Northwest Atlantic Fisheries Organization

Serial No. N4463 **NAFO SCR Doc. 01/81**

SCIENTIFIC COUNCIL MEETING – JUNE 2001

An Analysis of the Effects of a Change in Trawl Mesh Size from 130 to 145 mm, Within the Greenland Halibut and By-catch Species Fisheries in Subarea 2 and Divisions 3KLMN

by

Chris Darby

CEFAS, Lowestoft Laboratory, Pakefield Rd.,
Lowestoft (Suffolk), England NR33 OHT, United Kingdom

Abstract

The effect of a change in mesh size from 130 mm to 145 mm is examined for the Greenland halibut fishery of NAFO Subarea 2 and Divisions 3KLMNO. Changes in the yield and spawning stock biomass per recruit, of the target and two of the main by-catch species, are examined.

Introduction

The NAFO Fisheries Commission requested that the 2001 meeting of the NAFO Scientific Council: *provide information on the long-term effects of increasing mesh size from 130 mm to 145 mm in yield-per-recruit and stock spawning biomass-per recruit for Greenland halibut in 2+3KLMNO and in reducing by-catch of other species in that fishery. The Scientific Council has also been requested to evaluate the medium term consequences in terms of yield and stock size of any such changes in mesh size.*

Kulka (2001) lists the species that are taken as by-catch within the Subarea 2 and Div. 3KLMNO Greenland halibut fishery. They are American plaice, cod, yellow-tailed flounder, rough-headed grenadier, round-nosed grenadier, thorny skate, hake, monkfish, spotted wolfish, striped wolfish, redfish and witch. This paper examines the effects of a change in mesh size, from 130 mm to 145 mm, on the yield and spawning stock biomass per recruit of three species stock units for which age based assessments are available; Greenland Halibut in Subarea 2 and Div. 3KLMNO, American plaice in Div. 3L, 3N and 3O and cod in Div. 3N and 3O.

Historic Studies

Scientific Council examined the effect of mesh selection changes in the fisheries for Greenland Halibut and American plaice in the NAFO Scientific Council Reports of 1995, 1997 and 1998.

Greenland Halibut in Div. 2 and 3

Scientific Council Report (1995, p. 41) reviewed a yield per recruit study (Casey, 1995), which examined the effect of an increase in the length of first capture, to 60 cm, within the Greenland halibut fishery in areas 2 and 3. The paper showed that there could be substantial gains in yield if such a measure were to be introduced. The study assumed equal selection and natural mortality by sex with no discarding. Scientific Council concluded that: "it would be difficult to generate such an exploitation pattern for trawlers", and that "substantial improvements in the exploitation pattern would be achieved by adoption of alternative fishing methods such as, long lining and gill netting with mesh size around 200 mm". Scientific Council made the additional point that "restricting the Greenland halibut fishery to deeper than 1200 m should decrease the proportion of small Greenland halibut in the catch, since larger individuals are found in deeper water".

In 1997, Fisheries Commission asked that the Scientific Council: "*assess the possible changes in yield and spawning stock biomass based on the assumption of a dome-shaped exploitation pattern and a different age of maturity and mortality rates for males and females, for two scenarios a) the current situation, and b) a minimum landing size of 60 cm*".

Scientific Council (1997, p. 33) revisited the results and conclusions drawn from the yield per recruit analyses for Greenland halibut fishery in Div. 2 and 3, carried out in 1995.

Yield per recruit analysis was carried out using higher natural mortality rates for males aged 7 and older and a dome shaped selection pattern, with a maximum selection at age 9. The results showed that changing to the higher mesh size increased yield and SSB per recruit, but not to the extent shown previously using a flat topped selection pattern. Under a dome shaped exploitation pattern, the level of effort required to reach F0.1, using the lager mesh size, was estimated to be twice that of the smaller mesh.

Scientific Council (1997, p. 34) agreed that a dome shaped partial recruitment pattern in the trawl fishery and differences in mortality by sexes are the most likely scenario for Greenland halibut.

