NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N2865

NAFO SCR Doc. 97/33
Revised

SCIENTIFIC COUNCIL MEETING - JUNE 1997

Yield per Recruit for Greenland Halibut in Subareas 2 and 3, Considering a Dome Shaped Exploitation Pattern and Differences in Natural Mortality (M) Between Sexes.

by
Enrique de Cárdenas
Inst. Español de Oceanografía , Apdo 240, Santander, Spain.

and

Lorenzo Motos
AZTI, Avenida de Satrustegui 8, San Sebastián, Spain.

1.- Introduction.

The last analysis of yield per recruit presented for the Greenland halibut fishery in Divisions 2, 3 KLMNO (**Casey, 1995**) was carried out considering: a) that survival of specimens which pass through the mesh is 100% (there is no escapement mortality); b) that the trawl exploitation pattern is flat top; c) that growth is equal in the two sexes; d) that natural mortality is equal in the two sexes and has a value of 0.15; e) that the 205 mm mesh size has a knife edge selection pattern of 60 cm (age 10). With these assumptions, it was seen that as mesh size increased to 205 mm, long term yields per recruit would be trebled, and spawning biomass would be multiplied by 6 or 7 to the current level of F in 1994.

Although growth of both sexes may be considered similar (see **Nedreaas *et al.*, 1996; de Cárdenas, 1996**), the other four assumptions in the model are nevertheless dubious:

Recently, a series of papers has been published which indicate that post escapement mortality may be high (among others: **Robinson *et al.*; Suuronen *et al.*, 1993; Sangster *et al.*, 1996**).

It is not only incorrect to consider a knife edge recruitment pattern for the 205 mm mesh, but also, in some species, such as European hake, a positive relationship appears between mesh size and the selection range (**Fernández and de Cárdenas, 1985**), which probably also occurs in Greenland halibut.

We have not found any papers in the bibliography which allow the quantification of these two problems for Greenland halibut.

Apart from these points, there are studies which suggest that natural mortality of males after maturity increases slightly with respect to that of females (**de Cárdenas, 1996; Nedreaas *et al.*, 1996**).

Lastly, and no less important, is the problem of the exploitation pattern. **Jorgensen and Boje (1992)** carried out trawl and long-line hauls for the same areas, depths and dates, observing that long-lines are much more efficient than trawl in the catch of specimens of over 10 years, and that this efficiency tends to increase with age. This fact, together with the trawl catch being mostly made up of immature specimens independently of depth at which work is being done, suggests that the trawl exploitation pattern is dome shaped.

The aim of the present work is to simulate the long term changes in yields and spawning biomass per 1000 recruits which a mesh size change to 205 mm would bring about if there were sexual differences in natural mortality, and if the trawl exploitation pattern were dome shaped. The length at 50% maturity of the 205 mm mesh size gear is 60 cm as derived from the selection factor for Greenland halibut given by De Cárdenas et al. (1995).

2.- Materials and methods.

To simulate a different natural mortality by sex, we will assume that both sexes present *the same catchability and that the sex ratio at the time of their recruitment to the fishery at age 3* is 1, so that if 1000 fishes are recruited to the fishery at this age, 500 will be males and 500, females.

On considering that both sexes present the same catchability, we can construct two models, one for each sex. Males will be submitted to a natural mortality of 0.15 for the first six years of life. From age 7, M will take a value of 1.05 (see **de Cárdenas, 1996**). Females will maintain a value of M= 0.15 throughout their exploited life. Based on this characteristic and on the current knowledge about the sex estructure of catches, different age-plus groups were set for females (18+) and males (12+).

The global yield per 1000 recruits will be the sum of the yields obtained in each sex for each level of F and mesh size.

The mean lengths at age were derived from the Spanish catch for 1994, the last year in which an exhaustive sampling of the catch is available.

The length-weight relationship used was $W = 0.00639*L^{3.073}$, the same as that used by **Casey (1995)**.

In the exercise we will consider that escapement mortality does not exist.

With these assumptions two scenarios can be constructed: 1) trawl with a 130 mm mesh, which we will take as the current situation; 2) mesh size changed to 205 mm, whose L_{50} is equivalent to 60 cm.

The partial recruitment pattern (RP_i) is the result of the combined effect of gear selectivity (P_i) and fish availability (A_i):

$$RP_i = P_i * A_i$$

The partial recruitment for ages below 10 years with the 130 mm mesh was obtained from the equation which gives the percentage of retention of Greenland halibut with mesh size of 130 mm for four hours of trawling:

$$P_i = (1/(1+e^{24.226 - 0.54 * L_i}))^{0.178} \quad \textit{(de Cárdenas, 1995)} \quad (1)$$

In which P_i is recruitment for the length L_i.

