markets

by

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Abstract

High proportions of small herring in the trawl catches in the Gulf of Finland and in the northern Baltic Sea proper suggest, that an increase in the mesh size might be a justified management action. Also the higher price of large herring supports this suggestion. In this analysis we use selectivity and survival parametres of herring to assess the short term and long term impacts of an increase in codend mesh size for the catches and biomass and for the value of the catch per recruit. Natural mortality values and growth rates of years 1974 - 1992 are used as a basic material in the calculations. It is assumed that there will be similar changes in the production parameters also in the future as there has been in the past. The results indicate that change in mesh size would not lead to more valuable catches with the present price difference of the large and small herring. This is due to the high mortality of the codend escapees. If the survival of the escapees can be increased to 80% or more by new gear technology, the change would be profitable. This is dependent on the assumption, that the production capacity of the stock will not decrease. The impulse of saline water to the Baltic Sea might improve the present poor growth rate, but if the biomass of cod will also increase as a result of the impulse, the result from the change would not necessarily be positive. The reason for the poor growth of herring would be very valuable information in this decision. Also better knowledge on the level of the natural mortality of the stock would essentially decrease the overall uncertainty of this management decision.

Gear Selectivity/Technical Interactions Symposium

1. Introduction

A mesh size based fisheries management is often seen as an effective way to keep spawning stock on a safe level, and to increase the size and/or value of the catch per recruit in the long run. Effective mesh size management can be simple and can remarkably reduce the costs of the management compared to e.g. TAC based management. However, the lack of adequate research on the real effects of the mesh size changes has prevented the evaluation of the disadvantages and benefits of this management alternative. Selection studies are expensive, and usually the recommendations of increased (or decreased) mesh sizes are based only on such Y/R-calculations, where a knife-edge recruitment is used. Natural mortality values are usually based on assumed values. It is also commonly assumed that the escaping fish survive. Recent studies indicate, however, that for the Baltic herring (*Clupea harengus* L.) the survival of the codend escapees is poor in pelagic trawl fisheries (Suuronen et al. 1993).

In this analysis we assess the potential effects of a mesh size change of herring trawls in the northern Baltic (ICES Subdivision 29N and the Gulf of Finland (SD 32). The main part of the herring catches is taken by trawls on this area. Immature juvenile herrings frequently form a high proportion of the total catch of trawlers fishing in the area. According to the Fishery Rules of the International Baltic Sea Fishery Commission, the minimum mesh opening of herring trawls in the ICES subdivisions 29N-32 is 16 mm, which roughly corresponds to a 20 mm stretched mesh.

In Finland the demand and price of the large herring for human consumption is much higher than that of small herring,. Therefore, an increase in the recruitment age of herring might be justified, if the total catch and CPUE would not decrease too much. Small sized herrings have limited markets as low-value fodder fish, whereas there has been a lack of large herring especially in the processing (fillet) industry. Some amounts of small herring are likely to be discarded once the catch has been size-sorted onboard. According to the Fishery Rules, this is not allowed, and the sorting of the herring should rather take place at sea during fishing.

Our main goal in this paper is to assess, would the change from 20 mm to 36 mm be a rationale decision with the present information base. We will also assess which sources of uncertainty are the most crucial in the decision to increase the minimum stretched mesh size to 36 mm.

2. Methods and Data

As a basis in these calculations we used the selectivity data of Järvik and Shevtsov (unpubl.) for the 20 mm and that of Suuronen and Millar (1992) for the 36 mm diamond mesh codend (Table 1).

To estimate the mortality caused by trawls under different growth rates, we used the yearly length distributions of commercial trawl catches in ICES Subdivisions 29 and 32. The number of samples taken from trawl catches has been around 2000 - 4000 per year. The retention rates were calculated separately for the length distributions of each year and age group.