Scientific Council (1998, p. 44), following a request from The Fisheries Commission, repeated the previous year's yield and SSB calculations under an assumption of a mesh change from 130 mm to 155 mm. The results were as follows:

Scenario 1) M = 0.15 for Male and Females:

	Mesh size	Fmax	B at Fmax	Y at Fmax
Actual	130	0.34	952	389
New	155	0.45	918	447
Difference +19%		+32%	-4%	+15%

	Mesh size	F0.1	B at F0.1	Y at F0.1
Actual	130	0.23	1695	371
New	155	0.30	1674	426
Difference +19%		+30%	-1%	+15%

Scenario 2) M = 0.15 for Females, M = 0.15 for Males < age 7 and M = 1.05 for Males >= age 7:

	Mesh size	Fmax	B at Fmax	Y at Fmax
Actual	130	0.47	489	284
New	155	0.63	479	306
Difference +19%	+34%	-2%	+8%	

	Mesh size	F0.1	B at F0.1	Y at F0.1
Actual	130	0.24	1617	256
New	155	0.28	1820	265
Difference +19%	+17%	+13%	+4%	

Scientific Council concluded that for Scenario (1) in which M=0.15 for both sexes, a 15% increase in yield at both F0.1 and Fmax can be expected when increasing the mesh size from 130 mm to 155 mm, however, the equilibrium SSB would decrease by 4% for Fmax and 1% for F0.1. For Scenario (2), which assumes a substantial difference in natural mortality by sex, much smaller increases in yield would be expected between the respective mesh sizes (8% at Fmax and 4% at F0.1). SSB would decrease by 2% at Fmax but increase by 13% at F0.1. It was emphasized that these calculations are very sensitive to changes in the input parameters and the results should be treated with caution.

Note that the calculations carried out in 1995-1998 were based on an assumed selection pattern at age due to the lack of an age-based assessment. Natural mortality was assumed to be 0.15 at all ages and sex independent or 0.15 for males younger than age 7 and females and 1.05 for males 7 and older. Currently M is assumed to be 0.2 within the single sex assessment models. Maturity at age is currently assumed to be knife-edged at age 10.

American plaice in Div. 3L, 3N and 3O

Scientific Council (1996, p. 29) reviewed a yield per recruit study for American plaice in Div. 3L, 3N and 3O by Casey *et al.* (1996). The authors investigated the effect of increasing the age of first capture, on yield and SSB per recruit. The results indicated that significant gains in yield per recruit could not be realised by increasing the age of first capture, but that significant gains in SSB could. Scientific Council concluded that, due to the uncertainty in some input parameters, namely natural mortality and different growth rates by sex, it was unable to specify an optimal minimum size for American plaice in Div. 3L, 3N and 3O (and by implication an optimal mesh size).

Mixed species fisheries

Scientific Council (1995, p. 149) stated, in a review of minimum landing sizes, that if a single net rule were to be introduced for trawling in the NAFO region, then a 130 mm mesh size is a compromise corresponding to the optimum yield per recruit fishery for the traditional species – American plaice, yellowtail flounder, witch flounder and cod.

Methods

For the species of interest Greenland Halibut, American plaice and cod, selection parameters were available, for two selection at length functions; the generalized logistic (de Cardenas *et. al*., 1995) and logistic selection models (Walsh and Hickey, 2000; Lisovsky *et. al*., 2001).

The generalized logistic function has the formula:

$$P(i) = (1/(1+\exp(a + bi))^{c}$$

and the logistic function:

$$P(i) = (\exp(a + bi) / (1 + \exp(a + bi)))$$

where P(i) is the proportion of fish of length i retained by the mesh and a, b and c, species specific parameters. Selection at length can be converted to selection at age by transformation using an age length probability matrix. The elements of the matrix are the proportions of fish of length i, within each age group.