This equation produces a length of 25% of retention (L_{25}) of 30.46 cm and an L_{50} of 37.68 cm. To obtain the percentages of retention for these ages, with the mesh size of 205 mm, whose L_{50} is 60 cm, we calculated the differences between the L_{50}'s (22.32 cm) and displaced the retentions these 22.32 cm by transforming the equation (1) into:

$$P_i = (1/(1+e^{24.226 - 0.54 * (L_i - 22.32)}))^{0.178}$$

The dome shape (A_i) in the exploitation pattern for trawl in ages over 10 years was calculated from **Jorgensen and Boje (1992)** assuming that long-line has a flat top exploitation pattern for ages over 10 years, and so the CPUE's of trawl were divided by the CPUE's of long-line for these ages. These factors were multiplied by the corresponding retentions of the 130 mm mesh for these ages, and thus the probabilities of them entering the gear and escaping through the mesh were simulated. The resulting bell shaped partial recruitment vectors are shown in ***table 1*** and ***figure 1***. PR vectors for both mesh sizes were scaled to 1 for the highest value.

The exploitation pattern for long-line for ages less than 10 years was obtained from the comparison of the CPUE of trawl and long-line (**Jorgensen and Boje, 1992**), and the retentions of the 130 mm mesh size.

The maturity ogive used was presented *for females by* ***Junquera (1995)****. It was decided* for the analysis to consider that the spawning stock is only composed by females, since this sex in the only one producing eggs and drives the fate of the spawning stock.

In ***Table 1*** the following parameters are summarized: mean length, mean weight, partial recruitment to both meshes, and natural mortality corresponding to each age and sex. The maturity ogive, i.e. *proportion of mature specimens,* is only given for and applied to females.

3.- Results.

The results corresponding to the values of F_{01}, yields and spawning biomass per 1000 recruits and long term gains obtained using the revised mesh size or gear with respect to trawl with 130 mm mesh size are shown in ***Table 2.***

Figure 2 shows the spawning biomass and yields per 1000 recruits for the two scenarios described. These curves are derived from the analysis when the PR vectors are scaled to 1.

When the PR vector of the 205 mm mesh size is not scaled to 1, the analysis shows the levels of spawning biomass and yield per 1000 recruits achieved at the different levels of effort increase with reference to the 130 mm mesh size (***Figure 3***).

4.- Discussion.

Partial recruitments of ages over 10 years may be somewhat underestimated in this exercise if we take into account that larger fishes, which swim faster, can compete more successfully than the younger ones for the bait, thus increasing their catchability in the long-line (**Hareidem, 1995**). However, factors exist which may also reveal the dome shape in the total selection of the gear (gear selection + fishing strategy). For example, if the species became more territorial with age, fish concentrations would diminish with age, and this would lead trawlers to search for concentrations in order to optimize gains given by yields in weight and by the mean price of the catch, which is a function of the length of fishes. Thus, effort would be concentrated on these ages.

With respect to the problem of escapement mortality, it is generally assumed that cod-end escapement mortality is insignificant and that all escapees survive and grow. However, recent work suggests that this may not always be the case.

Pelagic fishes such as herring (*Clupea harengus* L.) seem to record a very high trawl induced mortality (**Suuronen *et al.*, 1993**). The studies indicate that factors other than passing through codend meshes caused most of the observed mortality for herring escapees. Among these factors, skin injuries and exhaustion while fish where inside the funneling rear part and the cod-end of the trawl were the most likely causes of escapees' mortality. The predicted 14 day post-capture mortalities where 91% and 62% for small (<12cm) and large(12-17cm) herring escapees.

Demersal fishes, however, seem to resist better the effect of trawl escapement. Experiments have been reported to investigate survival and escapee damage (mainly in gadoids) after escaping through the meshes of the trawl cod-end (**Sangster et al., 1996**). Survival rates were found to increase with mesh size from ca. 50-60% (70mm) to 85% (110mm) respectively. However, further analysis showed that the increase in survival as the cod-end mesh size increased was related to the survival of large individuals, and that smaller fish suffered higher mortality irrespective of mesh size.

The survival rates of cod, (*Gadus morhua*), American plaice (*Hippoglossoides platessoides* (Fabr.)) and yellowtail flounder (*Limanda ferruginea* (Storer)) in the Northwest Atlantic were found to be extremely variable and highly dependent on season (**Robinson *et al.*, 1993**).