Also the fishing mortalities were calculated separately for each year and age group. We assumed that the fishing mortality only depends on the trawl fishery. One general fishing mortality (F(y) below) was used in one simulation for every year. For a totally recruited age group the retention rate was 1 and the yearly momentary fishing mortality for each age group was calculated by multiplying the fishing mortality by the retention rate:

(1) $$F(a,y) = F(y) * r(a,y)$$

where $F(a,y)$ = fishing mortality of age group a in year y
$F(y)$ = general fishing mortality in year y (totally recruited age groups)
$r(a,y)$ = retention rate for age group a and year y

Natural mortality values of the multispecies VPA (MSVPA, Anon. 1993a) were used as a basis in the calculation of the natural mortalities. In the MSVPA analysis the natural mortality values depend on the size of the cod stock and on the stomach analysis and prey size preferences of cod. These natural mortality values have been accepted by ICES to be used also for the herring populations in ICES subdivisions 29 and 32 (Anon. 1992a). The selectivity of the gear and the low survival rates of the escapees generate such mortality to the stock, which must be added to the natural mortality values estimated by MSVPA. We used the following equation to estimate the total natural mortality of an age group:

(2) $$M_t(a,y) = M_{vpa}(a,y) + F(y) * (1-r(a,y)) * M_{esc}$$

where $M_t(a,y)$ = natural mortality used for year y and age group a

$M_{vpa}(a,y)$ = natural mortality estimated by MSVPA for year y and age group a

M_{esc} = mortality of escapees (relative, between 0 and 1)

In the calculations of the catch value we assumed that the price of herring over 36 grams is 1.60 FIM and under 36 grams 0.4 FIM. These correspond roughly to the prices of herring without the subsidies of the Finnish state. We didn't assume any price elasticity.

In the catch calculations we used the standard equations of VPA (e.g. Hilborn & Walters 1992, p. 354) and an assumption of constant recruitment (1000 individuals). In each simulation the catches, biomasses and value of the catches were calculated for the 19 years' time period (years 1974 - 1992). Mortalities per year and age group were calculated as explained above. Yearly values of the catch were discounted and the sum of these discounted values was used in the comparisons of the different options. We didn't include any density dependent interactions to the analysis and we assumed that the total effort does not depend on the mesh size.

To get the different results comparable with each other, we used the results of a basic simulation as a comparison level. Input values of the most important parameters in this basic simulation are given in Table 2. This simulation describes the yield, biomass and values of the catch in 1974 - 1992 with a constant recruitment of 1000 fish. The results of the different simulations with different assumptions were compared to the results of this basic simulation and the results are given as percentages compared to the results of basic simulation. This enables the comparison of the different effects to each other. The changes in the catches per recruit are proportional, depending on the absolute recruitment and considered area in the Baltic Sea.

3. Results

The growth rate of herring improved significantly after 1976 and 1977 salt water impulse (Fig. 1 and Parmanne 1992). The exact reason for this change is still unclear. It is, however, possible that growth will improve also after the recent impulse (1993) or at least in the near future. After the impulse in 1976 the cod recruitment increased remarkably, and the natural mortality values of herring increased to two-threefold due to the cod predation (Anon. 1993a). Even though the growth increased, the production capacity per recruit decreased after 1979 and increased again after 1986 (Fig. 2). During the whole period, a 36 mm codend would have given remarkably lower catches than the 20 mm codend. Difference is lowest in 1979 - 82.

The value per recruit would have been lower with 36 mm codend than by the 20 mm codend (Fig. 3). Difference is not as large as in the catches, because the high price of large herring compensates partly the decrease in catches. Highest peaks are in those years, when natural mortality values were quite low and growth rate was still moderate. With the 85 % mortality of the escapees the difference in biomass between 20 and 36 mm codend is very small.

The value of the catch would be lower for 20 mm codends than for the 36 mm codend, if mortality of escapees could be decreased to 20 % or lower (Tables 3 and 4). The value of the yield of 36 mm codend is more sensitive to the changes in the mortality of the escapees than that of the 20 mm. By the 20 mm codend the value of the catch is not very sensitive to the changes of the mortality of the escapees with present fishing mortalities. This is due to the fact, that only a quite small part of the herring stock can escape from the 20 mm codend, and therefore long term catches are not very sensitive to the changes of the mortality of escapees.