De Cardenas *et al.* (1995) present generalized logistic selection parameters for 130 mm mesh from two series of experiments using 1 hour and 4 hour tow lengths. The mesh selection estimated from the 4-hour tows is translated towards smaller fish lengths; this selection pattern was used for the generalized logistic analysis as it was considered a better representation of the fishery practice. Walsh and Hickey (2000) and Lisovsky *et al*. (2001) provide a series of parameters for logistic selection curves for Greenland halibut derived from various sources. The logistic curve parameters quoted from de Cardenas *et al* (1995) by Walsh and Hickey (2000) are in fact for the generalized logistic model, which has a longer tail at the smaller sizes than a generalized model. After comparing the curves from the various models a decision was taken to use the L50 and selection range from the Lisovsky *et al.* (2001) 130 mm logistic curve parameters for 5-hour tows. Modified partial recruitment vectors are presented, in Tables 1-3, for each of the selection models for which parameters were available. For Greenland halibut and American plaice generalized logistic and logistic curves were generated, only the logistic model was used for cod.

For each species, trawl selection at length for 130 mm and 145 mm nets was calculated using mesh retention parameters estimated by mesh selection experiments. Selection at length was converted to selection at age using an age length key. For each stock, the relative change in selection at age between the 130 mm and 145 mm mesh was used to scale the average partial recruitment at age, estimated within an age based assessment model. It was assumed that trawlers using 130 mm mesh have landed all of the recent catches from which the fishing mortality at age was estimated.

For each species, yield and spawning stock biomass (SSB) per recruit calculations were performed using the 130 mm and 145 mm partial recruitment vectors for ages 1-16 with age 16 treated as a plus group. Vectors of weight, natural mortality and maturity at age were taken from the input data used for each of the single species assessments; the values are tabulated in Tables 1-3.

Separate analyses using the two functional forms of the mesh selection curves established that the results are not sensitive to the choice of selection function. Therefore, the results generated from the logistic function are presented, as the parameters of this curve were available for all of the species.

Results

The results of the calculations are presented Fig. 1-3 and Table 4. Within each figure, panel (a) illustrates the logistic selection at length curves. Logistic model selection parameters were also available for a range of mesh sizes similar to 130 and 145 mm, the selection at length curves are plotted for comparison. Panel (b) illustrates the selection at age curve; panel (c) the fishing mortality at age estimated within an age based assessment (130 mm) and the transformed fishing mortality at age calculated for a 145 mm mesh. Panel (d) presents the results of the yield and SSB per recruit calculations for each species and mesh size.

From Table 4 it can be determined that only a slight increase in equilibrium yield (5% at F0.1) and SSB (7% at F0.1) results from changing from 130 mm to 145 mm mesh in the Greenland halibut fishery in Subarea 2 and Div. 3KLMNO (Table 4 and Fig. 1). For American plaice in Div. 3L, 3N and 3O (Fig. 2) there would be no increase in yield and a relatively small increase in SSB (8% at F0.1). For cod in Div. 3N and 3O (Fig. 3) the calculations indicate that the benefits gained from the mesh change are dependent on the response by management. If effort is increased to compensate for the reduced catches resulting from the mesh change, by a factor of 3, then there is only a limited benefit from increasing the mesh size (Fig. 3(d)). If effort is held constant there is a 200% increase in equilibrium SSB (Fig. 3(e)).

Discussion

The results for Greenland halibut and American plaice are consistent with previous advice from NAFO Scientific Council. They indicate that there would be only marginal benefits to changing the mesh size from 130 mm to 145 mm, in the Greenland halibut fishery, on yield and SSB of the Greenland halibut and American plaice. For cod there would be large increases in SSB and yield if effort were constrained. The analyses are conditional on the estimated mesh selection parameters, the partial recruitment vectors from the assessment models and the assumption of constant natural mortality.

The analyses presented here do not consider the effects on species for which age based assessments were not available.

References

CASEY, J. 1995. Yield-per-recruit approximation for Greenland halibut in Subareas 2 and 3. *NAFO SCR Doc*., No. 66, Serial No. N2581, 8 p.