In the case of Greenland halibut, increases in survival may also take place as mesh size increases, which would bring with it an increase in the survival of the fish which escape in each haul. Nevertheless, the number of fishes which would be forced to pass through the mesh would increase in such a way as to give a negative final balance.

There would be three possible reasons for the increase in the passage of specimens through the mesh: 1) to reach the new level of F_{01} with the 205 mm mesh size, it would be necessary to multiply the level of fishing effort corresponding to the 130 mm mesh size (***Table 2***) by 2.2; 2) the proportion of fish with the same length distribution which passed through the 205 mm mesh would be greater than those who passed through the 130 mm mesh; 3) the number of fish in the sea should, theoretically, increase, and so the gear would find a greater density of fish, and so a greater number of them would be forced to pass through the mesh.

Taking the above into account, it is highly likely that if post escapement mortality exists, the long term gains in yields and spawning biomass per 1000 recruits are overestimated for the 205 mm mesh size. The effect of the post-escapement mortality in the simulation is studied in De Cárdenas and Motos (1997).

The increase in the selection range with mesh size tends to occur depending on the fish being selected by the mesh due to its maximum contour and particularly to the size of the mesh it tries to pass through. The standard deviation of the contours of the fish increases with length, as does that of mesh size with mean mesh size of the gear. The combined effect brings about an increase in the selection range, which is also likely to occur in the case of Greenland halibut, and if this happens, failure to take it into account would lead to a slight overestimate of long term gains, derived from the mesh size increase.

Thus, due to the small long term gains both in spawning biomass and in yield which the model for the change in mesh size to 205 mm shows, we must be cautious in advising this change.

5.- References.

Anon. 1997. Scientific Council Reports 1996. NAFO: 226pp.

Casey, J. 1995. Yield-per-recruit approximation for Greenland halibut in Subareas 2+3. *NAFO SCR Doc.* 95/66 Ser. No N2581.

De Cárdenas, E. 1996. The female ratio as an indicator of sexual differences in mortality of Greenland halibut (*Reinhartius hippoglossoides*) at age 8+. *NAFO SCR Doc.* 96/35 Ser. No N2710: 10pp.

De Cárdenas, E., A. Avila de Melo, S. Iglesias and F. Saborido. 1995. Selectivity of 130 mm mesh size in deep sea bottom trawl fishery in NAFO Regulatory Area. *NAFO SCR Doc.* 95/47 Ser. No N2558: 7pp.

De Cárdenas, E., J.M. Casas, R. Alpoim and H. Murua. 1996. Preliminary results of the European long-line survey in the NAFO Regulatory Area. *NAFO SCR Doc.* 96/34 Ser. No N2709: 6pp.

De Cárdenas, E. and L. Motos, 1997. Influence of post-escapement mortality in the yield of a Greenland Halibut trawl fishery. *NAFO SCR Doc.* 96/76.

Fernández A. and E. de Cárdenas. 1985. La relación entre la longitud total, el contorno y la selectividad de la merluza del Cantábrico y Galicia. *Bol. Inst. Esp. Ocean.* 2 (3): 69-75.

Hareide, N.R. 1995. Comparisons between longlining and trawling for deep-water species -selectivity, quality and catchability- a review. In *Deep-water fisheries of the North Atlantic oceanic slope.* Ed. Hopper A.G. Academic Publishers (Netherlands): 227-234.

Jorgensen, O.A. and J. Boje, 1992. A Comparison of the Selectivity in Trawl and Long-Line Fishery for Greenland Halibut. NAFO SCR 92/53 N2105. 5pp.

Jorgensen, O.A. and J. Boje, 1995. A Comparison of the Selectivity in Trawl and Long-Line Fishery for Greenland Halibut. In *Deep-water fisheries of the North Atlantic oceanic slope.* Ed. Hopper A.G. Academic Publishers (Netherlands).

Junquera, S. and F. Saborido-Rey, 1995. Temporal and spatial variation in length at maturity in 3LM and 3NO Greenland Halibut. NAFO SCR 95/9 N2538. 7pp.

Robinson, W.E., Carr, H.A. and Harris, J., 1993. Assessment of juvenile bycatch and cod-end survivability in the northeast fishing industry. A report of the New England Aquarium to the National Oceanic and Atmospheric Administration pursuant to NOAA Award No. NA26FD 0039-01, December 1993.