The 36 mm codend is somewhat more sensitive to the changes in the prices and to the changes in the minimum size of the more valuable size class than the 20 mm codend (Table 5). Thus, the use of the 36 mm codend would increase the sensitivity of the fisheries to the market changes. Also the market knowledge plays an essential role in the prediction of the profitability of the mesh size change.

The price of the large herring (human consumption) should be more than six times higher than that of the small fodder herrings to get the change profitable compared to the continuous use of 20 mm mesh size (Table 6). Present price difference on the markets is fourfold. If all escaped herring would survive, the price difference should be threefold. These results are also quite sensitive to the fishing pressure.

A totally unselective gear would be the best from the point of view of the value of the catch (Fig. 4, compare to Table 6). Natural mortality and the mortality of the escapees are so high, that the saving of the young herring does not increase the total value of the catch. .

If a stable effort is assumed, the drop of the catches during the first years after the change depends on the growth and natural mortality levels of the population. Table 7 gives the changes in the catches of the first years after the mesh size change compared to a continuous use of 20 mm (compare to Fig 2). In these calculations the mortality values are calculated by the 20 mm codend during the years before the change and by the values of 36 mm codend after the change.

During the years of improved growth rates (1979 - 1980), these drops would have been about two times lower than during the poor growth in 1986 - 1990. The changing natural mortality due to the cod stock and due to the increased escapement through the large mesh has an important effect on these results.

It is not, however, sure that the growth and natural mortality will change in future in the same way as in the past. Therefore, we calculated the effects of the different growth and natural mortality combinations on the long term catches, catch values and biomass of the entire stock (Table 8). Natural mortality has very important effect on these results. Even though the present growth rate is only half of the rates in 1982, the change would be more profitable in present conditions than if the conditions would be as in the data of 1982. If the growth rate improves without cod invasion, the change to 36 mm mesh size would be profitable. In practice this assumption would mean that growth is not density dependent or recruitment of cod would not improve as result of higher salinity and water quality changes. If natural mortality increases without changes in the growth level, the result of the mesh size change would be poor.

Changes in the minimum size of the more valuable herring (changes in the markets and in the industry) and the discount value have not a very significant effect on the decision to use 20 mm or 36 mm codends (Table 9). This is probably due to the facts, that both the growth of the herring and the natural mortality changed during the calculation period of 19 years, and these changes partly compensate for the effects of the change in minimum size of the valuable herring class.

4. Discussion

The present calculations provide a general insight into what might take place after implementing a 36 mm minimum mesh size in the herring trawls in the northern Baltic Sea.

These analysis show interactions that must be taken in consideration, if the decision is planned to be implemented. The most important variables are the survival of the escapees, growth rate and natural mortality of herring. In the past the changes in the natural mortality values have compensated the changes in the growth, and the effect of the saline water impulse was actually negative on the production capacity per recruit.

Uncertainty from ecosystem and stock behaviour

These conclusions, and part of our other results are, however, heavily based on the assumption that the natural mortality values of the northern Baltic stocks would be roughly the same as in the central parts of the Baltic Proper. The natural mortality values of the MSVPA are calculated for a very large area, and the biomass of the cod stock was probably higher in the southern than in the northern part of the Baltic Main Basin. However, this is the case also for herring and therefore the natural mortalities are probably not very much overestimated by MSVPA. This is, however, such uncertainty which should be studied in more details.

The changes in the growth can be monitored with high accuracy. The problem is, that the future growth must be predicted at least five years forward. This prediction is probably impossible, if the exact reason of the growth change stays unclear. The estimation of the cod stock older than 2 year can be estimated fairly well (Anon. 1993b) and this gives some opportunities to predict the changes in the natural mortality.

The migrations of herring are part of the uncertainties. Large herring seems to migrate in autumn to the Baltic Main Basin from the Finnish coast (Parmanne 1990), and it is probable that fishery in the central Baltic Sea proper would get a large part of the potential utilities gained by the mesh size change in the northern Baltic. This gain would be paid by the Finnish fishermen by the lower catches of small herring.