CASEY J., P. A. LARGE, and M. J. MORGAN. 1996. On addressing the optimal size of first capture for American plaice in Divisions 3LNO. *NAFO SCR Doc*., No. 60, Serial No. N2736, 7 p.

DE CARDENAS E, A. AVILA DE MELO, S. INGLESIAS, and F. SABORIDO. 1995. Selectivity of 130 mm mesh size in deep-sea bottom trawl fishery in NAFO Regulatory Area. *NAFO SCR Doc*., No. 47, Serial No. N2558, 7 p.

KULKA D. W. 2001. Distribution of Greenland halibut and by-catch species that overlap the 200-mile limit spatially and in relation to depth – effect of depth restrictions in the fishery. *NAFO SCR Doc*., No. 40, Serial No. N4418, 42 p.

LISOVSKY, S. F., V. V. ESIN, and A. A PAVLENKO. 2001. Selectivity of trawl bags with different mesh size in trawl fishery for Greenland halibut in the NAFO Regulatory Area. *NAFO SCR Doc*., No. 30, Serial No. N4405, 12 p.

WALSH, S. J., and W. H. HICKEY. 2000. Review of bottom trawl codend mesh selection studies in the Northwest Atlantic. *NAFO SCR Doc*., No. 49, Serial No. N4281, 5 p.

Table 1 The input parameters for the 3NO cod yield per recruit analysis

	Logistic					
Age	F130	F145	M	Maturity	Catch Wt	Stock Wt
1	0.000	0.000	0.2	0.000	0.000	0.000
2	0.007	0.000	0.2	0.000	0.000	0.000
3	0.096	0.005	0.2	0.003	0.550	0.425
4	0.335	0.037	0.2	0.019	0.923	0.744
5	0.411	0.142	0.2	0.128	1.421	1.154
6	0.125	0.097	0.2	0.461	2.153	1.788
7	0.079	0.075	0.2	0.827	3.121	2.614
8	0.090	0.081	0.2	0.967	4.450	3.707
9	0.063	0.055	0.2	0.996	6.415	5.745
10	0.065	0.063	0.2	1.000	7.997	7.541
11	0.030	0.029	0.2	1.000	8.995	8.171
12	0.048	0.048	0.2	1.000	10.900	11.092
13	0.048	0.048	0.2	1.000	10.526	10.346
14+	0.048	0.048	0.2	1.000	10.894	10.709

Table 2 The input parameters for the plaice in 3LMN yield per recruit analysis

	Logistic		Generalised logistic					
Age	F130	F145	F130	F145	M	Maturity	Catch Wt	Stock Wt
1	0.000	0.000	0.000	0.000	0.2	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.2	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.2	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.2	0.000	0.000	0.000
5	0.002	0.001	0.002	0.001	0.2	0.015	0.158	0.108
6	0.014	0.006	0.014	0.006	0.2	0.037	0.268	0.194
7	0.041	0.018	0.041	0.018	0.2	0.090	0.348	0.303
8	0.086	0.047	0.086	0.047	0.2	0.202	0.432	0.387
9	0.141	0.095	0.141	0.095	0.2	0.392	0.551	0.487
10	0.199	0.158	0.199	0.158	0.2	0.622	0.677	0.610
11	0.255	0.228	0.255	0.228	0.2	0.808	0.837	0.750
12	0.255	0.242	0.255	0.242	0.2	0.915	1.043	0.931
13	0.255	0.246	0.255	0.246	0.2	0.965	1.315	1.167
14+	0.255	0.250	0.255	0.250	0.2	0.986	1.694	1.486

Table 3 The input parameters for the Greenland halibut in 2+3LMNO yield per recruit analysis