Sangster G.I., K. Lehmann, M. Breen. 1996. Commercial fishing experiments to assess the survival of haddock and whiting after escape from four sizes of diamond mesh cod-ends. *Fisheries Research* 25 (1996) 323-345

Suuronen, P. Lehtonen, E., Tschernij V., Orrensalo, A. and Jarvik, A., 1993. Behaviour and survival of Blatic herring (Clupea arengus L.) escaping from a pelagic trawl and possibilities to increase survival. Nordisk Ministrrad Project No. 66071, *ICES CM 1993/B:2,* Fish Capture Committee.

Table 1: Input data for the yield per recruit analysis of Greenland halibut. Length at age (L) from the Spanish catches in 1994 (De Cárdenas et al, NAFO SCS Doc. 95/15, Serial No. N2555). Weight at age (L) from the length-weight relationship given by Casey (1995, NAFO SCR 95/66). Partial recruitment pattern as explained in the text, using the selectivity at lenght (P_i) from (De Cárdenas et al, 95/47) and the ratio (Ratio T/L)) given by Jorgesen & Boje (1992 NAFO SCR 92/53) for the relationship between trawl and long-line catch levels. Maturity ogive from Junquera (95/29). Sex specific natural mortality (M) from De Cárdenas (96/47).

FEMALES

AGE	L	W	P_i (130)	P_i (205)	Ratio T/L	PR (130)	PR (205)	M	Mat.ogive
3	25	0.126	0.15	0.02	1.00	0.15	0.02	0.15	0.00
4	30	0.222	0.24	0.03	1.00	0.24	0.03	0.15	0.00
5	36	0.377	0.41	0.05	1.00	0.41	0.05	0.15	0.00
6	40	0.534	0.62	0.07	1.00	0.62	0.07	0.15	0.00
7	45	0.758	0.88	0.12	1.00	0.88	0.12	0.15	0.25
8	53	1.255	1.00	0.25	1.00	1.00	0.25	0.15	0.50
9	59	1.736	1.00	0.44	1.00	1.00	0.44	0.15	0.50
10	64	2.269	1.00	0.71	0.70	0.70	0.50	0.15	0.50
11	69	2.847	1.00	0.94	0.24	0.24	0.23	0.15	0.75
12	74	3.517	1.00	0.99	0.20	0.20	0.20	0.15	1.00
13	78	4.241	1.00	1.00	0.13	0.13	0.13	0.15	1.00
14	84	5.185	1.00	1.00	0.10	0.10	0.10	0.15	1.00
15	88	5.958	1.00	1.00	0.10	0.10	0.10	0.15	1.00
16	91	6.789	1.00	1.00	0.10	0.10	0.10	0.15	1.00
17	91	6.789	1.00	1.00	0.10	0.10	0.10	0.15	1.00
18	91	6.789	1.00	1.00	0.10	0.10	0.10	0.15	1.00

MALES

AGE	L	W	P_i (130)	P_i (205)	Ratio T/L	PR (130)	PR (205)	M
3	25	0.126	0.15	0.02	1.00	0.15	0.02	0.15
4	30	0.222	0.24	0.03	1.00	0.24	0.03	0.15
5	36	0.377	0.41	0.05	1.00	0.42	0.05	0.15
6	40	0.534	0.63	0.08	1.00	0.63	0.08	0.15
7	45	0.750	0.87	0.11	1.00	0.87	0.11	1.05
8	51	1.125	0.99	0.21	1.00	0.99	0.21	1.05
9	58	1.637	1.00	0.39	1.00	1.00	0.39	1.05
10	63	2.166	1.00	0.66	0.70	0.70	0.46	1.05
11	68	2.739	1.00	0.92	0.24	0.24	0.22	1.05
12	74	3.517	1.00	0.99	0.20	0.20	0.20	1.05

Table 2: Outputs of the y/r analysis. Values of yield and ssb per 1000 recruits are given for the $F_{0.1}$ reference point. Both PR vectors scaled to 1 for the the maximum value. They are also shown the proportion of long term gains obtained by the 205 mm mesh size with relation to the 130mm mesh size and the increase in effort necessary to reach the new level of F01

130 mm mesh size			205 mm mesh size			205 mm mesh size relative to 130 mm meshsize		
Y/R	SSB/R	F01	Y/R	SSB/R	F01	Y/R	SSB/R	effort ratio
264	1056	0.31	311	1423	0.67	1.18	1.35	2.16