We have assumed that there are no compensatory mechanisms in the herring stock (especially density dependent growth). This assumption is not critical, if the survival of the escapees is so low as the recent experiments suggest (Suuronen et al. 1993). If the survival can be improved, this might be an extra source of uncertainty, which should be taken into consideration.

Uncertainty from markets and fishermen

The sensitivity of the required price difference to the mortality values (Table 2) shows also that the actual price difference of the large and small herring is an important factor controlling the profitability of the fisheries. If there will be large changes in the markets (e.g. Finland joins EC) the economic result of the possible mesh size change might also change. It is probable, that in the future the price of the large herring will decrease. This would make the change less profitable. This is same kind of uncertainty for the manager as the uncertainties of the biological system. Use of 36 mm codend would increase the sensitivity of catch value to the markets, because the profitability of the 36 mm is based heavily on the higher price of large herring.

Also the assumption, that all herring can be sold with stable price, is probably unrealistic. The present demand of fodder herring is quite low. If the low demand does decrease the price of the small herring, the change to large mesh size becomes more profitable.

The use of the present minimum codend mesh size of 20 mm can also be critized. When taking into account the large changes in the growth and natural mortality of the stock, it seems to be difficult to find the basis for a such mesh size regulation, where the mesh size is decided to be 20 mm. Value of the catch, biomass of the stock and recruitment of the stock are mostly controlled by other variables than mesh size, and the probability that a mesh size regulation would have any meaningful effect on the future catches or biomasses of the stock seems to be very low. This conclusion is based on the poor survival of the escapees.

Suuronen et. al (1992) analyse the effects of the fishermen's reaction after the mesh size change on the catches and biomass. Depending on the assumption of the behavior of fishermen (constant effort, constant total catch, constant value of the catch), the changes in catches and in biomass differed a lot. This is also one source of uncertainty for the manager.

From the fisherman's point of view, the necessity and benefits of making technical regulatory action should basically be understood and accepted. By just slightly changing the fishing practices and gear rigging, fishermen can easily compensate most of the effects of an enforced mesh size increase. On the other hand, decreasing the catch of small herring will reduce the physical effort required for sorting out the unmarketable fish and in this way may positively affect the labour costs and profitability of fishing.

Are uncertainties under control ?

The most important uncertainties in the mesh size change decision are of the type, which actually can not be decreased remarkably by more detailed research or by some management action. They are not under the control of managers and the decision maker must simply face these uncertainties. They are part of the production system of the northern Baltic Sea, which seems to be a too unstable environment for this kind of management decision.

In the present situation the results of the change of mesh size are so uncertain, that this decision can not be recommended, at least if the total catch or the value of catch is the most important criteria. With the present biomass of the herring stock, there is no risk for a recruitment failure due to the too low spawning biomass. Thus, improving of the recruitment can not be used as an extra or single criteria in the decision. If the cod stock will increase again and also the effort will increase, the change of the mesh size might be one way to safeguard a certain part of the spawning biomass, if the escaping fish could be sorted out alive from the trawl.

5. Conclusions

1) The overall uncertainty of the decision to change mesh size seems to be very large. Large part of this uncertainty comes from the unstable nature of the Baltic Sea ecosystem.

2) Even though the biological uncertainties seem to dominate, the economic situation in the future is unpredictable, and the use of 36 mm codend would make the profitability of the herring fishery more sensitive to the changes in markets than a continuous use of 20 mm codend.

3) With the present data, the survival of the escaped herring should be at least 80 % to make the mesh size change profitable.

4) Use of the mesh size management in herring fishery must be reconsidered in the northern Baltic Sea.

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Table 1. Percentages retained in each length-class by the 20 mm and 36 mm codends and the main selection parameters.