	Logistic		Generalised logistic					
Age	F130	F145	F130	F145	M	Maturity	Catch Wt	Stock Wt
1	0.000	0.000	0.000	0.000	0.2	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.2	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.2	0.000	0.098	0.000
4	0.002	0.000	0.002	0.001	0.2	0.000	0.245	0.000
5	0.017	0.003	0.017	0.009	0.2	0.000	0.359	0.359
6	0.083	0.023	0.083	0.048	0.2	0.000	0.533	0.533
7	0.308	0.170	0.308	0.223	0.2	0.000	0.807	0.807
8	0.281	0.235	0.281	0.260	0.2	0.000	1.216	1.216
9	0.254	0.245	0.254	0.253	0.2	0.000	1.734	1.734
10	0.232	0.230	0.232	0.232	0.2	1.000	2.306	2.306
11	0.260	0.259	0.260	0.260	0.2	1.000	2.959	2.959
12	0.304	0.304	0.304	0.304	0.2	1.000	3.721	3.721
13	0.271	0.271	0.271	0.271	0.2	1.000	4.691	4.691
14+	0.271	0.271	0.271	0.271	0.2	1.000	5.815	5.815

Table 4. The yield abd SSB per recruit values derivedf rom analyses utilizing partial recruitment at age estimated fo two trawl mesh sizes.

Greenland halibut in Divisions 2 and 3KLMNO

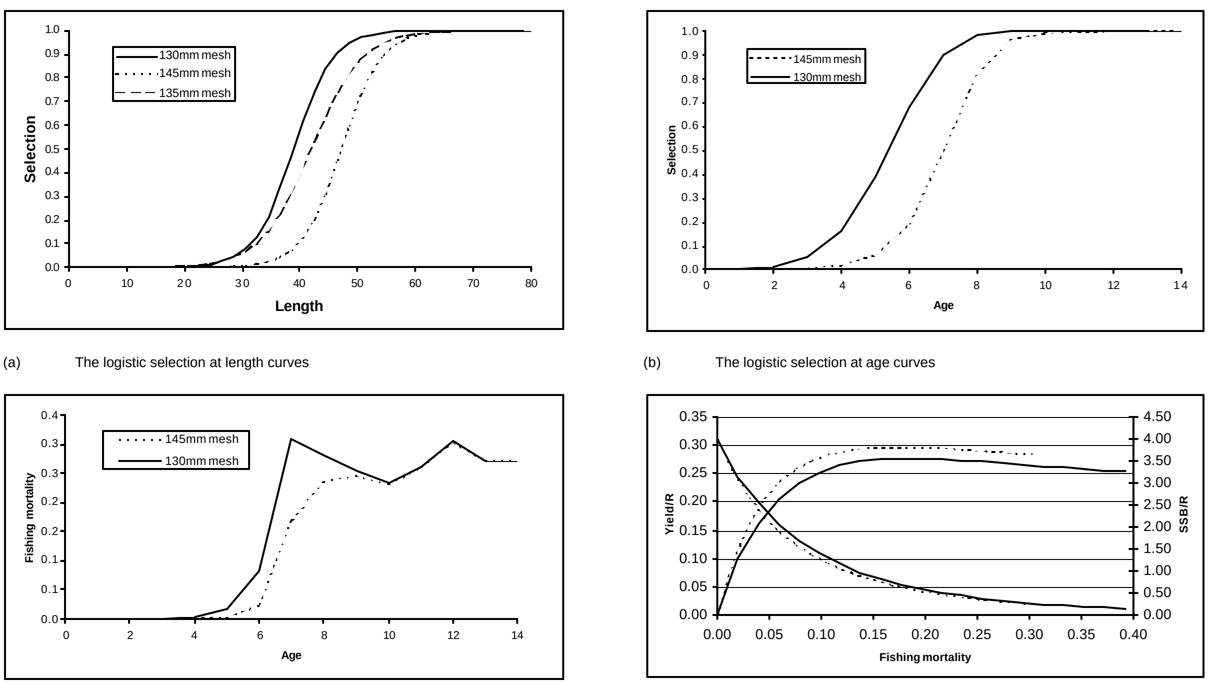
Mesh	F0.1	Fmax	SSB E=1	Y E=1	SSB F0.1	Y F0.1	SSB Fmax	Y Fmax
130	0.105	0.185	600	276	1278	259	763	276
145	0.090	0.174	783	295	1370	273	650	296