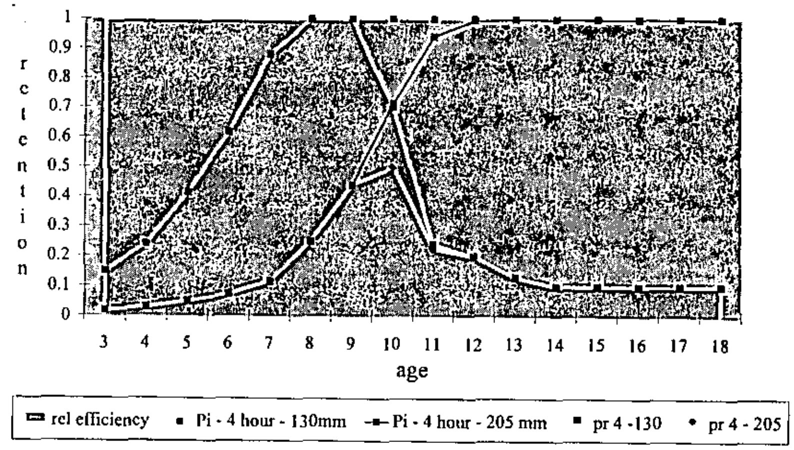

Figure 1: Greenland halibut Selectivity curves for the 130mm and 205 mm mesh (Cardenas et al., 1995) and relative efficiency of trawl with reference to long-line (Jorgensen and Boje, 1992). The combined effect of them result in a bell-shaped partial recruitment pattern for both mesh sizes (bold white lines).

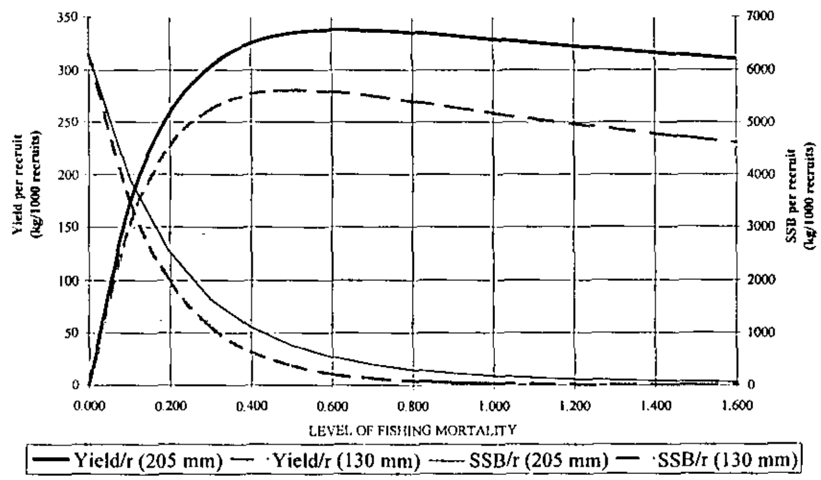

Figure 2: Plots of yield per (1000) recruit and SSB per (1000) recruit for the greenland halibut population under the two exploitation scenarios: 205mm mesh size trawl and 130mm mesh size trawl.

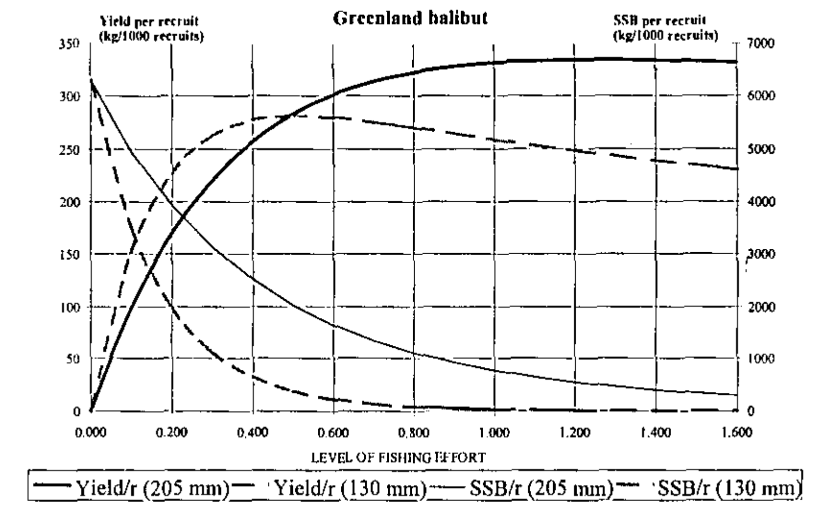

Figure 3: Plots of yield per (1000) recruit and SSB per (1000) recruit for the greenland halibut population under the two exploitation scenarios: 205mm mesh size trawl and 130mm mesh size trawl. PR not scaled to 1, so the plot shows the effort level necessary to achieve the yields and ssb per recruit relatively to the 130 mm mesh size.