Length cm	A=20 mm	A=36 mm
6	2.2	1.5
7	10.8	2.0
8	26.4	3.1
9	51.4	4.4
10	87.9	6.6
11	99.7	9.5
12	100	13.5
13	100	19.7
14	100	30.3
15	100	40.7
16	100	55.6
17	100	71.9
18	100	85.7
19	100	94.3
20	100	98.0
21	100	99.4
22	100	99.9
23	100	100
L25	7.9	13.6
L50	8.9	15.6
L75	9.7	17.1
SR	1.8	3.5
SF	4.4	4.3

Table 2. Values of the most important input parameters. In all calculations the catches and values of the catches are calculated for the whole 19 years' period (data from 1974 to 1992).

Parameter	**Value in the basic simulation**
Fishing mortality (for totally recruited age groups)	0.2
Mortality of the escaped herring (Suuronen et. al. 1993)	85 %
Minimum size of the more valuable size class	36 g
Discount rate	5 %
Price difference of large and small herring	400 %
Recruitment (stable)	1000

Table 3. Value of the catch compared to the basic simulation (20 mm codend, 0.2 fishing mortality and 85 % mortality of escapees) in percentages as function of mortality of the escapees and the over all fishing mortality of the totally recruited herring. Values estimated for 36 mm codend.

	Mortality of escaped herring (%)					
Fishing mortality	**0**	**20**	**40**	**60**	**80**	**100**
0.1	87	81	76	71	66	62
0.2	126	111	97	85	75	66
0.3	142	117	97	80	66	55
0.4	145	113	88	69	55	43
0.5	143	106	79	59	36	34
0.6	139	97	69	50	36	26
0.7	133	89	61	42	30	21
0.8	127	82	54	36	25	17

Table 4. Value of the catch compared to the value in basic simulation (20 mm codend, 0.2 fishing mortality and 85 % mortality of escapees) in percentages as function of mortality of the escapees and the over all fishing mortality of the totally recruited herring. Values estimated for 20 mm (present) codend.

	Mortality of escaped herring (%)					
Fishing mortality	0	20	40	60	80	100
0.1	90	89	87	86	85	84
0.2	111	109	106	103	101	98
0.3	111	107	103	97	96	92
0.4	106	101	96	91	87	83
0.5	99	94	88	83	79	74
0.6	94	88	82	77	72	68
0.7	90	83	77	72	67	66
0.8	87	80	74	68	63	63

Table 5. Difference in the value of the catch compared to the basic run by 20 mm and 36 mm codends as function of minimum size of the more valuable size class and the price difference. All other input values are like in basic simulation (Table 2).

20 mm

		Price difference				
Minimum size	No diff.	2x	3x	4x	5x	6x
30	56	76	96	116	136	156
34	56	72	88	104	120	137
38	56	69	82	95	109	122
42	56	66	76	87	97	107
44	56	65	74	84	93	103
48	56	63	71	79	86	94
52	56	62	69	75	82	89

36 mm

		Price difference				
Minimum size	No diff.	2x	3x	4x	5x	6x
30	30	48	66	84	103	121
34	30	45	60	76	91	106
38	30	43	56	69	81	94
42	30	40	50	61	71	82
44	30	39	49	58	68	77
48	30	38	45	53	61	69
52	30	37	43	50	57	64

Table 6. Required price difference (in percentages) between large herring (human consumption) and small herring (fodder) to get the change to 36 mm codend more profitable than the use of 20 mm. Price difference as function of fishing mortality (1/year) of totally recruited herring and mortality (%) of the escaped herring.

	Mortality of escaped herring (%)					
Fishing mortality	0	20	40	60	80	100
0.1	470	508	549	593	640	691
0.2	290	352	415	487	571	667
0.3	247	324	419	536	682	860
0.4	227	334	476	662	908	1232
0.5	221	366	570	865	1276	1850
0.6	221	417	715	1165	1838	2836
0.7	227	487	912	1594	2678	4386
0.8	236	579	1176	2199	3921	6795

Table 7. Effect of the change of the codend to 36 mm on the percentual difference in the values of catches compared to the continuos use of 20 mm. Yearly growth and selectivity parameters are used and constant overall fishing mortality (effort) assumed. Year of the change from 20 mm to 36 mm, change in values in first year and in third year. All other input parameters are like in Table 2.