American plaice in Division 3LNO

Mesh	F0.1	Fmax	SSB E=1	Y E=1	SSB F0.1	Y F0.1	SSB Fmax	Y Fmax
130	0.214	0.621	329	93	373	90	145	100
145	0.224	0.700	386	91	405	89	171	102

Cod in division 3NO

Mesh	F0.1	Fmax	SSB E=1	Y E=1	SSB F0.1	Y F0.1	SSB Fmax	Y Fmax
130	0.297	0.465	3260	484	3067	489	1544	513
145	0.188	0.306	66000	481	3752	646	2006	686



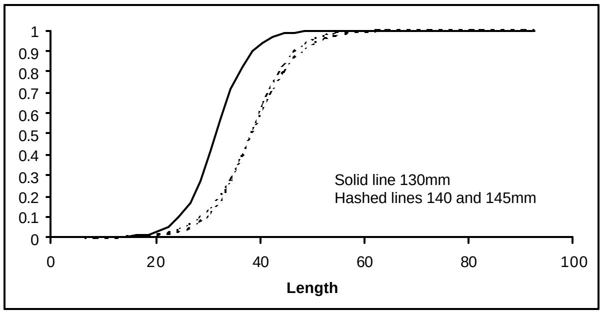
(a) The logistic selection at length curves

(b) The logistic selection at age curves

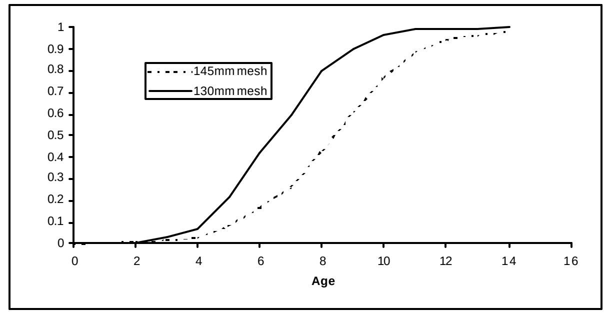
(c) The logistic selection, fishing motality at age curves

(d) The logistic selection yield and SSB per recruit curves

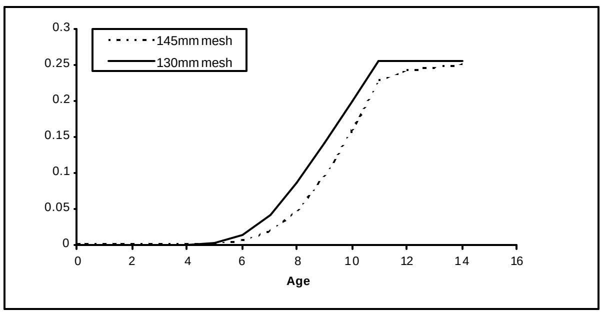
Fig 1. An investigation of the equilibrium yield and combined sex SSB for the Greenland halibut in 2+3KLMNO resulting from fishing with 130 and 145 mm mesh trawls



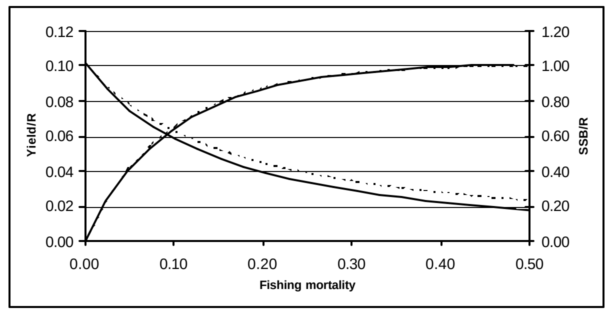
(a) The logistic selection at length curves



(b) The logistic selection at age curves

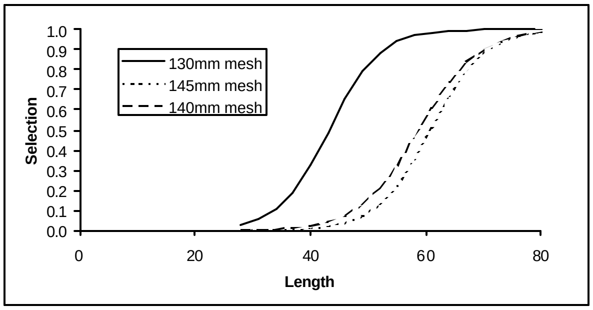


(c) The logistic selection fishing motality at age curves

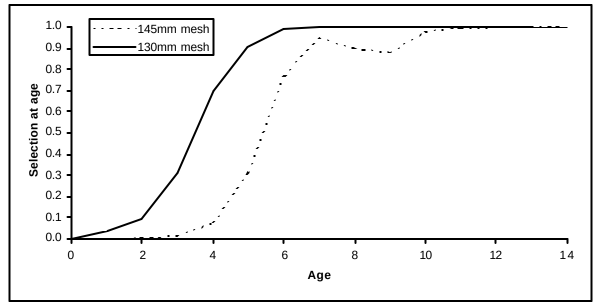


(d) The logistic selection yield and SSB per recruit curves

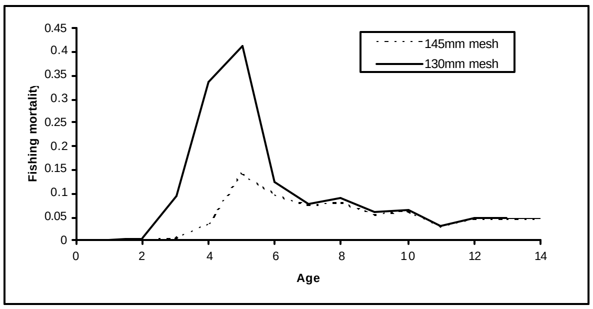
Fig. 2. An investigation of the equilibrium yield and combined sex SSB for the American plaice in Div. 3LMNO resulting from fishing with 130 and 145mm mesh trawls



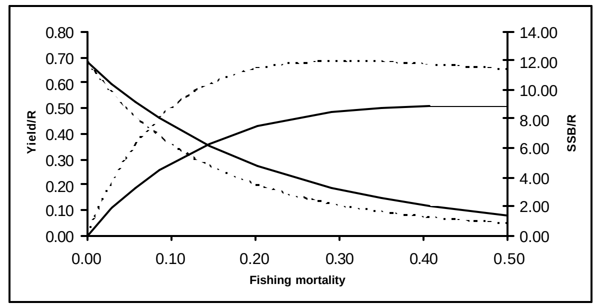
(a) The generalised logistic selection at length curves



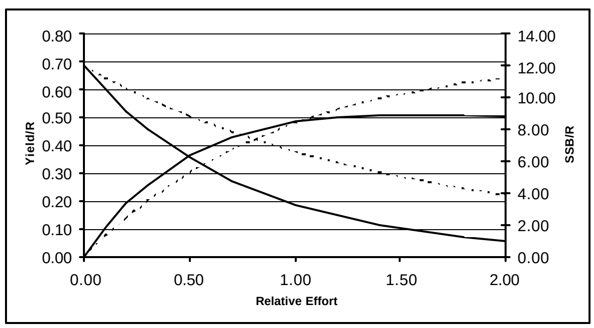
(b) The logistic selection at age curves



(c) The logistic selection fishing motality at age curves



(d) The logistic yield and SSB per recruit curves



(e) The logistic yield and SSB per recruit curves for relative effort

Fig. 3. An investigation of the equilibrium yield and combined sex SSB for the cod in Div. 3NO resulting from fishing with 130 and 145 mm mesh trawls