Year of the change	Decrease in first year	Decrease in third year
1975	- 40	-32
1976	-37	-25
1977	-33	-22
1978	-27	-19
1979	-23	-23
1980	-21	-21
1981	-24	-27
1982	-22	-28
1983	-28	-34
1984	-27	-38
1985	-35	-39
1986	-39	-39
1987	-40	-37
1988	-41	-36
1989	-38	-45
1990	-37	-53
1991	-46	-

Table 8. Total catch, total value of the catch and the maximum biomass during the 19 years' period compared to the basic simulation with different growth and natural mortality values. Values of the input years are used as constant for the whole 19 years' period. All other input parameters are like in Table 2.

Growth values	**Mortality values**	**Total catch compared to the basic simulation (%)**	**Value of the catch compared to the basic simulation (%)**	**Maximum biomass compared to the basic simulation (%)**
1992	1992	88	93	138
1982	1982	42	62	72
1982 (highest)	1991 (lowest)	172	290	185
1992 (lowest)	1980 (highest)	12	9	44

Table 9. Percentual (%) difference between the values of catch of 20 mm and 36 mm codends as function of discount rate and minimum size of the more valuable size class. In each case the value of the catch is calculated by 20 mm and 36 mm codends and the value of 36 mm is divided by the value of 20 mm. All other input values are like in basic simulation (Table 2).

	Discount rate			
Minimum size (g)	**0**	**0.04**	**0.06**	**0.1**
30	72	73	73	73
34	72	72	73	73
38	71	72	72	72
42	69	70	70	70
44	69	69	70	70
48	67	68	68	68
50	67	67	67	67

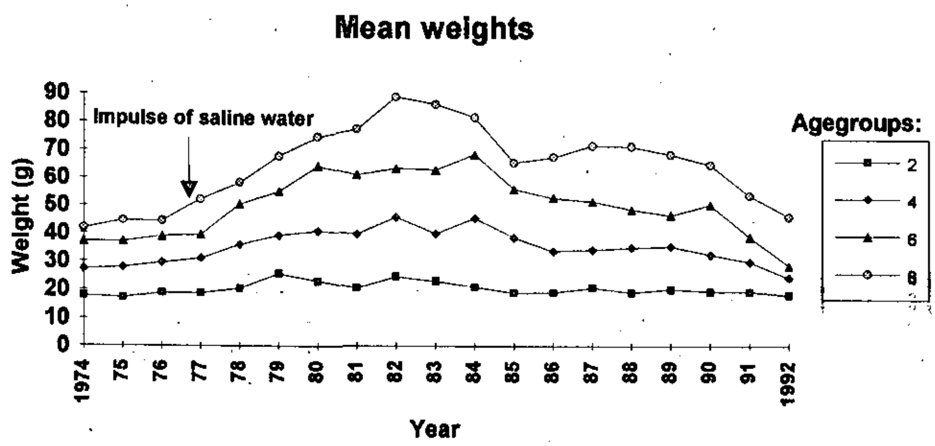

Fig. 1. Mean weights of the herrings sampled from the trawl catches in 1974 - 1992. Impulse of saline water took place in the 1976 and 1977.

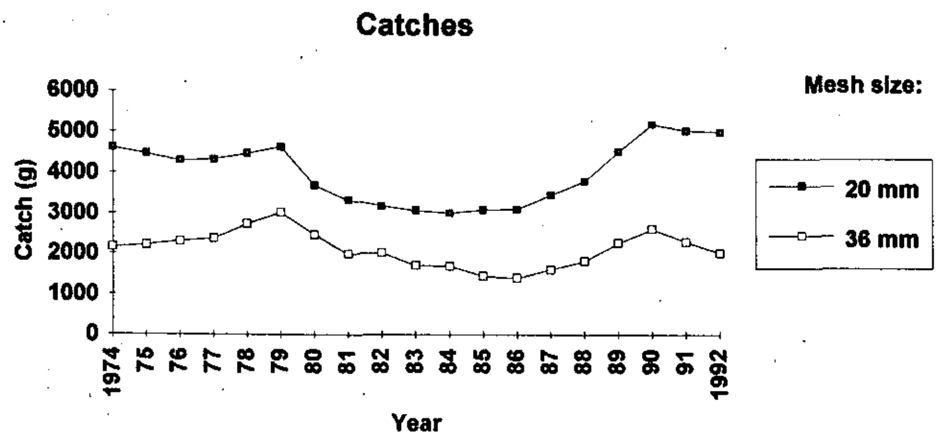

Fig. 2. Yearly catches (g) with stable recruitment of thousand herrings and the natural and fishing mortalities of the basic simulation (values in Table 2). Same total effort assumed.

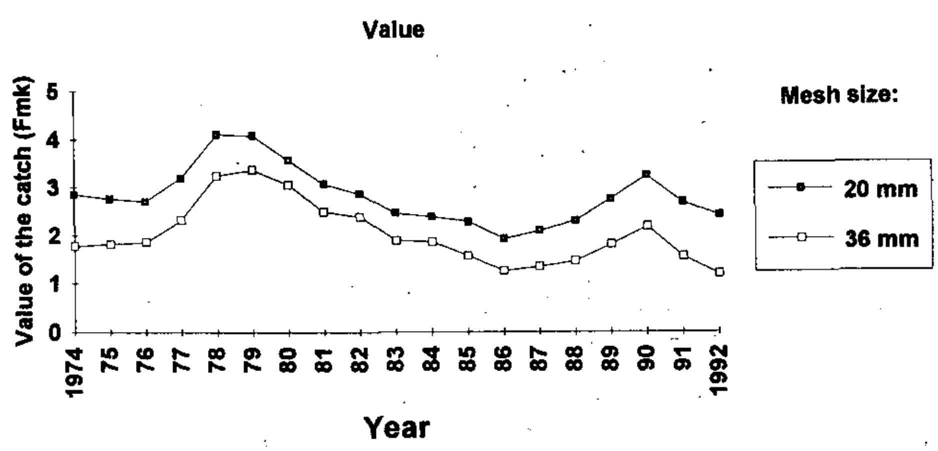

Fig.3. Value of the catch with stable recruitment of thousand herring and the natural and fishing mortalities of the basic simulation (values in Table 2). Same total effort assumed for both mesh sizes.

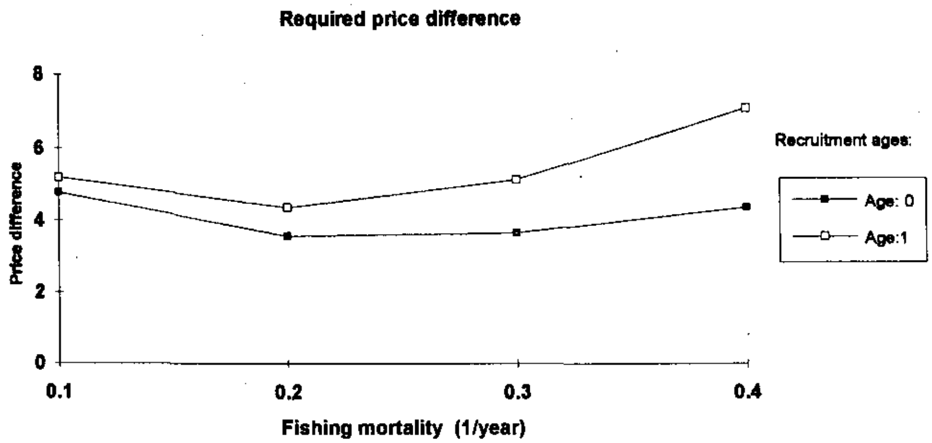

Fig. 4. Required price difference of the large herring and small herring to get the change to certain recruitment age profitable. Difference as function of fishing mortality. Knife-edge recruitment in age groups 0 and 1 assumed.